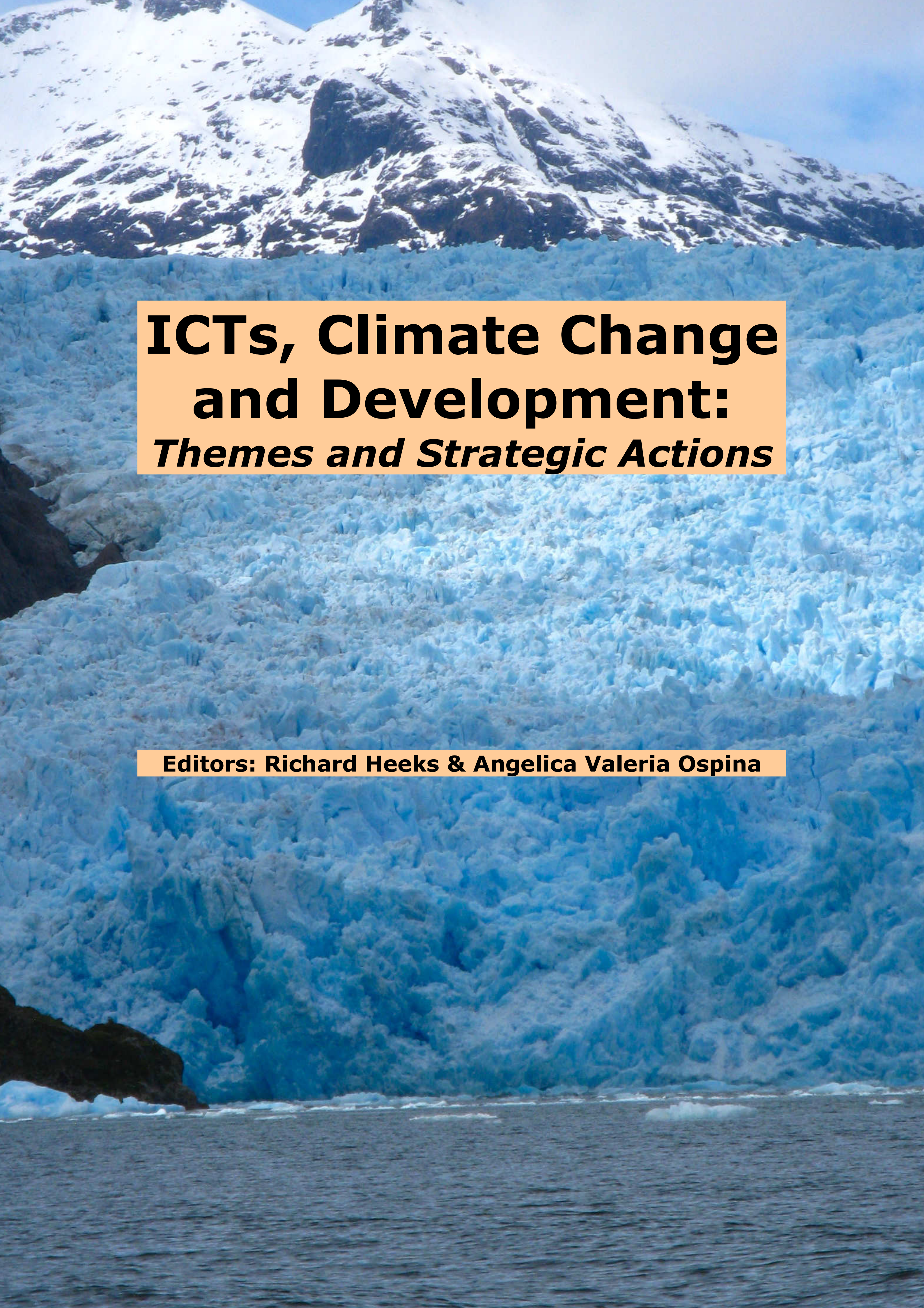

ICTs, Climate Change and Development:
Themes and Strategic Actions

Editors: Richard Heeks & Angelica Valeria Ospina

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Themes and Strategic Actions

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Introduction and Overview

As illustrated in Figure 1, this book – along with its companion volume "ICTs, Climate Change and Development: Case Evidence" – analyses evidence and makes recommendations for policy and practice at the intersection of three domains: information and communication technologies (ICTs), climate change, and socio-economic development sectors.

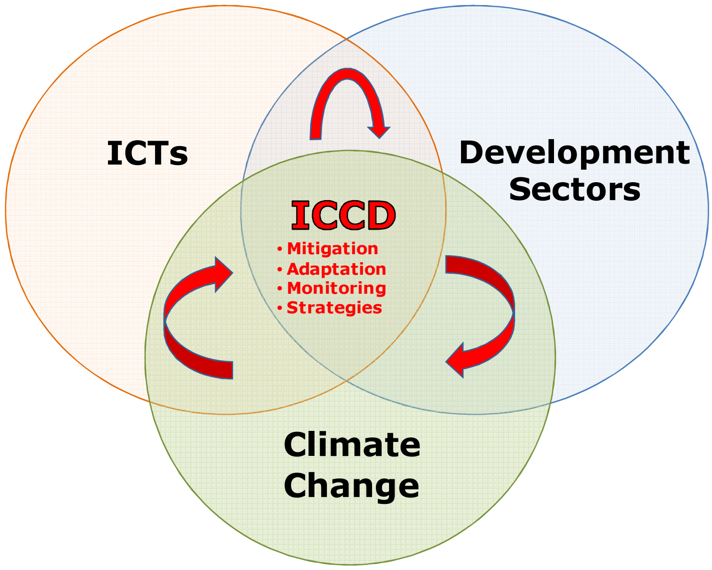

Figure 1: The Overlapping Domains of ICTs, Climate Change and Development

The three dual intersections of these domains have seen increasing research and action, particularly since the turn of the 21st Century:

(a) ICTs and development: successive waves of ICTs – telecentres, mobile phones, broadband, smartphones – have been diffusing into developing countries, increasingly reaching poor communities, and increasingly offering the potential to significantly change development processes and livelihoods.

(b) Climate change and development – from no explicit mention in the Millennium Development Goals, climate change has risen rapidly up the agenda of developing country governments and development agencies; in particular recognising the impact on livelihoods of the poor that climate change can already been seen to be having.

(c) ICTs and climate change – there has been growing recognition that the carbon footprint of the ICT sector is growing, but also that ICTs must play an important role in initiatives to address climate change.

Yet, prior to the IDRC-funded "Climate Change, Innovation and ICTs" project from which this book is developed, there had been very little attention paid to the "triple intersection". That is, to the specific role which ICTs can play in addressing climate change in developing countries. This role is specific, and cannot simply be rolled-up into the general "e-Climate Change" field for a number of reasons. These include:

- The greater resource-poverty of developing countries, which means they require context-specific solutions, often based on more "frugal" ICT innovations.
- The related dominance of basic mobile phones among all types of ICT, compared with dominance of the Internet-connected PC and 3G+ phones in developed countries.

- The different types of climate and climate change being experienced in developing countries.
- The "mirrored agendas" of global North and South: while climate change mitigation is the main priority in developed countries, in developing countries it is climate change adaptation.

IDRC therefore initiated this project with three main purposes in mind:
- To analyse evidence and ideas to date on ICTs, climate change and development (ICCD), in order to develop state-of-play reviews and conceptual models. The chapters in Part 1 of this book were developed to address this aim.
- To develop a new primary evidence base about the use of ICTs to address climate change in developing countries, and draw lessons from such initiatives. The case studies presented in the companion volume - "ICTs, Climate Change and Development: Case Evidence" – were commissioned to address this aim.
- To produce recommendations for strategic actors and strategic actions necessary to most-effectively utilise ICTs in relation to climate change and development. The chapters in Part 2 of this book were developed to address this aim.

Contents of this Book

In more detail, Part 1 begins with two foundational papers, which provide an overview of the ICCD field. In ***Chapter 1***, a **scoping study** charts strands and trends in the literature on ICTs, climate change and development, and develops an overview model of the key ICT application areas - mitigation, strategy, monitoring and adaptation – as shown in Figure 2. The scoping study identifies priorities for future research in this field, provides a glossary of field terms, and includes an annotated bibliography of key documents from 1997-2010 (provided in the Annexes at the very end of this book).

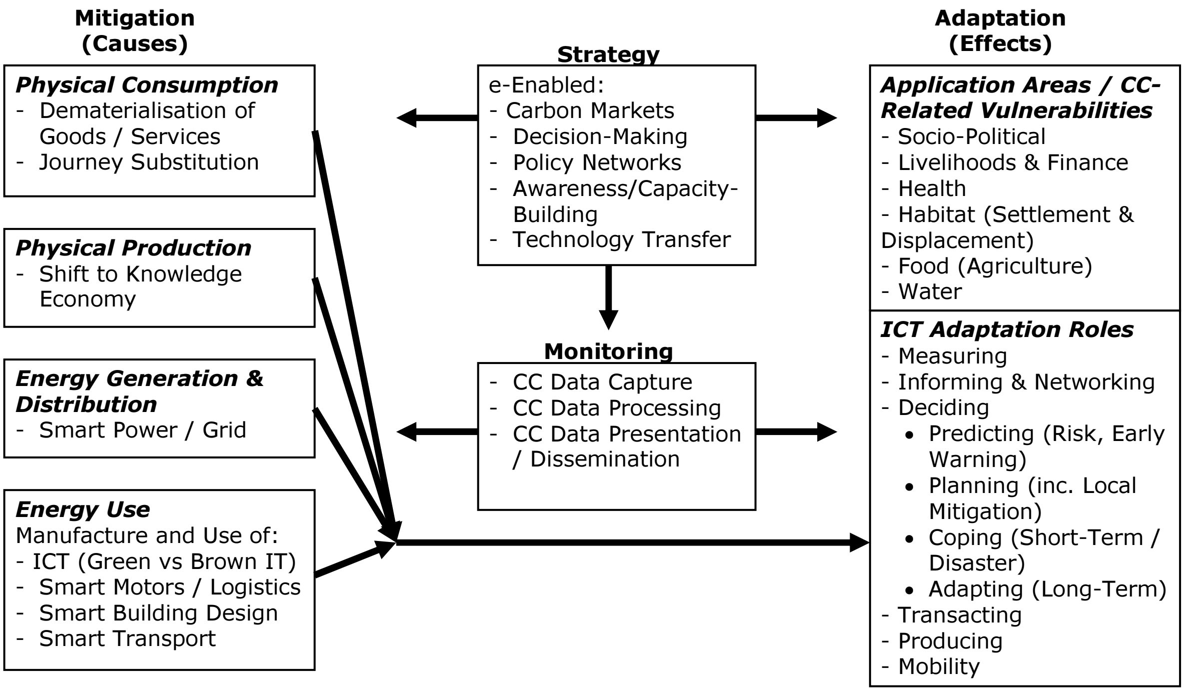

Figure 2: Overview Model on ICTs, Climate Change and Development (ICCD)

Chapter 2 is an analytical work which draws together ideas from different parts of the ICCD field in order to build four **new conceptual models** - i) Climate change vulnerability in developing countries; ii) Climate change adaptation and adaptive capacity of communities and wider 'livelihood systems'; iii) Climate change resilience; iv) The contribution of ICTs to 'e-resilience' and 'e-adaptation'. The models can be used as the foundation for research, consulting and strategy on ICTs and climate change.

The remaining chapters of Part 1 largely take their lead from the Overview Model shown in Figure 2: selecting one part of that model and then reviewing current evidence in order to provide an overall analytical and practical understanding of that ICCD sub-domain:

- ***Chapter 3*** focuses on the issue of **mitigation**, and identifies the need and opportunity in emerging economies for ICT-enabled climate change mitigation in areas such as energy generation, urban transportation and building, manufacturing, and international trade. It analyses the challenges to this form of low-carbon development, and recommends necessary actions by government and business.
- ***Chapter 4*** focuses on **adaptation**, and argues that mobiles have been helpful in building informational capacities for climate change adaptation. However, emergent, self-organised, transformational adaptation may need to build more on telecentre-based models, and should focus more on holistic rather than climate-specific applications.
- ***Chapter 5*** selects a topic that has been a key focus for climate change concerns in developing countries: the growth in **climate-related disasters**. It argues ICTs have a central role in management of such disasters. But strategic changes are needed. Information systems should be development- rather than disaster- or climate-focused. More interoperable and routinely-used rather than specialised applications are required. ICTs should also be used more to enable accountability of disaster response efforts.
- ***Chapter 6*** uses survey and other data to analyse how **ICT-for-development activist organisations** are strategically handling climate change as an issue. It identifies their key focus on adaptation, the challenges that exist within and outside organisations, and it makes recommendations for effective strategic response.
- ***Chapter 7*** is in some ways a mirror-image of the previous chapter. Where the latter looks at climate change strategy for ICT4D organisations, Chapter 7 looks at **ICT strategy for climate change organisations**. It analyses how organisations active in climate change should incorporate ICTs into their strategic thinking. It builds a model of "informational governance" with questions to help these organisations identify challenges and opportunities, and enable an effective strategic response.
- ***Chapter 8*** takes a more cross-cutting based on the latest wave of digital applications. It analyses the climate change application of **new and emergent ICTs** – wireless broadband, wireless sensor networks, GIS, Web-based tools – in developing countries. It identifies major uses in disaster management and climate monitoring, and lacunae around climate adaptation. It provides recommendations for more effective use of new digital technology
- ***Chapter 9*** highlights an issue that flows throughout the entire ICCD field: **gender**. It explains why, and how, women have been more constrained than men from using ICTs in tackling climate change. It then makes four digital empowerment proposals that can make e-climate change interventions more gender sensitive.
- Finally in Part 1, ***Chapter 10*** looks at one of the "application areas" recognised at the top right of the Overview Model. It focuses on the **water sector** and maps the linkages between climate change adaptation, water, and

ICTs to produce the "ICTs, Climate Change Adaptation and Water Project Value Chain" model. This is a conceptual tool that can be used by practitioners and researchers seeking to analyse and plan field interventions in contexts facing water stress due to climate change.

The Chapters in Part 1 are all connected to practice; they draw from the evidence of practice, and they make recommendations for practitioners working at policy, programme and project levels. That focus on action is all-embracing for Part 2 of the book, with all the Chapters written explicitly for policy makers and strategic planners in senior climate change and ICT4D roles.

This begins with ***Chapter 11*** which focuses on **ICCD policy**. It identifies the actors and priorities at three domain levels – international, national and sub-national – and lays out ICCD policy principles those actors should follow. It provides detail on the climate change issues that ICT policy should address, and the ICT issues that climate change policy should address. Alongside these policy content elements, the Chapter also recognises the need to put the right policy structure and policy process in place. Following an appraisal of policy benefits and risks, it then identifies the key entry points to ICCD policy for developing country-policy makers.

The next three Chapters are all strategy briefings: much shorter than the previous Chapters, and providing quick access to strategy-relevant ideas and recommendations:

- ***Chapter 12*** offers guidance on how best to use **ICTs for climate change mitigation** in developing countries. It outlines the drivers behind climate change mitigation, and three main application domains for mitigation-relevant use of ICTs: green ICT; smart ICT (energy, buildings, transportation, commerce, forestry); and community ICT. After identifying key challenges and opportunities for developing countries, it lays out strategic action steps on e-mitigation for international organisations, governments and private firms.
- ***Chapter 13*** covers the integration of **ICTs into national and sectoral processes of climate change adaptation**. It explains the five ways in which ICTs can support national adaptation plans such as NAPAs, and also the support that can be provided by ICTs for specific sectoral adaptation strategies. The Chapter highlights five guiding principles in strategic application of ICTs for climate change adaptation, and then outlines the strategic action steps that need to be taken in this area.
- ***Chapter 14*** narrows down to ICTs' role in meeting the specific climate change needs of **rural agricultural communities**. It analyses the particular climate change vulnerabilities faced by rural agricultural communities, and typical action priorities on climate change before then tabulating ICT interventions that can support the four areas for climate change action: awareness, mitigation, monitoring and adaptation. It identifies six critical success/failure factors that have determined outcomes of ICT use in rural agricultural climate change projects. It then presents the "Information-Plus" approach that such projects need to adopt before specifically laying strategic action steps for those involved with ICTs and climate change in these communities.

Finally, ***Chapter 15*** is also a briefing but one that sets out the **future research agenda** in the field of ICTs, climate change and development. Written for researchers, consultants and reflective practitioners working in this field, it outlines six key features which help map the ICCD research field. The main knowledge gaps – and, hence, research priorities – relating to climate change mitigation, adaptation, monitoring, and strategy are described, as are action steps required to take the ICCD research field forward.

Part 1: Analysing the ICTs, Climate Change and Development Field

Chapter 1: Unveiling the Links between ICTs and Climate Change in Developing Countries:
A Scoping Study

ANGELICA VALERIA OSPINA & RICHARD HEEKS

Executive Summary

Background

Amidst the unmistakable signs of a changing climate, the global community is just beginning to understand the potential magnitude and severity of its impacts, not just now but for generations to come. Melting glaciers, displaced populations seeking refuge after floods, crops lost during over-extensive periods of drought, or entire villages devastated by the implacable force of cyclones and hurricanes, are just some of the stories emerging from different corners of the planet; in particular from the poorest, most vulnerable countries of the world.

Emerging evidence indicates that both acute (i.e. extreme weather events) and chronic climate effects (i.e. longer-term changes in the environment) can have serious developmental effects that hit particularly hard those countries that are already experiencing the hardships of poverty and marginalization (IPCC, 2007).

But alongside increasing awareness of the manifestations of climate change and the growing momentum of the debate, the role of information and communication technologies (ICTs) is starting to emerge and to shed light on potentially innovative approaches to respond, prepare for, and adapt to climate change impacts.

Sources in the field started to explore the linkages between the information society and sustainable development in the late 1990s, shifting their focus in the early 2000s from broader global environmental issues to CO_2 emissions and mitigation, thus addressing more specifically the role of ICTs in climate change. However, these explorations on the role of ICTs – in the reduction of emissions through smart grids, dematerialization or intelligent transport systems and buildings, among others – have focused mainly on addressing the priorities of developed countries in regards to climate change.

Despite the prevalence of the mitigation lens among available sources, a growing body of literature indicates the emergence of research in the areas of adaptation and climate change strategies, acknowledging the priorities of developing contexts and the potential of ICTs. Experiences from vulnerable communities in Asia, Africa, Latin America and the Caribbean point to the use of applications such as mobile phones, the Internet and community radio as part of climate change responses, including the strengthening of local livelihoods, natural resources management and training, access to relevant information and networking opportunities, and awareness raising, among others.

However, this constitutes a very new field of enquiry where much remains to be explored. Developing country priorities and perspectives need to become a central part of the debate, if the potential of these technologies is to contribute to more holistic, inclusive responses to the challenges posed by the changing climate.

Contribution

This document responds to the need to explore further the links between ICTs, climate change and development, as these fields become increasingly interlocked due to the magnifying effect of climate change on existing development challenges and vulnerabilities.

This scoping study targets an audience of development strategists and practitioners – working on ICTs-for-development (ICT4D), on climate change, on disaster response, and other focal areas – interested in gaining a better understanding of the current trends and perspectives in ICTs-and-climate change research, with a focus on developing countries. It seeks to raise awareness on the potential and challenges associated with the use of these tools from a developing country perspective. And it seeks to identify emerging issues and research gaps that require further academic analysis and/or multi-stakeholder collaboration.

The main structure of the document consists of four parts. The first provides the reader with the 'big picture' of ICTs and climate change, based on a review of existing literature and identification of the main phases that have characterized the debate to date (Figure 1). Based on the above, the analysis will suggest some of the key gaps and issues that need to be considered as research on ICTs, climate change and development continues to evolve.

The second section deepens the analysis by identifying the key components of the debate, namely the role of ICTs in mitigation, monitoring, adaptation and strategies, while building up the basis of a conceptual model on ICTs, Climate Change and Development (Figure 2). This model will provide the reader with an overview of the main issues and trends that lie at the intersection of these three fields, mapping the links between its main components and serving as a tool to identify challenges and research gaps that need to be further explored.

Having identified the main issues on ICTs and climate change from a global perspective, the third part of the document will present some of the emerging examples of ICT use in climate change mitigation, monitoring, adaptation and strategies in Africa, Asia and Latin America. This section will allow the reader to contextualize the debate from a developing country perspective, while relating the ideas reflected in the ICTs, Climate Change and Development model to concrete actions in the field.

The study concludes by presenting key issues for future research, based on the gaps and developing country priorities identified throughout the analysis. It has three Annexes: one providing a timeline of key literature resources; one offering an extended bibliography of that literature; and a glossary of key terms.

It is expected that this scoping document will strengthen knowledge exchange on this topic, including exchange among an emerging network of researchers and experts working at the junction of the climate change, ICTs and development fields.

1. Contextualizing Climate Change: Where Do ICTs Stand?

1.1. The Evolution of the ICT and Climate Change Debate

Never before has humanity faced a global-scale natural challenge as imminent and as uncertain at the same time. Climate change is being felt around the world through the increased severity and frequency of climatic trends and extreme events that have may have critical consequences for the way populations achieve and sustain development.

Literature linking both potential and challenges of ICTs in the climate change field began to emerge at the beginning of the 2000s, preceded by some early explorations of the relation between the information society and the environment. Since then, it is possible to identify three distinctive, yet interrelated strands of the research in the field:

- **Sustainable development and the environment:** The first strand of research addresses broad issues concerning ICTs, sustainable development and the environment from a global perspective. It explores the use of ICTs in the context of development goals, in particular the achievement of the Millennium Development Goal (MDG) and targets related to ensuring environmental sustainability.

  Although literature in this area began to emerge at the end of the 90s coinciding with a growing awareness on environmental sustainability, it did not address climate change specifically. It rather identified key issues related to the negative and positive effects of ICTs in the field, including the potential of these technologies in monitoring the environment. This includes various reports that approached the growth of the information society from a more critical perspective, calling for environmental awareness and cradle-to-grave sustainability approaches.

- **Mitigation:** As awareness heightened on the negative effects of CO_2 emissions in the environment, climate change became the explicit focus of an increasing body of literature. The second strand is characterized by the emergence of more topic-specific and technical research covering aspects of climate change mitigation, and driven primarily by developed countries' priorities in the field.

  Within this strand, research focuses on the potential of ICTs towards CO_2 emission reduction, including a variety of highly innovative applications that aim at improving energy efficiency in the telecommunications, transportation, construction and services industries, among others. But within a context of increased international awareness over the magnitude of climate change and the human and economic impacts of extreme natural events (including the 2004 Asian tsunami), the release of Intergovernmental Panel on Climate Change's (IPCC) 2007 report was followed by a new growth of research in the field that reflected a shifting focus towards adaptation.

- **Adaptation and strategies:** This third strand is characterized by an increasing acknowledgement of developing country needs and priorities in the climate change field, and consequently, of the importance of adaptation issues. It emerged as literature began to reflect more in-depth explorations of the potential of ICTs in vulnerable environments, recognizing that climate change impacts, both chronic (over time) and acute (e.g. natural disasters) manifest more severely in developing contexts, magnifying existing vulnerabilities, poverty and resource deprivation.

This strand is also characterized by emerging evidence on the use of ICT applications in vulnerable contexts to climate change. Recent reports include examples and early anecdotal evidence on the potential of ICTs, particularly mobile phones, in adaptation strategies of developing countries, as well as examples of emerging applications that could help improve the access to environmental information for decision-making processes at local and national levels.

This emergence of this latter strand coincides with increased prioritization of climate change strategies in the international policy arena, particularly the design of National Adaptation Programs of Action (NAPAs) in least-developed countries (UNFCCC, 2010). At the same time, it reflects the increased interest of international organizations and donors working in the international development field, as the trends of research support indicate (*Annex 1*).

The following section develops in greater detail the overall evolution that literature at the intersection of ICTs, climate change and development has followed. Due to the fact that this field is still in its very early stages of exploration, some of the topics that emerged in the early literature continue to be relevant and addressed, albeit from new angles or levels of depth, in emerging sources. Therefore, the strands identified below do not constitute stages with an end-point but, rather, ongoing trends in the exploration of the links between ICTs, climate change and development.

(a) Sustainable Development & the Environment: A Global Approach

The links between sustainable development and the information society began to be explored in the late 90s (Felleman, 1997), as growing interest over the environment coincided with the unparalleled growth of the ICT sector. Issues related to the rapid expansion of ICTs and its potential effects began to be identified and addressed from a broad global perspective, increasingly in connection with the Millennium Development Goals (UN, 2010) and the achievement of environmental sustainability.

As research on the role of ICTs in development deepened, so did the links between their potential and issues such as water and sanitation, energy and transportation, and food security and agriculture (Tongia et al., 2005), while applications such as remote sensing, geographic information systems (GIS) and communication networks were increasingly linked to the effective monitoring and management of natural resources and to the implementation of sustainable development strategies.

The use of ICTs began to be explored in the context of environment and natural resource management (ENRM), livelihoods and health, as well as emerging biotechnologies and environmental remediation (Spence, 2003). At the same time, ICTs were recognized as key to harvest and analyze global meteorological data, including the use of radio-based and other telecommunication systems in the prediction and response to natural disasters (ITU, 2008).

Within this context, research began to explore the potential of environmental information systems (including the use of GIS applications) to help decision-makers monitor and evaluate the state of the environment, and introduced into the emerging debate the concepts of 'eco-efficiency' and 'eco-innovation', placing ICT applications at the centre of optimized processes aimed at reducing waste and pollution (Willard and Halder, 2003). Emerging research also identified the need to integrate traditional technologies such as radio, television and other Internet-based applications into the pursuit of sustainable development and environmental goals, as well as the need to promote a greater integration between these and national ICT policies (Willard and Halder, 2003).

Early on it became evident that literature in the field acknowledged both positive and negative aspects associated with the expanding information society. Illustrating this trend, the report titled "Sustainability at the Speed of Light" (WWF, 2002) suggested the need to avoid some of the mistakes that were made during the industrial revolution in terms of overlooking the effects of pollution and over-production of natural resources, integrating a sustainability approach throughout the production chain of emerging technologies, among others (WWF, 2002).

An increasing number of sources identified key areas of action needed to counter-balance the potential negative trends associated with ICTs in the environment. A series of analytical frameworks and research priorities that confirmed the need to harness the positive aspects of the information society for sustainable development purposes were developed (Willard and Halder, 2003), and research began to identify issues that would later form the core of the mitigation debate.

At this point, and well beyond the need to optimize business strategies, sources in the field recognized the importance of adopting a long-term systemic view on the relationship between innovation and sustainable development (Slob and van Lieshout, 2002, Willard and Halder, 2003).

The overall trend of the literature during this initial period was to assess the potential of the information society from a sustainability lens, questioning socio-economic patterns that focus solely on production and outputs while disregarding the potentially negative effects of the computer and telecommunication industries. Various reports introduced into the debate issues such as the environmental implications (even value) of the growth in services (as opposed to goods) production, the need to analyze the potential rebound effects of ICTs, as well as the need to assess the robustness of ICT systems (considering feedback mechanisms and cradle-to-grave perspectives) (WWF, 2002).

At the same time, sources in the field began to explore the role of information society policies vis-à-vis the environment, including the way in which these policies could address the demand side of consumerism (through measures that increase environmental awareness, laws or taxes), as well as the need to ensure greater coherence between sustainable development plans and strategies and those related to the information society at the national level (Willard and Halder, 2003).

Although this initial strand of literature did not refer specifically to the issue of climate change, it did present an environmentally-conscious perspective that would strengthen as the expansion of the ICT sector continued. This included identifying the close links that exists between socio-economic and ecological dimensions of the ICT industry, which in turn laid the foundations of a debate that would gradually evolve into the role of ICTs and climate change mitigation, and ultimately, adaptation.

The debate over sustainability and the effects of ICTs on the environment was soon joined by a new research strand focused on CO_2 emissions and the role of ICT applications in their reduction. Literature began to refer specifically to the challenges posed by climate change, and to respond to the growing interest of developed countries in mitigation.

(b) Mitigation: Developed Countries' Focus

Based on the recognition of the risks and uncertainties associated with the long-term impacts of ICTs in the environment, literature in the field began to evolve quickly from broader explorations of sustainability issues, to more focused research on the potential of ICTs to reduce CO_2 emissions.

Acknowledging that the ICT sector contributes directly around 2.5 per cent of greenhouse gases (GHGs), but that it also has the potential to help reduce the other 97.5 per cent of emissions in other sectors through the abatement of existing applications that generate CO_2 (ITU, 2008), the International Telecommunication Union (ITU) began to play a prominent role in the field. Exploring the direct, indirect and systemic effects of ICTs in carbon emissions, ITU suggested actions aimed at reducing the sector's energy requirements, fostering ICT use for carbon displacement (i.e. telework, dematerialization), and providing technology to implement and monitor reductions in other sectors of the economy.

The analysis on the potential of specific applications was deepened through reports commissioned by organizations such as the WWF (World Wide Fund for Nature) and the European Telecom Network Operators (ETNO), presenting the opportunities posed by ICTs through dematerialization (e.g. Internet-based distribution systems and their effect on CO_2 emissions reduction), transportation substitution and efficiency (e.g. telework and telematics), increased efficiency in industry and buildings (e.g. e-commerce, reduced need of retail space), as well as in production and planning (e.g. Internet-based supply-chains), including measures to ensure sustainable communities and city planning with the support of ICT tools (Pamlin and Thorslund, 2004b, 2005, WWF, 2008, Mingay and Pamlin, 2008).

The above-mentioned research trends, as well as the 2006 release of the Stern Review on the Economics of Climate Change discussing the effect of global warming on the world economy, laid the ground for the launching of the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007). This report suggested that over the next 50 years, climate change would probably be the single-most disruptive factor on economic growth and development.

While developed nations increased their focus on shaping policies and implementing solutions to decouple economic growth from increased industrial production and energy consumption (EC, 2007), research to be undertaken towards the design of comprehensive strategies to reduce emissions with the support of ICTs (WEF, 2008, CG, 2008). Recent sources have also presented innovative approaches in areas such as the potential of mobile technology for carbon efficiency (GSMA, 2009) and the use of ICTs to transform travel and mobility (SDC, 2010).

Although these sources focused on addressing the priorities of developed countries, including the provision of guidelines for the design of environmental strategies in OECD countries, they also began to acknowledge the importance of exploring the role of ICTs in emerging economies such as China and India. By 2008, research suggested the opportunity for developing countries to leapfrog the "CO_2-heavy, IT-poor solutions" of developed nations, through new and more efficient technologies and innovative policy approaches (Mingay and Pamlin, 2008).

Likewise, research in this area has suggested the need for a strategic planning framework in order to enhance the capacity of countries to use ICTs for environmental management. Following-up on this last point, ITU developed an e-Environment Toolkit and Readiness Index (EERI) (ITU, 2009a) aimed at facilitating the assessment of ICT's contribution to the reduction of energy consumption and greenhouse gas emissions, as part of national climate change strategies.

At this point, climate change was recognized as a priority in the agenda of both developed and developing countries. The increased awareness over its potential impacts translated into a new wave of research on the role of ICTs in adaptation, and in more holistic and inclusive climate change strategies.

(c) Adaptation and Climate Change Strategies: Developing Countries' Priorities

Research on the role of ICTs in local adaptation processes can be linked to prior work conducted in the fields of the information society and sustainability. These earlier studies explored the role of communication in natural resource management (NRM), including the potential and challenges associated with the use of new technologies in developing regions.

The findings of this initial research were a key contribution to what later developed into the climate change adaptation debate, as they identified the importance of communication processes in local natural resource management, as well as the potential role of ICTs in local livelihoods (e.g. the role of Internet radio and networking in indigenous forest management, in the creation of local organic markets, and in the provision of environmental education, among others) (FAO, 2003). Considering the high dependence on natural resources that characterizes developing economies, these factors lay at the core of the ability of vulnerable communities to adjust and adapt to the impacts of climate change.

From the mid 2000s, a series of documents began to emerge with a focus on adaptation and on the ability of governance processes to foster innovation and multi-stakeholder inclusion in climate change strategies (MacLean and St. Arnaud, 2008). The 'effects of ICTs' thus began to encompass not only the role of ICTs in mitigation, but also their potential in adaptation strategies and other areas of climate change-related concern for developing regions.

The growing interest in adaptation issues emerged along with recognition of the necessity to better understand the climate change needs and priorities of developing regions. Consequently, more development-oriented concepts began to be introduced by authors in the field, reflecting greater awareness of the differentiated impacts that climate change has in these countries. The direct effects of ICTs on the environment in this domain (i.e. separate from those related to emissions and mitigation) were portrayed in the literature as related to their use to monitor, measure and assess climate change; indirect effects as those emerging from the use of ICTs to increase awareness and facilitate public dialogue (e.g. via Web 2.0 and social networking), and systemic effects as the use of ICTs as enablers of "networked governance", key to adapting to climate change and achieving sustainable development (MacLean, 2008).

In-depth research was also conducted on the key ICT trends and impacts of ICTs on the environment with a particular emphasis on developing country perspectives (Labelle et al., 2008). Key sources in this research strand provide comprehensive accounts of ICT applications in all aspects of environmental management (from observation to analysis, planning and protection) (ibid), including guidelines and recommendations that pertain to developing country needs in the climate change field.

But the research addressing adaptation has not been limited to analyzing theoretical potential. It has increasingly involved evidence of ICT use within climate change actions in vulnerable regions.

By the mid 2000s, evidence on the role of ICT applications such as mobile phones in environmental action began to emerge from developing countries. For example, the "M-vironment" approach for poverty reduction and environmental protection in Kenya (Mungai, 2005) and the use of SMS to enable Filipino citizens to report air pollution in Manila bay ((Dongtotsang and Sagun, 2006) exemplified the opportunities that might be associated with e-environment initiatives more broadly, the potential for ICTs to enable environmental sustainability as part of national sustainable development strategies, and evidenced a broader debate about ICTs closely linked with sustainable development policies in developing countries.

Several areas of potential associated with the use of mobile telephony began to be identified by experts and practitioners, including their role in enabling financial sustainability for environmental protection efforts, awareness raising and information exchange, as well as employment creation and the protection of local livelihoods. These issues started to generate a further wave of research among both ICT and development advocates coinciding with, and in partly due to, the rapid expansion of mobile subscribers, which would reach 4 billion by the end of 2008 with a penetration level eight times higher than in 2000 in the developing world (UNCTAD, 2009).

Alongside recognising the potential – and increasingly the actuality – of ICTs to contribute, literature in the field started to acknowledge more explicitly the challenges faced by developing countries both in terms of environmental action and ICT use. And it supplemented this with some initial ideas on action strategies such as the importance of promoting citizen involvement and community-based initiatives enabled through different applications.

In September 2009, the Building Communication Opportunities (BCO) Alliance, a partnership of eleven development agencies working on information, communications and development, launched a report focused on climate change adaptation and the role of ICTs (Kalas and Finlay, 2009). The document reflects the progress that has been made in the field, as it provides practical cases from Africa, Asia and Latin America that demonstrate the ways in which these technologies are being used to address the challenges posed by adaptation.

Literature Summary

From broad global explorations on sustainability and the environment, to the increasing focus on the effects of ICTs in CO_2 emissions and the need to mitigate climate change impacts, to growing awareness of the adaptation needs and priorities of developing regions, literature at the intersection of the ICTs, climate change and development fields has been characterized by an ongoing, non-linear flux of complex topics.

As research continues to evolve, this non-exhaustive review of literature reveals that the debate is still in its early stages. Much remains to be done, documented and analyzed particularly in regards with the role of ICTs in marginalized and vulnerable areas; those hardest hit by the impacts of climate change.

In spite of the complexity, inherent to the systemic, global and uncertain nature of climate change, the additions to the literature over time can be summarised as shown in **Figure 1**.

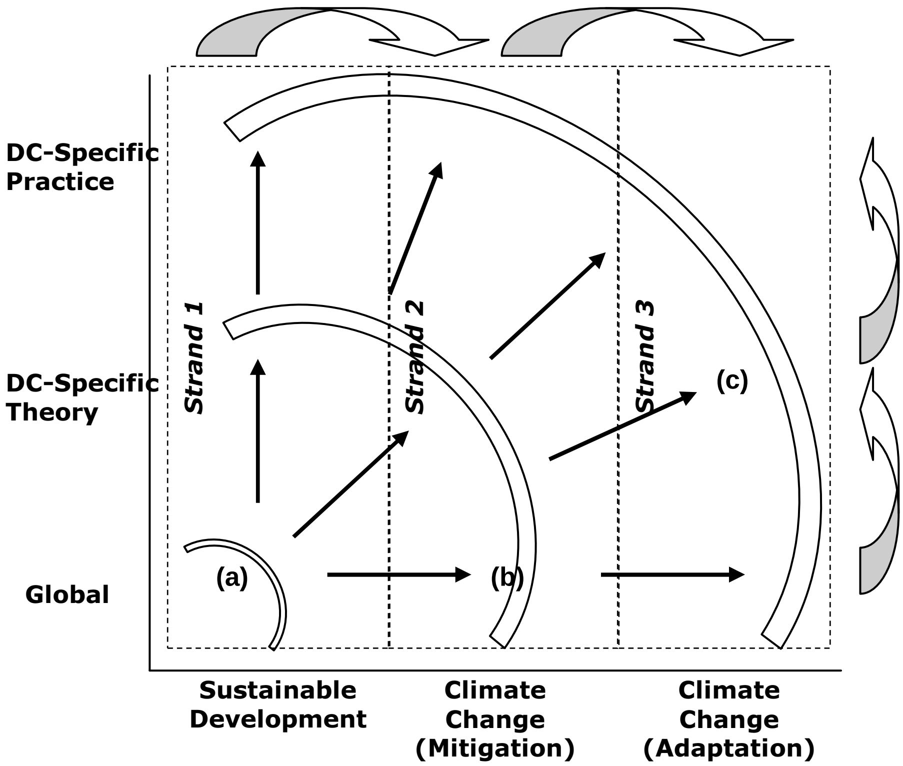

Figure 1: Additions to Literature on ICTs, Climate Change and Development Over Time

The starting point for each of the literature strands described above is indicated in the diagram, and they are linked to each other by a dynamic flux of topics and ideas (represented by the arrows and semi-circles, which illustrate the flux between (a) Sustainable Development, (b) Climate Change mitigation, and (c), Climate Change Adaptation).

The ***x axis*** reflects the evolving focus of research on ICTs and climate change around the core topics of sustainable development, which was then supplemented by an interest in mitigation, subsequently followed by discussion about climate change adaptation. On the ***y axis***, the diagram reflects the development of literature from a global approach, to theorisation about the potential of ICTs (first focused on developed countries, incrementally on developing), and the emergence of ICT and climate change praxis, more recently in developing contexts.

This diagram provides a broad categorization of the research conducted in a growing field of inquiry, a field that lies at the intersection of three complex areas and that in many senses can be considered "a moving target" for the conduct of academic research. As scientific and anecdotal evidence on the impacts of climate change continue to emerge, and new and more advanced technologies are being developed, the role and potential of ICTs in climate change strategies will continue to transform.

But although the topics have evolved and the research has deepened over time, the core issues of sustainability and monitoring, mitigation, adaptation and the need for holistic climate change strategies still persist at the core of an ongoing, and ever more relevant debate.

The following section will address some of the key challenges and research gaps that have been identified through the review of literature in the field. They constitute issues for consideration as the study of the potential of ICTs in climate change, particularly in developing contexts, continues to evolve.

1.2. From Theory to Practice: Identifying the Challenges

A review of the additions to the literature over time in the field of ICTs, climate change and development reveals not only the different issues and areas of study that have emerged since research began to be conducted in this field. It also suggests that, as evidence surfaces on the use of ICTs in response to the effects of climate change, research is starting to integrate the analysis of experiences from the field, and thus to reveal the challenges that, in practice, innovative approaches to climate change are facing.

As the literature has started to point out, some of these challenges are closely related to the complexity of mitigation, monitoring and adaptation actions within contexts - especially in developing countries - where poverty further exacerbates climate change vulnerabilities.

Building on the previous section, some of the key challenges and research gaps found have been classified according to the three main research strands identified before:

(a) Sustainable Development & the Environment

- **The challenges of 'decoupling':** Since the Rio Summit held in 1992, OECD countries have been discussing the need to decouple economic growth from environmental degradation, with much debate around the potentially-differing interests of both developed and developing countries (OECD, 2001). Without a solution yet in sight, and in a context of increased frequency and severity of climate-related events, this discussion has acquired renewed relevance. Many challenges remain in terms of establishing the role and potential of ICTs in climate change; not least its role in low-carbon growth strategies. There is a recognized need to retain the developmental benefits that its use may bring in vulnerable contexts, without losing sight of the need to re-think growth patterns, from cradle-to-grave processes to consumers' behavior.

- **Monitoring and local empowerment:** As available sources indicate, the use of ICTs is well established in the environmental monitoring field, especially as it relates to weather forecasting, climate monitoring, and predicting and detecting the effects of natural disasters, among others (ITU, 2008). However, literature in the field also suggests that most such initiatives have been led by and based on developed countries, and collaboration with developing country counterparts in terms of knowledge exchange and capacity building still has a long way to go.

  Existing challenges also relate to the fact that meteorological data, forecasts and analysis are often inaccessible in vulnerable environments that need them the most, due to lack not only of adequate infrastructure but also of the economic and human resources required to interpret the data and take adequate action. Capacity building, local empowerment and effective North-South collaboration remain both a challenge and an opportunity, particularly as it relates to the monitoring field.

- **Enabling participation:** The global scale of climate change impacts poses the challenge of achieving effective multi-stakeholder involvement in actions in the field; but it also offers the opportunity for greater citizen engagement through the use of ICT tools. Some examples have begun to emerge on the use of mobile phones and Web 2.0 tools in social activism and mobilization, accountability and monitoring of climate change issues (Heimbuch, 2009). However, further analysis is required on the risk and potentials of this trend in regards to citizen participation and policy influence.

(b) Mitigation

- **Avoiding the 'mitigation divide':** The significant body of literature that focuses on the role of ICTs in mitigation evidences not only the fast pace of development towards 'cleaner', 'smarter' and more efficient technologies, but also the emerging threat of broadening the digital divide. If mitigation goals are solely associated with the role of developed countries in reducing CO_2 emissions, developing countries face the risk of lagging behind a new wave of technical developments that have been, for the most part, focused on the needs and climate change priorities of developed nations. The challenge lies, therefore, in ensuring that developing countries are considered and play a role in emerging trends of dematerialization, travel substitution, building and energy efficiency, among others.

- **Fostering 'green' economic opportunities:** The analysis of ICTs' role in mitigation has been dominated by the identification and analysis of applications, as well as their technical robustness and effectiveness in lessening the causes of climate change (WEF, 2008, ITU, 2007). However, as the impacts of climate change deepen, so does the need to explore environmentally-sustainable business practices and models, including 'green' entrepreneurship in developing countries, which could foster the transition towards a less carbon-intensive society. This could be particularly relevant for developing contexts seeking to reduce their dependence on natural resources and move towards a knowledge-based economy (e.g. building on dematerialization trends, and promoting emerging creative and cultural industries).

- **Integrating low-cost technologies:** As access to ICTs increases at the global level (UNCTAD, 2009), technologies become deeply embedded into the socio-economic fabric of both developed and developing societies. Future and ongoing mitigation actions face the challenge of further integrating the wide spread of low-cost technologies into their strategies, including the consideration of potential rebound effects[1] and the growing rates of e-waste.

[1] "The rebound effect refers to the idea that some or all of the expected reductions in energy consumption as a result of energy efficiency improvements are offset by an increasing demand for energy services, arising from reductions in the effective price of energy services resulting from those improvements" (Dagoumas & Baker, 2009).

(c) Adaptation and Strategies

- **Awareness raising and capacity building:** Research in the field has recognized the need to increase the awareness of decision makers in terms of benefits of using ICTs to deal with environmental issues, as well as build capacity on the use of these tools among the various levels of stakeholders involved in climate change responses.

- **Multi-stakeholder engagement:** The magnitude of climate change impacts, especially in vulnerable regions already affected by poverty and marginalization, calls for strategies that integrate a variety of stakeholders. While adaptation actions are often led and undertaken at the community level (IIED, 2009), emerging experiences indicate the importance of engaging the private sector in ICT-based solutions for adapting to climate change, as well as integrating these actions as part of national e-government efforts (Labelle et al., 2008).

- **Enabling policy frameworks:** In the broader context of climate change strategy implementation, challenges include the need for a clearer role of public policies and regulatory frameworks; overcoming the uneven access to ICTs in developing regions; the lack of governance accountability and delivery; as well as the need to foster local appropriation and use of the information through adequate translation and understandable terminology (Kalas and Finlay, 2009 p. 45).

- **Articulation of efforts and lessons learned:** Despite the fact that adaptation is a complex, multi-dimensional issue, there is - as authors in the field point out (Kalas and Finlay, 2009) - no need to re-invent the wheel in terms of ICTs' role in climate change strategies, but rather to build on lessons learned and good practices already identified in ICT for development approaches. In this sense, the challenge lies in the ability of climate change and ICT stakeholders to articulate their efforts, and to build on relevant lessons and experiences in order to ensure that the use of ICT effectively contributes to strengthen the capacity of local communities to better prepare for, respond and adapt to the changing climate.

2. ICTs, Climate Change and Development: An Overview

Having undertaking a largely-chronological review of the emerging literature and debate in the field of ICTs, climate change and development, we now move to develop an overall model of the key contribution that ICTs can make in relation to climate change. Via further literature analysis, we identify four main areas that are pivotal for understanding the role and potential of these tools in climate change responses. From actions to mitigate its causes, monitor its progress and adapt to its effects; to holistic strategies that integrate stakeholders from all sectors, the study of ICTs in climate change requires an overview of the main components that lie at the intersection of these fields.

2.1. The Main Components of the Climate Change and ICT Debate

(a) Mitigation

As scientific evidence of climate change continues to emerge and awareness to increase over the rapid accumulation of greenhouse gases (primarily CO_2), interest in the impact of ICTs on the environment has escalated, and along with it, research on their potential role in both contributing to and mitigating climate change.

In order to understand the potential of ICTs in the climate change field it is important to start by identifying the areas in which they have an effect. The following categories have been suggested by authors in the field in their analysis of ICTs and climate change mitigation (ITU, 2008, Labelle et al., 2008, Houghton, 2009), and include the following issues:

- **Direct impacts:** This relates to the impact of ICTs' production, operation and disposal on the environment, including the energy required to make and run the technology, and the generation of e-waste. Some authors estimate the direct impact of the production and use of ICT equipment to be equivalent to 1%-3% of global CO_2 emissions (Houghton, 2009). Others refer to these impacts as the 'primary effects' of the information society, namely those associated with the cradle-to-grave impacts of the computer and telecommunication industries (Willard and Halder, 2003).

- **Indirect impacts:** This relates to the impacts of ICT applications, for example smart grids, intelligent transport systems or intelligent buildings. Emerging literature is exploring the potential positive impacts of these tools through processes such as de-materialization, including e-commerce and e-mail, transport and travel substitution through mechanisms such as telework or e-presence, as well as contributions to energy efficiency through improved physical products or processes.

- **Systemic or rebound impacts:** Systemic impacts refer to largely behavioral effects that humans develop as a result of ICT use (Labelle et al., 2008), including new habits and consumption patterns that arise through the use of these tools and services (Pamlin and Szomolanyi, 2005). Some authors also include in this category the 'rebound' impacts of the technology, which refer to the impacts enabled by the two other types described above (direct and indirect), which can counteract the positive effects (or eco-efficiencies) achieved through the use of ICTs (Houghton, 2009). (For example, more efficient applications lead to lower energy costs, and a consequent increase in the use of or demand for a product or service, leading back to further energy consumption, transportation or production.)

These levels constitute useful categorizations that reflect the complexity of ICT's potential in the field, and thus the need for a more encompassing understanding of their role.

With that aim, is possible to identify four main areas in which the use of ICTs intersects with climate change mitigation and development, offering potential towards the reduction of CO_2 emissions while allowing for concrete actions in both developed and developing contexts:

- **Physical consumption:** Refers to the role of ICTs in modifying current consumption patterns, including dematerialisation (or the replacement of "atoms" with "bits", including online publishing and digitization of movies and music) and journey substitution (through the use of e-mail, phone calls, text messaging, videoconferencing, among others) (ITU, 2008).

- **Physical production:** Refers to the role of ICTs in the reduction of physical production through the shift towards the knowledge economy, in which the effective utilization of intangible assets such as knowledge, skills and innovative potential are key for competitive advantage (Brinkley, 2006). This shift also involves a growing number of organizations using new technologies in process and organizational innovation and knowledge management practices.

- **Energy generation and distribution:** Refers to the role of ICTs in smart grids and power sources, in order to contribute to higher efficiency in generation and distribution (Tongia et al., 2005, CG, 2008).

- **Energy use:** Refers to the role of ICTs in the manufacture and use of 'green' ICTs, including smart motors and energy efficient logistics, smart buildings (which allow the remote management of sites though a combination of networked devices such as intelligent thermostats, presence sensors, lighting sensors and controls, among others) (Labelle et al., 2008).and transportation systems (i.e. "eco-driving", congestion charging, traffic management and parking optimization) (ITU, 2007). As noted above, though, this also covers the mitigation downside of ICTs in terms of energy use of ICT production and operation.

The acknowledgement of these effects should be at the core of any analysis of the role of ICTs in climate change mitigation, as they allow a broader understanding of both the opportunities and challenges associated with the use of these tools to lessen the causes of climate change.

(b) Monitoring

As noted above, ICTs play an important role in monitoring the environment. ICT applications help to observe, describe, record and understand weather and climate-related patterns and events, and are pivotal in environmental research, comparative analysis, real-time data capturing and analysis, as well as the visualization of environmental information (Labelle et al., 2008).

A growing number of experiences are available of emerging applications using remote sensing, GIS, earth browsers such as Google Earth and Visual Earth, Web-based clearing houses for disseminating information and capacity-building, as well as for environmental analysis and modeling, among others (eoPortal, 2010, Climateprediction.net, 2010, TEAM, 2010, UNEP, 2010a, USAID, 2010).

These emerging experiences show that use of ICT tools not only facilitates understanding of the complex physical and biological systems that are part of the environment (Labelle et al., 2008), but also provides important opportunities to further disseminate and broaden access to information that is critical to support decision-making processes. At the same time, ICTs such as mobile phones can allow the active engagement of communities in the monitoring of natural resources, documenting climate changes and their effects on local livelihoods and the environment, while strengthening the accountability of actions and processes in the field.

Within this context, it is possible to highlight three areas in which the use of ICTs intersects with climate change monitoring and development, which broadly follow a typical information systems lifecycle (e.g. Heeks, 2006):

- **Data capture:** This area includes the use of ICTs for information gathering by local actors, which can help strengthen local capacities and skills in the use of these tools while fostering the monitoring of context-relevant information. It would also include areas such as remote sensing and earth observation.

- **Data processing:** This involves the use of ICTs, including software and computer programs to record, summarize, analyze or convert data into usable information.

- **Data presentation and dissemination:** Based on the results of data capture and processing, this area involves the presentation and dissemination of relevant information to actors and stakeholders involved in the climate change field. This stage is key in order to ensure the use of data collected within decision-making processes, as well as for climate change awareness raising at both the public and the political level.

Environmental monitoring is closely linked to actions in both the mitigation and adaptation fields, as well as to the implementation of effective climate change strategies. The ongoing collection, processing, presentation and dissemination of information is at the core of climate change efforts, and can be seen as a transversal issue that takes place at a variety of levels, involving a wide range of actors and technologies.

(c) Adaptation

Since its emergence in 1990, the Intergovernmental Panel on Climate Change - the leading body for the assessment of climate change - has presented serious scientific grounds for concern about the effects of human actions on the global climate since the industrial revolution (Jepma and Munasinghe, 1998, p. 2). Despite the fact that future predictions are very complex due to large gaps in scientific, economic, social and technological knowledge (ibid), climate models indicate overall negative impacts particularly in the poorest regions of the world (IPCC, 2007).

Thus, although climate change is a global occurrence, it has differentiated effects that depend largely on the degree of exposure and susceptibility of different contexts. Equity is at the core of this debate. The differentiated role and priorities of developed and developing nations have been addressed by a growing body of literature that links climate change with sustainable development, indicating the magnifying effect that unpredictable weather patterns and more severe events are having on the socio-economic stresses felt by vulnerable populations (IPCC, 2007, Kalas and Finlay, 2009).

Available literature suggest that the effects of regional climatic variations and seasonal changes are expected to increase and be manifest in more vulnerable ecosystems and natural habitats (e.g. deforestation, desertification, land degradation), scarce water resources (e.g. melting glaciers, salinization and pollution of fresh water sources), decrease in agricultural production and heightened food insecurity, new health threats (e.g. heat- and cold-related illness, changing incidence of vector-borne and infectious diseases), as well as risks to human infrastructure and habitats (e.g. negative effects on transportation systems, increased population displacement and migration) (Parry et al., 2007, IPCC, 2007, Dumas and Kakabadse, 2008).

At the same time, and due to the limitations that developing countries already face at the socio-economic, scientific and technological levels, it is expected that increases in floods and droughts, severe storms, inundation of coastal areas, outbreaks of diseases and threats to agriculture production, among others, will affect them more severely. There is ongoing debate on whether acute events, in particular, are climate change-related or merely climate-related. However, these nuances are largely irrelevant to the communities that suffer them, and which are seeking all necessary means to both cope with, and adapt to, such events.

In 2009 ITU conducted its first international symposium on climate change in a developing country seeking to raise awareness and visibility for the issues that are most relevant to these regions of the world (ITU, 2009b). Key findings that emerged from that process and from related literature (Dumas and Kakabadse, 2008, PCL, 2009) include challenges related to deforestation and agricultural dependence, water security and the rapid melting of glaciers, as well as the devastating impacts of hurricanes and other natural disasters in already impoverished areas.

But the identification of these challenges only allows a partial understanding of the complex vulnerabilities that characterize developing regions, and of the way in which prevailing poverty increases the exposure and potential impact of climatic changes. The effectiveness of adaptation actions in these regions is also conditioned by availability of fewer resources, weaker institutional capacity, and a smaller pool of skilled human resources to draw on in times of crisis (Jepma and Munasinghe, 1998 p. 73).

As a response to this complexity, the analysis of systemic vulnerabilities has been conducted in depth from many different approaches in both the social and natural science fields, aiming to obtain a better understanding of the needs and priorities prevailing in vulnerable contexts to climate change.

One such approach was developed by Abraham Maslow (1943), who suggested a hierarchy of human needs based on two main groupings: deficiency needs (which correspond to physiological, safety/ security, social and esteem needs) and growth needs. He argued that the deficiency needs must be met before moving to the next higher level, where the individual could achieve the realization of its full potential. In practice, it is possible for various levels of needs to interact, occur simultaneously/ or in parallel. If we use this as the basis for understanding climate change responses, we recognise additional complexity in designing and implementing effective climate change strategies. Additionally, developing contexts already face systemic vulnerabilities associated with endemic poverty issues, which exacerbate the intensity of the needs felt when a natural disaster takes place or erratic climate trends affect local livelihoods.

At a general level, the recognition of different levels of needs can help to better understand the diversity of challenges that developing countries face when confronted with the impacts of climate change. This understanding can also help to better tailor climate change strategies, and at the same time, identify potential areas for ICT-supported actions.

Literature in the field has started to provide important indications of the potential of ICT tools in adaptation processes of vulnerable communities. Among them, access to locally relevant information and knowledge needed to reduce risk and vulnerability, strengthening the voice of the most vulnerable within decision making processes and towards greater political accountability, as well as networking and knowledge sharing to disseminate good practices and foster multi-stakeholder partnerships (Kalas and Finlay, 2009).

Based the recognition of existing vulnerabilities, needs and challenges, the potential of ICTs in processes of climate change adaptation can be associated with the following key livelihood assets which can also, conversely, be seen as key areas of vulnerability that climate change may induce or further impair:

- **Socio-political:** This include the potential of ICTs in fostering inclusiveness and participation in the design and implementation of adaptation processes, as well as opportunities for capacity building, training, social networking and awareness raising.

- **Livelihoods and finance:** This area refers to the potential of ICT within productive processes and local livelihood activities, including micro-enterprise development, access to credit and new financial transaction mechanisms (Duncombe and Boateng, 2009). In part this represents the ability of individual communities and whole nations to develop ICT-based livelihoods, which may be more resilient in the face of climate change-induced shocks.

- **Health:** Climate change-induced extreme weather events and changing climatic patterns have been associated with various health challenges that can occur as a result of greater prevalence of some vector-borne (i.e. malaria and dengue) and water-borne diseases, heat, declining food security and decreased availability of potable water (IISD, 2005). Within this context, ICTs have the potential to enable information sharing, awareness raising and capacity building on the main health threats related to climate change, enabling effective prevention and response.

- **Habitat (settlement and displacement):** In terms of human settlements, literature indicates that climate change could trigger large-scale migrations and redistributions of people placing heavy demands on urban infrastructures (Hardy, 2003). Populations displaced due to sea-level rise, drought, desertification or extensive flooding, as well as climatic changes such as increased patterns of precipitation, will have an effect on the existing capacity of flood and drainage systems, built environment, energy and transportation, among others. ICT applications could play an important role in urban planning (i.e. GIS), and in monitoring and provision of relevant environmental information to support decision-making processes contributing to the adaptation of human habitats.

- **Food (agriculture):** The role of ICTs in enhancing food security and supporting rural livelihoods, heavily dependent on agriculture, is a topic of increasing interest in the climate change field. The potential of ICTs in this field ranges from the strengthening of agricultural and livestock production systems (i.e through information about pest and disease control, planting dates, seed varieties and irrigation applications, and early warning systems), to improving market access (through information on prices and consumer trends) and capacity building opportunities for local farmers (Stienen et al., 2007).

- **Water:** According to the IPCC, climate change could have a strong impact on water resources, from increased flood magnitude and frequency due to increased precipitation events, to streamflow decrease and drought due to heavier evaporation (IPCC, 2001). Possible impacts also include the degradation of water quality due to increased temperatures and pollutants, which could have devastating effects on the livelihood resources of both rural and urban communities, while restricting their adaptive capacity. Areas in which ICTs could make a contribution include the improvement of water resource management techniques, monitoring of water resources and awareness raising.

But despite the link between climate change and ICTs in developing regions being increasingly acknowledged by authors and stakeholders, further analysis is required on the impact that these tools can have on vulnerabilities and livelihood options in the context of climate change.

This includes the analysis of their enabling role with respect to measuring, informing and networking, deciding (i.e. predicting/early warning, planning, short-term coping and long-term adapting measures), transacting, producing and mobilizing, within adaptive processes.

Without explicit consideration of the development challenges and resource limitations faced by developing countries, which ultimately determine the degree of vulnerability of any given context to climate change, the exploration of ICT potential runs the risk of being conducted in a vacuum, and of being disconnected from policy making processes and climate change strategies.

(d) Strategy

As an increasing number of developing countries advance in the preparation of National Adaptation Programs (NAPAs) through the UN Framework Convention on Climate Change process (2010, Reid et al., 2009), the need to identify and address climate change needs and design adequate strategies is becoming a priority in the international environmental agenda.

The potential of ICTs within these strategies can be explored around five main areas of action whose effective implementation can be enabled by the use of these tools, namely:
carbon markets, decision-making processes, policy networks, awareness and capacity building, and technology transfer.

From contributing to the efficiency and monitoring of carbon markets, fostering inclusion and participation in decision making process and policy networks, and fostering public awareness and capacity building on key issues related to climate change, ICTs could complement and strengthen strategies in this field.

But the design of successful climate change strategies that integrate the role of ICTs requires not only the identification of the potential offered by these tools, but also of the challenges associated with their use and adoption.

As the factors identified above evidence, many of these challenges are associated with the planning and implementation of strategies in vulnerable contexts characterized by resource and asset constraints. Some of them have been reflected to different extents in the literature of the field, and include the availability of trained personnel, especially managers, planners and technicians (Labelle et al., 2008), and the restrictive cost of some applications.

Physical infrastructure remains a limiting factor in many remote regions of the developing world, especially in mountainous and marginalized areas (Schild, 2008). Although mobile telephony remains generally more accessible than PCs and the Internet in these countries (UNCTAD, 2009), challenges include broader adoption of broadband mobile technologies and availability of spectrum.

At a policy level, the interpretation and effective use of environmental information in climate change strategies requires not only accessible sources and the presentation of context-relevant information, but also the establishment of appropriate channels for policy influence and awareness raising. An additional challenge is the integration of e-environment applications and practices into national development planning (Labelle et al., 2008), including the adoption of holistic strategies that recognize the close links and feedbacks that exist between climate change mitigation, monitoring and adaptation, and sustainable development.

The challenges mentioned thus far represent only a small portion of a complex and evolving debate over the role of ICTs in climate change. However, the analysis indicates that the areas of mitigation, monitoring, adaptation and strategies, and the close links that exist between them, are fundamental for understanding the potential of these technologies within the changing climate.

2.2. ICTs, Climate Change and Development: Overview Model

Through analysis of key literature on ICTs, climate change and development, we have identified four main areas in which ICTs relate to climate change; namely mitigation, monitoring, adaptation and strategy. Based on the more detailed analysis conducted above, we can build an overview model (see Figure 2) which summarises the various roles that ICTs can theoretically – and increasingly in practice – play; such roles being largely but not exclusively positive.

The model we present in Figure 2 illustrates the main components and links that characterize this emerging field. It should be seen so much as a reflection of what has already happened, but as an aid to identification of new areas of analysis on the role and potential of ICTs, particularly in developing regions. It can thus be seen not only as an overview guide to past and future research in ICTs, climate change and development, but also as a strategic guide which identifies which areas need to be included when designing policies or strategies to better prepare, respond and adapt to the impacts of both chronic and acute climate change.

Given the fact that the intersection between ICTs, climate change and development is a new field of enquiry, the model should be seen as providing a broad overview of key issues and links rather than as an exhaustive account of topics. It will continue to evolve as a tool for analysis as the field advances.

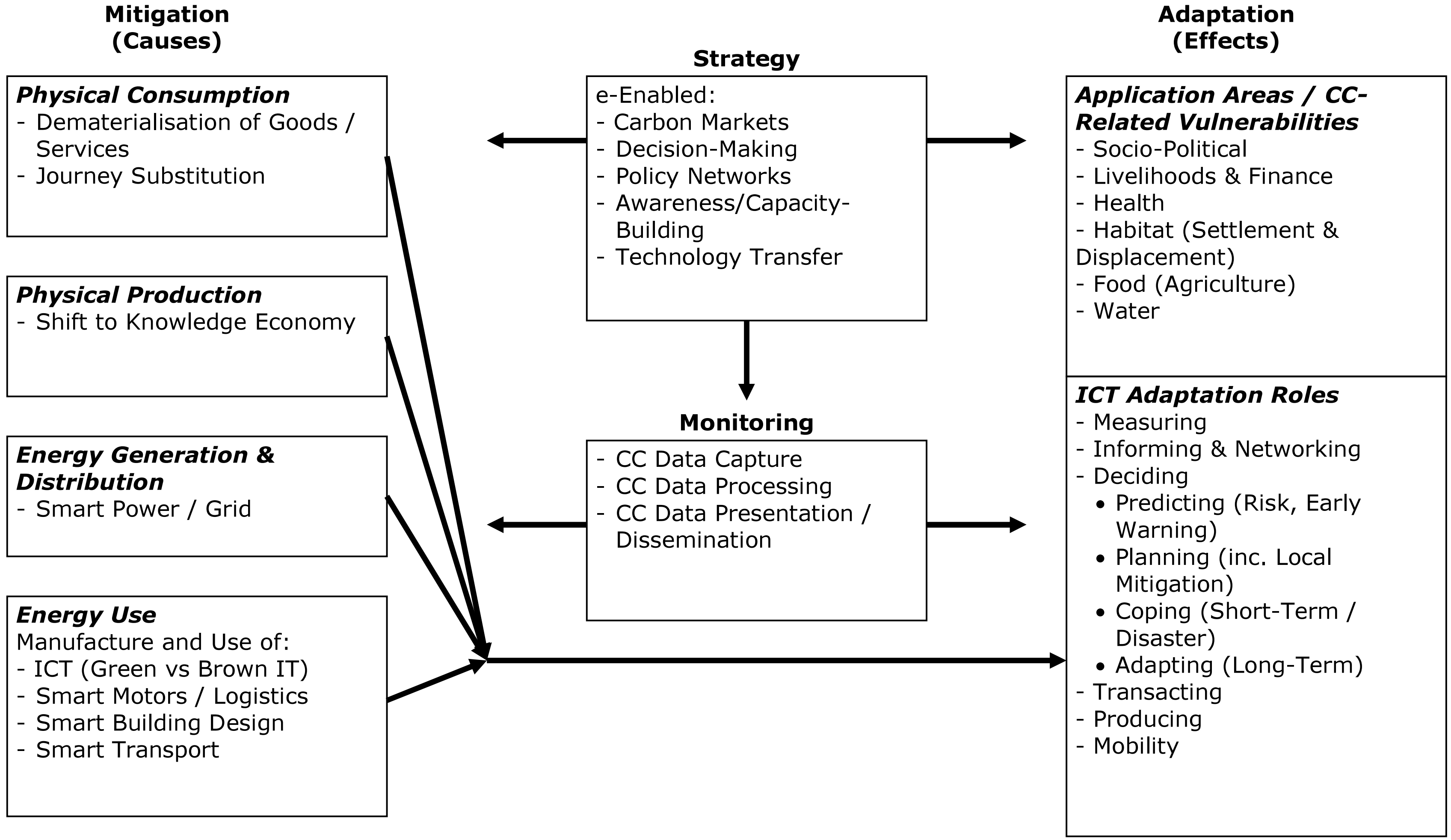

Figure 2: Overview Model on ICTs, Climate Change and Development

3. Emerging Experiences from Developing Countries

In our earlier analysis of literature trends in Section 1, we noted that material on actual practice in developing countries was a relatively recent addition to the field. Nonetheless, it is an addition that we should take note of. Thus, having just presented a relatively conceptual overview of ICTs in the climate change field (including the main issues and priorities of developing countries), we will now present some brief examples to help illustrate real-world applications of ICTs in the field.

The examples included have been identified from the available literature, and refer to cases of technology use in vulnerable contexts of Asia, Africa and Latin America. Because literature specifically addressing ICTs, climate change and development is at present rather sparse, we have perforce spread the net a little wider, to also draw on work that falls within the developing country-specific practice part of "Strand 1" of Figure 1 as well as equivalent parts in the other two strands. The examples are organized according to the main areas of analysis identified by the Figure 2 overview model.

(a) Mitigation and Monitoring

Some of the direct effects of ICTs, particularly the issue of e-waste generated by the ICT industry, are being increasingly addressed by developing countries. In an attempt to identify environmentally-responsible and -sustainable solutions to the problem of e-waste, SUR Corporation, with the support of IDRC, set up a regional platform that promotes the proper management and disposal of e-waste in Latin America and the Caribbean through applied research, capacity building and communications, including the exploration of social business opportunities offered by ICT recycling (RELAC, 2010).

At the same time, the protection of ecosystems and biodiversity is an area where the use of ICTs, in particular through GIS and remote sensing applications, is rapidly spreading. Several examples of Web-based applications reflect the growing adoption of remote sensing and other geo-information tools in the fields of sustainable agriculture, conservation of ecosystems and understanding the impact of climate change on the environment.

Specific applications have been developed in order to provide climate models and predictions, with the aim of helping inform decision-making processes and raise awareness on the magnitude of climatic effects on critical resources. With similar aims, Google maps are being used to present illustrations, satellite images and photographs, as well as other interactive media that depicts and describes human impacts on the environment (both past and present) (UNEP, 2010b, Climateprediction.net, 2010).

Likewise, ICTs are being used to generate real-time data to monitor long-term trends in tropical biodiversity. TEAM Network is an example of a global network that integrates field-data collection with the design of early warning systems to guide conservation action. Local teams based in developing country field sites use mobile technologies (smart phones and EcoPDAs) to facilitate the collection of data, which once it has been stored in servers and databases, is disseminated globally, free of charge, using near-real time. Data collectors in the field can upload data into datasets, and users can filter, select, view and download images captured at the field sites (TEAM, 2010).

The use of interactive community radio is being implemented by the AMARC (Association Mondiale de Radiodiffuseurs Communautaires) network in the field of disaster prevention and management (Asia-Pacific), food security and poverty reduction (Latin America) and desertification (Africa) (Kalas and Finlay, 2009).

(b) Adaptation and Strategy

Experiences from the field indicate the potential of both traditional and emerging technologies in the field of awareness raising and knowledge sharing in the climate change field. In marginalized and remote developing regions, community radio has proven to be a powerful tool to help inform and involve communities in local climate-related actions.

In Cameroon, an organization called *Protege QV* is implementing a project based on the use of radio programs to sensitize communities on climate change. This endeavor includes the production of a tool kit to support 15 community radio stations on awareness raising activities, as well as training workshops and field surveys (GKP, 2010)

Some adaptation examples also integrate emerging community monitoring. In the Lower Mekong Basin, Vietnamese villagers were provided with mobile phones and training in order to respond more effectively to the 2008 flood season, using the technology to report the likelihood of localized flooding to the Southern Region Hydro-Meteorological Center in Ho Chi Minh City – the local agency responsible for flood forecasting. Measurements taken twice a day by locals were sent via SMS to the responsible authorities, facilitating greater accuracy and more precise flood warnings to communities. Based on this information, they could better prepare for evacuations, and protect their livestock. Additionally, long-term flood patterns based on the information gathered will help better plan local irrigation systems and decide on crop diversification strategies (MRC, 2009).

In India, an integrated knowledge-system on climate change adaptation uses traditional and new media, Web 2.0, Internet and mobile phones to facilitate community access to locally relevant knowledge, helping locals to better adapt within a context of high vulnerability to extreme weather events and food insecurity (BCO, 2010a).

In Uganda, iPods and podcasts are being used in marginalized communities to access creatively-packaged content relevant to their livelihoods. Content includes information on improving agricultural productivity (seeds, crops or livestock breeds, importance of livestock vaccinations and preventative health management, information on small-scale machinery), best practices to adapt to climate change (e.g. alternatives to costly chemical fertilizers and pesticides, appropriate agro-chemical use), as well as awareness on the importance of collaboration via associations for bulk trading to more effectively brand and negotiate small quantities of produce (ALIN, 2010).

An emerging body of literature in the ICT4D field has documented the positive effects of mobile use in enabling access to markets to local farmers and fisherman (Jensen, 2007), and improving their ability to conduct transactions with more accurate price and demand information. At the same time, available literature refers to the effects of ICTs in providing access to information and knowledge to local farmers on new varieties of crops, crop diseases, and more effective production processes, fostering productivity and facilitating adaptation processes of local livelihoods (Scott et al., 2004).

In Peru, the Centro Peruano de Estudios Sociales (CEPES, 2010) has implemented a project based on a small network of telecentres in the Huaral Valley, a remote region where droughts and water scarcity have hindered agricultural production and local livelihoods. With the support of ICTs, an agrarian information system has been put in place to provide farmers with access to information that can help them increase crop productivity and marketing, as well as software to improve the distribution of water (APC, 2007).

In Madagascar, participatory videos and digital storytelling are being used to stimulate community debates over climate change issues, and raise their concerns to decision-makers and broader audiences (BCO, 2010b). Likewise, an Ecuadorian NGO is using the Internet to document and raise awareness on environmental challenges in that country, including issues of forest management and biodiversity (AccionEcologica, 2010).

Review

Evidence emerging from the use of these technologies in developing countries is still, for the most part, anecdotal, with no in-depth assessments yet available in terms of their social and economic impacts.

However, the experiences identified point out prevailing challenges in terms of coordination and communication between communities, institutions and authorities at the local, municipal and national levels. This lack of coordination can potentially prevent emerging information captured and monitored in the field from reaching the appropriate decision-making levels, and therefore fail to translate into more effective climate change strategies.

At the same time, they suggest that, in spite of the growing penetration and adoption of ICTs, developing countries lag behind in the use of these tools due to persistent barriers of access and the lack of local capacity necessary to undertake action in the mitigation, monitoring and adaptation fields. Further to that, issues of language (as most available applications operate and generate content in English) constitute an additional barrier for developing countries to benefit from the potential of these tools in areas pertaining to climate change.

Although the emergence of experiences on the use of ICTs as part of climate change responses in developing regions is encouraging, it also indicates important gaps in the available knowledge in the field, and therefore in the required research that is necessary to undertake.

4. Issues for Future Research

The analysis that has been presented up to this point evidences the complexity of an emerging field of inquiry that is intimately linked to unavoidable, yet uncertain effects of the changing global climate. As research continues to emerge at the intersection of the climate change, ICTs, and development fields, so does the need to explore new issues that affect the ability of developing countries to effectively adapt, monitor, and ultimately contribute to mitigate the impacts of climate change.

Based on the review of the additions to the literature over time in the field of ICTs, climate change and development (Section 1), as well as on the analysis conducted of the priorities related to mitigation, monitoring, adaptation, and strategy (Section 2) and the experiences emerging from developing countries (Section 3), the following issues have been identified as key areas for future research:

(a) Mitigation

- **ICTs and community-level mitigation:** Based on the fact that most available resources in this area have focused on the mitigation needs and agendas of developed countries, further research is necessary on community-based use of ICTs towards low-carbon societies (journey substitution, smart energy generation and use, dematerialisation of goods/services), including the challenges of their implementation and potential effects in developing contexts.

- **ICTs, climate change and global value and supply chains**: As globalization deepens, global networks of distribution and logistics are increasingly linked with issues such as e-waste and standardization of energy efficiency monitoring and labeling (Houghton, 2009 p: 15). This topic reflects the need to adopt more holistic approaches to the analysis of the role of ICTs in climate change, considering the trends of the knowledge economy and the role of the private sector, among other stakeholders, in tackling environmental sustainability as a process instead of an output-driven activity.

- **ICTs, climate change and emerging consumer trends:** Emerging trends advocate the modification of consumer demands and values, including the use of innovative approaches such as "immaterialisation" and "demarketing". The first one is related to social innovations that can lead to satisfying needs and wants with immaterial as opposed to physical means. The second one is a social marketing trend that seeks to discourage consumers from purchasing or using certain products or services (Willard and Halder, 2003). The potential of ICTs in the evolution of these trends remains to be explored particularly in regards to developing contexts, including the effects of behavioral changes and new consumer practices – enabled by ICTs – in economic growth.

- **ICTs, climate change and emerging business practices:** Research in this area could include the emergence of carbon-neutral livelihoods with the support of ICT tools, including 'green' IT opportunities, local entrepreneurship and business models.

(b) Monitoring

- **ICTs, climate change monitoring and local empowerment**: As recognized by literature in the field, access to the right information is a means of local and community empowerment and helps people enhance their capacity to sustain themselves (Labelle et al., 2008). But for this to take place relevant information needs to be accessible to local actors, which involves not only issues of physical access and connectivity, but also the clear presentation of findings (i.e. the use of non-scientific speech and local languages) as well as the use of dissemination channels appropriate to the local context (i.e. community radio, SMS, Internet access points, community video and other interactive media). Furthermore, for that information to be transformed into developmentally-effective actions – the so-called "information chain" – a further set of interpretation and action resources must be present (Heeks & Kanashiro, 2010).

(c) Adaptation

- **ICTs, climate change and localization:** Community access and use of ICT applications in climate change strategies, including issues of capacity building, local language, and sustainability challenges in developing contexts. This topic is particularly relevant in terms of effective ICT usage for monitoring climate change impacts (e.g. GIS and integrated data capture methods in remote communities).

- **ICT and local livelihoods:** including specific actions on the two main community issues: impact of climate change on local agriculture and natural disaster management.

- **ICTs, local voices and awareness raising:** The recent report supported by the BCO (Kalas and Finlay, 2009) identifies the need to document the challenges, techniques and knowledge on adaptation at the local level. This process can allow not only to build upon lessons learned, but also to give a voice to vulnerable communities to identify current priorities and play an active role in decision-making processes on the subject. ICTs can play a role in the different dimensions that this challenge presents, from documentation to access to the information, to enabling participation and change.

- **ICTs and emerging social aspects of climate change:** According to Jepma et. al (1998), these include: (a) implementing equitable and participative frameworks for action and decision making; (b) the reduction of potential for social disruption and conflicts arising from climate change effects; (c) the protection of threatened cultures and the preservation of cultural diversity (e.g. in small islands threatened by increasing sea level).

(d) Strategy

- **ICTs, climate change and inclusion**: Possible topics of research in this area include (a) ICT for climate change political inclusion (getting information out of communities into political networks, and sharing/mobilisation between communities), as well as (b) youth involvement and gender inclusion, particularly in the context of ICTs' use in climate change adaptation. Youth and women are key agents of change within local communities, and their role is vital to promote the effective implementation of ICT solutions. As indicated by research conducted by

IISD, female-headed households, particularly those with few assets, are traditionally more heavily affected by climate-related disasters (IISD, 2005) and by manifestations of chronic climate change. In this context, ICTs could play a key role in the provision of relevant information, capacity building and empowerment, ultimately strengthening their adaptive capacity.

- **ICTs, climate change and governance challenges:** Research conducted by IISD on issues of adaptation and the role of ICTs points out the need to further explore the role of these technologies in the systemic transformation of socio-economic structures, including the use of networked governance to advance sustainable development goals (IISD, 2005). One of the key topics identified is the need to reflect sustainable development goals in national e-strategies and ICT policies, integrating both environmental sustainability and information society perspectives in climate-related strategies. Further to this, research could address the role of ICTs in assisting national/global strategizing on climate change, as well as in enabling policy frameworks that foster their effective use in the field.

- **ICTs and climate change decision-making processes:** The role of ICTs facilitating climate change decision-making processes at the micro, meso and macro levels needs to be better understood, including issues of strategy awareness and planning, and the integration of multi-stakeholder perspectives. This includes their potential role enabling the articulation of efforts among different actors, as well as the integration of existent knowledge and lessons learned within decision-making processes.

In addition to emergent gaps – and hence future priorities – in research areas explicitly related to the four main components of the Figure 2 overview model, we also identify from the literature two cross-cutting issues of particular relevance to the climate change-related application of ICTs in developing countries:

(e) Disaster Management and Response

- **ICTs, disaster management and response:** Research in this area could explore the links that exist between disaster management and response strategies, and ICT-enabled actions taken in the fields of mitigation, monitoring and adaptation, with the aim of providing recommendations to further articulate efforts and reflect existing links/feedbacks as part of comprehensive climate change strategies.

(f) Technologies: Impacts and Issues

- **Low-cost and emerging technologies:** As available literature in the field indicates, further research is needed on the role and potential of low-cost and emerging technologies, including mobile phones, community radio, mass media, the Internet, among other emerging applications, in view of the vulnerabilities and challenges posed by climate change in developing countries. Although, as noted, little work overall has yet been done on ICTs, there is an additional need for research that differentiates the potential of the different types of ICT; but which also analyses cross-cutting challenges faced in applying ICTs to climate change.

5. Conclusions

The analysis of available literature on the role of ICTs in climate change reveals the emergence of a fast-growing, fascinating, yet complex field of analysis. Sources that range from the late 1990s to date evidence the close connection that exists between these fields and the achievement of sustainable development, which lies at the core of past and emerging explorations of the topic.

But while environmental sustainability remains an issue of ongoing concern, broader approaches have given way to more focused analysis on the areas of mitigation, monitoring, and increasingly, adaptation and strategy, which constitute the key components in the study of the field, as summarized by Figure 2's ICTs, Climate Change and Development Overview Model.

This increased focus has coincided with acknowledgement of the higher magnitude of climate change effects in developing countries, and consequently, of differentiated priorities in the field. This realization has been reflected in explorations on the role and potential of ICTs, increasingly linked to analysis of the existing vulnerabilities and resource constraints that characterize developing regions.

Sources to date have recognized that ICTs can have positive and negative effects on the environment, from efficient transport and travel substitution, to increased energy consumption and e-waste. While digital technologies can enable the reduction of travel and dematerialize some products, there is concern that current consumption patterns could also increase travel and demand for cheaper goods, offsetting initial eco-efficiencies (rebound effects).

These risks evidence the need to further analyze the potential impacts of ICTs in the climate change field by focusing not only on the effects of particular applications (outputs) but also on the lifecycle of ICT products (Pamlin and Szomolanyi, 2005), as well as on the behavioral or systemic effects that may be associated with new production or consumption processes. This suggests the importance of adopting a systemic perspective in the understanding of ICT's climate change role, while recognizing the close links that exist between mitigation, monitoring and adaptation actions and strategies.

At the same time, as evidence continues to mount on the use of different ICT applications in areas such as climate change adaptation, including the use of low-cost and emerging technologies (community radio, mobile phones, participatory videos, among others), so does the need to conduct further research on the opportunities and challenges faced by practitioners in the field, as well as to narrow the knowledge gap that characterizes climate change responses in marginalized regions.

The identification of applications that are technically sound or that hold potential in mitigation, monitoring or adaptation processes, does not imply that developing country needs are being addressed or their priorities reflected in prevailing climate change strategies. As experiences from the ICT4D field show, far beyond the technical promise of ICT tools, developing contexts face very real limitations in terms of access, capabilities and resources; all factors that lie at the core of their ability to benefit from the potential of ICTs to help respond to the effects of climate change. Consideration of the broader development context, including local livelihoods, capabilities and governance, among others, are pivotal to determine the viability, appropriateness, and ultimate sustainability of ICT-enabled responses to the changing climate.

Lastly, as climate change continues to evolve, new technologies to develop and literature to emerge in the field, it becomes critical for researchers and practitioners to share knowledge and experiences, thus helping deepen a growing debate over innovative approaches to climate change, while expanding our understanding of the role and potential of ICTs in developing contexts.

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Chapter 2: Linking ICTs and Climate Change Adaptation:
A Conceptual Framework for e-Resilience and e-Adaptation

ANGELICA VALERIA OSPINA & RICHARD HEEKS

Executive Summary

Background

Climate change constitutes a dynamic, interconnected, yet often uncertain field of study, where the magnitude of environmental impacts is closely related to the various development stressors that underlie vulnerability generally. Literature in the field suggests that challenges faced by developing countries in areas such as livelihoods and finance, socio-political conditions, health, habitat and migrations, food security and water, are intensified by the effects of climate change-related hazards, variability and trends (Hardy, 2003; IPCC, 2007; Parry et al., 2007). At the same time, the exacerbation of these existing vulnerabilities constrains the ability of developing contexts to cope with climate change; that is, to withstand and recover from climate-related shocks and disturbances, as well as to adapt, in the longer term, to changing climatic conditions. The coping abilities to withstand, recover from, and adapt to climate change – what can, overall, be termed 'resilience' – thus emerge as key factors for the achievement of development outcomes.

Despite the uncertainty and unpredictability associated with climate change, the best current indication is that climatic occurrences will increase in both magnitude and frequency, posing serious development challenges (IPCC, 2007; UNDP, 2007). The potential impacts of climate change are becoming increasingly evident through both acute and chronic manifestations. Acute impacts are the extreme hazards of 'shocks', which usually occur over a geographically limited area and require rapid response and relief (CISHDGC, 2010). They can include events such as heavy rainstorms or cyclones, which may produce effects such as landslides, flooding, disruption of transportation systems and the erosion of agricultural land, among others. Climate change threatens to augment the acute stress in vulnerable regions, typically as more and greater storms or more frequent high temperature episodes take place (Wilkinson and Buddemeier, 1994).

The chronic manifestations of climate change refer to subtler shifts in conditions (such as sea level rise, melting glaciers or changing oceanic acidity due to atmospheric CO_2 uptake), which happen over long periods of time and are, therefore, harder to identify. Chronic changes include climate trends (changes in expected conditions), as well as changes in the variability and intensity of weather cycles and events (e.g. changes in seasonality, temperature and precipitation, which can negatively affect productive sectors, particularly agriculture) (Cannon, 2010). Changes in trends and variability could have the largest and most significant aggregate impacts, particularly in low-income, resource-dependent populations. With limited resources and capacities to respond and adapt to both acute and chronic climate changes, developing contexts are particularly vulnerable to the uncertainty of their effects.

It is also within these contexts that the use of information and communication technologies (ICTs) is rapidly spreading (UNCTAD, 2009; ITU, 2010), creating new opportunities and challenges for developing countries that are at the forefront of climate change impacts. Defined as electronic means of capturing, processing, storing, and communicating information (Heeks, 1999), these tools offer an important development potential particularly in the low-income populations whose existing vulnerabilities are magnified by the effects of climate-related disturbances (IPCC, 2007; Moser and Satterthwaite, 2008). Yet, a review of available literature in the field of ICTs, climate change and development (Ospina and Heeks, 2010) suggests that adaptation remains one of the least explored areas for analysis of ICTs' potential in the global South.

Recognising the close links that exist between climate change vulnerability and the achievement of development outcomes, alongside the increasing use of ICTs within developing contexts, the aim of this paper is to set out a conceptual foundation that links climate change, livelihoods vulnerability, and the potential of ICTs in supporting systemic resilience. ICTs will be introduced as a system component that has the potential of contributing towards resilience and, therefore, helping to enable livelihood strategies that allow adaptation; that is recovery and adjustment in the face of climate change.

Contribution

The development of this 'e-Resilience Framework' is based on the recognition that the complex set of relationships that exists between climate change, adaptation processes and development outcomes cannot be fully understood through a series of compartmentalised elements. Instead, a systemic perspective is needed. This allows the identification of key components, processes and properties, as well as the feedback and interactions that play a role in the realisation of adaptation processes in vulnerable settings.

Within the emerging field of ICTs, climate change and development, this document responds to the need for building a solid conceptual basis upon which to analyse the role and potential of these tools, while recognising existing development challenges and vulnerabilities.

This document targets an audience of development strategists, academics and practitioners working in the fields of ICTs-for-development (ICT4D), climate change and/or related areas, interested in conducting more rigorous analysis of the linkages between ICTs and adaptation processes in developing countries. By drawing key principles from recognised conceptual approaches of the social sciences, the paper seeks to foster a more in-depth understanding of both the potential and the challenges associated with the use of ICTs within contexts vulnerable to climate change, while identifying the main concepts and systemic feedback that need to be considered in this analysis.

The proposed framework is developed in progressive, interrelated stages throughout the paper. The first section presents the conceptual underpinnings of livelihood systems' vulnerability to the potential effects of climate change. Drawing from the sustainable livelihoods approach, new institutionalism and Sen's capability approach, the analysis will explore the role of vulnerability determinants (assets, institutions and structures), capabilities and functionings in the realisation of adaptation processes in developing contexts.

Section 2 introduces the concept of resilience as a system property, arguing that, through a set of dynamic sub-properties, it plays an important role in enhancing the adaptive capacity of livelihood systems. Section 3 of the document develops the last component of the conceptual framework by exploring the potential of ICTs with respect to the sub-properties of resilience, introducing the concept of *e-resilience* and analysing the potential of ICT tools as enablers of adaptive processes within contexts vulnerable to climate change.

Recognizing that adaptive actions can be enacted at various levels, the study then analyses two broader roles of these tools. First, their contribution to adaptive actions at the national/macro level. Second, *e-adaptation*: the impact that ICTs can have on the key vulnerability dimensions impacted by climate change (i.e. livelihoods and finance, socio-political conditions, health, habitat and migrations, food security and water supply). Finally, this paper identifies challenges associated with the use of ICTs within adaptive processes, thus completing the analysis from a systemic perspective: from consideration of enabling environments and the role of national-level institutions and structures, to the realisation of adaptive functionings that reduce specific livelihood vulnerabilities to climate change.

Within contexts characterised by poverty and marginalisation, subject to the effects of both acute and chronic climatic effects, the proposed framework provides conceptual insights into the potential of ICTs within adaptation processes, including their role in reducing the prevailing vulnerabilities faced by developing countries in the midst of climate change uncertainty.

1. Climate Change Vulnerability: Conceptual Underpinnings

The prevailing vulnerabilities that poor people face lie at the core of their ability to cope with climate change, and therefore play a critical role in determining the severity with which climate change impacts will be felt in developing contexts (IISD, 2005; MacLean, 2008). The potential effects from heavy rainstorms, cyclones, heatwaves, sea level rise, extended periods of flooding or drought, changing patterns of temperature and rainfall, among others, need to be analysed within a broader set of development stressors and constraints. Understanding vulnerability is, therefore, critical in exploration of the potential effects of climate-related hazards and changing trends on low-income populations.

Available literature in the field evidences the existence of competing conceptualisations and terminologies of vulnerability (Fussel, 2007). However, a general understanding can be that vulnerability represents the likelihood of exposure to external shock combined with the ability to cope with the impact of that shock (Elbers and Gunning, 2003). Such shocks may be economic or related to security. Or they could be related to climate change.[2]

This definition suggests two things. First, that there is some concept of 'outside' (the context that is the source of shocks and variations), and 'inside' (the object of the shock that must seek to cope). This suggests the value of systems thinking in understanding vulnerability given its foundational notion of a system boundary that separates outside from inside. Second, that vulnerability relates partly to the external but partly to the internal; in the latter case to some notion of the capacity of the system to cope (Nelson et al., 2007, p. 396).

Vulnerability in our terms is therefore both a generic coping capacity (or capacity deficit) of systems in development – be they households, communities, regions or nations – and also a more specific set of externally-derived impacts (shocks and variations); in our case, related to climate change. The critical dimensions of those climate change-related impacts emerge as food security and agriculture, health, water supply, human settlement and displacement, socio-political issues, and livelihoods and finance (IISD et al., 2003; Parry et al., 2007; Magrath, 2008; Schild, 2008; OXFAM, 2009). Of course, these dimensions are not only relevant to climate change: they will also be appropriate for an understanding of other acute shocks and longer-term trends.

If the context is a source of acute and chronic risks that materialise via a set of potential impacts, what do development systems – such as communities – do to cope in the face of these threats? One thing they may do is not an active strategy (Thomalla, 2008; DHS, 2010), which is to withstand the external threat, resisting or absorbing and tolerating its impact. The other two things they may do are active. They may recover from the impact; that is act to return to some pre-existing state. In climate change terms, this would typically be in response to an acute shock such as a landslide. And/or they may change to accommodate the impact; becoming different from the pre-existing state. In climate change terms, this would typically be in response to a chronic trend such as temperature change or rising sea levels. These latter two – recovery and change – represent adaptation processes: "deliberate change in anticipation of or in reaction to

[2] Not surprisingly, there are similar definitions of vulnerability related specifically to climate change. One of the most widely-used is that provided by the IPCC (2001), which describes vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.

external stimuli and stress" (Nelson et al., 2007, p.395). We can therefore summarise with the following 'equation':

Coping = Withstanding + Recovery + Change = Withstanding + Adaptation

Given its potential to address external shocks and trends, adaptation will be critical for the achievement of development outcomes, which include the realisation of increased income and well-being, improvements in food security, and more sustainable use of natural resources (DFID, 1999). Development outcomes also include "reduced vulnerability" (ibid.: p25), indicating a two-way relation between vulnerability and adaptation: the realisation of vulnerabilities requires adaptation actions, but those actions in turn affect vulnerabilities; at least the 'inside' component that relates to the capacity to cope.

The linkages that exist between the concepts presented thus far are illustrated in Figure 1, showing a chain of causality, with context – including climate change – affecting the various dimensions of vulnerability that developing countries are subject to; with those vulnerabilities both determining but in turn also being impacted by, processes of adaptation; and with the enactment (or otherwise) of adaptation determining the ultimate development outcomes for those affected by climate change.

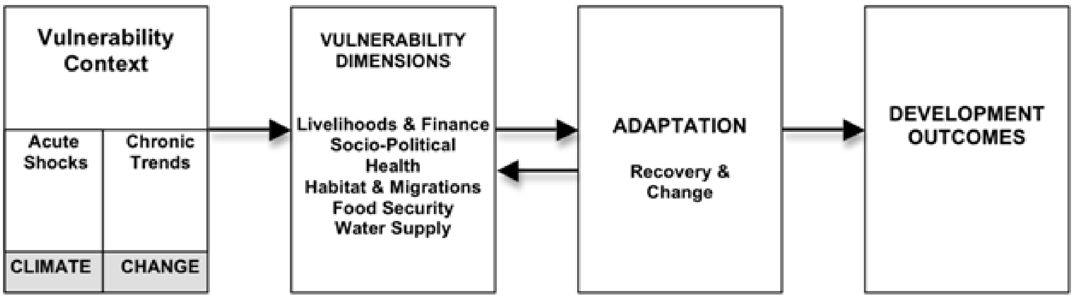

Figure 1. Vulnerability and Adaptation to Climate Change

These linkages suggest that, for the poor, whose socio-economic systems are heavily dependent on ecosystems services and products, the effects of climate change have the potential to intensify existing vulnerability dimensions, while placing further constraints on their ability to adapt and achieve development outcomes (IPCC, 2007).

However, in order to understand how adaptive processes are realised within developing environments, the identification of vulnerability dimensions is not sufficient. The analysis requires a more in-depth exploration of the components and processes that enable or constrain the ability of livelihood systems to adapt, while reducing their vulnerability to the effects of climatic variations and events. To understand this, we can draw on the idea mentioned above of 'adaptive capacities'. These are necessary preconditions to enable adaptation, including not only social and physical resources, but also the ability to mobilise them. In turn, adaptive capacity is generated by the interaction of broader structural determinants, which are dependent on each other and vary in time and space (Smit and Wandel, 2006). For example, a strong social network may allow greater access to resources and reduce the psychological stress caused by climatic disturbances, hence strengthening adaptive capacity.

The following section will explore further this idea of the capacity of systems in developing countries to adapt. It will build a picture of the generic vulnerability determinants (assets, institutions and structures), capabilities and functionings that lie at the core of livelihood systems, and that play a key role in adaptation. These livelihood components will be drawn from the principles of the sustainable livelihoods approach, new institutionalism, and Sen's capability approach. Reference to these frameworks will provide the conceptual foundations required to differentiate potential (i.e. adaptive capacities/capabilities) from actual livelihood strategies (i.e. adaptation as realised functionings), thus providing a more holistic understanding of interacting components within livelihood systems vulnerable to climate change.

1.1. The Capacity to Adapt to Climate Change: Livelihood System Components

Those most prone to suffer the effects of climate-related hazards are often marginalised geographically (e.g. live in hazardous places such as informal settlements or in remote locations), socially (e.g. lack social protection and health services), economically (e.g. low-income or resource dependent populations) and politically (e.g. excluded from political processes and effective representation in government structures) (Gaillard, 2010). Therefore, as noted above, alongside the component of vulnerability deriving from external shocks and trends, there is a component that is not hazard-dependent but is instead determined by constraints that are social, economic and political in nature, and which ultimately reduce the capacity of affected populations to respond and adapt to the effects of climate-related hazards and trends. This aspect of vulnerability and adaptive capacity are therefore two sides of the same coin: as one rises, the other falls.

Adger (2005) argues that this aspect of vulnerability – and, hence the capacity to adapt to climate change – is characterised by the presence of three main generic features, namely (a) the resources available to cope with exposure, (b) the distribution of these resources (social and natural) across the system, and (c) the institutions that mediate resource use and coping strategies. This suggests that, in addition to level of resourcing, it is structural factors that matter in determining vulnerability; both the organisational aspects that affect things like distribution of and access to resources, and also the absence or weakness of institutions. These could exacerbate the effects of hazards in vulnerable populations (e.g. if risk prevention and coping strategies are not put in place or are not organisationally-implementable to deal with the effects of climate-related events), hindering their capacity to adapt.

In order to understand how adaptive processes are achieved within developing contexts, the following section will explore the main vulnerability components (assets, institutions, structures and capabilities) that make up adaptive capacity; and the functionings that represent actual adaptation.

1.1a. Livelihood Systems: Assets, Institutions and Structures

What model should be used to investigate further the connection between vulnerability and adaptation to climate change? Figure 1 and the discussion to date suggest any such model should encompass elements such as vulnerability, context, processes/actions, and outcomes, plus resources and structures. The obvious choice, then will be the sustainable livelihoods approach (SLA), as summarised in Figure 2.[3]

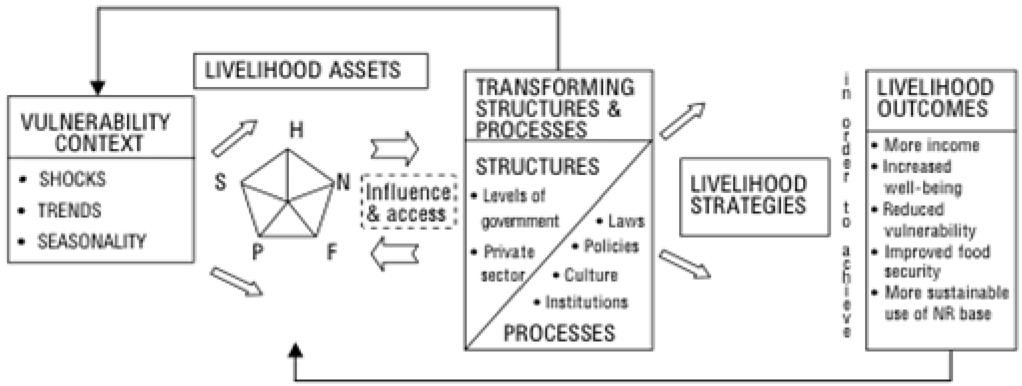

Figure 2. Sustainable Livelihoods Approach (DFID, 1999)

A number of elements within the SLA can already be seen within our climate change model: the vulnerability context of shocks and trends, the livelihood strategies of adaptation (recovery and change), and the livelihood/development outcomes. What follows, then, will be an investigation of the central elements of livelihood assets, structures and processes, which together form the capacity of a livelihood system to adapt to climate change.

The Role of Assets

Adger (2005) argues that the vulnerability of a given population is based on the context in which they reside plus the availability and use of natural and other resources. This and other research evidence points to the key role that access to livelihood assets[4] plays in determining vulnerability and, therefore, in the adaptive capacity of low-income communities (Duncombe, 2006; Smit and Wandel, 2006; Nelson et al., 2007). As shown in Figure 2's sustainable livelihoods model, the five core asset categories or capitals upon which livelihoods are built are human, natural, financial, social and physical capital.

The relationship to external vulnerability – including climate change-related vulnerability – is two-fold. In developing country communities, often highly dependent on agriculture and natural resources, climate-induced vulnerabilities can have a detrimental impact on availability of assets (in turn restricting the livelihood strategies that can be enacted). As well as being affected by context, those assets themselves play a key role determining the vulnerability of a given context to the effects of external disturbances such as climate change. Thus, lack of access to these resources significantly limits the ability of livelihood systems to cope with the effects of acute and chronic manifestations of climate change (Chambers and Conway, 1991; IISD, 2003). Conversely, the more varied the asset base (such as the means of production available to generate resources sufficient to reduce poverty), the more sustainable and secure is the livelihood, and the stronger the ability of the population to respond to the impacts of climate

[3] Though of course there is some conceptual tautology here since ideas from the SLA were already used to influence the understanding outlined in Figure 1.

[4] For the purposes of this document, assets are being treated as equivalents to resources. However, the term 'asset' will generally be preferred given its association with conceptualisations of livelihoods and given the rather broader notion sometimes attributed to assets, with 'resources' sometimes seen to refer just to tangible assets.

change. Therefore, livelihoods assets form the basis of both adaptive capacity and realised adaptation strategies (IISD et al., 2003).

However, the role of assets within adaptation cannot be analysed in a vacuum, as institutions, structures and capabilities also constitute important components of livelihood systems. These will now be analysed further.

The Role of Institutions and Structures

The SLA refers to a set of 'processes' that affect the conversion of assets into livelihood strategies; identifying laws, policies, culture, and institutions. It can readily be shown that these may either block or enable access to assets, and thus play an important role in the capacity of communities to cope with climate change (2009). However, what is not recognised within the SLA is that all these components are, in fact, institutions as understood by the ideas of new institutionalism; and can therefore be corralled under the single 'institutions' heading.

As defined by North (1990), one of the key new institutionalism theorists, institutions are humanly-devised constraints that shape political, economic and social interaction and human agency. They have been formed throughout history to create order and reduce uncertainty. These can be informal constraints such as sanctions, taboos, customs or codes of conduct (all of which are found within the notion of 'culture'), as well as formal rules such as laws, property rights or government policies (Dugger, 1995). Although these are typically referred to in the language of constraint, the notion of 'shaping' means more than just limitation; it also allows for the provision of opportunities for human action.

Institutions will thus have a key role to play in both the selection and implementation of adaptation processes and as such they are a key component of adaptive capacity. However, institutional forces are not free-floating. They are organised by both informal organisations (such as family groupings and power relations) and formal organisations (such as those of the public, private and NGO sectors) (Lowndes, 1996). This organisation also applies to assets, which are organised in terms of both distribution and access. Thus, alongside institutions, conceptualisations of adaptive capacity must also include organisation and structure. Hence, in practice, structures are seen to play an important role in fostering participation and empowerment of local communities in decisions that affect adaptive processes (Plummer and Armitage, 2007).

This suggests that adaptation processes also require effective governance and management structures as they entail steering processes of change through institutions, in their broadest sense (Nelson et al., 2007). Within systems affected by climate-related disturbances, structures themselves need to endure through processes of change, as well as cope with the changing conditions (ibid). Ultimately, within vulnerable livelihoods, both institutions and structures play a key role in determining access to resources, mediating the effects of hazards, and enabling the decision-making frameworks required for adaptation processes to take place (Burton and Kates, 1993).

The combination of assets, institutions and structures presented thus far in the analysis only constitutes part of the enabling foundation of adaptive processes within complex developing environments. In order to complement the analysis, whilst introducing the notion of agency, Sen's concept of capabilities will be explored as an important additional component towards the achievement of adaptive actions in vulnerable livelihoods.

1.1b. Adaptive Capacity as Capabilities

The SLA framework suggests that, given an understanding of context and then of assets, institutions and structures, we could understand that adaptation processes are part of the livelihood strategies that are selected by vulnerable communities. However, we can also incorporate ideas from Amartya Sen's (1999) work on development and capabilities to take us further. That Sen's ideas are compatible with our conceptualisation to date can be seen because the determinants of capabilities are assets, constraints and societal structures (Bebbington, 1999; Robeyns, 2005); corresponding to the elements identified in the preceding section.

We find two additional insights from the capability approach. The first derives from Sen's argument that development represents the expansion of freedoms (Sen, 1999). This is not an idea we will particularly pursue, given our main interest in concrete adaptation outcomes. However, this would lead to an understanding that the growth of adaptive capacity was itself inherently developmental, potentially regardless of the actual utilisation of those capacities. It also somewhat changes the perspective on other components; for example, "assets are not simply resources that the people use in building livelihoods: they are assets that give them the capability to be and act" (Bebbington, 1999, p.5).

The second insight is the differentiation between what a community is free to do – its 'capabilities'; and what it actually achieves – its 'functionings' (Heeks and Molla, 2009). The former are the opportunities afforded; the latter are the actually-lived livelihood actions. It is the distinction between capabilities and functionings, or between *potential* and *actual* livelihood strategies, what constitutes one of the most significant contributions of Sen's approach to the understanding of systemic adaptation. It suggests that the adaptive capacities that are available within a given system (as the social, economic and physical preconditions that are necessary to enable adaptation) (Nelson et al., 2007) cannot automatically be equated with actual achievements. Instead, there is a conversion process that will be subject to personal preferences, social pressures and other decision-making mechanisms, which ultimately determines the set of capabilities (as *achievable* functionings) that can be enacted into *actual* functionings (which would include processes of adaptation) (Zheng and Walsham, 2008).

Level of Analysis

Sen's work is typically based around the individual as the unit of analysis, and this prompts the question of the level of analysis to be used in our framework. As noted above, systems ideas require the drawing of a system boundary, which we can do – conceptually at least – to separate out the context from which vulnerabilities derive, and the development outcomes that derive from adaptation processes (and other realised functionings). But what will lie inside the boundary?

Inside, will be a 'livelihood system' which we can define – adapting Buckley's (1976) definition of 'system' – as "a complex of elements or components directly or indirectly related in a more or less stable way forming a causal network that purposively undertakes actions that have a developmental impact". Given the requirement from what has preceded that the livelihood components would include assets, institutions and structures, it is clearly not appropriate to select the individual as the analysis unit. And, indeed, it is argued that capabilities ideas can readily be scaled up to higher levels (Ibrahim, 2006).

Analysis of work on climate change adaptation shows three principal levels/units of analysis that are used (Brouwer et al., 2007; Stringer et al., 2009; Ibarraran et al., 2010): the micro, working at the level of the household; the meso, working at the level of the community; and the macro, working at the level of the region or nation. Each of these could be represented as three levels of system, each with its own boundary. However, given the porosity of those boundaries – for example, with institutions and assets created at national level readily having an impact at community and household level – we will merely register these as different levels within the overall livelihood system.

Having identified the various levels and components of livelihood systems that make up the capabilities of that system, the following section will explore the way in which those capabilities (i.e. potential livelihood strategies) can translate into functionings (meaning, in the context of climate change, actual adaptive processes and actions).

1.2. Adaptation to Climate Change: Livelihood System Processes and Realised Functionings

Beyond the capabilities required for households, communities or broader livelihood systems to cope with climate change, actual adaptation processes are the result of their ability to implement adaptive decisions, thus transforming that capacity into action (functionings). Capabilities can therefore be understood as the capacity to implement adaptive decisions. In turn, adaptation processes can lead to system transformations when new livelihood strategies are adopted (e.g. when climate-related disturbances force systems to depend on new, diversified livelihood options), as well as to system adjustments, when systems are improved to reduce vulnerability and strengthen future adaptive capacity.

The concept of functionings is key to understand that adaptation is about decision-making processes and the capacity to implement those decisions (Nelson et al., 2007); an ongoing process in which assets, institutions and organisations interact towards the generation of adaptive capabilities, which ultimately enable adaptive actions which contribute to the achievement of development outcomes. Based on the analysis conducted thus far – and recognising that the role and relevance of these elements will always be situation-specific (ibid) – Figure 3 illustrates the linkages between the core components and processes of vulnerable livelihood systems, all of which can contribute to climate change adaptation as a realised functioning (though also recognising there will be realised functionings that are not directly climate change-related).

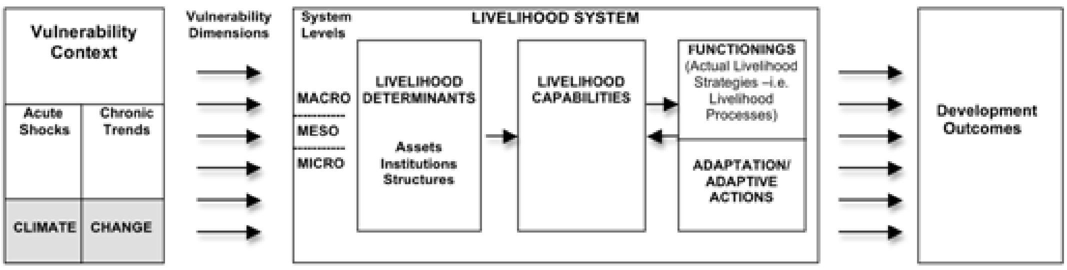

Figure 3. Adaptation to Climate Change: System Components and Processes

Based on the foundations provided by the sustainable livelihoods approach, new institutionalism and the capabilities approach, the model reflects key elements to consider in the analysis of adaptation in developing countries. It illustrates the components (e.g. asset-based, institutional and structural determinants of capabilities) and processes (adaptive functionings) that play a role in the achievement of adaptation and development outcomes, within systems vulnerable to climate change that can be understood at macro, meso and micro levels and relating to six key vulnerability dimensions. It recognises the forces shaping the processes of decision-making action within the SLA can be understood as institutions in a new institutionalism sense. And it reflects a division of livelihood strategies into potential (capabilities) and actual (functionings).

In moving from the model in Figure 1 to that in Figure 3, the analysis conducted so far has shown that drawing insights from a range of conceptual sources provides a more complete picture. It has shown, for example, that the identification of degrees of exposure and sensitivity to climate-related stimuli is not sufficient to understand the complex challenges faced by livelihood systems. Instead, a deeper knowledge of vulnerabilities and their related adaptive capacities is required (Smit and Wandel, 2006).

This process of providing a more complete picture – and also moving closer to understanding the potential role of ICTs – can be taken one further step by drawing insights from an additional conceptual source: the literature on resilience. Resilience is seen as the systemic property that allows livelihood systems to cope with the effects of climate change-related hazards, variability and trends (UNISDR, 2010). While adaptation research is often actor-based and focused on reducing vulnerabilities to specific risks, the resilience approach to climate change emphasises the functioning of a livelihood system as a whole (Nelson et al., 2007). It therefore allows us to analyse in greater depth the relationships that exist between system components and processes; something that is particularly relevant given the systems approach that is taken in this paper and that has been developed in Figure 3.

The following section will provide a more in-depth look into the concept of resilience as a property of livelihood systems, as well as its linkages with the components and processes presented up to this point.

2. Systemic Resilience to Climate Change

Resilience is a much-debated concept and one whose definition differs among different writers. In narrow, 'dictionary' terms, resilience means the ability to 'bounce back'; that is, to recover to some original state following an external disturbance. One finds this as a definition in the climate change literature (e.g. Norris et al., 2008). However, other definitions add two further abilities to our understanding of resilience. One ability – very much related to the first – is the ability to withstand an external disturbance (e.g. Adger, 2000). The other is the ability to change in the face of an external disturbance; going beyond sustainability and renewal to changing and occasionally transforming in a way that enables the survival of the system (e.g. Gallopin, 2006; Magis, 2009).

Seen in this light, then quite simply, resilience is the systemic ability to cope with external disturbances, be they acute shocks or chronic trends. It involves the ability to do the three things previously identified as 'coping': withstanding, recovery and change; the first two being associated with acute climate change-related events, the latter with chronic climate change. It allows that the livelihood system may alter in some way, but also sustain in terms of some aspects of its overall purpose, boundary and identity. And it can be seen as synonymous with 'adaptive capacity'[5]; for example defined as "the ability of a system to adjust to climate change (including variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (ibid, p. 300), a definition which allows resilience to be understood not just as a reaction to the threats associated with climate change, but also as a proactive embrace of the opportunities.

The resilience of livelihood systems is therefore the central facet of those systems in order for us to understand their ability to cope with climate change (and other sources of vulnerability). As such, it warrants further analysis here. But if resilience is taken as synonymous with adaptive capacity (itself the flipside of the internal component of vulnerability), then it can be argued that resilience has already been understood: as the system components summarised in Figure 3. This is true … but partial. Some of the resilience literature (e.g. Gallopin, 2006) sees it as an ability created by the assets, institutions and structures of the livelihood system.

But other parts of the resilience literature (e.g. Norris et al., 2008) provide a new insight; one that helps us to understand livelihood systems not just in terms of system components, but in terms of system properties and sub-properties. Seen in this way, the components – assets, institutions and structures – act together to form a livelihood system that has a set of sub-properties that can collectively be called 'resilience'.

The potential adaptive capacity of a system – its created capabilities – therefore derives from both components and properties. Developing that system by increasing its capabilities can be understood either as a strengthening of components or as a strengthening of properties (of course this is a conceptualisation: in practice the two are completely intertwined). Similarly, we can also understand Figure 3's 'back arrow' as meaning that adaptation processes affect both the components and the properties of the system: the system's assets, institutions and structures; and also its property of resilience.

Having recognised the importance of resilience, as well as its links with the components and processes of livelihood systems, the following section will explore the concept in more detail by presenting a set of resilience sub-properties, and analysing the way in which they can contribute to adaptation.

2.1. Resilience as Sub-Properties of a Livelihood System

As suggested above, resilience is a key property of livelihood systems. Some discussions of resilience treat it monolithically, but others break it down into a set of sub-properties (e.g. IISD et al., 2003; Folke et al., 2005). Those sub-properties are a function of the system's components, and they enable it cope (for example with climate change). As a reminder, coping is the ability to withstand external shocks, and the ability to adapt to shocks and trends. Adaptation, in turn, includes not only recovery from short-term climate change-related shocks but also change in the face of longer-terms climate trends; those changes including both response to threat but also grasping of potential opportunities from climate change.

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[5] Though one could argue that adaptive capacity is solely related to recovery and change, while resilience is slightly broader and related to recovery, change <u>and</u> withstanding.

What then, are the sub-properties of resilience, which enable a livelihood system to withstand and adapt in the face of climate change? Those proposed here are drawn from various sources. The first – robustness – relates mainly to the ability to withstand. The others relate mainly to the ability to recover and to change.[6]

- **Robustness** refers to the ability of the system to maintain its characteristics and performance in the face of environmental fluctuations, including shocks (developed from Carlson and Doyle (2002) and Janssen and Anderies (2007)). Within robust systems, reinforcing influences between components and processes help spread the risks and effects of disturbances widely, so as to retain overall consistency in system performance independent of fluctuations (Gunderson, 2000). This could include the strengthening of assets or of connection between assets. Examples of climate change-specific actions to improve the sub-property of robustness include investment in flood barriers such as levees, terracing on hills and resistant infrastructure, as well as the selection of crop varieties that (while perhaps not having an optimal yield) may be better able to survive under changing climatic conditions. It also includes the strengthening of institutions and structures so that they do not collapse in the face of climate change manifestations.

- **Scale** refers to breadth of assets and structures a system can access in order to effectively overcome or bounce back from or adapt to the effects of disturbances. It involves, for example, access to networks of support beyond those existent at the immediate community level, thus enabling access to resources that may not otherwise be available. Evidence emerging from the disaster management and recovery field (Few et al., 2006) suggests the key role that access to extended markets, networks and other structures can play in order to enable systemic resilience. In practice, it can manifest through the ability to access assets (e.g. financial, human) at the regional, national or international level.

- **Redundancy** is the extent to which components within a system are substitutable; for example, in the event of disruption or degradation. One part of this can be asset diversity, but this is not simply an issue of scale but the ability to access assets that are both in some sense 'surplus' and also interchangeable. Redundancy may also involve the availability of processes, capacities and response pathways that allow for partial failure within a system without complete collapse (RF, 2009). Collaborative and multi-sector approaches can contribute towards redundancy as they facilitate the existence of overlaps and multiple sources of support/expertise that can help fill the gaps in times of need, thus allowing the system to continue to function in the event of climate-related disturbances.

- **Rapidity** refers to how quickly assets can be accessed or mobilised to achieve goals in an efficient manner (Norris et al., 2008). This can be critical particularly when responding to an acute climate-related disturbance. Within climate change-vulnerable contexts, this sub-property can be manifested in the availability of financial mechanisms for savings, and in access to credit and insurance. Rapid access to information, both incoming to and outgoing from the system, will also be key to making quick decisions and mobilising quick support after climate-related events.

- **Flexibility** refers to the ability of the system to undertake different set of actions with the determinants at its disposal, while enabling them to utilise

[6] Hence the argument that adaptive capacity relates just to the six latter properties, while resilience relates to those six plus robustness.

the opportunities that may arise from change. Hence, Folke (2006) argues that system resilience includes the opportunities that disturbances open up in terms of recombination of evolved structures and processes, renewal of the system and emergence of new trajectories. This suggests the relevance of flexibility to respond to the challenges posed by climate change, as well as to the opportunities that it may pose in developing contexts. Climate change resilience entails flexibility at all three systemic levels – the micro, meso and macro – with each of them being able to respond and contribute to each situation, and shift as necessary under unpredictable circumstances (RF, 2009). Flexibility in the face of climate change can come from various sources, including the existence of knowledge (e.g. from social networks) that can suggest different courses of action for problem solving.

- **Self-organisation** is the ability of the system to independently re-arrange its functions and processes in the face of an external disturbance, without being forced by the influence of other external drivers (Carpenter et al., 2001). Fuchs (2004) argues that self-organisation is a threefold process based on cognition, communication, and co-operation, and the concept of information can help to grasp the dynamics of self-organising systems. According to this author, cognition refers to the individual dimension (i.e. the elements of social systems), communication refers to the interactional dimension, and co-operation to the integrational dimension (i.e. the social system itself that is constituted by the interaction of its elements). This definition reflects the various aspects of self-organisation, and at the same time demonstrates that the access to information alone is not enough to enable this sub-property, particularly in developing contexts characterised by asset deprivation, and institutional and structural constraints.

  To understand this further, we can call on the 'information chain' model (Heeks, 2005), which distinguishes stages that run from the provision of information to the asset and institutional capacity and freedom to make decisions and take actions on the basis of that information. Thus, for self-organisation to take place after the occurrence of a climate-related event, communities must be able to first access relevant data, assess its qualities, and apply it to their own particular needs (ibid). Additionally, communities must be able to access the key components that need to be present for the functioning of information chains, namely "overt resources (money, skills, technical infrastructure), embedded/social resources (trust, motivation, knowledge, power) and relevant raw data" (Heeks, 1999, p.7). Therefore, beyond access to assets and capabilities, self-organisation also involves control and hence power over assets and processes, as well as other psycho-social aspects that are necessary to enact actions (e.g. belief, motivation, hope, perceived self-efficacy) and self-organise in face of a climate change-related shock or trend. In practice, self-organisation also reflects enabling socio-political organisational structures and associated collective action that ameliorate vulnerability (e.g. presence of microcredit structures) (Brouwer et al., 2007).

- **Learning** is an attribute closely linked to the dynamic nature of livelihood systems, and relates to the capacity of the system to generate feedback with which to gain or create knowledge, and strengthen skills and capacities. Within systems that are vulnerable to the uncertain impacts of climate-related change, experimentation, discovery and innovation as part of learning processes, can constitute key factors in the ability of the system to spring back and adjust to new conditions. At the same time, understanding the problem is key for the implementation of appropriate responses; hence, the importance of accessing new knowledge that pertains to local priorities and adaptive options. Learning can also play an important role towards local empowerment, and the implementation of preventive and response actions to minimise system disturbances.

These resilience sub-properties constitute dynamic features that interact with available assets, institutions, structures and capabilities (system components) in a given livelihood system, and ultimately enable adaptation as realised functionings (system processes). The realised adaptations contribute towards achievement of development outcomes, including feedback into the capacity of the system to withstand or adapt to future disturbances and climate-related uncertainties. These connections form the model that is summarised in Figure 4.

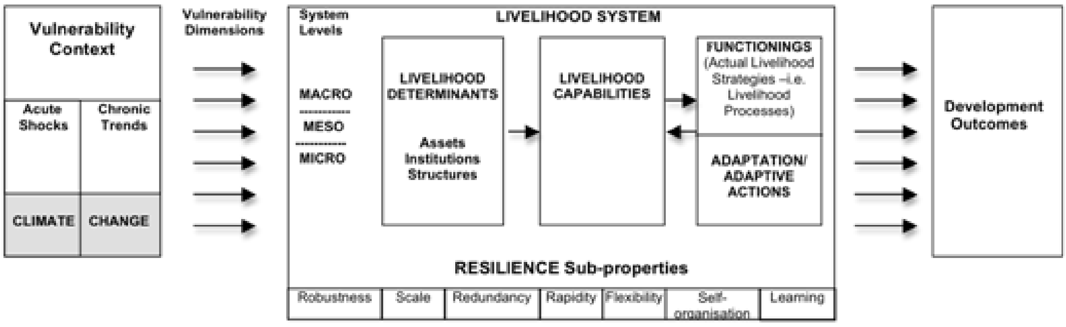

Figure 4: Adaptation to Climate Change: Resilience as a System Property

To summarise, the analysis of systemic adaptation to climate change is mainly concerned with the relationships between components, properties, processes and outcomes in a given system (Nelson et al., 2007), as reflected in Figure 4. Here, climate change-related shocks or trends within a particular context act as a stimulus that requires a response. The capacity of the system – whether at household, community or national level – to respond through adaptation can be understood in two ways. First, as a set of components. Second, as a set of (sub-)properties. Together these interact to create the adaptive capacity of the system, which can be thought of as the system's capabilities – what it is able to be and to do – in making a response to acute or chronic climate change manifestations. Therefore resilience interacts with assets and other components to shape the trajectory of functioning and adaptation after a disturbance (Norris et al., 2008).

A system with a high level of vulnerabilities will not just have lost adaptive components, but also resilience, both of which in turn imply a likely loss of adaptation, and a constrained ability to achieve development outcomes (Folke, 2006). Conversely, the reduction of existing vulnerabilities would mean a gain in adaptive capacity seen either in terms of components or resilience properties, potentially leading to better adaptation.

3. e-Resilience and e-Adaptation

Vulnerability, adaptive capacity and resilience are concepts that have been broadly discussed and analysed in the climate change adaptation literature for many years. They constitute closely linked, albeit complex areas of analysis that are key to understand the effects of climate-related hazards and shifting trends in developing contexts.

At the same time, within those contexts, ICTs – particularly mobile phones – have been diffusing rapidly (Heeks, 2010). This diffusion has been accompanied by an increasing body of literature on the potential and challenges of digital technologies. Part of that potential is the ability to address climate change. Yet a review of the literature on ICTs and climate change shows not only is the literature overall fairly limited to date, but there are particular deficiencies in discussion of developing country priorities and climate change adaptation (Ospina and Heeks, 2010).

Review of the existing literature on ICTs, climate change and development (ibid.) indicates that the potential of digital technology has not yet been integrated into a systematic understanding of adaptation and resilience, let alone from the perspective of a conceptual framework. This section of the paper will address that gap by exploring the potential of ICTs to strengthen resilience and its sub-properties, and thus contribute to adaptation processes in contexts vulnerable to climate change.

One way to understand the potential contribution of ICTs to climate change adaptation – and based on the model of livelihood systems summarised in Figure 4 – would be to chart its role as a component of livelihood systems vis-à-vis other system components: supporting human capital, supporting financial capital, etc; supporting formal institutions, supporting informal institutions; and so on. However, that understanding is already fairly well reflected in both literature and practice generally within the ICTs-for-development field, even if the main focus has been on ICTs addressing particular livelihood strategies or broader development goals, and even if the links to climate change are so far poorly made. Where a link has occasionally been made between ICTs and climate change – whether in literature or practice – these technologies have mainly been conceived as tools to address specific climate change challenges.

What has been missing in all cases – those dealing with climate change or with other development issues – is an understanding of the foundational issue – resilience – and the way in which ICTs can support the development of resilience. In response to this gap and as a contribution to the conceptual framework that has been developed thus far, the following section will explore the links between ICTs, resilience and adaptation in vulnerable livelihood systems, focusing first on how these tools can strengthen resilience sub-properties, and then on how they can address adaptation more broadly.[7]

3.1. ICTs and Resilience: 'e-Resilience'

For the purposes of this analysis, the role of ICTs in climate change resilience will be explored based on the linkages that exist between ICTs as a system

[7] Though at the same time recognising that, as noted above, there is only a conceptual rather than practical separation between understanding ICTs' contribution to system components (assets, institutions and structures), and ICTs' contribution to system properties (resilience). As such, discussion of ICTs' role vis-à-vis resilience will necessarily incorporate discussion of ICTs and assets, institutions and structures.

component, and the set of resilience sub-properties previously identified. This approach will serve as the basis to explore the technologies' potential contribution to adaptive capacities at the system level, and should be seen as illustrative rather than comprehensive.

- **ICTs and Robustness**

ICTs can help strengthen the physical preparedness of livelihood systems for climate change-related events through applications such as geographic information systems (GIS), and positioning and modelling applications. These can contribute to design of defences and determination of their optimal location; both making the livelihood system more robust. Illustrating this potential, remote sensing and GIS technology have been used to map and then rehabilitate and sustainably manage mangrove forests in Kenya (Kairo et al., 2002). Given mangroves' role in reducing storm damage, this technology has helped enhance coastal defences and make these areas more robust in the face of climate events such as increased cyclone intensity (Kelly and Adger, 2000).

ICTs can also strengthen institutions and organisations needed for the system to withstand the occurrence of climatic events, including the support of social networks and the facilitation of coordinated action (Duncombe, 2006). For example, ICTs can strengthen social networks through enhanced communication within those networks; communication that increases the network bonds by building trust and a sharing of norms and values.

- **ICTs and Scale**

ICTs can help increase the breadth and depth of assets to which households, communities, etc have access. ICT can facilitate access to a broader set of capital assets, fostering the ability of livelihood systems to recover from climate-related events. Illustrating this potential, ICTs available in Village Resource Centres in rural India have enabled end users to interact with scientists, doctors, professors and government officials located in urban locations (Nanda and Arunachalam, 2009). This has increased the information assets available (e.g. oceanic weather forecasts), and human capital (e.g. via tele-health and e-learning), all of which help when climate-related events occur.

ICTs can increase the scale of available assets by combining the distant and the proximate. In relation to information assets, for example, in remote areas of the Philippines, participatory 3-dimensional modelling – a community-based tool which merges GIS-generated data and local peoples' knowledge to produce relief models – is being used to establish visual relations between resources, tenure, their use and jurisdiction, thus contributing to the ability of the community to deal with climate change hazards and trends (IAPAD, 2010).

Mobile applications have improved the breadth of structural access by enabling integration of local producers – small entrepreneurs and farmers – into regional and global supply chains, which also broadens the scale of asset availability, typically in terms of financial and physical capital. In India, the Foundation of Occupational Development (FOOD) promoted the use of cell phones enabling women entrepreneurs from poor communities to exchange goods, place and receive orders, and develop new markets for their products (InfoDev, 2003). Such applications can also increase the scale of institutional forces. For example, m-microfinance services extend the reach of microfinance organisations (Garcia Alba et al., 2007). Not only does this increase the scale of financial assets and organisational structures; it also scales the penetration of the institutional norms and values associated with microfinance organisations. Finally, access to extended social networks through ICTs can also help asset, institutional and structural scale by improving the links between local systems and the meso/macro-level organisations that play a key role in the provision of enabling environments for adaptation.

- **ICTs and Redundancy**

Redundancy with respect to ICTs refers to the potential of these tools to increase the availability of resources to such an extent that there is some spare, excess or possible substitutability of assets. One of the key ways in which ICTs can contribute towards system redundancy is by supporting access to additional financial capital. Mobile phone and Internet usage among Tanzania's small farmers was found to increase their participation in markets and provide information for improved productivity (Lightfoot et al., 2008). This may enable the generation of spare income usable in strengthening local preparedness and response in the event of climatic events (e.g. buying additional food to store, or improving the building structure of the household). Likewise, the advent of m-finance systems has facilitated remittance flows which may be called upon during an acute shock to substitute for income that can no longer be produced locally, thus offering some measure of redundancy (Porteous and Wishart, 2006)

Just as asset redundancy can improve the resilience of livelihood systems, so does redundancy in institutions and organisations (e.g. markets), which allows systems to continue to operate even in the event of partial failure of some of its components. One example is the broadening of job markets through use of ICTs such as mobile applications (e.g. job searching mechanisms such as Babajob, which uses web applications and mobile technology to connect informal sector workers – maids, cooks, drivers, etc – with potential employers in India) (Babajob, 2010; VanSandt et al., 2010). Then, if there was a collapse or failure of the informal networks through which most poor people find jobs, the spare capacity provided by the ICT system can enable continued operation. Another is the use of m-commerce systems such as those offered in the Philippines by SMART Padala, through which users can make purchases from a variety of participating retailers (Wishart, 2006). Releasing commerce from the constraints of geography (i.e. enabling purchases from retailers outside the local area) provides 'commercial redundancy' through substitutable trading links.

- **ICTs and Rapidity**

ICTs can enable swift access and mobilisation of financial assets, particularly through applications for mobile banking and mobile finance (Duncombe and Boateng, 2009). By enabling rapid access to financial capital and transactions, ICTs have the potential not only to strengthen local livelihoods but also to improve the speed and efficiency with which local communities are able to cope with and adapt to climate change-related hazards and events.

ICTs can also speed up access to information. This is particularly important when an acute climate-related shock such as landslide or flood occurs. Mobile-based telecommunications networks allow rapid communication of information, thus improving the speed of disaster warning, response and recovery (Aziz et al., 2009; Samarajiva & Waidyanatha, 2009)

- **ICTs and Flexibility**

Within vulnerable livelihood systems, ICTs can help identify and undertake different actions to better withstand the effect of climate change-related events, and utilise the opportunities that may arise from change. Identification of diverse action possibilities arises from the sharing of knowledge – something that ICTs are particularly good at – by enhancing the social contacts that provide access to tacit knowledge; and by enhancing access to the explicit knowledge that is now held, for example, on web sites and e-learning systems worldwide. Access to information can also promote flexibility through identification of alternative possibilities, such as information about different income-generating opportunities including information on demand and prices at different markets.

The multi-functionality of ICTs themselves can also be argued to introduce greater flexibility into the livelihood systems of which they become a part and, perhaps, to encourage flexibility by embodying it as an inscribed value. That inherent quality of ICTs may enable greater flexibility of action where ICTs are part of the action processes within a livelihood system, as they increasingly are in relation to not just communication but also transactional processes such as finance, banking, education, and health. Where ICTs form part of a livelihood, the technology's flexibility can enable livelihood flexibility; for example, the ability to diversify relatively easily from one form of ICT activity (e.g. data entry) to another (e.g. digital photography) (e.g. Heeks and Arun, 2010).

- **ICTs and Self-Organisation**

ICTs can enable access to the set of resources that livelihood systems require to effectively self-organise in the event of climate change-related shocks or disturbances. As argued through examples related to the sub-properties of scale, redundancy, rapidity and flexibility, in addition to access to relevant data, ICTs can facilitate access to assets such as physical and economic capital (overt resources), as well as to other embedded social resources such as trust, motivation, knowledge and power (e.g. through social networks, local empowerment and inclusiveness, or the active engagement of local actors in participatory processes).

At the same time, ICTs can play a valuable role in the coordination of efforts between stakeholders, facilitating the different stages of cognition, communication and co-operation that, according to Fuchs (2004), play a role in self-organisation processes at a systemic level. More specifically, ICTs provide access to relevant data and information that is first processed at an individual level (cognition), then facilitate communication and interaction between a wide range of stakeholders, and ultimately enable co-operation, which can translate into adaptive actions being implemented with the participation of a wide range of stakeholders.

Exemplifying this multi-stage influence in self-organisation, in the Philippines SMS is being used for citizen engagement campaigns that seek to reduce air pollution while encouraging citizen participation (Dongtotsang and Sagun, 2006), suggesting the potential of these tools to foster environmental action and raise policy awareness. In cases such as this, ICTs can play a role from accessing relevant data and awareness on environmental issues at the individual level, to enabling communication and interaction using mobile telephony, to fostering co-operation with wider networks of stakeholders towards action, through social networking tools and the strengthening of participatory processes.

At the same time, studies in the field indicate that localisation and decentralisation play a key role in the success of self-organisation and adaptation strategies. One example would be the rural weather stations in Kenya, Zimbabwe and Uganda that help decentralise the analysis of climate information and design strategies at the local level (Kalas and Finlay, 2009). Contributing to communication and co-operation, ICTs can facilitate the implementation of participatory processes of natural resource management, as well as promote more inclusive processes of policy formulation and enforcement. They can foster better reporting mechanisms on the status of environmental initiatives through the engagement of individuals and civil-society organisations in monitoring. This includes enabling communities to monitor changes in local climatic conditions such as the number of frost days, the length of growing seasons or the changes in rainfall patterns, which can ultimately help strengthen local adaptive actions in sectors such as agriculture and forestry.

Social networks can be fundamental in self-organisation, including community subsistence in times of scarcity and drastic climatic events, as well as for monitoring environmental changes, and identifying new mechanisms to reduce risk and uncertainty. They play an important role in peer-to-peer knowledge sharing and dissemination, which in remote villages could be key in the (self) organisation of effective early warning systems and coping strategies.

In turn, within decision-making processes that enable self-organised actions, ICTs can facilitate the assessment of options and the analysis of potential trade-offs that are involved in the adoption of particular courses of action (e.g. via climate change modelling, prediction and spatial planning applications). The availability of ICT infrastructure can also support the role of other system components for resilience and adaptation. ICT applications such as geographic information systems can reduce the uncertainty that characterises climate change scenarios, providing valuable input to inform decisions on issues such as land-use planning, environmental resource analysis, demographic analysis, and infrastructure planning, key in both rural and urban contexts that are vulnerable to the effects of climate change.

As Heeks and Leon (2009) identify in their exploration of information chains in remote areas, psycho-social factors are an important part of the ability of systems to independently self-organise. Where ICTs can provide such factors – an increase in hope, in motivation, or in perceive self-efficacy – they will increase system self-organisation; reducing dependency on external sources. There are already some signs that ICTs can do this (e.g. Pal et al., 2007). The information chain model also identifies a critical component in the analysis of ICTs' role within self-organisation as the capacity (knowledge) of the user to judge the accuracy, completeness and relevance of data in order to assess it and ultimately act on it. This knowledge is in turn linked to the potential of ICTs to foster learning, as explained next.

- **ICTs and Learning**

Experiences from the field suggest the role of ICT-enabled skills and access to knowledge in enhancing the capacities of local actors and empowering marginalised groups (Labelle et al., 2008). We may conceive this role in relation to the cycle of experiential learning that, according to Kolb (1984), involves four elements: concrete experience, reflective observation, abstract conceptualisation and active experimentation. ICTs can particularly facilitate reflection and thinking – the key constituents of systemic feedback – but will impact the whole cycle.

For example, Web 2.0 and new media applications can turn this into a collective learning process (GTZ, 2008). By sharing observations and reflections through ICT tools (e.g. blogs, wikis, environmental observations and monitoring), users foster new ways of assimilating or translating information (e.g. changes in their natural environment), which can be shared through wider networks, and then influence action (e.g. encourage testing or experimentation), enabling new experiences/practices to take place. This generation of new and broader learning cycles will in turn strengthen systemic resilience.

This potential is reflected in initiatives such as the DEAL project in India, which aims to create a digital knowledge base by involving various actors in the content creation process, while making this knowledge accessible to farmers and other agricultural practitioners (DEAL, 2010). Based on the use of Web 2.0 tools, it provides a way for the farmers to explain their problems and establish a dialogue with scientists and researchers through an audio blog. The blog captures tacit, experiential knowledge from the farmers through uploaded audio files, while ensuring collaborative practices for reflection, knowledge generation and reuse through action (GTZ, 2008). In this way, ICTs can expose the collective experience of rural farmers and existent traditional knowledge, which plays a critical role in the success of adaptation, while fostering new learning processes on issues that are key for the sustainability of local livelihoods amidst a changing climate.

e-Resilience

A systemic analysis of resilience allows us to broaden the understanding of adaptation beyond the vulnerability inherent to developing livelihoods, in order to understand that adaptive capacities are also built on resilience sub-properties that can be strengthened by ICTs, thus contributing to the achievement of development outcomes.

The analysis undertaken above of ICTs' potential contribution to resilience sub-properties is not easy at present. It was based on a retrospective re-analysis of ICT4D case studies; case studies that as yet rarely talk about climate change adaptation, let alone resilience. Nonetheless, the preceding material suggests we can analyse the contribution of ICTs to adaptive processes in two ways. First, through their dynamic links with resources (asset-base and enablers), with institutions (dis-abilities/constraints) and structures (at micro, meso and macro levels) to create capabilities (abilities or disabilities to act). Second, through their enhancement of resilience sub-properties.

While this document has adopted the latter approach, the summary framework shown in Figure 5 illustrates both possible routes to understanding ICTs' role. It also reflects the fact that ICTs are a component of livelihood determinants (i.e. part of the asset base of livelihood systems, while also inscribing institutional values and helping to structure processes), but that they should be specifically highlighted in order to emphasize the focus of this study.

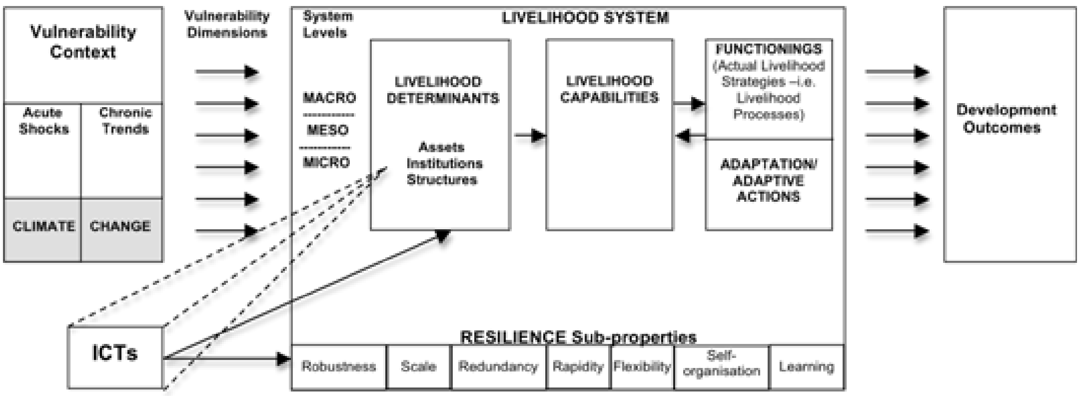

Figure 5: e-Resilience Framework

Conceiving ICTs' contribution to climate change adaptation in terms of their effect on resilience sub-properties, the concept of '*e-resilience*' emerges. e-Resilience can be defined as a property of livelihood systems by which ICTs interact with a set of resilience sub-properties, enabling the system to adapt to the effects of climate change. e-Resilience specifically and this model more generally aim to facilitate the identification, integration and analysis of ICTs' potential contribution to climate change adaptation, as part of the complex set of linkages and interactions that exist within the context of vulnerabilities faced by developing countries.

Having identified the main areas of potential in the use of ICTs vis-à-vis resilience, and in order to have a clearer understanding of their role within adaptive processes, the following section will address their role in adaptive actions and the achievement of development outcomes, which constitutes the last stage (right-hand side) of the e-Resilience Framework.

3.2. ICTs and Adaptive Actions

The systemic perspective reflected in this analysis suggests that ICTs can be conceived as contributing to adaptive processes not only through their influence on resilience sub-properties, but also through their dynamic linkages with other system components, namely assets, institutions, structures and capabilities, ultimately contributing towards adaptive functionings (unless not converted into functionings due to constraints).

In the previous sections, the focus was on ICTs and resilience (albeit incorporating discussion of technology's role vis-à-vis system components). However, whether discussing system properties or components, these are essentially precursors. What practitioners, at least, are more interested in is the downstream impact of ICTs on adaptation processes. We can assess this by considering the potential impact of ICTs in two different ways: first, with respect to livelihood systems at the macro/national level (which is key to adaptive actions); and second, their impact on the vulnerabilities identified at the beginning of this study (i.e. livelihoods and finance, socio-political conditions, health, habitat and migrations, food security and water supply), which constitute areas in which the likely impact of climate change is considered to be highest, and which play a critical role in the capacity of the system to achieve development outcomes.

ICTs' potential contribution to climate change adaptation either in these ways or if thought of in terms of e-resilience cannot, however, be taken for granted. The analysis will therefore conclude by discussing some of the challenges associated with the use of ICTs in adaptation processes in practice.

3.2a. The Impact of ICTs on National-Level Adaptation

While livelihood systems may most readily be conceived at household or at community level, as discussed above, those systems are themselves held within a larger system which both contributes and draws assets, institutions and structures. That larger system must therefore be a subject of enquiry if we are to build a more complete picture of ICTs and climate change adaptation. We set the scope of that system as the global but – given the critical role of the nation-state and of national-level actors in setting and implementing relevant policies in the field of ICTs, climate change, agriculture, urban development, etc – we choose instead to focus at the level of the nation.

In order to conduct this analysis, three main areas of potential ICT impact at the national level have been identified, namely (i) policy on the ICT infrastructure and applications that are the foundation for e-resilience and e-adaptation, (ii) ICT-enabled formation of new structures (typically network-based) that can play a role in adaptation, and (iii) ICTs' role in the cycle of national-level data gathering, analysis, and decision-making that then leads into actions and policies which have an effect on climate change resilience and adaptability. Each of them will be addressed through illustrative examples of ICTs' potential.

- **Encouraging ICT Infrastructure and Climate Change-Related Use and Application of ICTs**

  The telecommunications sector can play a key role in climate change adaptation through the provision of technical and financial support, as well as the establishment of multi-sectoral alliances to implement ICT-related solutions in the field (Labelle et al., 2008). At the policy level, developing country institutions can support the provision of broader access and connectivity in rural areas, particularly in marginalized regions affected by climate change-related hazards or trends. Multi-sectoral alliances providing adequate infrastructure can be pivotal in the implementation of effective early-warning systems (ITU, 2007), as well as for the provision of incentives for ICT entrepreneurs to play an active role in the diversification of local livelihoods, thus reducing dependence on natural resources and vulnerability to the impact of climatic events.

  Faced by the daunting risks posed by climate change to agriculture and food security, developing country structures and institutions could play an important role through the provision of national ICT-based programmes that target small farmers and producers, aimed at strengthening local knowledge on crop diversification and production under variable conditions (e.g. agricultural models and techniques to reduce climate risks, on-farm product management and seed management). ICTs can also strengthen the internal capacity of nation-wide organisations to serve as effective facilitators of local adaptive actions (FAO, 2003).

- **ICT-Enabled National-Level Structures for Climate Change Adaptation**

  Despite the recognised value of self-organisation as a foundation for resilience, adaptive capacity is also increased by integrating communities into higher-level structures that can enable flows of catalytic assets and institutional values. ICTs can help this by, for example, fostering or strengthening social and socio-political networks. For example, the technology can help build multi-level, hybrid governance systems – based on flexible organisational topologies including social networks – to combine both external inputs and participatory contributions in order to address climate change uncertainty through more effective natural resource management (Folke et al., 2005). One example would be AMARC (World Association of Community Radio Broadcasters) in Latin America, which has used ICTs to share strategies developed by local communities to address the effects of climate change in food security (Kalas and Finlay, 2009).

  One can view the enabled flows largely at the meso-level: helping local communities to shape their local actions on the basis of knowledge developed with peers or from institutions of national expertise. But upward flows can be equally important, giving voice to the climate change-related experiences of individual communities, and ensuring these are heard and melded into the formation of appropriate national policies that will foster adaptation in the long term.

  At the same time, ICTs can facilitate coordinated adaptational action by creating and supporting policy networks or policy communities between different national-level stakeholders, and around specific climate-related issues. The technology typically strengthens information exchange between the scientific community and policy makers, as well as with civil society organisations working on environmental issues in the field.

- **ICT-Enabled National-Level Climate Change Adaptation Data-Gathering, Analysis, Decision-Making and Action**

  ICTs can strengthen the capacity of national organisations working on climate change by enabling better-informed, and more participative decision-making processes. The use of ICT tools can help Ministries and pan-governmental agencies to coordinate actions and implement national-level campaigns, and facilitate the provision of locally appropriate mechanisms of prevention and response. ALERTA, for example, a disease surveillance application implemented in Perú, enables health professionals in rural areas to submit reports to health authorities via telephone or Web-based applications, as well as to receive information and assistance through voice mail, thus enabling the community to respond faster to short-term health-related emergencies, and also helping to track some of the longer-term changes in disease prevalence with which climate change is being associated (InfoDev, 2003).

  ICT applications (e.g. geographic information systems) form an increasingly-embedded role in gathering data about urban environments, and in assisting urban planning and development decisions by government agencies. This includes data of specific relevance to climate change vulnerabilities such as patterns of current and likely future water supply (eoPortal, 2010). By drawing information from a variety of stakeholders, from communities to meteorological departments, ICTs help these agencies not merely understand the present situation but model future – including climate-affected – scenarios, leading to decision-making on measures to improve climate resilience such as sea walls, reservoirs, or large-scale irrigation systems.

  Similarly, and based on the use of applications that allow advanced mapping and visualisation, piloting and modelling, as well as participatory approaches that reflect local needs, ICTs could support the design of new policies and regulations on human settlements, as well as rules on building standards implementation, contributing to reduce existing vulnerabilities in this area. The role of these tools can also support advocacy from organisations (e.g. to secure rights of access to water supplies for small-scale farmers and ensure water availability), among other adaptive actions.

  Alongside policies that aim to have a direct effect on climate change vulnerabilities, adaptation will also require action on more contextual, institutional shapers such as access to markets or fiscal policy. Solid information systems are a key pre-condition for policies such as effective tax administration or incentive structures designed to encourage environmental practices. This suggests the existence of linkages between e-government strategies and the effective promotion of environmental and adaptive practices at the national level.

3.2b. The Impact of 'e-Adaptation' on Climate Change Vulnerability Dimensions

Having identified key areas of potential ICT adaptive impact at the national level, a systemic analysis of their role also requires exploration of their contribution in delivery of adaptive actions that directly address (i.e. reduce) climate change vulnerability dimensions in developing countries.

- **Livelihoods and Finance**

  Emerging experiences from the field suggest the potential of ICTs to support local livelihoods (i.e. productive processes and local livelihood activities) in regions vulnerable to climate change. One way they do this is by providing information on the climate-related aspects of livelihoods. An example would be providing local farmers with information on new varieties of crops, crop diseases, and more effective production processes, fostering productivity and facilitating adaptation processes of local livelihoods (Scott et al., 2004). In Uganda, for instance, a country that is highly susceptible to climatic variations and shocks (Magrath, 2008), iPods and podcasts are being used in marginalized communities to access creatively-packaged content relevant to their livelihoods. Most content to date is generic agricultural improvement information, but it can readily incorporate climate-relevant content such as changing seed/crop choices, and changes in agricultural practices (ALIN, 2010).

  The way in which ICTs can help bring finance into communities affected by climate change has been noted above. As yet, few studies, have looked specifically at the financing of climate change adaptations, and the way in which ICTs can help. Similarly, ICTs can help build more-resilient livelihoods: for instance, providing more accurate price and demand information that enables sales with higher profits or to a wider range of markets (Jensen, 2007); or by creating ICT-based micro-enterprises that may provide additional and/or more robust income streams (e.g. Heeks and Arun, 2010). Again, though, there is little evidence yet viewing this from a climate change-specific perspective.

- **Socio-Political Conditions**

  The broader socio-political conditions within which local community adaptation sits has been discussed already in the previous section. There we saw that ICTs can help enable new structures within the socio-political environment which can foster inclusiveness and participation in the design and implementation of adaptation processes, thus reducing the potential for the emergence of social tensions or instability. In the Caribbean, a study of women organic farmers found these tools strengthened networking, cooperation and advocacy among the farmers, improving their resilience in the face of climate change-related changes (Tandon, 2009).

- **Health**

  The ALERTA example given previously showed how ICTs can help monitor alterations in patterns of disease that are predicted to arise as a result of climate change. ICTs can also drive new health information back into communities, using technologies that are accessible in the field (e.g. mobile phones, community radio) to provide climate literacy on key health topics, to improve the local response to shifts in vector-borne (e.g. malaria and dengue) and water-borne diseases, heat, declining food security and decreased availability of potable water (IISD, 2005); as well as to internalise other health-related adjustments that may become necessary within local communities (Kalas and Finlay, 2009).

- **Habitat and Migration**

  ICT applications can help alleviate the pressures posed by migration and redistributions of people triggered by sea-level rise, drought, desertification or extensive flooding, among other potential impacts of climate change. As noted already, applications such as remote sensing and GIS can facilitate urban planning, thus improving the habitat conditions of displaced populations that are forced to settle in deprived and/or over-populated areas. At the same time, ICTs can enable communication between family members separated or disrupted due to climate events, thus ameliorating the psychological stress these types of migrations can cause among vulnerable populations (Dempsey, 2010).

- **Food Security**

  Crop yields affected by drought or flooding, or by an overall decrease in agricultural productivity due to climate variability can create food shortages, triggering malnutrition and related problems within vulnerable populations. Within such contexts, ICTs can play an important role in support of agricultural extension services, broadening the reach of such programmes particularly in rural, marginalised area of developing regions. In many ways, this overlaps with the agricultural livelihoods role described earlier. For tribal farmers of North-East India, for instance, where inadequate dissemination of farm information and technologies have led to low productivity and food insecurity, ICTs (including radio and television) are being used to disseminate information on pest and disease management information, among others (Saravanan, 2008; e-Arik, 2010). However, ICTs will have a food security role beyond just production; providing information for the planning and operation of food storage, distribution, and consumption.

- **Water Supply**

  ICTs can help improve water resource management techniques, monitoring of water resources and awareness raising at the community level. In Peru, the Centre for Social Studies (CEPES, 2010) has implemented a project based on a small network of telecentres in the Huaral Valley, a remote region where droughts and water scarcity have hindered agricultural production and local livelihoods. With the support of ICTs, an agrarian information system has been put in place that includes software to improve the distribution of water (APC, 2007). As with other vulnerabilities, though, most cases to date relate to the vulnerability generally rather than identifying ICTs' role in specifically assisting water supply management issues that are arising as a result of climate change.

As just noted, the examples reported here are almost all drawn from the ICT4D literature rather than the 'ICT4CCA' (climate change adaptation) literature; not least because the latter hardly exists. Likewise, although we have drawn out the vulnerability-specific aspects of each case, in practice, ICT projects often overlap several vulnerabilities. A single rural information system, for example, might well cover livelihoods, food security, health and water.

On the one hand, this reinforces the need for a rapid expansion of climate change-specific analysis of ICT projects. On the other, though, it indicates the value of taking a holistic perspective towards ICTs and climate change adaptation: one that goes beyond short-term solutions for individual climate change shocks and symptoms; and which addresses the underlying causes of vulnerability and exposure to longer-term trends and uncertainties. That, of course, is exactly what the e-Resilience Framework seeks to do.

One common aspect that could be drawn from the vulnerability areas identified – and also reflected in the e-Resilience Framework – is the potential of ICTs to help bridge and converge the priorities of actors at the micro, meso and macro levels, as well as to broaden access to assets, capabilities, and supporting organisations and institutions towards the enactment of adaptive functionings. ICTs could also contribute towards the implementation of more inclusive, participatory processes that reflect the needs and power relations that exist within local contexts.

Solutions that are disconnected from the priorities and characteristics of the local social fabric will not have the long-lasting effects that are necessary for future adaptation and the achievement of development outcomes. Within development contexts, the potential of ICTs could complement integrated approaches that include not only monitoring and early warning, but also broader measures to reduce vulnerability in areas such as livelihoods diversification, socio-political conditions, food security, water supply, habitat and migrations, among others. Put another way, ICTs alone do not represent the solution to climate change adaptation; they must be an integrated part of a holistic approach.

3.2c. Challenges of Using ICTs to Support Climate Change Adaptation

The analysis conducted thus far indicates the existence of positive, valuable linkages between ICTs and the resilience of systems vulnerable to climate change. However, developing countries are characterised by the interplay of a complex set of stressors and inequalities including socio-political contexts where power relations and potential divisions are based on factors such as gender and ethnicity, and where the implementation of innovative ICT approaches must be assessed carefully (Duncombe, 2006). Thus, analysis of ICTs' role must also acknowledge their potential to impact negatively on livelihood systems, possibly reducing their resilience and adaptive capacity to climate-related hazards, trends and variability.

Perhaps most obviously, ICTs can act as a resource sink, drawing away valuable assets from within any system, such as a community. ICTs cost money and will typically divert expenditure from other uses (e.g. Diga, 2007). Less tangibly, ICTs might divert time and motivation, thus undermining adaptive capacities and actions. Even where they do deliver new assets, those assets are not necessarily usable. For example, ICTs may provide unreliable information or information that does not correspond to the local realities or that is made available in a language that is inaccessible for the local actors. This can not only undermine the potential of these tools within adaptive processes, but also contribute more generally to an increase in uncertainty or even encourage mistaken and maladaptive actions.

Adaptation as a response to a particular climate-related disturbance can undermine systemic resilience by making the community more vulnerable to other shocks, or by constraining generic sub-properties such as flexibility (Nelson et al., 2007). If used within adaptive actions that do not integrate or acknowledge these factors, ICTs could contribute to overall maladaptation; for example, by focusing attention and resources on one initiative – say a disaster early warning information system – and thus drawing those assets away from application to other initiatives.

At the same time, it is necessary to recognise that livelihood systems in developing contexts involve complex power relations and inequities which determine access (e.g. to assets and opportunities), and can turn the potential benefits of ICT interventions into situations where the power of more privileged groups is strengthened (e.g. those with greatest access to decision making), widening the gap with those that are most at risk. According to Pettengell (2010), "addressing existing conditions that cause vulnerability to climate change or limit adaptive capacity is a vital component of adaptation" (ibid, p. 29), those conditions including distributions of power.

For example, actions that do not acknowledge the specific vulnerabilities and role of women within adaptive processes face the risk of deepening existing gaps; say, in regards to ownership of land, rights to assets, or access to assets such as financial credit (ibid). ICTs might also facilitate the adaptation of individuals, but not necessarily that of broader groups. Applications that strengthen the livelihood options of a family or group do not necessarily have the same effect at community level, in some cases deepening the gap between the 'haves' and the 'have nots' within particular communities. If ICTs are used without considering the gender and other imbalances and power relationships within a given community, the use of these tools can reinforce existing inequalities, giving voice to the interests of certain groups that may not be the most vulnerable. Therefore, ICT solutions must acknowledge the role and contribution of power and inequality to adaptation processes, targeting them if effective and inclusive adaptation is to be achieved. These examples suggest that, within contexts characterised by poverty and inequality, the reduction of climate-related risks is not sufficient to indicate success. The analysis of ICTs' potential requires careful consideration of the underlying factors of vulnerability within developing environments, as well as the existing institutions and structures that characterise a given livelihood system.

4. Conclusions

Despite the fact that much remains to be explored in terms of the role and potential of ICTs within the climate change field, the analysis conducted here sheds light on key conceptual foundations that help better understand the complex linkages that exist within vulnerable livelihood systems, and that ultimately determine the role of digital technologies in achieving development outcomes amidst an uncertain climatic future.

The framework developed integrates the key concepts that mediate ICTs' role in climate change: vulnerability, adaptation and resilience, and development outcomes. Based on the foundations provided by the sustainable livelihoods approach, new institutionalism and the capabilities approach, the model constitutes a conceptual tool for the understanding of climate change resilience in vulnerable systems. It provides a basis to analyse how the dynamic interactions between components (e.g. asset-based, institutional and structural determinants of capabilities) and processes (adaptive functionings) that play a role in the achievement of adaptation and development, can be understood at macro, meso and micro levels.

The analysis conducted suggests that, in the event of climate change-related shocks or trends within a particular context, the capacity of the system (at the household, community or national level) to respond through adaptation can be understood either as a set of components or as a set of (sub-)properties, which interact to create the adaptive capacity of the system. Resilience, thus, emerges as an important property to consider in the analysis of livelihood systems that are subject to climate-related changes and uncertainty; a property that interacts with assets and other components to shape the trajectory of functioning and adaptation after any acute or chronic disturbance (Norris et al., 2008).

The systemic analysis of resilience allowed us to broaden the understanding of adaptation beyond the vulnerability inherent to developing livelihoods, in order to understand that adaptive capacities are also built on resilience sub-properties that can be strengthened by ICTs, thus contributing to the achievement of development outcomes.

Within these contexts, the concept of *e-resilience* is defined as a property of livelihood systems by which ICTs interact with a set of resilience sub-properties, enabling the system to adapt to the effects of climate change. Thus, e-resilience is suggested as an emerging area of study to understand how innovative ICT tools and approaches can strengthen the response of vulnerable systems to the challenges and uncertainty posed by climate change.

The value of this approach resides in its contribution to better understand the complex set of relations between livelihood system components, properties and processes, which in turn are characterised by the presence of multiple development stressors. It is expected that the model can serve as a tool to explore the potential and challenges of ICTs' role within processes of adaptation, while facilitating the identification of strategies that could contribute to the enhancement of adaptive capacities, and ultimately to the achievement of development outcomes in the face of long-term climatic uncertainty.

The analysis recognised that information has both an analytical and functional role within the livelihoods framework, and should be considered as part of a dynamic process of change rather than as a static resource (Duncombe, 2006). These attributes are particularly relevant considering the dynamism and unpredictability that characterise the climate change field. It also recognised that

ICTs must be seen not simply as a tool for processing and communicating information, but also increasingly as a means to undertake digital transactions, and as a means of production for new ICT-based enterprise.

The study suggested the relevance of considering both short-term (e.g. hazards) and long-term (e.g. trends and variability) climate change impacts, as well as differentiating between short-term coping/rebound actions, and longer-term processes of adaptation that may involve system transformation. Related to this recognition, the development of the e-resilience framework indicates that the study of ICTs' potential in the climate change field requires the acknowledgment that dynamic ICT processes can be formal or informal, can fulfil both short-term (coping/rebound) and long term (adaptation/transformation) needs, and be actionable at different levels (micro/ meso/ macro), in addition to fostering interaction between structures and institutions, capabilities and functionings (ibid.). ICTs can, therefore, make a contribution to adaptation, something that can be considered directly under the heading of 'e-adaptation'.

Within this context, innovation and flexibility have proved to be key characteristics in building local resilience to changing conditions in the short, medium and long term (IISD, 2005). Innovation, thus, emerges as the ability of the system to do new things with existent determinants, and is therefore, closely related to flexibility as a resilience sub-property.

Carpenter et al. (2001) argue that the best way to cope with surprise is resilience. The development of the e-resilience framework suggests that ICTs have the potential to contribute towards adaptive capacities, helping vulnerable systems to change and adapt in the face of climate change disturbances and uncertainty. This perspective of resilience provides a valuable context for the analysis of systems' responses to climate change in developing countries, as well as for the identification of the potential and challenges associated with the use of ICTs within adaptive processes.

The analysis also suggests the possibility that, because of their emphasis on information models or development goals, projects in the field of ICT4D have been poor in addressing and building resilience. It is hoped that this study will stimulate greater research and discussion of the possibilities and potential of ICTs in climate change adaptation, particularly with respect to the challenges posed by climate change in developing regions.

Ultimately, the challenge for developing countries resides not only in their capacity to withstand and recover from climatic events, but mostly in their capacity to adjust, change and transform amidst slow changing trends and unpredictable variability; while facing a future where the only certainty is uncertainty itself, and within which, development outcomes will be determined, to a large extent, by their ability to foster 'development epiphanies' and innovate with the support of tools such as ICTs.

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Chapter 3: ICTs and Climate Change Mitigation in Emerging Economies

HELEN ROETH & LEENA WOKECK

Executive Summary

This paper discusses needs and opportunities for ICT-enabled climate change mitigation in emerging economies. It was written against the backdrop of challenges to reduce greenhouse gas (GHG) emissions globally, increases of emissions in rapidly growing emerging economies, and the need for technological 'leapfrogging' to low-carbon development trajectories. It demonstrates how ICT-enabled climate change mitigation could help pave the way for low-carbon development pathways in the world's developing countries.

Section 1 outlines the challenge of climate change mitigation in emerging economies which is compounded by the need for sustained economic growth and the alleviation of widespread poverty on the one hand and the imperative to reduce GHG emissions on the other. There is an urgent need for emerging economies to make the transition to a low-carbon development pathway whereby economic growth is decoupled from an increase in GHG emissions.

Section 2 describes the critical role that ICTs can play in mitigating climate change in these economies and lists some key opportunity areas. Each country faces its own set of opportunities in the context of national development objectives and constraints. But a number of main sectors with significant ICT-enabled carbon reduction opportunities can be identified across all economies which include energy generation, urban transportation and buildings, manufacturing and international trade.

While the opportunities for ICT-enabled carbon reductions in emerging economies are compelling, major barriers to widespread commercial deployment of these solutions remain. Such barriers, discussed in section 3, include the lack of awareness of technological developments, and the limited or uncertain suitability of these technologies. In many emerging economies there is no favourable regulatory and political environment incentivising necessary investments and research. Small and medium-sized enterprises, the main users of low-carbon technologies in these countries, also face limited access to capital and limited capacity and skills to adopt low-carbon technologies.

In conclusion, section 4 outlines key recommendations for governments in emerging economies and large businesses leading on low-carbon technologies. The support of both stakeholders will be crucial to enable a transition to low-carbon development. Governments will need to create an enabling policy and market environment to encourage necessary investments and research. Big businesses will need to make technology available to small and medium-sized enterprises in emerging economies, and to help build innovation capacity in these countries.

1. Introduction

To date, the global discussion on the potential of ICT-enabled climate change mitigation has largely revolved around the developed countries. This is where current levels of total greenhouse gas (GHG) emissions are highest, where governments are demanding significant greenhouse gas emission reductions, and where a few leading companies are already contributing to the advancement and deployment of low-carbon solutions. However, with a major part of future emissions growth expected to take place in the world's emerging economies, there is an urgent need for these countries to make the transition to a low-carbon development pathway. This pathway would balance the need for economic growth with the global imperative to reduce GHG emissions significantly.

Against that background, this paper discusses the potential of ICTs in mitigating climate change in emerging economies. Emerging economies are characterised by rapid economic growth and are increasingly contributing large shares of GHG emissions. Their role in contributing to mitigating climate change therefore is becoming ever more urgent and will necessitate the rapid deployment of alternative low-carbon growth trajectories if the climate is to be protected without hampering growth and development in these countries.

This paper is based on an extensive literature review and comprehensively analyses and evaluates the current state of ICT deployment for low-carbon growth in emerging economies. It identifies areas of opportunity for ICT-enabled climate change mitigation based on the national carbon footprint of key emerging economies. Taking into account key development needs as well as the very specific nature of the challenges that are identified for a number of key emerging economies, the paper identifies opportunities where ICT-based solutions can contribute to both emission reductions and enhanced economic development, e.g. micro-grids for poor remote communities.

It contributes to the existing literature by adding a perspective that goes beyond an analysis of ICT applications and their potential to contribute to climate change mitigation to take into account and address the very specific and diverse challenges in a number of emerging economies. A thorough engagement with development needs and priorities – plus an analysis of how growth imperatives necessary to enable development may be reconciled with the urgent necessity to mitigate climate change – provides the background for making the case for innovative and collaborative approaches to enable inclusive low-carbon growth and utilising the potential for ICT effectively and universally in that context. The presented needs and opportunities to pave the way for ICT-enabled transformations of sustainable and low-carbon growth trajectories in emerging economies are further employed to stimulate reflections on how some of the emerging economy cases described and analysed can be useful reference points for developing countries more generally and their future options for sustainable development trajectories. Important insights are generated and specific recommendations offered to inform key questions on how technological innovation in the ICT sector and improved implementation of available technological solutions across the globe can contribute to meeting two of the world's most pressing challenges simultaneously: protecting the climate whilst not hampering growth and development.

1.1. The Climate Change Challenge in the World's Emerging Economies

Emerging economies, or developing countries that are experiencing rapid growth and (partial) industrialisation, are fast becoming a major source of greenhouse gas emissions globally.

The share of greenhouse gases emitted by the world's developing countries is increasing and, in total terms, emissions of developed and developing countries are converging. Developing countries already account for 50 percent of global GHG emissions and by 2030 this figure is expected to rise to 65 percent.[8]

Emissions from fossil fuel combustion increased by 41 percent between 1990 and 2008 – an increase significantly driven by emerging economies where fossil fuel emissions more than doubled during that period. The growth of fossil fuel emissions in emerging economies can largely be ascribed to the use of coal as the primary energy source and the production and international trade of goods and services.[9]
Emerging countries are expected to be leading source of future growth in GHG emissions as robust economic growth further drives an increase in energy use from industrialisation, new buildings, increased traffic and deforestation. It is predicted that between 2005 and 2030, 50 percent of the increase in world primary energy demand will come from China and India alone.[10]

The four major emerging economies - Brazil, China, India and South Africa - are among the world's largest emitters (on a net emissions basis):

- China and India are the largest emitters of GHGs in the Asia/Pacific region, contributing 51 percent and 15 percent of the region's emissions.
- Brazil is the largest emitter in the Latin America/Caribbean region accounting for 32 percent of the region's GHG emissions.
- South Africa is the largest emitter in Africa, responsible for 24 percent of emissions.[11]

Average GHG emissions per capita are still comparatively low in these countries. But due to rapid economic development, per capita emissions are increasing and in particular in China quickly approaching levels common in the industrialised countries. Per capita emissions reached 6.1 tonnes in China in 2009, up from only 2.2 tonnes in 1990. In comparison, per capita emissions in 15 nations of the European Union were 7.9 tonnes in 2009 (down from 9.1 tonnes in 1990) and in the United States the figure was 17.2 tonnes (down from 19.5 tonnes in 1990).[12]
South Africa's per capita emissions are already among the highest at 9.25 tonnes in 2008.[13]

The world's least developed countries are a minor contributor to global climate change. They contributed only 0.5 percent of the cumulative GHG emissions between 1995 and 2008[14]. The majority of the least developed countries have emissions of less than 2 tonnes CO_2 per capita with, for example, countries such

[8] Tan, X. and Seligsohn, D., 2010.
[9] Le Quere et al., 2009.
[10] WWF, 2008.
[11] UNFCCC, 2005.
[12] Kanter, J., 2010.
13 Union of Concerned Scientists, 2010.
[14] UN-OHRLLS, 2010.

as Rwanda exhibiting per capita emissions of 0.3 tonnes, Bangladesh 0.9 tonnes, and Cambodia 1.6 tonnes CO_2 per capita in 2005[15].

Major differences in GHG emission accounts between developed and developing countries reflect challenges related to economic growth, industrial development and access to modern energy services in many developing and emerging economies. While the challenge to mitigate climate change is global, developing countries face the urgent need to expand provision of affordable energy services to the world's poor. Experts argue that "energy services play a critical role not just in supporting economic growth and generating employment, but also in enhancing the quality of people's lives".[16]

Thus, the development pathway pursued by developing countries is an important factor in global efforts to mitigate climate change. A key question is whether and to what extent developing countries will follow the high-carbon development pathways of developed countries. The fact that a major part of the infrastructure necessary to meet development needs is still to be built in developing countries represents both a risk and an opportunity:

- A risk of so-called lock-in effects whereby infrastructure, technology and product design investments are being made without climate change considerations, leading to significant GHG emissions during the infrastructure life-time.

- An opportunity for technological 'leapfrogging', whereby developing countries can overleap emissions-intensive intermediate technology in favour of cleaner technologies.[17] Thus they would implement low-carbon strategies from the outset and avoid the legacy infrastructures and technology lock-ins that constrain available options in more advanced economies.[18]

A discussion around climate change mitigation specifically in the emerging economies is crucial, based on the fact that these countries face significant carbon risks as well as opportunities and, moreover, because they can lead the way by demonstrating possibilities for a low-carbon development pathway for both developed countries and other developing countries.

A comparison of GHG emissions by sector between developed and developing countries indicates that – even if emissions levels within emerging economies are converging – the two groups have distinctively different sets of energy issues and emissions sources, suggesting that mitigation opportunities will differ significantly. The latest and most accurate emission figures are provided by the World Resources Institute through its Climate Analysis Indicators Tool (see Box 1). Charts provided in this tool show that the carbon footprint in developing countries is quite dissimilar from that of developed countries:

- the share of emissions from electricity and heat related sources, from transportation and other fuel combustion is lower, while

- emissions from manufacturing and construction, land-use change and forestry (LUCF) and agriculture related activities are significantly higher (see Figure 1 and Figure 2). An explanation of emission sources can be found in Box 1.

[15] Climate Analysis Indicators Tool Version 7.0., World Resources Institute, 2010.
[16] UNDP, 2007.
[17] Metz, B., et al., 2007
[18] WWF, 2008.

GHG Emissions by Sector in 2005
CO2, CH4, N2O, PFCs, HFCs, SF6
(includes land use change)

Annex I		
Sector	**MtCO2e**	**%**
Energy	15,120.4	85.0
Electricity & Heat	6,520.4	36.6
Manufacturing & Construction	2,123.3	11.9
Transportation	3,572.1	20.1
Other Fuel Combustion	2,156.3	12.1
Fugitive Emissions [1]	748.3	4.2
Industrial Processes	710.0	4.0
Agriculture	1,467.2	8.2
Land-Use Change & Forestry	39.5	0.2
Waste	459.6	2.6
Total	**17,796.7**	

Figure 1: GHG Emissions by Sector in 2005 in Annex I (industrialised) Countries.
Source: Climate Analysis Indicators Tool Version 7.0., World Resources Institute, 2010[19].

GHG Emissions by Sector in 2005
CO2, CH4, N2O, PFCs, HFCs, SF6
(includes land use change)

non-Annex I		
Sector	**MtCO2e**	**%**
Energy	12,719.5	54.5
Electricity & Heat	5,581.4	23.9
Manufacturing & Construction	3,019.4	12.9
Transportation	1,703.9	7.3
Other Fuel Combustion	1,522.8	6.5
Fugitive Emissions [1]	892.0	3.8
Industrial Processes	1,137.6	4.9
Agriculture	3,748.5	16.1
Land-Use Change & Forestry	5,000.7	21.4
Waste	746.7	3.2
Total	**23,353.0**	

Figure 2: GHG Emissions by Sector in 2005 in non-Annex I (Developing/Emerging) Countries.
Source: Climate Analysis Indicators Tool Version 7.0., World Resources Institute, 2010.

[19] For explanation of fugitive emissions [1] please see Box 1

Box 1: The Climate Analysis Indicators Tool

The Climate Analysis Indicators Tool (CAIT) was developed by the World Resources Institute to provide an information and analysis tool on global climate change. CAIT is a database providing comprehensive and comparable GHG emissions data and other climate-relevant indicators for over 185 countries. Data sources used by CAIT include:

- Carbon Dioxide Information Analysis Center (1751-2006)
- United States Energy Information Administration (1980-2006)
- International Energy Agency (1960-2006)

To explain CAIT emission sector categories further:

- The "Electricity & Heat" subsector includes CO_2 emissions from electricity generation, combined heat and power generation, and heat plants.
- The "Manufacturing & Construction" subsector includes emissions from fossil fuel combustion in activities such as iron and steel, chemicals and petrochemicals, mining and quarrying, food and tobacco, wood and wood products, and construction operations.
- The "Transportation" subsector includes CO_2 emissions from fossil fuel combustion in activities such as air transport, road vehicles, rail, pipeline transport, and navigation.
- The "Other Fuel Combustion" subsector includes emissions from biomass combustion, from stationary (machinery combusting fuels such as boilers, heaters, furnaces, or ovens) and mobile sources and other sectors.
- The "Fugitive Emissions' subsector includes emissions from natural gas flaring (burning of gas that is released in association with oil production), from oil and natural gas systems, and from coal mining.
- The "Industrial Processes" sector includes emissions from cement manufacture, from adipic and nitric acid production, and from other industrial (non-agriculture) processes.
- The "Agriculture" sector includes emissions from enteric fermentation (livestock), livestock manure management, rice cultivation, agricultural soils, and other agricultural sources.
- The "Waste" sector includes emissions from landfills, wastewater treatment, sewage and other waste.
- The "Land-Use Change And Forestry" (LUCF) subsector includes emissions from deforestation and conversion of land from forested to agricultural land. Deforestation is the largest source of CO_2 emissions in this category, releasing sequestered carbon into the atmosphere from the burning and loss of biomass.

CAIT allows for emission comparisons between developed and developing countries based on the list of parties to the United Nations Framework Convention on Climate Change (UNFCCC) which are grouped as follows:

- Annex I Parties: These are industrialised countries which made the commitment to return their GHG emissions to 1990 levels by the year 2000. They encompass the 24 original OECD members, the European Union, and 14 countries with economies in transition.
- Non-Annex I Parties: These encompass most developing countries and particularly those vulnerable to the impacts of a changing climate. They include emerging economies such as Brazil, China, India, Indonesia and South Africa.

The CAIT is available at: http://cait.wri.org

A closer look at the breakdown of GHG emissions for each country reveals further differences and shows that a discussion around solutions to mitigate climate change in emerging economies has to happen on a per country basis and that there is no one-size-fits-all approach (see Figure 3 to Figure 7).

- In China and India, the largest sources of GHG emissions in 2005 came from sources related to electricity and heat, manufacturing and construction, and agriculture.

- South Africa shows a similar picture with the main difference being greater contribution from electricity/heat, and that transportation-related activities resulted in as much GHG emissions as agriculture in 2005.

- In contrast, GHG emissions in Brazil and Indonesia were dominated by land-use change and forestry activities, which contributed 64.4 percent of emissions in Brazil and 71.5 percent of emissions in Indonesia.[20]

China

Sector		MtCO2e		%
Energy		5,278.5		73.4
Electricity & Heat	2,668.1		37.1	
Manufacturing & Construction	1,594.0		22.2	
Transportation	332.1		4.6	
Other Fuel Combustion	542.4		7.5	
Fugitive Emissions [1]	141.9		2.0	
Industrial Processes [2]		669.2		9.3
Agriculture		1,112.5		15.5
Land-Use Change & Forestry		-47.3		-0.7
Waste		174.2		2.4
Total		**7,187.0**		

* Represents shares of total emissions excluding LUCF.

Figure 3: China GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010[21].

India

Sector		MtCO2e		%
Energy		1,251.8		67.1
Electricity & Heat	691.1		37.0	
Manufacturing & Construction	254.1		13.6	
Transportation	98.3		5.3	
Other Fuel Combustion	160.8		8.6	
Fugitive Emissions [1]	47.4		2.5	
Industrial Processes		87.8		4.7
Agriculture		402.7		21.6
Land-Use Change & Forestry		--		--
Waste		123.8		6.6
Total		**1,866.1**		

Figure 4: India GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

[20] Climate Analysis Indicators Tool Version 7.0.World Resources Institute, 2010
[21] For explanation of fugitive emissions and [1] and industrial processes [2] please see Box 1

South Africa

Sector	MtCO2e	%
Energy	343.1	81.1
Electricity & Heat	210.5	49.8
Manufacturing & Construction	51.3	12.1
Transportation	42.9	10.1
Other Fuel Combustion	30.6	7.2
Fugitive Emissions [1]	7.9	1.9
Industrial Processes	16.1	3.8
Agriculture	41.8	9.9
Land-Use Change & Forestry	--	--
Waste	21.9	5.2
Total	**422.8**	

Figure 5: South Africa GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

Brazil

Sector	MtCO2e	%
Energy	346.2	12.2
Electricity & Heat	58.6	2.1
Manufacturing & Construction	97.3	3.4
Transportation	137.1	4.8
Other Fuel Combustion	43.9	1.5
Fugitive Emissions [1]	9.4	0.3
Industrial Processes	32.4	1.1
Agriculture	590.5	20.8
Land-Use Change & Forestry	1,830.0	64.4
Waste	42.8	1.5
Total	**2,841.9**	

Figure 6: Brazil GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

Indonesia

Sector	MtCO2e	%
Energy	397.7	19.5
Electricity & Heat	125.3	6.1
Manufacturing & Construction	93.1	4.6
Transportation	73.9	3.6
Other Fuel Combustion	48.3	2.4
Fugitive Emissions [1]	57.1	2.8
Industrial Processes	18.5	0.9
Agriculture	132.2	6.5
Land-Use Change & Forestry	1,459.0	71.5
Waste	34.5	1.7
Total	**2,041.9**	

Figure 7: Indonesia GHG emissions by sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

It becomes evident that each country faces its own unique set of challenges and opportunities in defining a low-carbon growth path. The sectoral breakdown of national GHG emissions needs to be considered as much as the country's specific economic circumstances. The mitigation options considered by each country in the national climate change strategy therefore differ:

- China has set a target to reduce energy consumption per unit GDP by 20 percent and to deploy most efficient technologies in the iron and steel, cement, oil and petrochemical, and agricultural machinery industries.

- India seeks to significantly increase the share of renewable energy and aims for a increased deployment of solar pholtovoltaic and hydropower sources.
- South Africa aims to accelerate energy efficiency and conservation across all sectors and targets to reduce transport emissions.[22]

[22] WRI, 2009

- Brazil aims to reduce deforestation by 30 percent during 2013-2017 and to double the area of forest plantation to 11 million ha by 2020.
- In Indonesia, which has not developed a strategy yet, the exploitation of geothermal power and efforts targeting the land-use change and forestry sector (e.g. reducing deforestation, promoting reforestation, conserving peat land, and preventing fires) are key mitigation options being explored.[23]

Technology can play a fundamental role in advancing efforts to address climate change and the areas listed above indicate potentially significant opportunities for technology-enabled mitigation options in the respective countries. However, to date, the deployment of technology in general has remained slow in developing countries and this is particularly true for ICT-based low-carbon technology deployment.

2. ICT-based Climate Change Mitigation in Emerging Economies

This section provides a general introduction on the critical role of ICTs in mitigating climate change in emerging economies. It then briefly outlines key opportunity areas for ICT-enabled GHG emissions reduction and provides examples of ICT-based carbon reduction projects in textboxes.

2.1. The Need for ICT-enabled Climate Change Mitigation in Emerging Economies

ICTs have a critical role to play in shifting towards a more sustainable low-carbon society. They can be used in numerous ways to mitigate environmental impacts and climate change by providing solutions that help measure, monitor, manage, and enable more efficient use of resources and energy. ICTs provide immense opportunities to improve the operation of infrastructure and systems and can contribute to dematerialisation, transport substitution, and smarter ways to live, work and spend our leisure time.

The ICT sector has the potential to play a powerful role in tackling climate change by enabling other sectors (such as transport, construction, power and industry) to become more efficient. In fact, ICT-enabled emission reduction potential far exceeds the ICT sector's own carbon footprint.[24] A report published by The Climate Group and the Global e-Sustainability Initiative (GESI) found that

> *ICTs could reduce global carbon emissions by 7.8 $GtCO_2e$ by 2020 (from an assumed total of 51.9 $GtCO_2e$ if we remain on a BAU trajectory), an amount five times larger than its own carbon footprint. Savings from avoided electricity and fuel consumption would reach € 600 billion.* (The Climate Group and GESI, 2008)[25]

Some of the most widely discussed ways through which ICT applications can help reduce global GHG emissions include:

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[23] Indonesian Ministry of Finance, 2009
[24] For example The Climate Group and GESI, 2008 and ITU, 2009
[25] BAU means "business as usual" and refers to emission levels that would occur if emissions grew at the same rate as has accompanied economic growth in the past and no actions to reduce emissions were taken.

- Dematerialisation by replacing physical goods, processes or travel with 'virtual' alternatives, such as video-conferencing or e-commerce (online shopping).[26]
- Machine-to-machine (M2M) communication, which enables a large share of GHG emission savings by means of process optimisation. These include for example smart grids, smart logistics, smart buildings, or smart motor systems.[27]
- Systemic impacts, i.e. behavioural effects such as new habits and consumption patterns that humans develop as a result of ICT use.[28] This is an important area of intervention since consumers control or at least influence 60 percent of all GHG emissions (through their own consumption and use consumers directly control 35 percent of these emissions). Thus, consumer targeted carbon reduction measures can result in significant reductions in global GHG emissions.[29]

Table 1 summarises some of the most widely discussed ICT-enabled GHG emission reductions and potential carbon and cost savings.

Table 1: ICT-based Carbon Solutions (Source: Accenture, 2009)

Areas of savings	Identified Opportunities	Carbon Savings	Cost Savings
Smart Grid	• Reduction in Transmission losses • Integration of renewable energy • Reduction in consumption	2 Gt CO_2e	$125 billion
Smart Building	• Intelligent Commissioning • Building management systems • Voltage optimization	1.52 Gt CO_2e	$442 billion
Smart Logistics	• Optimization of logistics network • Optimization of route planning • In-flight fuel efficiency	1.68 Gt CO_2e	$341 billion
Smart Motor Systems	• ICT smart motor system • ICT-driven automation of industrial processes	1 Gt CO_2e	$107 billion
Dematerialization	• Online-media, e-commerce, e-paper, • telecommuting	1 Gt CO_2e	N/A

* Figures extracted from the Smart 2020 report – The Climate Group - GeSI
12

To date, discussions on ICT-based climate change mitigation strategies have largely focussed on the general opportunities. With the exception of an ITU draft paper[30], discussions have not considered how far the enabling effect of ICTs will be influenced by the development status of a country - which in turn helps determine the investment climate and the state of ICT diffusion and applicability – and influenced by the specific pattern of carbon emissions to be mitigated. They have also not focussed much on the application of ICT-enabled mitigation

[26] Vodafone and Accenture, 2009
[27] Ibid.
[28] Pamlin and Szomolanyi, 2005
[29] IISD, 2008
[30] ITU, 2009

solutions in the specific high-carbon sectors dominant in these countries such as agriculture or forestry.

The marked growth in ICT uptake in emerging economies[31] will result in an increased share of these countries in ICT-related GHG emissions from increased energy demand. At the same time it provides the opportunity to deploy smarter solutions as technologies become deeply embedded into the socio-economic fabric.[32]. There is an urgent need to develop and adopt IT architectural paradigm shifts (e.g. virtualisation across all ICT assets) to counter the increased energy demand for ICTs in countries such as India and China (see Box 2). In these countries we are seeing a roll-out of mobile networks, a larger share of the population being able to afford ICT devices as well as a rapid growth in data centres.[33]

This marked growth in ICT uptake prompts the urgent need to integrate low-cost technologies to bring down GHG emissions from fast growing user devices. Reducing the carbon footprint of ICTs is a crucial step in reducing GHG emissions in these countries and should be considered in any efforts to "bridge the digital divide" - an issue still high on the development agenda.

There is a risk of further broadening the 'digital divide' if technology-based mitigation efforts are solely devised for developed countries. This would exclude developing countries from the new wave of developments and trends towards 'cleaner', 'smarter' and more efficient technologies[34] crucial in achieving sustainable economic growth and leave them at risk to carbon being "locked in" to their infrastructures, networks and operations.

The imperative for deploying ICTs to facilitate a transition to a low-carbon growth pathway in emerging economies is high. In deciding on where to make investments in order to unleash the enabling effect, it is important to consider where the largest carbon reduction opportunities lie, in the short- and long-term. In an emerging economy context, however, it is also important to consider whether such investments will contribute to the overall sustainable development of the country. Challenges related to bridging the digital divide, poverty alleviation and sustainable resource management are still prevalent in emerging economies and should not be overlooked.

Developing and emerging economies face numerous challenges in the provision of infrastructure as economic growth progresses, with demand rapidly increasing for reliable electricity supply, transport infrastructure and commercial buildings. Some experts argue that difficulties faced in meeting this demand are driving investments towards more energy efficient solutions.[35] As major infrastructure investments are taking place in the world's emerging economies there is a great opportunity to "leapfrog" to smarter infrastructures and processes and to avoid the carbon-intensive development stages experienced by developed countries. In developing countries, much of the energy efficiency potential in life-long assets such as buildings, energy grid and industry stock is associated with greenfield opportunities, i.e. new constructions. Infrastructure investments not taking advantage of this opportunity can lock in energy- and emissions-intensive infrastructure for at least the next 40 years. Retrofit opportunities to partially

[31] ITU, 2008
[32] Ospina, A.V. and Heeks, R, 2010
33 The Climate Group and GESI, 2008
[34] Ospina, A.V. and Heeks, R, 2010
[35] OECD, 2009

reverse this situation tend to be more expensive than energy efficient investments in the greenfield.[36]

A small number of emerging economies have already successfully deployed low-carbon technologies in certain industry sectors and thus partially avoided the high-carbon investments made in developed economies. Examples include the substitution of 40 percent of gasoline fuel with sugar cane-based ethanol in Brazil's transport sector[37] and the rapid development of wind power in China which has made the country the fourth largest wind power generator in the world[38].

The opportunity for technological leapfrogging is increasingly being seen and realised by the private sector which expects substantial financial savings from investments in smarter solutions. For instance, North Delhi Power Limited (NDPL), which distributes electricity to approximately five million people in the Delhi metropolitan area, has invested in a host of technologies for a smarter grid which has already reduced energy losses from 54 percent to less than 18 percent over a five-year period through the company's automation strategy. Technological investments included an Outage Management System which allows the control room to pinpoint the location of a failure and trigger a repair operation - a solution that allows faster restoration of power.[39]

Against this background there is a need to further explore the potential of ICT-enabled climate change mitigation in emerging economies and build upon on-going activities in these countries to develop domestic capacity to tackle climate change.

[36] The Secretary General's Advisory Group on Energy and Climate Change (AGECC), 2010
[37] ESMAP, 2010 Brazil case study
[38] WRI, 2010b
[39] GE, 2009

Box 2: ICT's Rapidly Growing Carbon Footprint in Emerging Economies

To date, the ICT sector itself (excluding the radiocommunication sector) produces between 2 to 2.5 percent of total global GHG emissions, though some experts consider its carbon footprint to be significantly higher. Howsoever, there is agreement that this share is rising with the rapid growth of the ICT industry in particular in the world's emerging economies.

- China and India are huge growth areas with populations of 1.3 billion and 1.1 billion respectively. Overall private consumption in the Indian economy is expected to quadruple by 2025 and the middle class population in China is expected to grow by more than 80 percent by 2020.
- It is expected that by 2020 a majority of the population in emerging economies will be able to afford ICT devices and will have achieved developed country ownership levels, in particular with regards to mobile networks and PCs. This in turn will make them account for more than 60 percent of global ICT-related GHG emissions up from about 50 percent today.
- But the fastest-growing elements of the footprint constitute data centres. Despite first-generation virtualisation and other efficiency measures data centres will grow faster than any other ICT technology. This is largely driven by the need for storage, computing and other ICT services.

The proliferation of user devices contributes the largest share of global ICT-related GHG emissions, due to the devices' need for power and radiation of heat. There have been remarkable growth rates of user devices in developing countries. Mobile cellular penetration in these countries, for example, has more than doubled since 2005 and has now passed the 50 percent mark.

As deployment of ICT continues at rapid scale, the sector faces the challenge to limit and reduce its own carbon emissions. The Climate Group and GESI (2008) argue that there is scope for reducing the carbon footprint of the ICT sector by some 36 percent by 2020 using existing technologies.

Source: The Climate Group and GESI, 2008; ITU, 2009; ITU, 2010

2.2. ICT-enabled Carbon Reductions in an Urban Context

In emerging economies, cities are an important engine for economic growth and socio-economic development. They are the main driver behind increased energy consumption and related GHG emissions.[40] But experts argue they also have the greatest potential for reducing GHG emissions through ICT.

To date, one-third of the world's population, i.e. 2.6 billion people, live in emerging-market cities and by 2030 the number is likely to increase by an additional 1.3 billion.[41] It is expected that the urban population of developing countries will reach 50 percent in 2020. By 2030, Asia and Africa will both have higher numbers of urban dwellers than any other area of the world.[42] In China 43.6 percent of the population lived in urban areas by the end of 2006. This rate

[40] See for example WWF and Ericsson, n.d.
[41] WW, n.d.
[42] UN Habitat, n.d.

is rapidly increasing, with 75 percent of the population estimated to live in cities by 2050.[43]

The massive growth in size and number of emerging-market cities, alongside the burgeoning middle-class households within them, drives housing and infrastructure investments and brings with it a rapid increase in energy consumption and related GHG emissions. Urban energy consumption per capita is estimated to be three times higher than that of rural areas, and this will be exacerbated as rural populations continue to migrate to urban areas: a flow which, in China alone for example, is estimated at 10 million people annually.[44]

Solving the climate challenge is, therefore, very much tied to infrastructure and urban development and there is great potential for ICT-based climate change mitigation in the urban centres of emerging economies. In fact, WWF argues that

> *There is an untapped opportunity to drive economic growth while at the same time making transformative emissions reductions by focusing on cities and urban infrastructure development.* (WWF and Ericsson, n.d.)

There is great potential for ICTs to help reduce direct emissions in cities resulting from cars, buildings and energy production by by finding smart, less carbon-intensive ways to provide the same services.[45] Among such solutions are smart transportation, which is explained further in Box 3.

Buildings, as one of the largest urban energy consumers, offer a significant energy and carbon reduction opportunity, with smart buildings discussed in Box 4. ICT-enabled smart connection between buildings and other critical urban infrastructure components (e.g. utilities, transportation, government services) can create "smart city" solutions. Based on the combined use of software systems, server and network infrastructure, and customer devices, such solutions enable optimised energy flows throughout an entire city and envision new ways of urban life.

Energy efficiency can offer practical solutions to budget-constrained cities to meet their energy needs without sacrificing their development priorities. Energy-efficient activities are generally cost-effective as the higher upfront investment is offset in the long-term by lower energy costs.[46] This is explored further in the next section including the example of smart grids (albeit in non-urban settings) in Box 5: Smart Micro-grids for Remote Areas.
Another area to tackle is imported emissions, i.e. reducing the emissions resulting from products and services imported to or exported from a city such as emissions from the production of steel and other construction materials (outside a city's boundaries) used in a city's building developments. Here, ICTs can play a role in developing smart solutions to logistics, motor systems, energy production and consumption, and industrial processes.[47]

Cities are not only centres of growth for population, buildings, infrastructure and demand for services and materials, they also have the potential to develop a leadership role in promoting ICT-based low-carbon innovations and low-carbon living. WWF (2008b) argues that urbanisation will be a key driver for future technology development and institutional innovation, and that the way in which China and India adopt new urban solutions will shape this development, not only

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[43] WWF, n.d.
[44] Ibid.
[45] WWF and Ericsson, n.d.
[46] Energy Sector Management Assistance Program, n.d.
[47] WWF and Ericsson, n.d.

in those two countries, but also globally. The rapid urban development of emerging economies thus has great potential for a low-carbon transition.

Box 3: Smart Transportation – ICTs and Electric Vehicles

ICT-driven applications across transportation have the potential to achieve a reduction in total global emissions of 1.52 $GtCO_2e$. Many industries already rely on software systems to optimise transportation systems to reap big energy savings.
Transport challenges faced by emerging markets include increasing urbanisation (especially in the mega cities) and worsening congestion leading to adverse economic, health and safety impacts. An increasing number of emerging economy cities are rethinking their transportation systems to better meet these challenges. This represents a huge potential for ICT-driven solutions including software to improve the design of transport networks with specific levers such as intermodal shift, eco-driving, route optimisation, inventory reduction, or moving to the most efficient type of transport.

The use of electrical energy in road traffic requires the merger of energy and transportation systems. New ICT-based technologies and services are being developed in relation to areas such as systems integration (smart charging and vehicle-to-grid systems), vehicle navigation and driving assistance, fees and bill payment systems, vehicle fleets, and mobility services.

Megacities in emerging economies will be one of the key drivers of the electrical vehicle (EV) market by 2010. At present car ownership in China and India is below 5 percent but growing faster than any other place on Earth. Over the next five years, Chinese and Indian consumers are projected to buy as many as 70 million vehicles -- more than the total number of cars that exist in the UK and Germany today.

Ambitious and innovative projects are implemented in relation to the EV market. For example, Chery Automobile of China is partnering with the Danish ICT company Better Place to co-develop prototype vehicles and charging stations. The pivotal element is sophisticated software to manage information and electricity flows between the end user, car and battery manufacturers, electricity providers, grid operators and governments. China has set an industrial policy with the objective of becoming the largest EV developer and manufacturer in the world. HSBC research predicts that China's share of the global EV market will grow from 2.7 percent in 2010 to 35 percent by 2020.

Sources: AltTransport, 2010; The Climate Group and GESI, 2008; IBM Institute for Business Value, 2009; and Better Place, 2010

Box 4: Smart Buildings

'Smart building' technologies help improve the efficiency of building design, construction and operation for both existing and new-build properties. ICT can help address the two main drivers of energy consumption in buildings, i.e. energy intensity and surface area through:

- Monitoring and optimising operations at every stage of a building's life cycle, from design and construction to use and demolition.
- Optimising building design through, for example energy modelling software. Such software can help architects determine how design influences energy use and compare energy models with actual construction.

There is a large range of smart building technologies include building management systems, metering technology, environmental sensors, lighting control systems, energy auditing/optimisation software and services, data loggers, and building optimisation software.

While some of the most ambitious innovations in smart building designs are happening in developed countries such as the US and Canada, there are interesting developments in emerging economies such as India and China. In fact, a growing number of buildings in China and India are pursuing Leadership in Energy and Environmental Design (LEED) certification – an internationally recognised rating system developed in the US to evaluate the environmental performance of a structure.

An interesting initiative is Lavasa City, the first e-city in India. Lavasa is a hill city comprising 12,500 acres of land. Designed in accordance with the "new urbanism" principle it aims to offer an inclusive environment for residential and office areas, as well as education and leisure facilities. The city is developed by Lavasa Corp. Ltd., part of the Hindustan Construction Company, which has signed agreements with companies Wipro and Cisco to provide ICT services for the new development. Smart city solutions that will be deployed include:

- Combined geographic information system (GIS) and global positioning system solutions to develop a robust operation and maintenance plan for facility managers
- Optic fibre cable network and telecom infrastructure to promote e-governance (including utility services, facility management, security enablement, on-demand services, tele-medicine, traffic management, online communities, voice and video services)
- A centralised information and communication hub

This is just one of numerous initiatives indicating that emerging economies are already exploring the use of ICTs in making their cities more efficient and less carbon intensive. A number of leading companies in emerging economies are either working in partnership with global businesses or on their own in applying modern ICT services to operations in their countries.

Sources: UK Centre for Economic and Environmental Development, n.d.; Lewis, G., 2009; and Lavasa Corporation Limited, 2009

2.3. Decarbonising Energy Supply and Demand

It is estimated that the world's primary energy needs will grow by about 45 percent from 2006 to 2030, and that this growth will largely occur in developing countries (about 87 percent) where carbon-intensive fossil fuels remain the dominant source of primary energy. Developing countries need to meet their growing energy needs in order to maintain robust socio-economic development.,[48] but therefore also need urgently to find ways to decarbonise energy supply and use.[49]

ICTs have the potential to bring about this systematic change and realise carbon reduction opportunities through a number of applications:

- **Energy generation**: This includes using smart grids that will allow the monitoring of power consumption and use over the electricity grid. The goal is to allow more efficient power distribution and power use by the grid itself, including the possibility of making greater use of renewable and non-GHG emitting sources of energy.[50]

- **Energy transmission and distribution**: These include remote measurement and monitoring of energy use, remote grid element management and energy accounting, which together would help utilities monitor energy use across the grid better and allow them to trace the source of energy losses.[51]Energy transmission and distribution (T&D) monitoring is the most significant single carbon reduction opportunity and can significantly reduce the share of electricity losses; a key problem for developing countries.

- **Efficient end-use technologies**: These technologies are expected to play a fundamental role in the transition to low-carbon societies[52] and include smart meters which can influence consumer patterns.

- **Decentralised energy production**: This could allow renewable energy such as solar and micro-hydro sources to be integrated into the grid, reducing carbon-intensive coal-based generation. Decentralised energy sources could also allow the grid to respond to local power surges and shortages, making it easier to manage.[53]

The Climate Group and GESI (2008) found smart grid technologies to be the largest opportunity for GHG emission reduction with a potential to reduce 2.03 $GtCO_2e$ globally.[54] Moreover, smart ICT solutions for optimised electricity grids hold various other benefits for emerging economies with rapidly increasing energy demands and large T&D losses such as in India or South Africa.

The energy systems in many developing and emerging economies' cities face substantial challenges related to a rapidly rising demand for energy, high carbon intensity of supply, high grid losses, rising energy costs, and the need for large investments in infrastructural development in the coming years. This is the case for India in particular. Smart grids, therefore, are of key relevance in driving down energy-related GHG emissions in emerging economies to prevent them

[48] International Energy Agency, 2008.
[49] See for example Ockwell et al., 2009.
[50] ITU, 2009.
[51] The Climate Group and GESI, 2008.
[52] Ockwell et al., 2009.
[53] The Climate Group and GESI, 2008.
[54] Ibid.

from becoming locked-in to high emissions trajectories for the next 30 years. Incorporating smart ICT solutions not only helps tackle energy losses and improve efficiency but can also reduce power generation investment costs and contribute to energy security.

In India, the private sector and the Indian government are expected to invest significantly in the energy sector.[55] This presents an opportunity to put in place a "best in class" system early and leapfrog to smart grid technology. The Climate Group and GESI (2008) argue that T&D losses in India's power sector can be reduced by 30 percent through better monitoring and management of electricity grids, first with smart meters and then by integrating more advanced ICTs into the so-called "energy internet". This will lead to significant financial savings and emissions reductions from prevented T&D losses; creating a potential economic and environmental win-win.[56]

ITU (2009) sees great potential for energy demand side management in emerging economies, as important energy savings for consumers and electrical utilities can be realised through ICT applications to even out energy loads and reduce brown outs. ITU notes that "in some cases, this practice may be the only alternative to help existing electrical utilities avoid black outs and brown outs without adding to existing energy generation capacity".[57] Energy efficiency measures are seen as "no regrets" (i.e. as producing economic benefits regardless of their environmental necessity) and highly cost-effective options even in a pricing regime where tariffs do not reflect costs as is the case in many emerging economies and developing countries. Energy efficiency measures help increase megawatt capacity without necessitating the buying or building of new plants.[58]

In Bangladesh, for example, the World Bank invested US$15 million to replace customer incandescent bulbs with high efficiency compact fluorescent lamps to help reduce peak hour deficits and improve power supply reliability in particular in rural areas. It was found that lighting coincides with the peak load hours and contributes over 20 percent of the demand. The investment compared very favourably to the alternative of installing a comparable amount of new peak generation capacity at an estimated cost of US$235 million.[59]

There is also a great opportunity for ICTs to contribute to greater deployment of renewable energy in developing countries which would contribute to both low-carbon energy generation and alleviation of energy poverty, an issue high on the development agenda in particular in India. Examples of ICT-based solutions in this regard include smart micro-grids as further explained in Box 5.

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[55] Chadha, M., 2010.
[56] The Climate Group and GESI, 2008.
[57] ITU, 2009.
[58] Sarkar, A. and Singh, J., 2009.
[59] Ibid.

Box 5: Smart Micro-grids for Remote Areas

As stated by the UN Secretary-General's Advisory Group on Energy and Climate Change:

> "Developing countries in particular need to expand access to reliable and modern energy services if they are to reduce poverty and improve the health of their citizens, while at the same time increasing productivity, enhancing competitiveness and promoting economic growth. Current energy systems are inadequate to meet the needs of the world's poor." (UN, 2010)

The Advisory Group points out that as a result of "energy poverty" many of the world's poor face negative consequences related to health and economic development. For example, inefficient combustion of solid fuels in inadequately ventilated buildings leads to indoor air pollution and insufficient power limits opportunities for productive income-generating activities.

There are three basic approaches to open access to electricity in remote areas: grid extensions, micro-grid access and off-grid access (i.e. generating capacity for a single point of demand, typically a solar household system). ICTs can play a significant role in extending existing grids and in the development of micro-grids.

A micro-grid is "A small power system that includes self-contained generation, transmission, distribution, sensors, energy storage, and energy management software with a seamless and synchronized connection to a utility power system but can operate independently as an island from that system." (Hertzog,C., 2010). It can be connected to the public grid and exchange energy with it or, in the case of remote areas, it can operate in island mode.

In remote areas of developing countries micro-grids can make a significant contribution to a secure supply of energy at reduced costs and to the integration of renewable and less carbon intensive energy sources available locally. In many cases connections to the public grid are too expensive or not feasible in such areas – a fact that makes isolated micro-grids the ideal choice for the electrification.

If there is no connection to an external power infrastructure, then all balancing has to be done using local resources, which can be adjustable diesel generators, photovoltaic panels, hydro generators, battery sets and others. The main challenge of operating a micro-grid lies in the fact that at all times the balance between generation and demand has to be maintained: this is where ICT applications come in. In a smart micro-grid, ICT applications help optimise the transmission and distribution portions of the grid for distributed energy generation/storage and enable the integration of larger amounts of fluctuating and decentralised renewable energy sources.

In addition, smart micro-grids also allow for the deployment of different communication and outreach programmes to encourage energy efficient behaviour, for example, through the use of electricity meters.

Sources: Hertzog, C., 2010; Murthy Balijepalli, V.S.K. et al., 2010; Martinez-Cid, R.B., 2009; Kupzog, F. et al., 2009; and UN, 2010

2.4. Export of Manufacturing-based Emissions

Manufacturing in developing countries is a key growth engine as the world economy is fuelled by the role that these countries play as "workshops of the world" and preferred manufacturing locations. However, there has been an increase of 29 percent in fossil fuel emissions between 2000 and 2008 as contributions from emerging economies grew. There is growing evidence that this rise was driven to a large extent by the production and international trade of goods and services, and from the use of coal as the main fuel source.

Overall, around one-quarter of the growth in developing country emissions (including emerging economies) since 2000 was associated with international trade.[60] More specifically, 30 percent of the growth in emissions in China between 1990 and 2002 was attributable to the production and international trade of goods exported for consumption in other countries. This figure increased to a staggering 50 percent in the following three years (2002 to 2005). Over half of the exported products were destined for developed countries where consumption-based emissions – those linked to in-country consumption of goods irrespective of their production site – have also been on the increase. For example, in the UK between 1992 and 2004, within-country emissions decreased by 5 percent, but consumption-based emissions rose by 12 percent.[61]

This issue highlights the shared responsibilities of developed and emerging economies in reducing global GHG emissions and in realising low-carbon development paths. There is a need to develop and transfer low-carbon technologies from advanced to emerging economies, which would serve two goals – reduce international trade related emissions and support catch-up growth in those economies. Reducing global GHG emissions can not only depend on the international coordination of carbon emissions trading and carbon tax schemes (as indicated by the carbon leakage problem[62]), but will also largely depend on the success of technology transfer to improve the performance of energy- and carbon-intensive industries in emerging economies.

Tackling GHG emissions related to international trade via such technology transfer can happen on two fronts: a) cross-border transportation and logistics, and b) manufacturing in emerging economies.

International trade is based on countries specialising in and exporting goods in which they have a comparative advantage and importing other goods from their trade partners. This process of international exchange requires vast transport and logistics networks. As a result of globalisation and global economic growth, global goods transport is continuously increasing.

According to The Climate Group and GESI (2008), global goods transport and logistics are inherently inefficient, e.g. vehicles often carry little or nothing on return journeys. At the same time, they are increasingly under pressure to become more efficient as fuel costs and taxes rise and as the risk for increased costs from carbon regulation increases.

The transport sector is a large and growing emitter of GHGs, responsible for 14 percent of global GHG emissions. Optimising logistics using ICT could result in a 16 percent reduction in transport emissions and a 27 percent reduction in storage emissions globally. Efficiency gains come with significant economic benefits since

[60] Le Quere et al. 2009
[61] Ibid.
[62] Carbon leakage is the effect that regulation of emissions in one country/sector has on the emissions in other countries/sectors that are not subject to the same regulation.

the sector operates a high-value market, with the global logistics industry estimated to be worth $3.5 trillion in 2005.[63]

ICTs can improve the efficiency of logistics operations in a number of ways by helping to monitor, optimise and manage operations. This in turn helps reduce the storage needed for inventory, fuel consumption, kilometres driven and frequency of vehicles travelling empty or partially loaded.

"Smart logistics" solutions include software enabling improved design of transport networks, running of centralised distribution networks and of management systems facilitating flexible home delivery services (see Box 3 for further examples).[64] Various machine-to-machine (M2M) technologies can help improve operational efficiency including onboard telematics, loading monitoring devices, and tracking systems such as Helveta's supply chain software introduced in Box 6.[65]

In emerging economies, we are witnessing rapid growth in consumption as well as manufacturing, for both domestic and foreign markets, which results in a continuous increase of GHG emissions. The logistics sector is already contributing a large part of these emissions and they are set to rise further with manufacturing increasing for both domestic and overseas markets. A major challenge in tackling these emissions is the fact that in emerging economies the logistics sector is largely fragmented. ICTs hold the promise to address this challenge but have not been widely deployed in emerging economies and developing countries. As trade and transportation grow, thereby further exacerbating the need to devise innovative low-carbon solutions, there is a need for governments in these countries to incentivise the deployment of smart solutions. Moreover, underdeveloped trade and logistics infrastructure not only contribute to excessive GHG emissions but also adversely affect GDP. It has been estimated that underdeveloped trade and logistics infrastructure costs India 13 percent of its GDP.[66] Some leading logistics and transport companies are therefore already adopting smart logistics solutions for network tracking and monitoring.

Transport and logistics operations, however, are not the only contributors to GHG emissions. The manufacturing process of products also plays a significant role as outlined above. "Smart manufacturing" solutions can be used to

- increase manufacturing process efficiency by automating communications between production sub-processes,
- support predictive maintenance by remotely monitoring machinery to improve maintenance planning and overall service management, and
- optimise order fulfilment by integrating order capture in production planning, output and dispatch, and increasing the intensity of batch production to reduce continuous production.[67]

In particular, energy-intensive motor systems, largely used in China's manufacturing sector, hold significant efficiency potential through the adoption of smart technologies (see Box 7). Within manufacturing, a particular focus will also be on the cement sector – an industry expected to double by 2030 and which is

[63] The Climate Group and GESI, 2008.
[64] Ibid.
[65] Accenture, 2009.
[66] Youngman, R., n.d..
[67] Vodafone and Accenture, 2009.

already responsible for about 5 percent of the world's CO_2 emissions.[68] Cement production and demand are increasing rapidly in developing countries where already 80 percent of global cement production takes place, and application of ICTs in cement production in the developing world thus form an important path of new ICT-enabled development patterns.[69]

Box 6: Helveta's Supply Chain Software

British company Helveta developed a software platform to track and manage every stage of global supply chains. It is used, for example in the timber sector in countries such as Malaysia, Cameroon, Liberia, the Democratic Republic of Congo, and Bolivia where it enables traceability of every log, truck and mill involved in the supply chain. This helps companies in proving the origin of products to meet requirements set by legislators or customers. Products can be tagged with RFID labels which in turn can be read by handheld computers loaded with Helveta's data capture software. Thus information on each tree can be recorded and transferred to a central server via Internet or mobile phone connection.

In a developing country context, such software can replace time-consuming and potentially more expensive traditional techniques for forest monitoring. Helveta's system also makes provision for users with low literacy levels. Users can record GPS-referenced information using touch-screen handheld computers, which can contain a database of icon images in place of text.

Timber is almost exclusively sourced from developing countries where with an estimated 12 to 17 percent of global timber trade stemming from illegal logging. Such logging – typically done without concern for replanting, and often damaging large swathes of surrounding forest – is also a significant contributor to climate change. By verifying sourcing from sustainable, legal sources of timber, supply chain software can help tackle illegal logging and thus address some deforestation-related greenhouse gas emissions.

Source: Youngman, R., n.d.

[68] GreenBiz Group, 2009.
[69] World Business Council for Sustainable Development, 2009.

Box 7: Smart Motor Systems, China

Optimising and improving efficiency in China's manufacturing sector can significantly reduce the country's carbon footprint. Failing to do so will result in the country's motor systems accounting for 10 percent of national GHG emissions and two percent of global emissions by 2020. Optimising motor systems and industrial automation globally could reduce as much as 0.97 GtCO2e in 2020. In China such measures could potentially reduce emissions by 200 MtCO2e.

Motor systems are one of the key drivers behind China's rapidly increasing energy demand. They currently constitute 70 percent of total industry electricity consumption and are often very energy inefficient. The Climate Group and GESI suggest that the following smart applications could help reduce industrial energy use in China and improve the efficiency of motor systems:

- Variable Speed Drives (VSDs): VSDs control the frequency of electrical power supplied to the motor, thereby adjusting the rotation speed to the required output and are the most effective means of saving energy – up to 25-30 percent.
- Intelligent Motor Controllers (IMCs), IMCs monitor the load condition of the motor and adjust the voltage input accordingly. They offer minor efficiency gains (3-5 percent), but have the benefit of extending the motor lifespan, which reduces the number of new motors required and therefore the associated manufacturing emissions.

Source: The Climate Group and GESI, 2008

2.5. ICT-based Approaches to Land-use Change and Forestry Emissions

Emissions from land-use change and forestry (LUCF emissions including deforestation, logging and intensive cultivation of cropland soils) are the second largest source of global anthropogenic GHG emissions (estimated between 15 to 20 percent).[70] The largest driver of LUCF emissions is deforestation caused by the conversion of forest to agricultural lands, primarily in developing countries.[71] One third of total emissions of developing countries is caused by LUCF with the largest contributors being Indonesia and Brazil (other countries include Malaysia, Myanmar and the Democratic Republic of Congo).[72]

The Intergovernmental Panel on Climate Change (IPCC, 2007) notes that reducing and/or preventing deforestation is "the mitigation option with the largest and most immediate carbon stock impact in the short term".[73] It is estimated that reducing deforestation by 50 percent over the next century would help prevent 500 billion tonnes of carbon from being released into the atmosphere per year.[74] ICTs can help monitor land-use change and deforestation and enhance data collection on the condition of forests. Satellites are now able to take images through clouds and at night making remote sensing applications a critical and effective tool in monitoring deforestation and illegal logging (see also Box 6). For

70 IPCC, 2007.
71 Baumert, a. et al., 2005
72 Ibid.
73 IPCC, 2007.
74 ITU, 2009.

example, Google maps are being used to present illustrations, satellite images and photographs that depict human impacts on the environment (both past and present).[75] Alongside illegal logging such impacts include forest loss from the construction of road networks, and from establishing farms, plantations and pastures.

ICT solutions can make data collection on the ground more efficient at lower cost and environmental impacts. Remote sensing technologies and communication networks, for example, enable more efficient monitoring and resource management.[76] This is critical in emerging and developing countries where environmental protection agencies and organisations are usually understaffed and underfunded.

However, for effective monitoring remote sensing data need to be complemented by in-situ ground data and geolocation information. Team Networks, for example, works with local groups based in developing country field sites using mobile technologies (smart phones and EcoPDAs) to facilitate the collection of data. Once this data has been stored in servers and databases, it is disseminated globally, in a timely manner and free of charge.[77] Through such applications ICT can encourage better land use planning and contribute to more informed land use decision making.

Moreover, by facilitating information gathering and dissemination, ICTs can contribute to capacity building including efforts to increase public awareness of critical environmental issues, the development of professional staff, involvement of and collaboration among relevant stakeholders, and the integration of environmental content into education and policy enforcement. The increasing availability of satellite data imagery data has spurred the establishment of NGO imagery activities around the world. The Global Forest Watch (GFW) programme by the World Resources Institute (WRI), for example, urges better forest management by monitoring and publicising information on forest loss around the world. This information combines reports from ground observers with satellite imagery data and GIS. Members of the Indonesian Forest Monitoring Network (IFMN) are sharing information via the Internet and developing a database of satellite imagery and information on local forests in an effort to influence government policy on illegal deforestation.[78]

ICT applications can also contribute to empowering groups and supporting them in efforts around environmental conservation. For instance, Amazon Indians in South America combine use of ICT solutions like Google Earth and Global Positioning System (GPS) mapping, with traditional knowledge of the rainforest to help detect illegal activities and thus fight deforestation.[79]

2.6. Community-based Solutions and Importance of the Rural Poor

The rural societies of Brazil, China, India and South Africa constitute one fourth of the world's population. They are the world's largest producers of food, are involved in the management of millions of hectares of land and forest, and significantly contribute to the global economy. But for all that they constitute

[75] Ibid.
[76] SPIDER, n.d.
[77] TEAM, 2010.
[78] Baker, J.C., and Williamson, R. A., n.d.
[79] Brahic, C., 2007.

about one third of the world's poor and almost half of the world's rural poor, and are challenged by one of the lowest levels of human development.[80]

In emerging economies we are now seeing a rapid and deep economic, social, demographic, cultural and political transformation of rural areas. While such transformation is necessary and even indispensable for the sustainable development of these countries, it is putting enormous pressures on the environment. Because of the scale of rural societies and of the resources involved - be they "forests in Brazil, water resources in India, biodiversity in South Africa, or the pressures on land for urbanisation in China" - these pressures have global implications.[81]

ICTs are emerging as an important medium not only for communication and exchange but also for development at local and community levels.

In relation to agriculture, ICTs are currently seen to have only low potential to enable GHG emissions reductions in the rural areas of poorer countries[82] However, given the high share of GHG emissions in emerging and developing economies related to the agricultural sector there is need to further explore opportunities for ICT-enabled emissions reductions on a country-by-country basis.

The rapid proliferation of mobile communications in developing and emerging economies, and in particular in the rural and remote areas of these countries, is opening up new markets and development opportunities while also reducing the need for travel to access crucial services. Low bandwidth services and wireless services can pave the way for e-government, e-commerce, and e-health initiatives. All these will mitigate some carbon emissions through journey substitution. However, they will also lead to greater energy demand thus driving the search for lower-energy end-user ICTs.

Introducing low-cost energy-efficient user devices, online services and travel replacement technologies in rural and remote areas will not lead to significant impacts in terms of energy saved and GHG emissions prevented at a national level. But the enabled socio-economic benefits can be significant to the individuals involved and their families.[83] With judicious technology selection, carbon emissions could also be minimised. An example (albeit not specific to the rural poor) is the deployment of virtual desktops for schools in all of Brazil's municipalities (see box 8 below). This initiative has contributed to improving the student-to-computer ratio at minimal economic and environmental costs.

The rapid proliferation of mobile communications in rural areas will demands efforts to reduce ICTs' own carbon footprint, for example through greater use of renewable energy. In 2008 Celtel in Uganda started converting all diesel-driven radio base station sites outside the power grid to a hybrid energy solution developed by Ericsson. The new off-grid system replaces one of the two previously-used diesel generators by a battery bank with specially designed batteries and a photo-voltaic array. The batteries can handle the large number of charge/discharge cycles required for connection to solar panels. The hybrid solution enables a less carbon-intensive energy supply at sites too large to be economically viable for a solely renewable energy based solution. In this way the

[80] Planning Commission of India and Institute for Human Development, 2009.
[81] Ibid.
[82] See, for example, GESI, n.d.
[83] ITU, 2009

hybrid energy system contributes to increased network reliability in remote areas while also reducing GHG emissions related to energy generation.[84]

Box 8: Virtualised Desktops for Schools, Brazil

In 2009, the Brazilian Ministry of Education realised the world's largest virtual desktop deployment in order to provide computer access to schools in all of Brazil's 5,560 municipalities. The initiative also achieved a record low-cost for PCs with the deployed PC-sharing hardware and software costing less than US$50 per seat.
Compared to traditional PC-per-workstation solutions, the virtual workstations achieve savings of up to 60 percent in up-front costs and 80 percent in annual power demand. The Desktop Virtualisation Deployment created 356,800 workstations by transforming one PC to support up to ten simultaneous monitors, keyboards and users which are all managed at once through a central website.
This initiative has demonstrated the potential of simultaneous developmental and environmental benefits, by significantly increasing the availability of ICTs in schools but at relatively low cost both financially and in terms of carbon emissions.

Source: Userful, 2009

3. Challenges of ICT-based Climate Change Mitigation in Emerging Economies

As shown in the sections above, the carbon footprint of emerging economies is diverse. In Brazil and Indonesia the major GHG emission sources are land-use change and agriculture, in China manufacturing, and in India and South Africa electricity and heat-related energy consumption. With the exception of Brazil, these countries heavily rely on coal as a source of energy, thus accentuating the need to decarbonise energy supply as energy demand is expected to grow significantly.

A considerable share of the growth of GHG emissions in emerging economies and particularly in China can be associated with the manufacturing of goods for international trade. The diversity of sources of GHG emissions in these countries – and others – will necessitate equally diverse and innovative approaches to their reduction. ICTs and associated opportunities to enable other sectors to achieve significant efficiency gains and improve processes to minimise emissions can play a key role, in many cases by deploying already-available technology.

Major barriers, however, prevail in emerging economies for a broader deployment of ICT-based solutions to climate change mitigation and for low-carbon technologies generally. While these barriers will differ from country to country and even within countries (e.g. between urban and rural areas) the following barriers can be assumed to be prevalent in many emerging economies:

- Lack of awareness of technological developments and their potential for more carbon- and energy-efficient solutions.[85] A challenge for many small firms is to take informed decisions on ICT adoption (or

[84] Ericsson, 2008
[85] ITU, 2009.

non-adoption), as they are not familiar with ICT options and the business opportunities they offer.[86]

- Limited access to capital as the result, for example, of a conservative banking sector and scarce as well as highly sector-specific venture capital and private equity sources.[87]

- High or uncertain costs of new technologies and no proven commercial viability for large scale investments, in particular for smart grids and smart cities.[88]

- Limited or uncertain suitability of technologies for local conditions: There is a challenge of ensuring technology compatibility across countries or even single companies (e.g. with smart grids and smart logistics). To ensure compatibility and accelerate technology adoption there is a need for technology and telecommunication providers and affected industries to collaborate and develop common operating standards.[89]

- Limited resources, capacity or technical and managerial skills to identify suitable technologies, adapt them for specific local application, and conduct installation and maintenance services.[90]

- Unpropitious regulatory and political circumstances such as market distortions and subsidies in favour of fossil fuels[91] on the one hand and lack of policies and incentives to encourage investment in smart ICT solutions on the other.[92]

Barriers to successful deployment of low-carbon technologies in developing and emerging economies are frequently compounded by the lack of a central organisation acting as the focal point and bringing together the academic, business and government communities to address the low-carbon innovation challenge in a co-ordinated manner.[93]

It has to be noted that the challenge of a broader deployment of low-carbon solutions in emerging and developing economies goes beyond technology-related barriers as outlined above. As pointed out in Box 9, technology is only one part of the equation. There is a risk that efficiency gains can potentially be offset by a change in consumption patterns triggered by the very same technology.

[86] European Commission, 2010.
[87] Carbon Trust, 2008.
[88] Vodafone and Accenture, 2009.
[89] Vodafone and Accenture, 2009.
[90] ITU, 2009 and Carbon Trust, 2008.
[91] Carbon Trust, 2008.
[92] ITU, 2009.
[93] Carbon Trust, 2008.

Box 9: Rebound Effect

Any discussion on the enabling effect of ICT in climate change mitigation needs to consider the risk of rebound effects which might outweigh any potential emission reductions. Rebound effects can be both direct and indirect. A direct rebound effect would be a fuel-efficient vehicle enabling longer trips at no additional cost. An indirect rebound effect would be car fuel costs saved being spent on other energy-intensive activities such as a long distance air travel.

There is a concern that lower energy costs resulting from efficiency gains may lead to increased energy consumption. E-commerce, for example might encourage long distance delivery, and tele-working could lead to increased household energy use and demand for electronic equipment such as routers and printers. It is argued that technology in itself will not lead to energy-saving consumption patterns as indicated by the promised "paperless office" which has not materialised.

To date, rebound effects from energy efficiency improvements in developing and emerging economies have not been well studied. Some experts expect these to be larger in these economies as energy demand has not yet been saturated.
The discussion on rebound effects stresses that energy savings do not result from technology itself but instead from how it is deployed and used, noting that policies play a crucial role in encouraging desired behaviours.

Sources: OECD, 2009 and Houghton, J., 2009

4. Conclusions and Recommendations

The barriers outlined in the previous section indicate the need to extend existing technology transfer and finance schemes under the United Nations Framework Convention on Climate Change (UNFCCC) to include broader deployment of ICT in developing and emerging economies. Cap-and-trade and offset mechanisms that result in the transfer of ICT technology to developing countries need to be further promoted and new mechanisms may need to be added to drive inclusive low-carbon growth by utilising the opportunities ICT could bring if technology were widely available and effective implementation viable.[94]

More importantly, there is a need for mechanisms that support technology transfer to focus on how to constructively build innovation capacity in developing and emerging economies, rather than simply conceiving a one-way flow of technology from global North to global South. This would have the potential to transform developing countries from being consumers of technologies and dependent on continued imports to being low-carbon technology producers and innovators in their own right. In turn this will foster competitiveness of local industries and create new business opportunities.[95] Creating centres of low-carbon innovation in selected developing countries would catalyse domestic capacity to adapt and develop technologies and help diffuse innovations.[96] It would also help enhance the political and economic justifications for a low-carbon development path.

[94] Vodafone and Accenture, 2009
[95] Ockwell et al., 2009
[96] The Carbon Trust, 2008

While globally the pace of technology deployment has dramatically accelerated over recent decades, technology deployment and low-carbon technology deployment in particular, remains slow in low- and middle-income countries. An exception is China where the deployment has accelerated over recent decades transforming the country into a major manufacturer of a number of low-carbon technologies.[97] In looking for ways to build low-carbon innovation capability in and diffusing climate-smart technologies across developing countries there is a need to look at experiences in China and other success stories in emerging economies (e.g. low-carbon energy in Brazil) to capture the lessons learned that have enabled these economies to leap-frog into the global elite of low-carbon innovators, if only in certain sectors.

Recommendations to **governments in emerging economies** include:

1. Make a deliberate, holistic plan and long-term commitment to the localisation of low-carbon technology or a number of key technologies that provide solutions to major GHG-emitting sectors

2. Design national-level and in particular sector-wide regulation, laws, policies, and subsidies. This will incentivise investment, scale-up commercialisation, create domestic markets, and drive down the costs for implementing the widespread use of low-carbon technology. For example, regulation could require the integration of low-carbon energy-efficiency modules into high-value capital investments. There is also a need to promote enforcement mechanisms for intellectual property rights.

3. Establish research and development funding programmes to support the launch and scale-up of low-carbon technology innovation. This should include reinforcing multidisciplinary research and technical development and bring together academia, ICT providers and targeted industry sectors to promote interoperability and standardisation of services. It will encourage the deployment of large-scale pilot projects and allow the technical feasibility and anticipated capital expenditure requirements of technologies to be assessed.

4. Support and drive business innovation by making funding available as well as providing "soft" support e.g. by creating additional linkages between businesses, research institutions and civil society. The strategic use of challenges and awards may be another effective approach to incentivising and nurturing innovation and creative solutions. With the majority of economic activity in emerging (and developing) economies generated in small and medium sized enterprises, such supportive mechanisms will be essential to enable business innovation otherwise hampered by lack of investment capital.

5. Expand local lending capabilities and access through local commercial banks and micro-finance institutions to scale up investments. The existing systems could be adapted to the emerging challenges, e.g., by adding special incentives for off-grid areas or the deployment of renewable energy, and making access to funding mechanisms more conducive to the needs of SMEs in these countries.[98]

Sector-based approaches can be an effective tool in emerging economies. Some experts argue that national development paths do not result from integrated policy programmes but rather emerge from fragmented decisions made by

[97] World Resources Institute, 2010b
[98] Recommendations were derived from various studies and include UN, 2010 and WRI, 2010b

numerous private actors and public agencies. Moreover, critical decisions are being made in carbon-intensive sectors by ministries and companies that do not regularly attend to climate risks.[99] Mainstreaming low-carbon development within the national policy making process will represent a major challenge in those emerging economies that lack sufficient institutional and regulatory capacity. Against this background a national sector-based approach focussing on key industry sectors can be more effective in streamlining efforts and enabling stakeholders to bring about a low-carbon growth in that particular area. Focused efforts at the sector level have significant potential to spur national level growth.

Realising GHG emission reduction will depend on effective international cooperation in numerous areas, ranging from building innovation capability in the world's poorer countries to harmonising technical standards for key energy-consuming products and equipment. Business is playing a crucial role in developing and commercialising far-reaching technological solutions suitable for an emerging economy context. Public-private partnerships are needed in these countries to leverage private resources, build capacity and find innovative low-cost solutions.

Recommendations to **business**:

1. Make all efforts necessary to reduce the carbon footprint of the ICT sector and its products and help understand lifecycle impacts of ICTs in a emerging economy context.

2. Establish best practice projects to benchmark and showcase the potential of smart ICT solutions to climate change mitigation in emerging economies.

3. Invest in R&D for improved technology and applications suitable for poorer country contexts and their specific challenges.

4. Establish ambitious GHG emission reduction targets and extend these through the value chain: take responsibility to support small and medium sized suppliers in emerging and developing countries to meet those targets. This can happen, amongst others, by investments to support the implementation of low-carbon technologies and ICT-enabled efficiency enhancing processes – a strategy that also has the potential to significantly contribute to technology transfer.

5. Take a leading role in developing and disseminating low-cost low-carbon products and services in developing and emerging countries, e.g. by engaging in joint ventures with small and medium-sized enterprises in those countries and thereby contributing to the dissemination of technical know-how and building local innovation capacity to avoid the perpetuation of import dependency.

6. Engage in policy advocacy at international and national levels to promote the regulatory and policy reforms needed for better investment opportunities and the removal of market barriers.

A discussion on the potential for ICT-enabled climate change mitigation in an emerging country context has to take into consideration the specific development needs in these countries and has to help contribute to a low-carbon development trajectory. To reiterate, then, analysis of national carbon footprints suggests that a sectoral approach might be most effective in cutting national greenhouse gas

[99] See for example Metz, B., et al. (2007)

emissions. This sectoral approach needs to focus on carbon intensive sectors crucial for economic growth in emerging and developing countries such as the manufacturing, transport, forestry and potentially agricultural sector. A major objective should be the building of innovative capacity within emerging and developing economies rather than a solution whereby these countries depend on technology transfer from industrialised countries.

Against this background priorities for future research are outlined in box 10 below. The key issues to be further explored include specific ICT solutions for key high-carbon sectors, challenges and capacity needs in terms of technology deployment in specific country contexts, lessons learned of successful low-carbon technology developments in emerging economies, and experiences made with regards to ICT solutions in international technology transfer schemes.

Box 10: Priorities for Future Research

This research paper has provided an overview on the status of ICT-enabled climate change mitigation in emerging economies. It identified key challenges and opportunity areas as well as major action points for governments and large businesses in further driving a low-carbon pathway in emerging economies.
The research paper also indicates key priorities for future research as follows:

- More research is needed to explore ICT solutions for specific high-carbon sectors in emerging economies. The desktop survey indicates that there have been few studies on ICT-enabled emission reductions in the agriculture sector. More insights are also needed into the challenges and opportunities for smart energy solutions in an emerging economy context where electricity grids are challenged with a number of system failures (e.g. poorly planned distribution networks, overloading of system components, lack of reactive power support and regulation services, and low metering and bill collection efficiency).
- A number of emerging economies are already leading the way when it comes to efficiency improvements and low-carbon technology developments in certain sectors. For example, Brazil has been successful in the development of alternative energy sources and the wide introduction of flexible fuel vehicles. Much can also be learned from China and the deployment of low-carbon technology in its steel sector and coal-fired power generation. There is a need to more systematically evaluate lessons learned. Experiences in these countries demonstrate some successes from which other countries can benefit in their own efforts to accelerate deployment and diffusion of low-carbon ICT-based solutions.
- A thorough analysis into the capacity needs and challenges in developing and emerging economies is required to help formulate recommendations on how best to facilitate innovative capacity development in these countries.
- More research is needed into the challenges and opportunities of technology transfer in the context of smart ICT solutions. Best practices and lessons learned need to be disseminated and key challenges such as intellectual property rights or foreign investments better understood.

There is a great need to engage the private sector - both small and large businesses - in these discussions and research projects. As a major driver and user of crucial digital technologies they are a key stakeholder in achieving a low-carbon development path. With some leading businesses already engaging in partnerships with emerging economy companies it is expedient to collect and analyse best practices and derive and make available lessons learned to further promote these partnerships and business-driven efforts for a low-carbon future.

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Chapter 4: ICT-Enabled Development of Capacity for Climate Change Adaptation

LAXMI PRASAD PANT & RICHARD HEEKS

Executive Summary

Climate change and related stressors are posing an increasing challenge to livelihoods in low-income communities. Those communities need to develop the capacity to adapt to climate change: coping with short-term shocks and long-term trends. ICTs will form an essential part of that development.

Mobile technologies have been the dominant force in ICTs, and we review here a number of initiatives that have successfully combined local and external information and knowledge. We find these initiatives have made a valuable contribution to deliberate, pre-planned strategies for adaptation, focusing on the informational role of ICTs and combining local and external capacities (though limited in their development of local capacity). However, we argue that climate change adaptation also demands emergent actions that cannot be foreseen in advance, and which require the development of communities more as self-organising systems. This will require ICTs to be transformational as much as informational, developing collective as much as individual capacities.

As yet, though, signs of self-organisation through mobile-based applications appear limited. While no panacea, we suggest that a reworking of telecentre models – creating new 'mobile-telecentre' architectures that support the development of local infomediaries – may be one way to help develop local capacities that are more congruous with the demands of an emergent strategy perspective on climate change adaptation. More generally, we see ICTs' contribution most likely coming not through climate-specific applications but through information systems that address the broad range of vulnerabilities in a holistic and systemic manner.

1. Introduction

"*Mobile phone access will soon be universal. The next task is to do the same for the internet.*"[100]

Statements as optimistic as this about information and communication technologies (ICTs) in developing countries are widespread. Yet availability of emerging technologies to address the complex problems of the twenty-first century is relatively limited, particularly among the poor. One such complex problem is climate change[101]. Climate change is negatively impacting livelihoods of already vulnerable communities that survived over centuries on local knowledge and practices[102]. Stresses include abnormal changes in air temperature and rainfall, increases in frequency and intensity of drought, heat and cold waves, and floods and landslides. Climate change is also associated with changes in seasonality, rainfall patterns, and the emergence and re-emergence of water-borne, vector-borne and food-borne diseases[103].

Recognising the urgency of addressing these problems, expert – often science-based – knowledge about climate change has been well established, but knowledge about existing and potential adaptation strategies and their positive and negative development impacts on livelihoods is still emerging. Thus more work is needed to understand how to build capacity to adapt to climate change and to reduce ecological, economic and human vulnerability at the community level. It is already realised that climate change is one among several causes of vulnerability, and thus there is a need to adopt holistic, systems approaches to develop adaptive capacity to multiple stresses. Partly in recognition of this need, the emerging theory and practice of climate change adaptation is converging with the field of development studies[104], and beginning a scholarship of new ways to develop climate change adaptive capacity[105].

Creation, storage, exchange, regulation and application of information and knowledge are a key part of developing climate change adaptive capacity.[106] Particularly when knowledge is held by a myriad of public and private stakeholders, an integration of local adaptation practices and expert recommendations is difficult to achieve. There are technological as well as social, economic, political and cultural barriers to this component of adaptation, often complicated by physical isolation of rural and remote communities. In the face of increasing frequency and intensity of climate change, this paper argues that ICTs can facilitate the processes of knowledge integration and learning that form part of capacity for adaptation[107].

In spite of the potential of ICTs to facilitate climate change adaptation – particularly through increasing access to, and control over real-time data, information and knowledge – this remains one of the least explored areas in

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[100] The Economist, 2009: 13.
[101] The use of the term 'climate change' in this paper includes climate variability, extreme weather events and related stresses, and 'climate change adaptation' refers to "[a]djustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." (IPCC, 2007: 869).
[102] UNFCCC, 2007.
[103] Morens et al., 2004; Smit & Wandel, 2006; Hardoy & Pandiella, 2009.
[104] Pant & Hambly Odame, 2009.
[105] Adger, 2006; Gallopin, 2006; McLaughlin & Dietz, 2008.
[106] Data is a set of discrete, objective facts, which becomes information when a pattern is imposed through processes such as contextualisation, categorisation, calculation, and condensation. Knowledge is a fluid mix of meaningful experience, values, contextual information, and expert insights that provides a framework for evaluating and incorporating new experiences and information (Röling, 1990; Davenport & Prusak, 1998).
[107] Kelly & Adolph, 2008; Chiabai, 2009.

research[108]. In practice, too, ICTs' potential has been limited by the divide in the coverage, uptake and use of digital technologies among vulnerable communities[109]. Telecentres and cyber cafes have been established to bridge this digital divide, but these models of facilitating pubic access to ICTs have limitations[110]. Particularly in rural and remote areas, the ability of telecentres to contribute to adaptive capacity-building has been limited by their uncertain economic viability, technical problems, skill shortcomings including digital illiteracy, and social, economic, cultural, political and psychological barriers to accessing and using ICTs in such centres[111]. In parallel with the travails of the telecentre model, there has been an explosive increase in the availability and use of mobile phones in poor communities, and these must therefore be central to any consideration of ICTs' role vis-à-vis climate change adaptive capacity. We are also seeing emergence of more sophisticated mobile devices such as smart phones and Personal Digital Assistants (PDAs)[112]. This paper therefore sets out to investigate the use of ICTs – particularly mobile devices but also their relationship to more traditional telecentre models - in the development of climate change adaptive capacity.

The following section reviews strategies and processes in the development of climate change adaptive capacity, particularly seeking to understand the role of information and knowledge. Section 3 begins with an overview of the ICT architecture models which may underpin capacity-building. Identifying mobile technologies as most-widespread, it reviews some empirical examples of their application, seeking to understand how they relate to climate change and capacity to adapt. Through a deeper conceptualisation of the role of ICTs in adaptation, Section 3 then argues that there are adaptive capacity shortcomings in some of the existing initiatives which a combination of telecentres and mobiles may at least partly address. Finally, conclusions are drawn, and a set of recommendations provided for using ICTs to facilitate the National Adaptation Programmes of Action (NAPA) that are being implemented across developing countries.

2. Information, Knowledge and Climate Change Adaptation

This section reviews climate change adaptation strategies and processes, identifying a key necessary component to be the integration of external, expert knowledge and local adaptation practices. This sets the scene for understanding the role of ICTs.

2.1 Climate Change Adaptation Strategies

Climate change adaptation requires creativity and innovation. Human creativity is the key source of adaptation to local and global changes. While creativity represents new ways of thinking[113], innovation is the process by which that novel thinking is transformed into new products, new processes, new structures and new institutions in response to climate change (and other stressors such as

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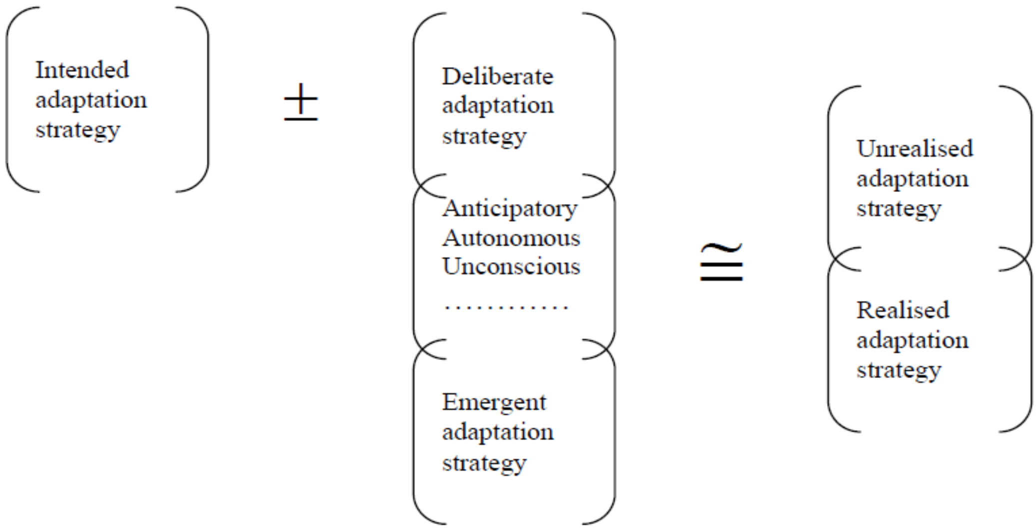
[108]Ospina and Heeks, 2010a; 2010b.
[109]Fuchs & Horak, 2008; Heeks, 2009.
[110]From now on telecentres refer to all kinds of public Internet access facilities in low-income countries.
[111]Ariyabandu, 2009; Pant, 2009; Brown, 2010.
[112]Personal Digital Assistants (PDAs) are low-cost, simple-to-use and energy-efficient handheld computers, and Smart Phones use 3G mobile technology with data connection capability.
[113]Amabile, 1996.

natural resource degradation, civil unrest, and financial and economic downturns)[114].

Creative thinking and innovative action can be applied strategically to climate change in two main ways: deliberate and emergent (see Figure 1)[115]. Deliberate planning and implementation will be part of the response to climate change, but development contexts and communities are so multi-dimensional that they must be understood as complex adaptive systems[116]. As such adaptation strategies will also be emergent from these systems, and thus there is a need to understand creativity and innovation from a systems perspective. A relevant systems perspective could be that drawn from the work on innovation systems, defined as the network of public and private organisations, enterprises, and individuals which is focused on bringing new products, new processes, and new forms of organisational structure into economic, environmental and social use together with the institutions and policies that affect the way these different agents interact, share, access, regulate, exchange and use existing and new data, information and knowledge[117].

Figure 8. Typology of Climate Change Adaptation Strategies



Source: Author Pant with reference to Mintzberg and Waters (1985) and Mintzberg (2007)

Innovation systems literature focuses on multiple sources of innovation beyond just 'top-down' scientific research, and emphasises the importance of drawing on information and knowledge from 'bottom-up' practice[118]. In this context, individual as well as collective capacity to put existing and new knowledge into practice is crucial as capacity includes "abilities, skills, understandings, attitudes, values, relationships, behaviours, motivations, resources and conditions that enable individuals, organisations, networks/sectors and broader social systems to carry out functions and achieve their development objectives over time."[119] Thus

[114]Bacon, 1901; Ruttan, 1971; Shapiro, 2002.
[115]The father of business strategy Henry Mintzberg and his colleagues (Mintzberg et al., 1976; Mintzberg and Waters, 1985; Mintzberg, 2007) argue that deliberate and emergent strategies are the two ends of a continuum along which real-world strategies to address complex problems such as climate change can be formulated.
[116]Hall & Clark, 2010.
[117]Lundvall ,1992; World Bank, 2006.
[118]Biggs, 1990; DFID, 2005; Lenné, 2008.
[119]CIDA, 2000: 2.

capacity is an emergent property of a system that comes through the interrelationships and interactions among various elements of the system, including biophysical, technological, social, political and cultural components[120]. Adaptive capacity can therefore be understood as innovation capacity, which entails agile systems of collective context-specific skills, practices, routines, institutions and policies to put existing and new information and knowledge from research as well as practice into productive use in response to technological, economic, social, climatic and environmental challenges and opportunities[121]. Specifically in the field of climate change, adaptive capacity refers to "[t]he ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."[122].

We can then draw four conclusions in our recognition of the relevance of innovation to this systems-based understanding of adaptive capacity development. First that data, information and knowledge will be key resources within adaptation to climate change. Second that adaptive capacity will involve the capacity to access, assimilate, create and utilise data, information and knowledge. Third that, for a community, this will specifically require some means to integrate the local and the external. Fourth (and a point returned to later) that we need to recognise capacity as both individual and collective.

2.2 Climate Change Adaptation Processes

As presented in the previous section, putting local and external information from research and practice into collective learning, innovation and action is central to the development of climate change adaptive capacity. An entry point to facilitate the adaptation processes will therefore be to recognise that there are multiple stakeholders with multiple knowledge traditions that shape their handling of data and information. Building on this and the work of Brown[123], we can suggest a three-step process of developing adaptive capacity as follows.

Firstly, identify the range of stakeholders and worldviews that relate to the core problem. For example, what do climate change and climate change adaptation mean to stakeholders such as scientific communities, and local communities, and public and private sector actors? Specifically in the context of climate change, scientific data and information are available on the greenhouse gases and other causes of climate change, but there are (and will be) different views and different understandings regarding actual and potential impacts of climate change vis-à-vis agriculture, food security, natural resource management, and patterns of infectious disease. In particular, local communities may well have quite different worldviews on these issues to those espoused by the scientific community.

Secondly, identify the multiple knowledge traditions – multiple ways of data collection, of transforming the data into useful information and knowledge, and of storage, exchange, regulation and application of information – that these different stakeholders adhere to. For example, how do the data, information and knowledge systems of local communities in relation to climate change and adaptation compare to those of external stakeholders?

Thirdly, consider how these differing information and knowledge resources can be integrated as part of building capacity for climate change adaptation. It is clearly

[120]Morgan, 2005.
[121]Hall, 2005.
[122]IPCC, 2007: 869.
[123]Brown, 2010.

important to bridge the divide between local and external/expert systems, but the presence of the different worldviews and different information and knowledge systems presents a challenge to this activity.

One method of addressing divergent worldviews and systems practices is the use of intermediaries. Intermediaries play important roles in bringing heterogeneous actors together, particularly the public and private, formal and informal, external and local, and rural and urban actors engaged in knowledge production, storage, exchange, regulation and application[124]. Individual and/or organisational intermediaries can play diverse brokering roles depending on a particular context: boundary spanning, social and environmental activism and innovation, and generating positive social and environmental changes. Our particular interest here, though, is their role as 'infomediaries' in information and knowledge brokering: bringing together information and knowledge from multiple and differing sources, and blending it in order to provide this important foundation for climate change adaptation.

In doing this, however, intermediaries face many barriers. They are constrained by the structural and institutional frameworks within which they operate. They are challenged by the capacity and resources limitations such frameworks often impose. They face the more technical challenges of accessing data and synthesising data formats drawn from different knowledge traditions. Given the recent diffusion of digital technologies in developing countries, the question then arises of whether ICTs can help address some of these barriers to formation of the informational basis for climate change adaptive capacity; either in an informational sense or in a more structural and transformative sense.

3. ICT-Enabled Development of Climate Change Adaptive Capacity

To address the issue of how ICTs can help develop climate change adaptive capacity, this section first introduces the archetypes of ICT infrastructure. It then reviews some field experiences of using the dominant technology type – mobile – to address climate-relevant development challenges. But a deeper understanding of ICTs' role in climate change adaptation suggests there are limitations to current models which a rehabilitation of the telecentre model might partly address.

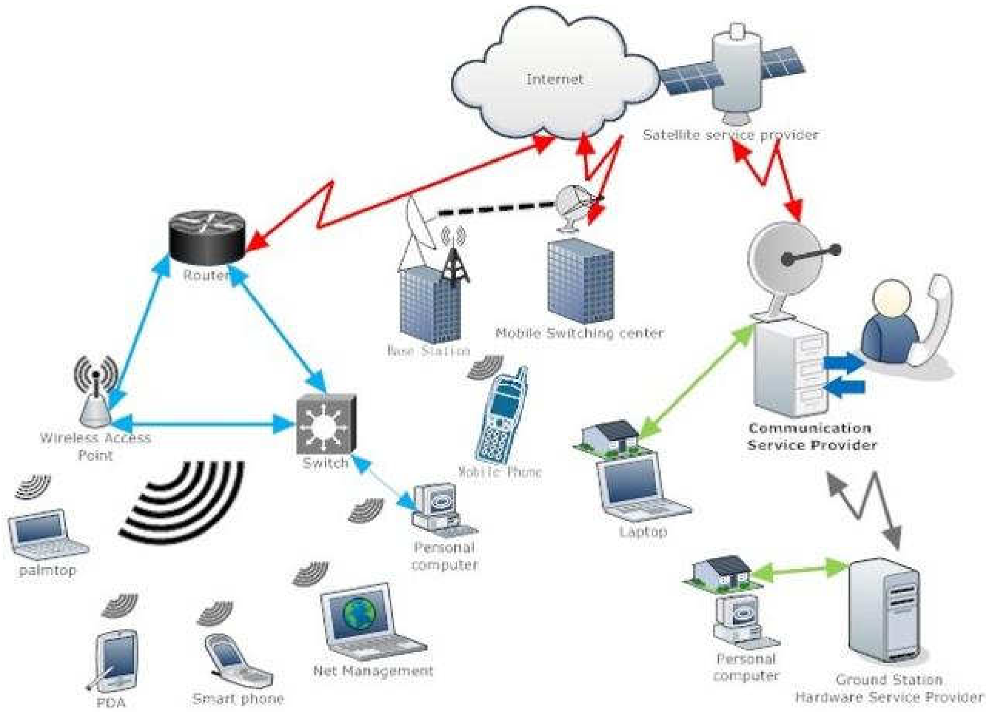
3.1 ICT Infrastructures for Climate Change Adaptation

We can identify six main categories of ICT architecture of relevance to climate change adaptive capacity-building in developing countries: advanced Internet network-based, ordinary mobile phone-based, telecentre-based, a combination of ordinary mobile phone and telecentre, a combination of ordinary mobile phone with central Internet-linked server, and a combination of emerging ICTs with conventional media, such as radio and television. The first three of these are illustrated in Figure 2. The advanced Internet network – incorporating the type of wireless devices only just emerging in low-income countries – is shown at the left side of the diagram. Ordinary mobile phone-based access to cellular networks is depicted in the middle. As the quote at the very start of the paper indicated, this is becoming universally accessible but with a limited data transfer functionality

[124]Klerkx & Leeuwis, 2008; Klerkx et al., 2010.

given the relatively slow roll-out of 3G mobile telephony[125].

Figure 2. Three Archetypes of ICT Infrastructure



Source: Author Pant with reference to personal communication with B.M. Bhattarai (2010)

The third category is the telecentre-based Internet access architecture illustrated on the right side of Figure 2. The telecentre model of public ICT services was initially conceptualised as a way to provide telephone services when wired telephones were still rare and before mobile phones were really available. With emergence of the Internet in the 1990s and, in developing countries, early 2000s, telecentres gradually transformed into public Internet access points. Now, with increasing access to Internet through mobile devices, telecentres may need to transform further.

Such transformation is seeing appearance of the fourth ICT architecture: the combination of ordinary mobile phones and telecentres. As discussed further below, this can open new possibilities for real-time and emergency communication, and facilitate integration of local and external information and knowledge by combining the power of Internet access with the relative ubiquity of the mobile phone. That power is also harnessed in the fifth model, which uses mobile phone calls (including interactive voice response systems (IVR)) or texting to connect to a central server, or to an operator using that central server. Finally, an alternative converged infrastructure involves use of basic mobile telephony for data transfer – via voice or short messaging service (SMS) – together with community radio, television, community billboards, conventional print or a combination of these.

Given the pervasive availability of mobile devices – particularly standard phones – it is this technology that we will initially focus upon. A few examples of the

[125] Compared to 2G mobile services that are virtually isolated from the Web, 3G mobile services provide options for Internet access through cellular networks, including multimedia messaging services (MMS).

mobile-related ICT architectures are shown in Table 1, with applications of relevance to climate change effects including those on agriculture and health[126].

Table 2. Project Examples of Different Mobile-related ICT Architecture Models

Project	Description	Country
Food security monitoring[127].	Use of PDAs to collect data regarding changes in food security situations [Model 1]	Nepal
NetMark malaria-control project[128].	Use of PDAs to conduct household surveys about insecticide-treated bednets [Model 1]	Uganda
Health Information Network[129].	Electronic data upload and download using PDAs and mobile phones to facilitate decision making among health workers located in remote health centres [Model 1/5]	Uganda, Mozambique
DatAgro[130]	SMS to farmers using low-cost mobiles regarding information on weather forecasts, market prices and cultivation practices [Model 2]	Chile
Fisher Friend Programme[131].	Weather forecasts, optimal fishing zones, market prices and related messages to fishers using mobile phones [Model 2]	India
Farmers' Text Centre[132].	Farmers send text messages to Farmers' Text Centre where the information is processed and responses are sent back via SMS [Model 5]	The Philippines
The Farmer's Friend service[133].	Farmers send text to a central Internet-connected server where information is processed and responses are sent back [Model 5]	Uganda
Flood Warning Systems[134].	Use of mobile phones to collect data for flood forecasting and forward to central early warning system, which are then disseminated via traditional media [Model 5/6]	Cambodia Laos, Vietnam

Source: Author Pant compilation

3.2 ICT-enabled Information and Knowledge Exchange

We can now look at these examples of climate change-related uses of ICTs, to analyse how they are supporting the information and knowledge exchange that was seen above to be an important component of adaptive capacity.

3.2.1 Local Information and Knowledge Generation

Empirical evidence is emerging on the use of PDAs and mobile phones to generate local information to enhance anticipatory adaptation. In the floodplains of the Mekong River Basin in Cambodia, Laos and Vietnam, villagers have been provided with mobile phones and flood markers, and trained to record water levels in remote areas and to report the figures to weather agencies through text messages[135]. Flood management experts analyse the data and convert them into flood forecast figures which are sent back to the community. The villagers then

[126]The paucity, as yet, of ICT applications directly relating to climate change and climate change adaptation mean that we have to utilise somewhat broader applications as our examples.
[127]NeKSAP, 2009.
[128]AED, 2008.
[129]AED, 2008; MoH, 2010.
[130]Cagley, 2010.
[131]MSSRF, 2010.
[132]Pascua et al., 2010.
[133]The Economist, 2009.
[134]MRC, 2009a, 2009b.
[135]MRC, 2009a, 2009b.

publicise the figures on local billboards established at strategic locations along the flood plain and also announce through loudspeakers.

Application of handheld digital mobile devices has also emerged in data collection, analysis and providing information for problem-solving and decision-making that can potentially enhance autonomous climate change adaptive capacity of vulnerable communities. Examples include a PDA-based food security monitoring system of Nepal[136], and surveys of malaria-control project households in Uganda. It is believed that climate variability and change, and extreme weather events, such as droughts and floods have negatively impacted both food security, and vector-borne disease outbreaks, such as dengue fever in Nepal and malaria among vulnerable communities in Uganda. Handheld mobile digital devices are useful for continuous monitoring and reporting of food security such as cropping and stock details, and of relevant diseases[137].

These applications therefore show particularly how a 'voice' component of adaptive capacity can be strengthened, enabling data from vulnerable communities to be attended to by external institutions, and aggregated and processed in a way that then helps protect those communities, and offers them adaptive guidance. There is, as yet, less sense within these applications that local knowledge is being much utilised or generated.

3.2.2 Access to External Information and Knowledge

As with the data upload utility of handheld mobile digital devices, empirical evidence is also emerging on the use of PDAs and mobile phones to access external information from the Web. In Chile the DatAgro project transfers searchable content from the Internet into news feeds (RSS) and then the content is passed on to farmers via SMS[138]. Specifically-written software allows such searching to be undertaken via simple, low-cost mobile phones and slow networks with sporadic connectivity, a typical situation of prepaid mobile users in low-income countries. In the face of climate change, farmers benefit from improved access to weather forecasts and information on new and emerging production and post-harvest technologies. This can help improve short-term climate-related decision-making (e.g. in relation to heat waves, rainfall patterns or potential flooding) and long-term climate-related decisions around changes to cropping choices and mixes. Recognising the need to integrate the local and the external, the project allows farmers to customise the information feeds they receive, and also provides a basis for follow-up interaction from the central project team if the content of SMS messages has not been well understood.

The Fisher Friend Programme of the MS Swaminathan Research Foundation (MSSRF) processes satellite information in order to provide weather forecast and fishing zone information in local languages via mobile phone[139]. Alongside the financial gains of improved fish stock location, this system can also have climate-related benefits: it has successfully forecast storms and other extreme weather events that have led fishermen to avoid particular areas or simply not put to sea. In addition, with climate change associated with changes in sea currents, the fish shoal availability information is seen as an integral part of building longer-term adaptive capacity[140]. Future plans include making the information available via IVR to enable hands-free and low-literacy user access, and adding global positioning system capability into the phones, to enable tracking in the event of a

[136]NeKSAP, 2009.
[137]Morens et al., 2004.
[138]Cagley, 2010.
[139]Nanda & Arunachalam, 2009; MSSRF, 2010.
[140]Mittal et al., 2010.

local weather-related disaster.

If the first set of examples represented bringing the local to the external, the examples in this section represent the reverse. They show how external information and knowledge can be brought down into local communities, and integrated into local practices that increase the capacity of those communities to adapt to various aspects of climate-related change.

3.2.3 Two-way Exchange of Information and Knowledge

Although various initiatives prioritise either download or upload of data to and from the Web, there are also initiatives that focus on two-way information exchange (albeit recognising that in all the previous examples, there is always some form of interaction). The Health Information Network projects of Uganda and Mozambique have utilised existing mobile telephone networks and PDAs for this purpose[141]. In Uganda, this project was conceived to provide two-way communication connecting the local (rural and remote health workers) and the external (district and national health system managers). Through this project, the district/national level obtains information on, for example, emerging and re-emerging patterns of disease, and the amount of drugs and other services needed at the local level. The PDAs come with a digital 'Mobile Medical Library', including a range of reference materials that health workers consult for treatment of patients. The network also supports health information exchange via data collection and text and voice messages, so that local-level questions about treatment for particular patients can readily be answered. Via upflow, downflow and interchange of both data and information, the key stakeholders can have greater capacity to adapt to various aspects of climate change including understanding climate-related changes in disease patterns, planning for the implications of such changes, and also handling the health impacts of short-term climate-induced emergencies such as heatwaves or floods.

In the Philippines, an SMS-based system of two-way data exchange has been implemented using basic mobile phones[142]. Information seekers – e.g. a farmer, extension worker, agribusiness owner, or others – can send a text message to the Philippine Rice Research Institute's Farmers' Text Centre to get free guidance on rice growing. This system can provide timely information useful to minimise impacts of climate change on rice farming ranging from short-term advice on planting and harvesting in relation to extreme weather events, to medium-term guidance on planting techniques to reduce methane production or to cope with fluctuations in seasonality, to information on coping with longer-term changes to pest and crop suitability. A similar initiative in Uganda, called The Farmer's Friend service, responds to text message queries on everything from weather forecasts to pests to planting techniques[143]. Relatively complicated texts are relayed to human experts, who either call back within 15 minutes or promise to provide an answer within four days based on their own knowledge and/or searches via the Internet or within a locally-constructed database.

These systems are allowing a relatively-rich interchange between the local and the external. In general, the emphasis is still on local data but external knowledge. Nonetheless, these applications are forcing the two knowledge traditions to overlap, and pushing the external knowledge systems and stakeholders to at least take account of local worldviews. By thus combining the local and the external, they are creating a broader foundation for adaptive capacity and one that is thus not merely larger but also potentially more resilient.

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[141]Jaramogi, 2010; MoH, 2010; Nakkazi, 2010; UHIN, 2010.
[142]Pascua et al., 2010; The Philippine Star, 2010.
[143]The Economist, 2009.

3.3 Opportunities and Challenges of Using ICT for Climate Change Adaptation

The above presentations of project examples, although brief, are symptomatic of the current picture of ICT use vis-à-vis climate change adaptive capacity; and not just because they place mobile technologies at their core. They demonstrate the way in which capacity can be built by integrating local and external data and, to some extent, knowledge. They are not climate change-specific, but they show how generic ICT-for-development initiatives can readily address climate change issues and so enhance climate change adaptive capacity. They also fit with the more general conclusion that approaches to using ICTs for climate change adaptation should be more holistic than reductionist, and should recognise the way in which climate change's main effect is the exacerbation of existing vulnerabilities. Put another way, we regard the lack of climate change-specificity in ICT initiatives as "a feature not a bug": a design approach that is to be recommended.

To investigate this further, we can turn back to the model of strategies presented in Section 2.1. We noted the distinction between deliberate, pre-planned strategies, and emergent strategies for climate change adaptation. We noted further that – given climate change is a complex problem characterised by multiple stresses and non-linear interactions – deliberate planning and implementation of adaptation interventions will not be enough. With vulnerable communities in developing countries understood as complex adaptive systems, then there must also be capacity within those systems for strategies to emerge autonomously, for example in response to unexpected events. As summarised in Table 2, while deliberate strategy may work best for simple and known problems, emergent strategy would be effective in solving complex problems[144]. Our earlier examples show ICTs can help with both.

Table 3. Deliberate and Emergent Strategies for Climate Change Adaptation

	Intended strategy	Unintended strategy
Anticipatory	Deliberate strategy, e.g., early warning systems. Effective in simple and known systems	
Autonomous		Emergent strategy, e.g., agriculture and health information systems. Effective in complex adaptive systems

Source: Author Pant

Deliberate strategies can be anticipatory as well as intended. Anticipatory adaptation strategy involves proactive use of ICTs in planned adaptation to climate change and related stresses before actual impacts are known but when the general nature of those impacts is known, such as mobile phone use in flood warning systems in the Mekong River Basin[145]. In this case multi-purpose information networks potentially useful at the time of extreme events, but not necessarily dedicated to climate change alone, would be effective in creating a

[144] Snowden & Bonne, 2007.
[145] MRC, 2009a.

nimble information and knowledge infrastructure for overall capacity development of relevant stakeholders. Examples of intended use of ICTs in response to known climate change stresses include the use of PDAs and mobile phones to identify optimal fishing zones in response to decreasing and/or changing fish stocks in the Indian Ocean[146]. These intended uses of ICTs can specifically facilitate planned climate change adaptation, such as sustainable harvesting of natural resources from ecosystems that are already vulnerable.

Emergent strategies are not planned in advance and can be autonomous as well as allowing for unintended impacts; they therefore emerge when a need arises. Autonomous, emergent adaptation strategy can make use of ICT initiatives set up without actually knowing and/or specifically targeting climate change impacts. Examples include the use of PDAs and mobile phones in food, agriculture and health information systems in Nepal, Chile, Uganda and Mozambique[147]. At the time of additional stresses caused by climate change and extreme events these networks provide the capacity for real-time exchange of information and knowledge for agile problem-solving and decision-making. Similarly, ICT-enabled exchange networks that are established for economic and social development interventions can have emergent use during the time of extreme events albeit such uses may initially be unintended. For example, the two-way information exchange systems cited above that are operational in food, agriculture and health also help develop adaptive capacity to handle additional stresses in the face of climate change. However, this – by-and-large – represents potential applications for these ICT initiatives rather than use for which we have actual evidence at present.
Further, we must recognise a key difference between the two strategies and the demands they place on ICT-enabled systems and capacities. Deliberate, planned strategies can rely significantly and principally on capacities external to the local community. Hence, in the pre-planned uses of ICT systems noted above, the local is often the 'junior partner' to the external. Most of the systems involve connections and they are additive of capacities at local and national level. But it is the community – in the main – that taps into capacities of the wider world much more than vice versa. Yet emergent responses to climate change rely far more on local capacities: conceptually that is inherent to the notion that these are autonomous more than anticipatory; and practically that may be the case at least with extreme climate-related events when it may be more difficult to draw on external capacities for assistance.

We therefore turn to ask what kinds of capacities these ICT systems are building. That requires us to understand more about the emergent capacities of self-organising systems in relation to climate change.

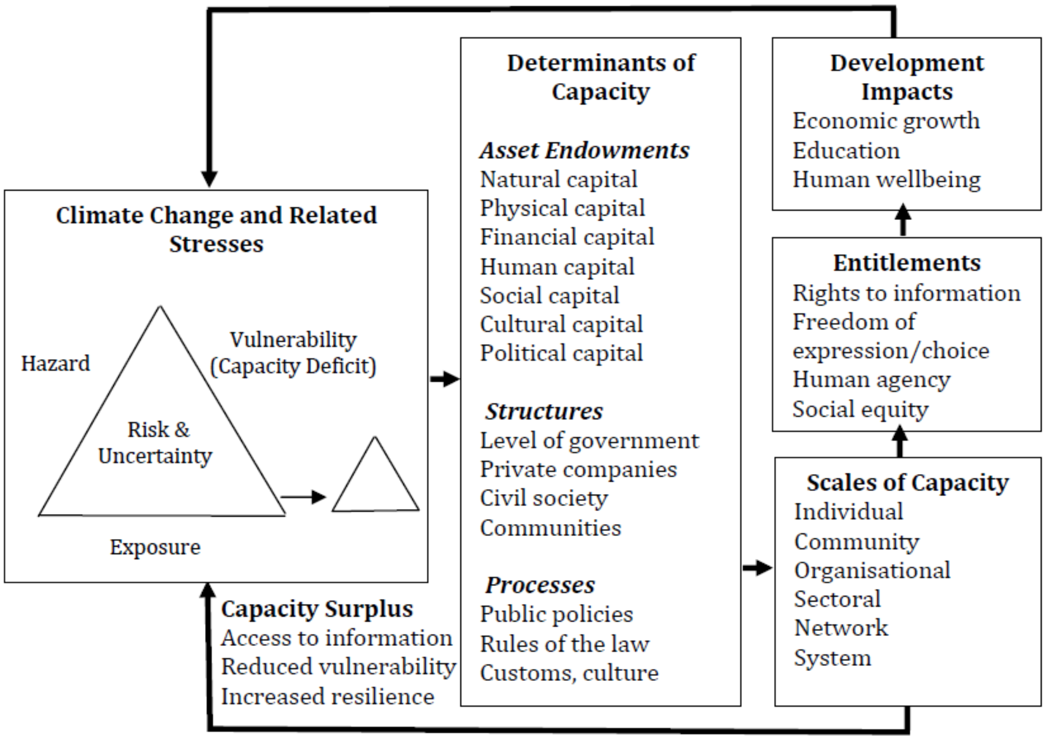
3.3.1 ICTs and Self-organising Systems of Adaptive Capacity Development

To build a model of ICT-related climate change adaptive capacity, we start by recognising that the risks of climate change derive from Crichton's "risk triangle"[148]. This asserts that risk arises from a combination of the intensity and frequency of particular climate change-related *hazards*, such as floods or droughts, the degree of *exposure* to those hazards (for example exacerbated by absences of drainage or irrigation systems), and the inherent *vulnerability* of the particular population; that vulnerability being greater for those who are poor, elderly, chronically-ill, etc[149]. Given that hazard is largely outside the sphere of

[146] AED, 2008; MSSRF, 2010.
[147] NeKSAP, 2009; Cagley, 2010; UHIN, 2010.
[148] Crichton, 1999.
[149] Hardoy & Pandiella, 2009.

human control (if we set aside the issue of climate change mitigation actions), then climate change adaptation becomes the process of seeking to reduce exposure and vulnerability. This is done (see Figure 3) by making improvements in assets (natural, physical, financial, human, social, cultural and political capital), social structures (at various levels), and institutional processes (both formal such as policy and law, and informal such as custom and culture) [150]. If successful, this reduces the triangular 'area' of risk and uncertainty.

Figure 3. Climate Change Adaptive Capacity Development Framework



Source: Author Pant with reference to Crichton (1999), Chambers & Conway (1992), Scoones (1998), CIDA (2000), and Sen (1999)

Using Figure 3's foundation, we can then modify this framework in order to take a greater focus on the role of ICTs (see Figure 4). From this we recognise that the main determinants of ICT-enabled development of climate change adaptive capacity will be asset endowments (both technical and human), organisational structures of relevance to ICT, and the institutional environment including ICT policies and the ICT-related habits and practices of multiple stakeholders.

There are two structural features of this ICT-related capacity development. First, that it is multi-level: capacity development for climate change adaptation demands action to develop individual, organisational, network and system level capacity to bring positive economic, environmental and social change[151]. When interrogating ICT initiatives, we must therefore ask at what level capacity is being developed. Second, Clarke & Oswald[152] caution that the conventional approaches to development of climate change adaptive capacity view skills and knowledge as things to be transferred to fill a deficit, in specific individuals, organisations, networks and systems without due considerations of collective capacity

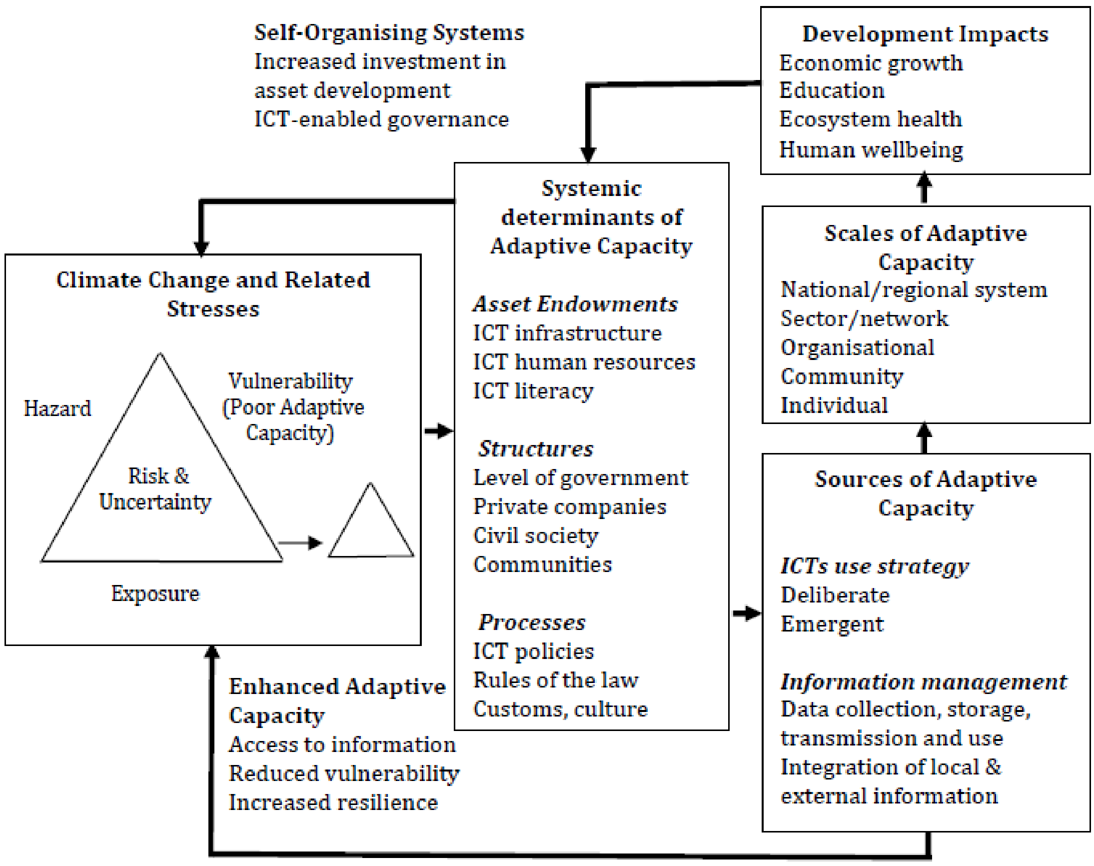
[150] Crichton, 1999.
[151] CIDA, 2000.
[152] Clarke & Oswald, 2010.

development for emancipatory change; unleashing the potential of vulnerable communities, economies and ecosystems to self-organise. As argued earlier, the latter is particularly important if emergent strategy on climate change is to be enabled.

Building these ideas into our framework as shown in Figure 4, we can note two main ICT-relevant feedback loops that we require to operate if communities are to build climate change adaptation capacity. The first is an *informational loop*. Very much along the lines already discussed and illustrated in the examples, this involves the development of ICT-related asset endowments which then draw together data and knowledge from various levels and sources, and generate improved access to information. This improves local knowledge, decision-making and problem-solving action (see examples above) and so reduces vulnerability and increases resilience.

The second is a *transformational loop*. This moves beyond a simple information management perspective, to a deeper structural view, recognising that ICTs may be utilised to alter the structural location of capacity; in particular transforming community systems to enable them to become more self-organising and, hence, facilitating the type of autonomous, emergent strategy-making that we have argued will be one key part of the response to climate change.

Figure 4. ICT-enabled Climate Change Adaptive Capacity Development Framework



Source: Author Pant with reference to Figure 3.

Armed with this deeper perspective on ICTs and climate change adaptation, we can now re-view the ICT experiences to date that were outlined above. From this, we see that – while there was potential for ICT-for-development projects to support both deliberate and planned strategies – in practice, our evidence to date is that they have been working far more in the top-down, pre-planned, anticipatory mode than in the autonomous and emergent mode. Phrased in Figure 4 terms, the informational loop is certainly working but has largely been about the insertion of external data and knowledge into local communities, potentially increasing dependency rather than autonomy and self-reliance. The transformational loop has largely not been seen to work so far – communities have not particularly become more self-organising, they have not particularly developed local informational capacities – or, at least, not to the extent necessary given the demands being placed on them by the increasing intensity and frequency of climate change and related stessors. And, given the growing model of individuals using mobile phones or PDAs to connect to distant server systems, any capacity-development has tended to be atomised with no role for a community-based infomediary. Far from creating the collective capacity identified above as crucial, the type of ICT initiatives that are currently in vogue might even, then, be dispersing that capacity.

3.3.2 Transforming Conventional Telecentres into Mobile Teleservices

What, then, can be done to help develop the climate change adaptive capacity that is local and self-organised, and which can support emergent strategies? We must be clear that there are no panaceas. However, it may be time to look again at the local telecentre. As noted above, telecentres have had a relatively bad press in recent years, fuelled by failed projects and recognition of the many challenges and barriers they face.

One reaction to this has been functional, particularly the development of telecentre multi-functionality. In service breadth terms, this has meant telecentres providing as broad a range of ICT-related services as possible, moving well beyond the traditional confines of e-government, e-agriculture, e-health, etc. In service depth terms, this has meant telecentres moving beyond digital data flow to provide the "information chain" support necessary to turn that digital data into developmental impact: digital literacy training; assistance with online searching about jobs, weather, pest risks, etc; support for finding sources of capital, goods, etc[153]. In locational terms, this has meant incorporating telecentres in multi-use locations such as meeting places, libraries, markets, etc[154].

We noted above that "adaptive capacity will involve the capacity to access, assimilate, create and utilise data, information and knowledge". The mobile- and PDA-based models described earlier develop individual capacity within communities to access and, sometimes, create data. By contrast, it can be seen that telecentres develop both individual and collective capacities across the whole range of information and knowledge activities. One key asset of telecentres is the telecentre operator, who – as an infomediary – becomes an important part of community capacity; for example in performing the role identified earlier of mediating between local and external sources of data and knowledge. They have thus frequently been shown to assist in: identifying external data sources for local users, explaining external knowledge frames, and in translating local 'knowledge traditions' for external users[155].

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[153] Heeks & Kanashiro, 2009.
[154]E.g. initiatives in Cape Town, South Africa (Chigona & Licker, 2008) and in Chile (Kleine, 2010) that incorporate telecentres within public libraries.
[155]GIS, 2010.

Yet the reach of telecentres still remains limited. Mobility is the answer. One approach has been to physically bring the telecentre to the users. In North India, telecentre operators have brought *tele-thela* – carts equipped with ICTs – into peri-urban and rural settlements providing a range of services to the communities, such as telephone calls, email, Internet browsing and digital literacy classes[156]. Similarly, the well-known "telephone ladies" in Bangladesh are increasingly moving on from circulating around their village with mobile phones to providing mobile Internet services using netbooks and laptops[157]. The operators then represent "mobile informediaries" who not only bring both technology and adaptive capacity to individuals, but also represent a collective source of capacity that is steadily being built within the community[158].

An alternative approach to telecentre mobility is to bring the telecentre virtually to the users by adopting 'Model 4' of the ICT architectures discussed above: the combination of telecentre and mobile phone. There are already a number of projects using this model, which have demonstrated their value. For example, the "Warana Unwired" project in Western India enabled farmers – whether at home or in the field – to access telecentre services via SMS-based mobile phone[159]. While at one level similar to the initiatives that connect users in poor communities to server-based services in the national capital (as per 'Model 5' above), there is a crucial difference here that the connection is via the local telecentre operator. Not only are they able to 'infomediate' both ways better than a distant contact, bridging the gap between local and external information and knowledge, for example by explaining guidance to the farmers. But in doing so and in learning, they are building capacity that is captured within the local community. This therefore supports the type of capacity necessary for a more self-organised and emergent approach to climate change adaptation.

4. Conclusions and Recommendations

ICTs will play a crucial part in the development of climate change adaptive capacity in developing countries. They will do this in four ways: i) by combining existing data in new ways; ii) by enabling access to new data, information and knowledge; iii) by reducing costs of access to transactions and services; and iv) by their productive role in ICT-based enterprise. Our focus here has been largely on the first two applications, with the more transactional and productive roles that ICTs can play set aside due to lack of evidence, at least in relation to climate change adaptation.

The dominant pattern of thinking on climate change adaptation has been top-down, deliberate, planned. This is a vital part of capacity building, but it is only a part. There needs to be equal recognition that many climate change adaptive actions will be emergent – unplanned and arising from within individual communities and regions that should be understood as complex adaptive systems. The application of ICTs to climate change adaptation must also be shaped by this equality of recognition.

To date, ICT applications – which are dominated by mobile technology-centred models – have also been dominated by the 'planned strategy' worldview. They have been quite good in an informational role that links the local and the external: sometimes concentrating on upload from local to external, sometimes

[156]Singh. 2007.
[157]The Economist, 2009.
[158]Kiran et al., 2009
[159]Veeraraghavan et al., 2009.

on the reverse download, sometimes on exchange between the two. These applications have been quite poor at delivering a transformational role that truly builds local adaptive capacity. Even where they link local and external, this has not been a meeting of equals: communities bring their data, external experts deliver their information, their knowledge and their worldviews. The different knowledge traditions of these two groups mean this exchange is not always as effective as it might be.

The telecentre model with its local infomediary has the potential to partly challenge this current status quo, but has itself been challenged from all sides: the technical, the socio-political and the financial. One way forward may be the integration of mobile devices with local telecentres, but this model has been rather rare compared to the mobile-devices-with-national-servers architecture.

While implementing their National Adaptation Programmes of Action, developing countries are invited to bear in mind the following recommendations:

1. Climate change cannot readily be separated out as an issue for local communities: it exacerbates and is exacerbated by other vulnerabilities. There has been concern at the lack of climate change adaptation-specific ICT applications. Given, the indivisibility of climate change from other development issues, this may be no bad thing. It may make more sense to understand the climate change-related uses of existing ICT projects and systems, rather than seeking to developed new applications that are climate-specific.

2. In the balance between the local and the external in current ICT applications, the emphasis has been too little on the former, too much on the latter; even running the risk of reducing local capacities and increasing dependency on those from outside. Emergent actions demand the greater development of local capacities e.g. those within individual communities. An acid test, then, for ICT projects will be the extent to which they truly develop those capacities with a true appreciation of diverse knowledge traditions. Where local users are, for example, providing climate impact-related data, can they be made more than just dumb data sources? Can their knowledge and practices be incorporated into the information system?

3. The same issue applies for that part of adaptation-relevant systems which offers external information, often wrapped within an external knowledge framework. Such information will almost always require 'translation' if it is to be relevant to local knowledge traditions and local practices. How will that local translation capacity be fostered and engineered into the system? Expanding this point more generally, effective use of data requires an 'information chain' of resources that enable the data to be accessed, assessed, assimilated, applied and actioned. Adaptation project design must ensure that the resources necessary to complete that entire chain – from data through information and decisions to actions – are either available or can be created.

4. Mobile phones are an incredible technology and their significant perceived value within poor communities is reflected in their very rapid diffusion rates. As a result, climate change-related projects are likely to be mobile-dominated for many years. But mobiles can atomise capacities, can deliver only the first part of the information chain. Adaptation project design needs to incorporate some means for collective capacity development. That may often be through infomediary development. While not the only model, the telecentre operator is one possible hub for this, with new telecentre architectures based around smart mobile 'info-carts' or around mobile-plus-fixed-telecentre presenting possible

ways forward. The technology question is thus not 'mobile phone or telecentre?' but how to implement 'mobile-telecentre'.

Finally, further research on the use of ICTs for developing climate change adaptive capacity needs to look at how nation states have proposed to use a range of ICTs in their National Adaptation Programme of Action. Specific research questions can relate to whether and how existing ICT architectures are being utilised to enhance national, regional and local adaptive capacity, and what are the strategic priorities to develop and/or expand ICT infrastructure over time and space. We also need to understand how ICTs can be used in ways that move beyond their basic 'data flow' role: with ICTs now able to handle digital transactions, and able to form the basis for new ICT-based enterprises, how can these newer roles contribute to capacity building?

We have recommended the value of avoiding climate change adaptation-specific ICT applications, but how does this materialise in practice. Are there such specific applications emerging in field projects and, if so, what lessons can we learn? The same questions also apply to the 'mobile-telecentre' models advocated above: these are as yet quite rare, and we need to better understand their good and bad practices and, more importantly, impact on local capacity formation.

Finally, we need research to empirically test the conceptual framework developed in this paper and to understand more about two issues put forward. What role will local infomediaries play in climate change adaptation? Is the telecentre operator the only model here or will there be others, perhaps more emergent from within communities? And what of emergent actions on climate change adaptation: what are these, and how can we better understand the role of ICTs in supporting them?

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Chapter 5: Disaster Management, Developing Country Communities & Climate Change: *The Role of ICTs*

NONITA T. YAP

Executive Summary

Climate change presents two types of disaster threat in developing countries. One is the potentially devastating impacts on vulnerable communities of more frequent and more intense extreme weather events. This contributes to the second threat, the compounding of what are already complex development problems leading to a potential downward development spiral for the world's poor.

Effective disaster response demands rapid access to reliable and accurate data and the capacity to assess, analyse and integrate information from varied sources. ICTs can obviously help, and this paper focuses on the role of ICTs in reducing the impacts of acute climate-related events. The centrality of the community in effective disaster management is argued while acknowledging the important role of governments, donors, businesses, epistemic communities and NGOs. Some ICT applications in hydrometeorological disasters are described. That the majority of applications are funded externally raises concerns about further dependency and unsustainability but the paper argues there are grounds for optimism.

Development of new wireless technologies; convergence of telecommunications, computing, and multi-media; multi-stakeholder partnerships; and the use of FOSS by socially minded ICT-savvy professionals are enabling greater standardisation and interoperability, more data availability, greater reach at lower costs, and to some extent transparency and accountability of disaster resource allocation and delivery.

The paper closes with some recommendations on how the use of ICTs in community-centred disaster management may be enhanced. ICT systems should be developed that accommodate interoperation. Some of this, including a commitment to standardised disaster data collection, could be mandated on NGOs and other local agencies by those that fund them. ICT systems should be based around routinely-used rather than specialised applications. Further, we recommend integration rather than specialisation: with climate change becoming an integral part of disaster management systems rather than separately catered-for; and with generic information systems being created that encompass both disaster and development purposes. Finally the paper argues that we also need to clarify how ICTs can address barriers to interagency coordination and collaboration, and how the new technologies can help evaluate the effectiveness and financial performance of disaster response programmes.

1. Introduction

Information that reaches the public on disasters has tended to focus on disasters of large magnitude, involving tremendous loss of life, property and infrastructure. This has helped create a public perception that disasters are comparatively rare. The dissociation of disasters from the normal has had serious consequences, in particular the mindset that normal development decisions on settlement, construction, production, trade and commerce can proceed without considering the hazards that they may create or disaster vulnerabilities that they may exacerbate.[160,161]

The link between disasters and development began to be seriously examined from various perspectives in the 1990s. What the different perspectives share is a recognition that disaster impacts depend to a large extent on historical and current development activities.[162] This rethinking was partly triggered by social science research largely in industrialised countries, showing that the impacts of natural hazards could be lessened if early warning systems were in place, conditions imposed on settlement patterns, and industrial siting and building codes established and enforced.[163] It was also triggered by the observation that in developing countries disaster relief agencies were struggling with disasters that appeared larger, more frequent and more complex; that regardless of the resources mobilised, disaster relief provided at best a palliative, at worst dependency-creation; and that just as disasters eroded development gains, certain development directions contributed to an increase in disaster vulnerabilities and impact intensity.[164]

An estimated 92% of natural disaster-related deaths occur in countries within the low and medium development indexes[165,166]. The attendant economic loss as a percentage of GNP also far exceeds that in developed countries, albeit smaller in absolute figures.[167] For example, in 2007 the Asia Pacific region suffered slightly over a third (37%) of all natural disasters but over 90% of all reported victims and almost half of the economic damage.[168] These disproportionate impacts reflect the vulnerabilities arising from high population densities, inadequate infrastructure, environmental degradation and poverty in all its faces.[169] Disasters have become "teaching moments",[170] not only on the relationship between humans and the natural world but also on how individual and societal decisions and social relations can aggravate or mitigate the impacts.

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[160] Lewis 1999.
[161] The introduction of environmental impact assessment in the U.S. in the late 1960s was a recognition of the need for change. The practice was not adopted in developing countries until the 1990s.
[162] Allen 2006; Berke et al. 1993; Drabek and Key 1976; Lewis op.cit.; Paton and Johnson 2001; Tobin 1999; Wisner et al. 2003.
[163] See for example Hewitt 1983; Quarantelli 1989.
[164] Christoplos et al. 2004; Hay 1986; Lewis op.cit.; Ross, Maxwell and Buchanan-Smith 1994; Siddiqui 2008; Sylvester 2004.
[165] IFRC 2009.
[166] The Human Development Index, established by UNDP, combines three dimensions: (a) *life expectancy* at birth, as an index of population health and longevity, (b) *knowledge and education,* as measured by the adult literacy rate (with two-thirds weighting) and the combined primary, secondary, and tertiary gross enrolment ratio (with one-third weighting) and (c) *standard of living*, as indicated by the natural logarithm of gross domestic product per capita at purchasing power parity. A HDI ratio of less than 0.5 is considered Low Development Index, a ratio of 0.5 to 0.8 is considered Medium Development Index (http://www.eoearth.org/article/Human_Development_Index).
[167] UN ISDR 2004.
[168] UN ESCAP 2008.
[169] See for example Lewis op.cit.; Quarantelli 1998.
[170] Laituri 2010: 6.

Global climate change is expected to exacerbate these vulnerabilities, particularly among communities dependent on rain-fed agriculture or fisheries. Viewed as the single most disruptive factor in economic development in the next 50 years,[171] global climate change will amplify and further complicate the development challenges that have vexed development policy makers, practitioners, researchers and thought leaders for the past half century.[172] The local level impacts of increased average global temperature remain uncertain but there is general agreement among climate scientists on what we might expect to see. The incidence and severity of extreme events – droughts, heat waves, hurricanes, cyclones and floods – is likely to increase and sea level will continue to rise. In regions where water plays a significant role in socio-economic welfare, water scarcity or excess will cause socio-economic and further ecological distress as those impacted by a succession of disasters resort to environmentally-compromising survival tactics.[173] The shift in rainfall patterns and climate zones will result in increased pressure on freshwater sources and on sensitive ecosystems such as coral reefs, tundra, and coastal wetlands; an attendant lowering of resistance to water-related diseases; an increase in the number of environmental refugees; and a heightening of social tensions and potential conflict.[174] The annual economic losses for developing countries are estimated to be in excess of 10% of GDP.[175]

Some argue that "climate change is already with us".[176] In 2010 global bleaching of coral reefs was reported from Thailand to Texas, only the second time that the phenomenon has been observed. Scientists have argued that corals, highly sensitive to excess heat, would serve as an early indicator of the ecological distress caused by the buildup of greenhouse gases.[177] Unpredicted and unexpected weather is becoming part of the reality in many climate-vulnerable communities. People are struggling to cope with weather patterns they no longer recognise.

IFRC reports on some observations from the ground: "I don't remember we had floods like this before. The water rose so quickly to four meters, reaching our second floor", a resident said of the floods that hit Jakarta, Indonesia in February 2007. In Kenya, the manager of the Kenya Red Cross society notes, "the weather is upside down … In the months that used to be rainy there may not be rain. The winters that used to be cold are no longer cold. When it rains it floods and that kills people. When it does not rain there is drought and that kills people too".[178] The eastern part of El Salvador has reportedly seen a decline in rainfall of up to 800 mm and consequent reduction of surface waters in the past 70 years. The dengue season, which normally appears in April, is starting to appear in March.[179]

The sudden and unexpected climate changes are challenging local traditional knowledge of the environment such as when to harvest, what to plant and when. In the Pacific island of Tonga, local people are noticing changes in the flowering and fruiting time of trees. Fishermen who depend on traditional knowledge about the seas lament that "it's cold when it should be warm and warm when it should

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[171] UNDP 2007a.
[172] A 2010 assessment of progress towards the Millennium Development Goals concludes that only two of the eight MDGs are likely to be achieved by 2015 (MacFarquhar 2010).
[173] Polsky &Cash, 2005.
[174] Coyle & Meier 2009; ECA Working Group 2009; UN ISDR 2004.
[175] Stern 2007.
[176] IFRC 2009: 98.
[177] Gillis 2010.
[178] IFRC 2010: 107.
[179] IFRC 2009.

be cold… things are all wrong… the fish are confused and not breeding when they would normally breed. It becomes difficult to know when is the right time to fish for different types of fish because they are no longer behaving as they used to".[180]

Climate change thus presents two types of disaster threats in developing countries. One is the potentially devastating impacts on vulnerable communities of more frequent and more intense extreme weather events. This contributes to the second threat, the compounding of what are already complex development problems, potentially leading to a downward development spiral for the world's poor. The IFRC reminds us, "Whether the changing climate with all its uncertainties, contributes to more disasters that affect more people, does not depend merely on what happens to the weather. Climate change and the accompanying risks will be superimposed on an unequal world, where vulnerability to disasters is directly linked to poverty".[181] Other trends further complicate the picture including population growth and weakening of governance structures. Addressing any one trend will not significantly change outcomes.[182] Climate change responses need to be integrated into a broader development strategy that addresses the root causes of vulnerability.

During disasters, information is as much a necessity as water, food and medicine. Information and communication technologies[183] (ICTs) are thus among the lifelines. The right kind of information communicated and used at the right time can save lives, livelihoods and resources.[184]

Responding effectively to disasters demands rapid access to reliable and accurate data and the capacity to assess, analyse and integrate information from varied sources (including *ad hoc*, before, during and after the disaster).[185] It requires speedy communication to the right parties to marshal resources (e.g., food, water, medical supplies); to mobilise, deploy and coordinate emergency personnel; and to coordinate response activities among agencies involved.[186] Communication and information sharing is critical.

The role of information and communication technologies in community and national adaptation strategies to the long-term impacts of climate change has been reviewed in several recent publications.[187] This paper focuses on the role of ICTs in minimising and managing the impacts from acute climate-related events, a topic that is to date under-examined.[188] Actual ICT applications in

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180 IFRC 2009: 96.
181 IFRC 2009: 102.
182 Ibid.
183 ICT (information and communications technology) is the umbrella term for the range of tools, applications, systems used to input, store, edit, retrieve, analyse, synthesise and process information and share data in all its forms. ICT encompasses: radio, television, broadband, satellite and cellular mobile phones, computer and network hardware and software, websites, portals, remote sensing, satellite systems and so on, as well as the various services and applications associated with them, such as data storage, analysis and integration, videoconferencing and distance learning (TechTarget 2004; UNESCAP 2008; IBRD 2010).
184 Coyle & Meier 2009; Denning 2006; Gunawardene & Noronha 2007.
185 Bunker & Smith 2009; IFRC 2009; Laituri op.cit.
186 See for example Dawes et al. 2004; NRC 2007a; Törnqvist et al. 2009.
187 See for example Apikul 2010; Kalas and Finlay 2009; Ospina & Heeks 2010a and 2010b; Wattegama op.cit.
188 Essentially this paper is situated between Strand 2 and Strand 3, along the direction of Stream (a) in Ospina and Heeks' typology of the literature on ICTs, climate change and development. It elaborates on the role of ICT in "Coping with Short-Term/Disasters" indicated in the Overview Model (Ospina & Heeks 2010b). Note that, given that ICTs are changing at a rapid pace, and their use in disaster management and the necessary institutional arrangements, evolving, this paper can only be an indicative, not an exhaustive discussion of the subject.

hydrometeorological disasters will be described and analysed in the context of developing countries.[189]

The importance of a people-centred approach to disaster management is argued in Section 2 while acknowledging the important role of other actors. The applications of ICTs in disaster management in low- and middle-income countries described in Section 3 also showcase the critical role of these other actors in enabling communities to prepare for and cope with the impacts of extreme climate-related events. Section 4 presents some reflections on the use of ICTs in disaster management under the conditions of scarcity in developing countries. The paper closes with recommendations for ICT practitioners and researchers on how the use of ICTs in disaster management in developing countries may be made more effective.

2. The Community in Disaster Management

Disasters vary in scale, severity, and duration, but there is one constant: the impacts are inherently local. During the disaster "there are important decisions to make, some of which – often very crucial ones – belong essentially to the community."[190]

This is recognised in the Code of Conduct for the International Red Cross and Red Crescent Movements and NGOs in Disaster Relief, which calls on aid agencies to involve local people in their decision-making. The SPHERE Standards[191] stipulate that local participation in the assessment, development, implementation and monitoring of responses be maximised. Effective climate change responses will ultimately depend on community capacities to reduce their medium and long-term risks as well as the ability to cope with the impacts of acute climate-related events.

There are challenges.

Studies in Mozambique and Nepal on community risk perception suggest that the risks highlighted by disaster management authorities may not necessarily be those at the forefront of community concerns. Vulnerability is often defined by the community in socio-economic terms. Cholera, earthquakes, fire, and storms can rank lower than issues of governance and poverty.[192] Reports from Bangladesh, Nepal, India, and Peru abound with evidence that not everybody who receives an early warning heeds it. Individual response is conditioned by cultural norms, access to resources and personal assessment of what else is at risk e.g., property, 'face', life of family members.[193]

Note also that no distinction is made in this paper between climate change-related disasters from climate-related disasters. From the point of view of the affected communities this distinction is largely irrelevant.

[189] This focus imposes some limitations on the discussion of each case study. Research done on ICT use in disaster management in low and middle income countries is simply not as rich as that done in developed countries, e.g., ICT use in the response to Hurricane Katrina, or the terrorist attack on the World Trade Centre (Dawes et al., 2004).

[190] Benini 1991: 4

[191] The SPHERE Project was launched by humanitarian agencies and the International Federation of Red Cross and Red Crescent Societies to define and uphold the standards by which the global community responds to the plight of people affected by disasters (http://www.sphereproject.org/content/view/91/58/lang,english/).

[192] Ibid.

[193] IFRC 2005 and 2009. A study by Bunker & Smith (2009) of community response to EWS in New South Wales Australia led to a similar conclusion, quoting a front-line responder that "to develop and

At-risk communities should therefore be involved in assessing the risk of different disasters. Risk information – particularly when gathered and assessed through sophisticated technologies must be expressed in terms and language meaningful to those at risk, and framed within their overall development aspirations and survival strategies.

This is precisely what the International Red Cross did in one of the earliest published uses of ICT in disaster management, during a prolonged drought in southern Sudan in 1990. Computer simulation was used in choosing the most acceptable food allocation strategy among those preferred by donors and humanitarian NGOs and local traditional practice. A portable computer with a spreadsheet program was used to simulate five scenarios with assumptions about food stocks, receipts, the number of needy households and the disbursement behaviour of local food suppliers. The outcomes were displayed graphically for the local relief committees, governments and international agencies. The local strategy was shown to be the least risky.[194] The use of ICT enabled the community to persuade donors and relief agencies to respect local knowledge.

Slow-onset disasters provide more opportunities for risk information to flow from the bottom up. At-risk communities can 'see' the creeping onset of drought through for example observing crop and livestock health and perhaps their children's health, or seeing changes in flowering or shedding of leaves of local trees[195, 196]. Community knowledge related to flooding can be systematically structured into GIS (Geographic Information Systems) compatible hazard databases. In Dagupan City Philippines, the Asian Disaster Preparedness Centre used participatory mapping to develop an end-to-end[197] flood early warning system including evacuation routes, emergency response and small-scale mitigation projects.[198]

2.1 Other Actors

Allen, working on community-based climate change adaptation in the Philippines, cautions against what she calls "extreme localism".[199] She argues that linkages reaching beyond a community's borders are equally important for effective community responses to disasters of any kind. This echoes an argument made a decade earlier by Berke and co-researchers that the timing and outcomes of disaster recovery and reconstruction depend not only on the tightness of the community's social network but also on the strength of its vertical integration with extra-community political, social and economic institutions.[200] There are other actors.

Prompt and adequate response from the local fire department, health professionals, police and the military reduce loss of life and property. National and local governments can facilitate disaster planning and management.[201] The

deploy effective CW [community warning] systems is a long process of informing, educating, reinforcing and re-education of the public" (p.10).

194 Benini op.cit.

195 Pratt 2002.

196 A good example is the community drought preparedness programme of World Vision, Practical Action and Oxfam GB in the Turkana and Taita Taveta districts of Kenya (Ng 2007).

197 An early warning system is called end-to-end if it connects the technical (upstream) and societal (downstream) components of warning through identified institutions.

198 Apikul op.cit.

199 Allen 2006.

200 Berke et al.1993.

201 IBRD op.cit.; IFRC op.cit.; Laituri op.cit.; Wattegama op.cit.

mass media is important for communicating disaster alerts and keeping the public informed as the disaster unfolds, and monitoring disaster aid allocation and delivery.[202]

In developing countries disaster management increasingly involves many more actors: UN agencies, donors, regional organisations and non-governmental humanitarian relief agencies such as the Red Cross/Red Crescent Societies, Médecins Sans Frontières and many others. Businesses are generally among the first to provide material goods and technical assistance in the aftermath of a disaster, independently or in partnership with NGOs. The private sector is also involved in developing ICT products and services that enable continuity when telecommunication structure is damaged. Experts from research and teaching institutions are frequently called upon to provide specialised input in designing monitoring programmes, integrating data, and translating scientific and technical information into EW messages.[203]

3. Use of ICTs in Climate-Related Disaster Management

Fig 1 Disaster Management Cycle

There is no complete consensus on the different phases of disaster management,[204] but there is general agreement that the different activities are most-productively conceptualised as a cycle.[205] "The disaster cycle has the distinct merit of highlighting development responsibilities in relation to disasters, as well as the need for post-disaster rehabilitation as a link to development".[206]

For the purposes of this paper we will distinguish four stages: preparedness, response, recovery/rehabilitation and reconstruction.[207]

As shown in Figure 1 the different phases form a continuum and the reconstruction phase (frequently presented by other disaster researchers not as

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[202] A good example is AlertNet, a humanitarian news network around a popular website. It has a network of 400 contributing humanitarian organisations and its weekly email digest is received by more than 26,000 readers. It delivers operation-critical information to relief charities worldwide, encouraging them to share information with one another, and raises public awareness of humanitarian emergencies. It reportedly attracts more than 10 million viewers a year.
[203] Coyle & Meier op.cit; Hall 2007; IBRD op.cit.; IFRC op.cit.; Roeth 2009; Wattegama op.cit.
[204] It might be added that neither is there a common definition of what constitutes a disaster. For example there is no shared definition of what is drought (see for example IDRC 2005; Lewis 1999; Wisner et al. 2003).
[205] DFID n.d.; IFRC op.cit.; Wattegama op.cit.; Wisner et al. op.cit.
[206] DFID n.d.: 25.
[207] Most UN agency depictions of the disaster management cycle show six phases - "mitigation", " risk reduction", and "prevention" replace the "reconstruction" phase in Fig 1 (e.g., Wattegama 2007; UNDP 2007b). Other agencies show six phases but different from those of the UN (e.g., Weets 2006).

one phase but as three: disaster mitigation, disaster risk reduction and disaster prevention phases[208, 209, 210]) is effectively indistinguishable from development.

Disaster preparedness includes actions taken in advance of disasters such as establishing early warning systems and training front-line responders. *Disaster response* refers to actions taken in the immediate aftermath of a disaster, to save and protect life, property, and infrastructure. It encompasses dissemination of disaster alerts, and subsequent search, rescue and care of casualties and survivors.

When the physical impacts of the hazard event are over and search and rescue operations subside, short-term actions are necessary to re-establish essential physical and social systems: finding replacement homes for the displaced, restoring services and re-establishing the local economy.[211] This is generally referred to as the *disaster recovery* phase. It presents opportunities to 'reshuffle the deck' since support for hazard mitigation is generally strongest immediately following a disaster. Unfortunately recovery decisions tend to be subject to intense and conflicting pressure from the affected communities and not infrequently from the donors, to rebuild as quickly as possible, with inadequate time and resources devoted to complex problem solving.[212] This is a critical phase. "It is the aftermath which will eventually become the context for the next disaster – of whatever kind".[213]

Disaster reconstruction is considered achieved when all pre-disaster services and structures, e.g., homes, hospitals, schools, water systems, roads, electric power are restored. This clearly takes years and reconstruction activities generally become indistinguishable from normal economic development projects. In developing countries, reconstruction often becomes dependent on overseas development assistance with all the benefits and the vulnerabilities this implies.[214, 215]

A disaster thus presents a particular context for ICT use. Data need to be acquired and analysed under severe time pressure. The data users are frequently without adequate training and working under difficult circumstances. Uncertainty and ambiguity are an inherent part of the environment. A disaster may have discrete origins but its effects propagate and interact in such a way that intensifies the complexity and uncertainties. Further complicating an already highly-dynamic situation is the fact that there are usually several actors involved, working on different aspects of the crisis, each one with its own decision structure, administrative culture and quite likely, operating different sets of technical equipment.[216] There are also volunteers who need coordination.[217] The information typically needed in disaster management is shown in Table 1.

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208 See for example Apikul op.cit.; Lewis op.cit.; Wattegama op.cit.
209 One vision is where development is drawn at the core of the cycle and disaster is imposed as an interruption (Wisner et al. op.cit.).
210 Figure 1 is supportive of, but not identical with Lewis' "bicycle". Lewis (1999) pictures disaster management as a bicycle with the two wheels representing disaster and development as concurrent processes; he argues that development still occurs even while a disaster is unfolding.
211 Wattegama op.cit..
212 Berke et al. op.cit.
213 Lewis op.cit., p xvi.
214 Donors do not always deliver on commitments for reconstruction made during the height of a disaster. A good recent example is the earthquake in Haiti. More than US$1.35bn was committed but less than US$23m had been delivered three months later (MacFarquhar 2010b).
215 The very few studies on reconstruction suggest that the key to successful redevelopment lies in a capacity for embracing error, learning with people, building new knowledge and institutional capacity through action (Paton &Johnston 2001).
216 Bunker & Smith op.cit.; Buzna et al. 2007; Dawes et al. op.cit.; NRC 2007a; Quarantelli 1998; Törnqvist et al. 2009.

Table 1: Disaster-Relevant Information Needs[218]

Information	Prepared-ness	Response	Recovery	Recon-struction
1. Contacts at local community, regional and national levels	X	X	X	X
2. Local disaster plans, procedures and policies	X	X		
3. City and housing plans	X	X		
4. Phone management data bases	X	X		
5. Emergency centres: where, who, what	X	X		
6. Telecom: infrastructure, laws, organisations	X	X	X	
7. Social, demographic and economic data	X	X	X	X
8. Safety and environmental standards and codes	X	X		
9. Cultural asset information: significance, age, construction material and condition	X	X		
10. Land use plans		X	X	X
11. Critical infrastructure inventories	X	X		
12. Building inventories	X	X		X
13. Property ownership records	X	X		X
14. Birth and medical records			X	X
15. Hazard maps: nature, site and real time changes	X	X		
16. Vulnerability data: who, where, how	X	X	X	X
17. Loss/damage data		X	X	X
18. Weather data: short and mid-term	X	X		
19. Available resources: what, how much, who	X	X	X	X
20. Formal key decision-making: who makes what decisions, when, how	X	X	X	X
21. Informal local authority structures in the family, in the community	X	X	X	X

[217] Quarantelli 1989, 2003. During Katrina for example, the American Red Cross had to deal with over 250,000 volunteeers (Asplund et al. 2008).
[218] Various sources: e.g., Coyle & Childs op.cit.; Coyle & Meier op.cit.; Dawes et al. 2004; UNESCAP 2008; IBRD op.cit.; NRC 2007a and 2007b.

The specific communication and information processing requirements will vary with context, type of disaster, distance of disaster site, time relative to disaster onset, latency of disaster and available bandwidth. However, we can identify some requirements typical of developing countries, drawing on findings of several ICT for emergency (ICT4E) studies.

A 2007 study by the Disaster Resource Network examined the factors contributing to effective ICT use in emergencies.[219] Also in 2007 the US National Research Council's Committee on Using Information Technology to Enhance Disaster Management identified areas of ICT capabilities necessary for improving ICT use in disaster management.[220] The EU ICT Strategy for Disaster Mitigation lists five key elements.[221] In 2010 a post-Haiti earthquake meeting of 20 technology and development experts identified opportunities facing ICT use in disaster response.[222] The four sets of recommendations are summarised in Table 2.

Table 2: Recommendations for Enhancing ICT Effectiveness in Disaster Management

DRN Report 2007[223]	**NRC Report 2007**[224]	**2010 Post-Haiti T&D**[225]	**EU Strategy 2006**[226]
Adequate penetration of broadband internet	Enhanced infrastructure survivability and continuity of social functions	Public education about use of alternative communications channels during an emergency	Full availability of broadband communications and positioning systems
Inter-and intra-agency coordination	Improved situational awareness and a common operational picture	More collaboration around an integrated framework	Shared operational picture and situational awareness among first responders
Competence in data analysis, interpretation, integration, maintenance and repair of hardware	Greater organisational agility	Self sufficiency of organisations involved in ICT response on the ground	Continuous monitoring through ubiquitous sensor systems
Interoperability of different user devices, network equipment and communication systems	More robust, interoperable, and priority-sensitive communications	Appropriate balance between reliance on Internet/cloud and localised content/resources	Full geo-spatial data interoperability
Sustained advance preparedness	Better public engagement	Better ICT pre-planning	Effective EW alerts for all hazards, all media
Technical & operating standards & policies on flexible access to ICTs	Improved decision support & resource tracking & allocation	Hospitable policy environment	

219 Coyle & Meier op.cit.; Kalas & Finlay op.cit.; UNESCAP op.cit.
220 NRC 2007a.
221 Weets 2006.
222 Blantz op.cit.
223 UNESCAP op.cit.
224 NRC 2007a
225 Blantz op.cit.
226 Weets op.cit.

These studies can help structure our discussion of ICTs used in climate-related disaster management in low- and middle-income countries. We will not utilise all of these different recommendations but will instead draw from them developing country-specific needs. In developing countries, the need is for ICTs that enable (a) timely and effective communication of disaster alerts to the 'last mile'; (b) rapid reliable two-way communication in challenged environments; (c) creation of a common operational picture, and (d) transparency and accountability of resource allocation decisions. These will form the focus for the sections that follow.[227]

3.1 Timely and Effective Delivery of Early Warnings to the 'Last Mile'

'Last mile' is the term used "to express the sentiment that warnings and the means to respond to them often do not reach those who need it the most",[228] people who for reasons of age, gender, culture or poverty, are not reached by disaster preparedness. It is viewed as the weakest link in the communication chain and seen as the cause of many casualties.[229]

People-centred approaches to early warning systems (EWS) are predicated on the assumption that people can be capable, resilient and able to protect themselves given accurate, timely, consistent and actionable information from a trusted source.[230] Such approaches require that individuals and communities at risk, particularly those at the 'last mile', understand the threats to their lives and property, share this awareness with others, and are able to take action to avoid or reduce their exposure. The use of different technologies, preferably one-to-many, is viewed as the effective strategy to deliver early warnings. Any one or a combination of the following media has been used.

3.1.1 Radio and Television

Radio and television remain the traditional media used in disaster management, because they are relatively cheap, provide a reliable one-to-many communication medium and most importantly, do not require literacy. Radio in particular is the most accessible medium to the poor, especially women in their homes, or fishermen at sea, workers out in the fields. Television, while more powerful, is more expensive and therefore not as available.

It is not surprising then that radio is the principal medium for delivering early warnings in Chittagong, Bangladesh. A highly populated coastal district, Chittagong faces several types of hazards – earthquakes, cyclones, floods – but has EWS only for cyclone and storm surges. With a high level of illiteracy and low level of telephony, radio remains the most frequently used, most publicly accessible and most effective medium, although television is reportedly making inroads.[231]

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[227] Unless otherwise specified, most of the cases presented refer to uses in the preparedness and response phases.
[228] IFRC 2009: 43
[229] Gunawardene & Noronha 2007; Sriramesh et al. 2010.
[230] IFRC op.cit.; Wattegama op.cit.
[231] Ahmed 2007; Wattegama op.cit.

In the poorest communities however, even battery-powered radio is a luxury. The Freeplay Lifeline radio was designed for precisely these conditions. Both wind-up and solar powered, it provides dependable access to AM, FM and shortwave frequencies; it can withstand dust, water and extreme temperatures. The Mozambique Red Cross integrated the Freeplay Lifeline radio into its cyclone and flood early warning activities. A volunteer is charged with listening to the radio. When a warning is heard, the volunteer alerts village leaders and a pre-planned response is launched. This has been credited with the dramatic reduction in devastation from cyclones and floods. There were 700 casualties in the year 2000 flood, 30 in 2007 and none in 2008. This type of radio has also been used in hurricane preparedness in Haiti, and in RANET[232] projects in Niger, Kenya, and Uganda.[233]

Radio and television are however limited by the fact that they provide only one-way communication[234] and are generally turned off in the evenings.

3.1.2 Satellite Radio

Satellite radio receives its signal from a communication satellite[235] and therefore has a wider geographical range than terrestrial radio. It is very useful when transmission towers are damaged. A satellite radio, combined with fixed or mobile phones was shown to be the most effective and reliable of five ICT tools in eight combinations tested for transmitting early warning information from government agencies to 32 at-risk villages in Sri Lanka. This Addressable satellite Radios for Emergency Alerting (AREA) system is being combined with GPS to issue hazard alerts in text and audio formats directly to specific at-risk communities in Bangladesh, India, Indonesia and Thailand.[236]

But satellite usage is very costly for both service set up and the purchase of a satellite-enabled radio, and service can be interrupted by trees, buildings and some weather conditions.

3.1.3 Telephones (Fixed and Mobile)[237]

Telephones (fixed and mobile) are useful in disseminating one-to-one disaster warnings. In some countries 'telephone trees'[238] are used to speed up the diffusion of the warnings. The drawback is that they are a one-to-one

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[232] RANET is an initiative using RAdio and InterNET for the communication of hydro-meteorological information for rural development.
[233] IFRC op.cit.
[234] Community radio has the advantage of providing two-way one-to-many communication, very important during disasters. However it has been difficult to find reported cases of successful use of interactive community radio for early warning, as it is not a common media channel in developing countries. But the effectiveness of interactive community radio in disaster response has been studied by AMARC (Association Mondiale de Radiodiffuseurs Communitaires) Indonesia, looking at use of community radio for public education on disaster prevention, food security and poverty reduction (Kalas & Finlay 2009). It is also being tested in Sri Lanka through a disaster warning system implemented by Sarvodaya, an NGO (Wattegama op.cit.).
[235] A satellite is essentially a radio-frequency repeater that is launched into orbit (circular or elliptical) around the earth. It transmits data (from the simplest digital data to the most complex television programmes) to and from the earth (with a latency period depending on how high their orbit is) via ground stations and hubs connected to the Internet backbone (http://www.widernet.org/projects/satellite/moreaboutstatellites.htm).
[236] Apikul op.cit.; Gunawardene & Noronha op.cit; Rangajarn & Rao 2007.
[237] The disadvantages of mobile phones will be discussed in Sec 3.2.
[238] In telephone trees individuals basically serve as nodes. These nodes receive the EW message from the centre, through whatever means and relay the message to a pre-assigned list of individuals by phone or whatever means available. This ensures timely delivery of EW and minimisation of duplication of effort (Wattegama 2007).

communication medium, the lines can get congested before and during a disaster, and in many areas telephone access remains a luxury although many rural areas with low fixed telephone penetration are seeing increasing use of mobile telephony.[239]

Mobile phones were the main tool for implementing a community-based flood monitoring and early warning system in An Giang and Dong Thap provinces of Vietnam, established after the devastating August 2008 Mekong floods. Thirty-eight at-risk villages were provided with mobile phones, and villagers in seven villages trained to take wet season water level measurements twice a day. They report their water level readings, via text messages, to the Southern Region Hydro-Meteorological Centre in Ho Chi Minh City, the local agency responsible for flood forecasting. The information is entered into the Centre's computer and the calculated flood forecast fed back to the villagers who publicise the information on information boards at central locations. Any imminent flood threat is publicised via loudspeakers.[240]

Voice communication through mobile phones was similarly useful when Hurricane Ivan made landfall in Jamaica in 2004. Jamaican Red Cross volunteers and parish disaster committee members used cell phones to issue early warnings the day before, when the hurricane hit the neighbouring island of Grenada.[241]

Short message service (SMS), a feature available in most mobile phones is an additional tool for delivering one-to-many text-based disaster alerts. It is used in Wenling China where sensor detection of building integrity (in relation to cyclones) is part of the EWS. Evacuation alerts via SMS are sent to residents before a cyclone hits.[242] The use of SMS is limited by the fact that it is affected by traffic load, and can only be delivered to pre-registered numbers and literate users.

3.1.4. Cell Broadcasting

Cell broadcasting (CB[243]) is a one-to-many geographically focused text messaging service. It is already integrated in most existing network infrastructure so there is no additional cost from laying of cables, purchase of new software or new handsets. It uses a dedicated channel and therefore is not affected by traffic load nor does it add to main channel load. It is geo-scalable so one message can reach millions in a minute; it is geo-specific, so the broadcast can be targeted at specific at-risk areas thus avoiding widespread panic. Equally important, a single CB channel can broadcast the message in multiple languages.

However, the user must have a CB-compatible handset switched on to the appropriate channel. This makes CB vulnerable to oversight or malice of the network operator who may turn off the CB feature to avoid paying for the channel. This possibility could be reduced with appropriate government regulation, or agreement with the private sector.

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[239] Best 2003; Yonazi 2009.
[240] The system proved to be very labour intensive so support committees were set up in each village to share the responsibility of implementation and maintenance: monitoring, recording and reporting (MRC 2009; IFRC 2009).
[241] IFRC op.cit.
[242] UN ISDR 2008.
[243] Note, not citizen-band radio, also referred to as 'CB'.

Such a public-private sector arrangement has been set up in Bangladesh where UNDP is supporting the development of instant network alerts using SMS cell broadcasting. Agreements were reached with Grameenphone and state-owned Teletalk to send alert messages to their subscribers, with the alert automatically flashing across the mobile phone screen. The programme is being piloted in flood-prone Shiraganj and cyclone-prone Cox Bazaar. If successful it will be expanded to other high-risk areas.[244]

A bigger problem with CB is the lack of standardisation across networks so it cannot be used as a stand-alone public warning system. This was recognised in the Maldives, an island under serious threat from sea level rise. After the 2004 tsunami the government launched several parallel disaster management initiatives including: (a) use of cell broadcasting for delivering alerts; (b) use of bulk SMS[245] on a mobile network; and (c) priority calling and national roaming during disaster response.[246]

3.1.5 Satellite Remote Sensing and Other Technologies

Preparing for drought requires the collection and analysis of weather, rainfall, vegetation data to monitor changes over time, and modelling the impacts on cropping systems. This is best done with satellite remote sensing.

This was the tool used in the Famine Early Warning Systems Network (FEWS NET) developed with funding from USAID in 1986, originally to monitor food security from Mauritania to Ethiopia.[247] Sensors including AVHRR[248] and MODIS[249] monitor vegetation vigour and density. Meteosat [250] infrared data is combined with rain gauge reports and microwave satellite observation to estimate rainfall. Using GIS, all the satellite data are combined with regional analyses of grain stocks and prices, political conditions and input availability to create early warning for drought-related food shortages.[251]

In Addakdal, Andhra Pradesh in India, ICRISAT uses the satellite-plus-GIS combination slightly differently in its drought preparedness programme. Weather forecasts and crop prices are provided to the community regularly, establishing the programme's credibility. Using GIS, colour-coded local vulnerability maps are generated based on water budgets under different rainfall scenarios. The maps allow planners to establish drought mitigation strategies and more importantly, farmers to decide which crops to plant and whether or not to take up off-farm employment.[252]

This combination is also used for cyclone preparedness in the Bay of Bengal. Meteorological data collected by India's Kalpana-1 and INSAT-3A satellites are

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[244] Coyle & Meier op.cit.
[245] This means mass delivery of SMS messages to mobile terminals via the Internet by making a standard HTTP request, although other technical interfaces are also available (http://www.textalert.com/t3/default.asp).
[246] Udu-Gama 2009.
[247] Ruth & Ronkin 1991.
[248] AVHRR – Advanced Very High Resolution Radiometer – a space-borne sensor on the NOAA family of polar-orbiting platforms.
[249] MODIS – Moderate Resolution Imaging Spectroradiometer, is a key instrument in the TERRA (EOS – AM) and AQUA (EOS –PM) satellites.
[250] Meteosat is a second-generation weather satellite.
[251] A similar satellite-cum-GIS-based system is used in the Global Monitoring for Food Security initiative, funded by the European Space Agency to predict drought and famine to provide early warning in Sub-Saharan Africa.
[252] Ganaparam et al. n.d.

processed in cyclone warning centres which issue early warnings. Community emergency response plans are developed with GIS, allowing the visual display of critical disaster data specific to each location.[253] South Africa's Advanced Fire Information System combines satellite data with mobile phone technology. Developed by the Council for Scientific and Industrial Research both MODIS and Meteosat data are used to detect hotspots and alerts sent to 40 fire protection associations across the country automatically via e-mail and text messages. They form part of the weekly weather forecast on national TV. Anyone can sign up to receive alerts in their area. The system can be extended to flooding alerts.[254]

While clearly a powerful combination the use of satellite data with other technologies including GIS and mobile phones is not easily affordable in developing countries without their own space programmes, although more open access to shared satellite data is becoming more feasible (cf Sec 3.3).[255] There are also limits to what satellite technologies can detect compared to on-the-ground data gathering.

3.2 Rapid, Reliable Two-way Communication in Challenged Environments

The period immediately after a disaster strikes is considered the most difficult, fluid, and confused.[256] Both one-to-one and one-to-many, preferably two-way communication channels are needed. For front-line responders the biggest need is mostly for maps that can be updated in the course of the disaster event, to locate the most affected areas, high-risk areas, and relief distribution centres. For affected communities it is to communicate with the front-line responders, look for family and friends, and increasingly also connect with diaspora communities.[257] The biggest communication surge is said to be in the first 12 hours after the onset with the intensity of demand declining somewhat but remaining high for up to three days.[258]

Frequently however, large parts of the telecommunications infrastructure are destroyed or incapacitated for several days if not weeks; those that survive suffer overload. The complex interdependencies of technology systems (e.g., dependency of financial services, transportation, on ICT networks) make them vulnerable to failure from ignorance, human malice and technical malfunction. It also means the failure of one system can lead to failure of another. Communication and coordination under such uncertain conditions has benefited from technological development and the creativity of committed ICT professionals.[259]

3.2.1 Mobile Phones

The usefulness and the limitations of mobile phones in crisis situations were demonstrated during the 2008 floods in Bihar India. Widespread mobile phone subscribership and 24-hour connectivity allowed large-scale SMS-based evacuation and rescue operations. Survivors who were marooned used mobile phones to guide rescue teams to where they were, to tell district officials of their

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[253] Apikul op.cit.
[254] Frost 2009.
[255] Wattegama op.cit.
[256] Asplund et al. 2008; Quarantelli 2003; NRC 2007a; Shklovski et al. 2008; Törnqvist et al. op.cit.
[257] IFRC 2009; Shklovski et al. op.cit..
[258] Coyle & Childs 2005.
[259] Asplund et al. op..cit.; Shklovski et al. op.cit.; Törnqvist et al. op.cit.

immediate needs, and local television and newspapers, their plight. The prolonged non-availability of electricity however meant that the mobile phones could not be recharged.[260]

3.2.2 Wireless Ad-hoc Mesh Networks with GPS

When infrastructure is compromised or damaged the common response currently is to deploy satellite communication equipment, cellular and wireless infrastructure and microwave links since they are immediately usable and scalable. Wireless technologies are particularly attractive because they function in difficult terrains and their deployment is relatively inexpensive.[261]

After Myanmar was hit by Cyclone Nargis in 2008, a local NGO, EGRESS, developed the *Dumbo*-*Sahana* Project in partnership with the Myanmar Computer Professionals Association to enhance the communication and coordination aspects of Myanmar's emergency response system. The Project provides training on setting up of *Dumbo* (Digital Ubiquitous Mobile Broadband), wireless ad-hoc mesh networks, GPS mapping, *Sahana* (cf Sec 3.4) and *OpenStreetMap*.[262] *Dumbo* is a set of network technologies that allows users to chat, transmit video and update their location. The wireless mesh networks[263] penetrate remote, isolated areas with sensors to monitor environmental conditions, e.g., temperature, wind direction and speed.[264] It is rapidly deployable, relatively inexpensive, reliable, resilient and effective in harsh environments.

3.2.3 Internet and e-Mail

The Internet is acknowledged to be one of the most reliable information infrastructures even under adverse physical conditions, and electronic mail, its most widely used application. This was a critical tool during the 1997 Cambodia floods. The floodwaters had washed up venomous snakes and people were being bitten. The local WHO field offices did not have the antiserum in stock nor the taxonomic information on Cambodian snakes. The field officers sent e-mails to members of the Global Health Disaster Network (GHDNet) who forwarded it to several mailing lists. Specialists and institutions in the region were identified resulting in a speedy sourcing of the antiserum.[265]

The utility of the Internet and email in disaster management is however limited by the low Internet penetration (2 to 5%) in developing countries and the fact that many of those with connection are not regular users.[266] The non-English content of the Internet also remains limited.

3.2.4 Radio

For the small island of Granada a simpler technology proved to be the most cost-effective tool in 2004 when Hurricane Ivan hit. Approximately 90 percent of the country's homes and nearly every major building in the capital city, including the

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[260] Manocha 2009; Verclas 2008.
[261] Asplund et al. op.cit; Tornqvist et al. op.cit.
[262] *Open Street Map* is a free editable world map. The maps are created by users with data from portable GPS devices, aerial photography, other free sources or simply from local knowledge (http://en.wikipedia.org/wiki/OpenStreetMap).
[263] Wireless mesh network is effectively a router network without the cables between nodes. Signal strength is sustained by breaking long distances into a series of shorter hops. Nodes act as routers to transmit data from nearby nodes to peers that are too far away to reach in a single hop, resulting in a network that can span larger distances (http://en.wikipedia.org/wiki/Wireless_mesh_network).
[264] Myanmar Egress 2008.
[265] Sriramesh et al. op.cit.
[266] Coyle & Meier op.cit.; Wattegama op.cit.

emergency operations centre, suffered structural damage. Power lines and all communication links were down. A private company, Mobile & Marine Systems received a call for help from the Grenada Police Force. Within 24 hours, Mobile & Marine Systems had in place, portable repeaters, mobile radio base stations and portable handheld radios, which provided the emergency backbone for island-wide communications.[267]

3.3 Creating a Common Operational Picture

Voice communication is typically viewed as the immediate need prior to and after the onset of a disaster, but as noted above geospatial data are equally critical for assessing damage, planning relief operations and coordinating relief activities.

The different agencies involved are likely to operate different sets of technical equipment with different data units and standards. Coordination will thus require the extraction, processing and integration of information from multiple sources to create a common operational picture, the lack of which is considered a major barrier to intra- and inter-agency coordination.[268]

3.3.1 Geographic Information Systems (GIS)

Geographic information systems[269] are perhaps the most versatile of all ICT tools and useful in all disaster phases. The power and strength of GIS lie in their ability to integrate spatial with non-geographic data into one encompassing system, and graphically display spatial patterns, creating a common operational picture. GIS allow real time monitoring for emergency early warning as well as modelling of possibilities, e.g., "if we add a road to this community will it significantly reduce evacuation times?". During a disaster event GIS allow one to answer questions of location, e.g., "how many primary schools are within 1 km from this flood flash point?". For recovery and reconstruction the use of historical data with GIS allows one to answer trend questions, e.g., "how has population density changed in the last ten years? For vulnerabilities to decline what should the settlement pattern look like?".

3.3.2 GIS, Satellite Remote Sensing, GPS

The combination of remote sensing[270] with GIS introduces more planning information and enables more predictions to be made. The combination is frequently used for assessing and mapping of hazard and risk areas, vulnerable groups, planning of evacuation routes, location of emergency centres, as well as assessing post-disaster damage. When all these data are integrated and mapped into a common operational picture, responses can be better targeted, and priorities established.

[267] Radio has also been used to provide emotional support to survivors particularly those who lost family members. A weekly radio programme in Indonesia sponsored by UNDP after the 2004 Indian Ocean tsunami that reached 13,000 internal refugees was reportedly very effective in helping survivors cope with their loss by enabling them to talk to others on the tragedy. Some survivors phoned in for advice on how to deal with stress. A counsellor and psychologist were made available for that purpose (Apikul 2010).

[268] Bunker & Smith op.cit.; Buzna et al. op.cit.; Dawes et al. op.cit.; ECBP 2008; NRC 2007a; Quarantelli 1998; Törnqvist et al. op.cit.

[269] GIS refers to an organised collection of hardware and software for storing, indexing, retrieving, processing, spatially analysing and displaying spatially referenced data (Dash 1997).

[270] Remote sensing is an information gathering technique using sensors and other instruments aboard vehicles (for example satellites, aircraft, spacecraft) not in physical contact with and at distance from the object being observed.

The most crucial element of GIS, and thus also the most critical barrier to its effective use is the data. The data may not be in a usable format, or at the correct scale and aggregation. Additionally the use of GIS, satellite communication and remote sensing require high bandwidth, high-speed networks and highly skilled professionals, [271] generally scarce in most low-income countries. External assistance has been indispensable in most reviewed initiatives.

The International Telecommunication Union (ITU) with support from FedEx, IGO global communication, Inmarsat, Iridium, TerraStar Global, Thuraya and Vizada, deploys mobile satellite terminals and other equipment to help establish communication links for coordinating relief operations. The European Commission/Joint Research Centre's Global Disaster Alert and Coordination System (GDACS) (cf Table 4) sends alerts in real time and provides tools – updatable reports, maps, online discussion forum – to help coordinate response. The platform has been used to detect floods in Vietnam and fires in Nigeria.[272]

The International Charter on Space and Major Disasters (ICSMD), established in 1999, provides a unified system of space data acquisition and delivery to disaster-affected communities when so requested by member agencies. It delivers high quality satellite imagery to front-line responders generally within 24 hours.[273] In early 2009, the Charter was activated by UNDP in response to floods in the north-central and north-eastern regions of Namibia which affected 17% of the country's population. Satellite imagery showed the extent of the flooding along the Chobe River in Capribi as well as the flood changes over time. This dictated a phased return of the evacuees; the common operational picture facilitating consensus among the different agencies.[274]

Non-profit ICT-expert organisations are likewise active in providing access to satellite data to low-income countries in disaster response. TSF (*TelecomSansFrontieres*) deploys its teams and telecom equipment from one of three regional bases. These reach disaster sites within 48 hours and provide communication to emergency personnel facilitating coordination of response efforts.[275]

3.4 Establishing Transparency and Accountability

A major disaster generally triggers an outpouring of technical and financial assistance from ordinary citizens around the world, usually channelled through donors and NGOs. The potential for waste, misappropriation and misuse of these resources is high.276 Lack of transparency and accountability can lead to

[271] Dash op.cit.; Laituri op.cit.
[272] Coyle & Meier op.cit.
[273] Non-members may make the request through members (Lateiri 2010).
[274] The Charter was also successfully activated during the Senegal and Burkina Faso floods of September 2009. The United Nations Institute for Training and Research Operational Satellite Applications Programme (UNOSAT) offers developing countries free enhanced access to satellite imagery and GIS services for disaster preparedness, response and reconstruction. It offers both regional as well as focused maps, informed by experts. UNOSAT deploys to the field to understand the specific needs of users (cf Table 1).
[275] The equipment includes a satellite receiver and several Global System mobile phones with local SIM cards. TSF provides free phone calls to disaster-affected families; it also provides training in emergency telecommunications to information technology or logistics officers. Since 2006 TSF has offered satellite communication and a computer connected to a small data transmitter in 12 remote and isolated communities in Niger to implement an early warning system on food scarcity (Coyle & Meier 2009). MapAction is another NGO with a similar mission (Laituri 2010.; MapAction 2010).
[276] The chaos in the 2004 tsunami response included "Ten international field hospitals set up none of which worked at full capacity… 20 surgeons competing for one patient". The chaos was attributed to

irreversible loss of goodwill and generosity. Donors and the intended beneficiaries need to know what has been delivered where, to whom and when. Such a task is beyond the capacity of a single organisation. Self-organising, self-managed social networking tools with free and open source platforms have proven powerful in meeting this need.

Web 2.0 tools enable information sharing, collaboration and creation of user-generated content, in areas with broadband Internet connection. People serving as 'sensors', crowdsourcing information from mobile phone, email, RSS feeds, the web, and feeding it to decision-makers, add immense value to search and rescue operations and impose transparency in aid allocation and delivery.[277]

In the Philippines during typhoons Ondoy and Pepang in 2009 a local web developer set up a site using Google Maps to give flood updates and locate people needing rescue. The local news networks embedded the map in their news sites and Google created a link to the website below the keyword search box for *Google Philippines*. Other volunteers joined to improve the capabilities and interface of the map facility. Within a short time the site became a central hub of information on the latest developments in the flood relief effort.[278]

Ushahidi (meaning "witness" in Kiswahili) combines SMS, Twitter and Google maps to crowdsource crisis information. It is a free, open source, decentralised platform developed by Kenyan bloggers in the aftermath of the 2008 Kenyan elections but is now used in other disasters. Location-specific information is communicated directly to subscribers. Ushahidi has developed Swift River as a rapid verification system for crowdsourced information by crosschecking tagged information from different sources.[279]

*Sahana (*meaning "relief" in Sinhalese) is a free and open source disaster management system developed by volunteers from the ICT community in Sri Lanka in response to the 2004 Indian Ocean Tsunami. *Sahana* architecture allows users to modify the system. It now has six modules (a) an online Bulletin Board for missing persons; (b) a Registry that keeps track of all relief organisations and civil society groups (c) a Registry that keeps track of all shelters: location, basic facilities, capacity; (d) a Central Online Repository that matches requests for aid and supplies with pledges of support; (e) a Volunteer Coordination System; and (f) an updatable Situation Awareness module. *Sahana* has been used in Indonesia, Pakistan, Philippines, China and Myanmar.[280]

The ICT tools described here can support the earlier-described task of providing an overall operational picture but they can also help establish transparency and accountability for resource allocation decisions. However safeguards are needed against misinformation and caution must be exercised on unlimited sharing of information.[281]

"too much money" with competition to "spend unprecedented budgets" (IFRC 2005: 4). Out of over 200 agencies in Aceh only 46 submitted reports to UN coordinators. A review of 34 Australian NGOs that fund-raised for the tsunami showed that only three indicated how much of the funds raised would be targeted at the tsunami and less than half indicated how the excess funds would be used. Two years after the tsunami more than one-third of the NGOs had not provided any report on the funds to the donors, although most still had unallocated funds (Abraham 2007). See also the article "Too much of a good thing" (The Economist 2010).

[277] Coyle & Meier op.cit.; IBRD op.cit.; Laituri op.cit.; NRC op.cit.

[278] Apikul op.cit.; Ubalde 2010.

[279] Coyle & Meier op.cit.

[280] Treadgold 2006

[281] Information on shelter locations for example can facilitate criminal activities (ECBP 2008; Wattegama op.cit.)

3.5 Strengths, Weaknesses and Emerging Trends

The ICT applications described in Sections 3.1 to 3.4 show the power of ICTs in enabling rapid, efficient and interactive communication during disasters. Fig 2 summarises the ICT tools used in response to specific information and communication needs at particular points in climate-related disasters.

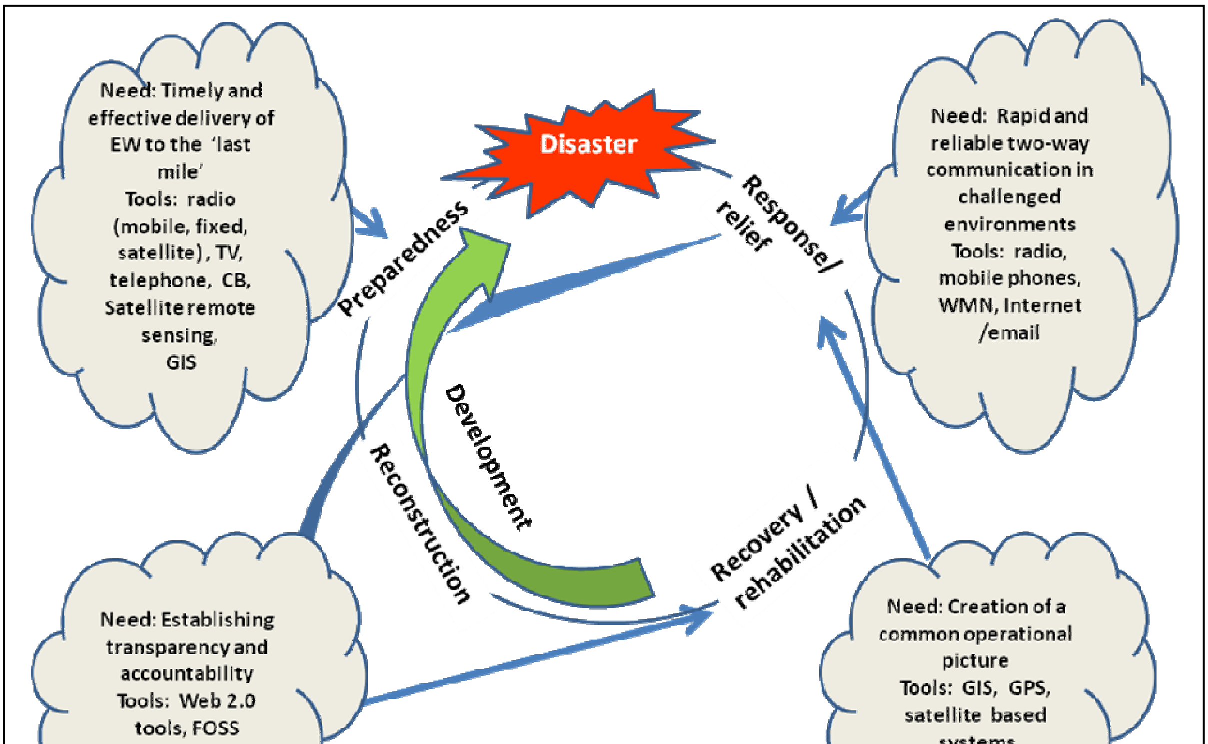

FIG 2
Profile of ICTs tools responsive to climate-related disaster needs

3.5.1 Advantages and Disadvantages

Each specific technology has its strengths but also its limitations. These are summarised in Table 3, drawing largely from the cases cited in the sections above.

Table 3: Comparison of Different ICTs for Disaster Management[282]

Channel	Advantages	Disadvantages
Radio and Television	Most accessible to low income households One-to-many Portable	Takes time to get the warnings Limited use at night
Community Radio	Excellent for rural poor and remote communities One-to-many Portable	Not widespread Obtaining a license can take time in some countries

[282] Various sources: Apikul op.cit.; Asplund et al. op.cit.; Coyle & Meier op.cit.; Dash op.cit.; IFRC 2009; Karanasios 2010; UNESCAP 2008; Wattegama op.cit.

Telephone (fixed)	Quick delivery	One-to-one Requires expensive infrastructure Vulnerable to congestion and delay
Telephone (mobile)	Relatively low cost Increasingly high penetration in rural areas	One-to-one Vulnerable to congestion and delay
SMS	Available on most mobile phones One-to-many Quick delivery	Vulnerable to congestion and delay Does not reach non-registered numbers Literacy required
Cell Broadcasting	One-to-many Not affected by nor adding to traffic Message can be differentiated by cells or sets of cells Geo-scalable Geo-specific targets Greater authenticity	Phone must be switched on and set to receive message Does not reach non-users Requires literacy No standardisation across networks to date
Internet/email	Fast and interactive Multiple sources can be checked for authenticity	Limited penetration in developing countries Limited local language content Subject to overload
GIS	Integrates spatial with social, economic and cultural data One-to-many Visual display of patterns	Require high bandwidth and high speed networks Utility depends on data Costly hardware and software Requires expertise – interpretation, integration
Satellite-based Systems	Large geographic range One-to-many Independent of terrestrial infrastructure Two-way, one-to-many communication Provides broadband connectivity Rapid deployment Reaches 'last mile'	Expensive, requires technical specialists Requires line of sight Data less accurate than ground-based systems (expanse over detail) Delays in propagation depending on satellite orbit
Web 2.0 Tools	Many-to-many and hence resilient Self-organising, self-managed	Requires Internet connectivity No security, open to false information Heterogeneity of wireless standards complicates inter-operability

3.5.2 Emerging Trends

Although the evidence base is relatively limited, it is already clear that ICTs will be increasingly used in climate change-related disaster management in developing countries. What, then will be the technical and organisational trends emerging from the development of new wireless technologies; from convergence of telecommunications, computing, and multi-media; from ICT-friendly policy revisions; and from lessons learned on previous disaster management initiatives? Some of these – including greater standardisation and interoperability, more data availability at lower costs and better inter-agency collaboration – are discussed below.

Standardisation

Several global initiatives are targeting this problem. GEOSS promotes the use of common technical standards so that geospatial data from thousands of different instruments can be combined to form a coherent dataset.[283] The International Charter on Space and Major Disasters (ICSMD), UNOSAT and EPIC have similar goals (cf Table 4). The Common Alert Protocol standardises early warning messages from different sensors and feeds them to different alerting technologies. This reduces inconsistencies and cost.[284]

Interoperability

There are strong market interests pushing for technological interoperability of ICT devices and networks. "There can be no mass market without seamless interoperability."[285] The use of free and open source software and open standards for data storage, communication and discovery is the favoured approach (cf Table 4).[286] Among public safety agencies this is reflected in the move towards partly or completely infrastructure-less ICT solutions such as those based on Tetra (Terrestrial Trunked Radio) standards[287] and mobile ad hoc network (MANET) communication platforms based on software defined radio (SDR).[288]

Increasing Data Availability at Lower Cost with New Technologies

Unmanned aerial vehicles (UAVs) or 'drones' are being adapted to monitor disaster impacts. UAV images are cheaper to produce and have higher resolution than satellite images because UAVs are not affected by cloud cover since they fly at low altitudes. Although still relatively costly, the decreasing size and increasing use of UAVs through partnership arrangements between donors/NGOs and research institutions are expected to reduce cost.[289]

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[283] Coyle & Meier op.cit.
[284] CAP is an open, non-proprietary standard digital data interchange format that can be used to collect types of hazard warnings and reports at the local, regional and national levels, for feeding into a wide range of information and early warning systems. CAP essentially standardises the content of alerts and notifications across all hazards to different audiences. It provides a speedy, single authoritative and secure alert message. The CAP specification was approved by the Organisation of Structured Information Standards in April 2004 (Wattegama 2009).
[285] Graziano & Lűtteke 2006:11.
[286] Asplund et al. op.cit.; ECBP 2008; Graziano & Lűtteke op.cit.; NRC 2007a; Treadgold op.cit.
[287] Terrestrial Trunked Radio (TETRA) is a digital trunked mobile radio open standard developed by the European Telecommunications Standards Institute. Targeted primarily at the mobile radio needs of public safety groups, the interfaces, services and facilities are specified in sufficient detail to allow the development of fully interoperable infrastructure and radio terminal products. Encryption provides security of voice/data communication.
[288] SDR units can be programmed to interoperate with any legacy radio device (Törnqvist et al. 2009).
[289] Some examples include the World Food Programme, which has partnered with the University of Torino Italy and developed two UAV prototypes that would capture and map visual data early to plan and monitor the delivery of relief food aid. The European Commission's JRC, in collaboration with TerraPan Labs and University College London, has also developed a cheap and portable UAV prototype – the LOw cost Unmanned Imaging System (LOUIS). LOUIS can be assembled in less than three minutes and used by personnel with no previous UAV experience. In 2009 they integrated *OpenStreetMap*'s new Walking Papers with visual images from a UAV to produce a printable map that the user can annotate from the ground and then upload (Coyle & Meier 2009).

The use of wireless mesh networks may also become more affordable. In Feb 2010, ITU signed an agreement with Singapore-based SmartBridges Solutions to provide WiMAX and WiFi systems to strengthen ITU's on-the-ground disaster response capabilities. The equipment is sent to disaster sites to provide fast wireless phone and Internet connectivity when terrestrial networks are destroyed.[290]

Intra-and Inter-agency Coordination

Weak intra- and inter-agency coordination in disaster response is a significant problem in both developed and developing country contexts. Greater technological interoperability has not necessarily brought about the organisational behaviour change needed to achieve full interoperability. The problem is widely recognised as one of trust.[291] Most of those responding to a disaster will not likely have met face to face before but will nevertheless need to collaborate during and after the disaster, "often in a complex, chaotic or completely unplanned environment…"[292] Some researchers writing in the European disaster context, view ICTs as critical in facilitating collaboration among "hastily formed networks",[293] arguing that trust and efficient knowledge sharing can be achieved with collaborative technologies and appropriate social processes.[294] Others, focusing on international humanitarian agencies, stress that "many of the challenges of inter-organisational coordination cannot be solved by ICTs"[295] but that informal contacts, common language, professionalism, standardisation, and frequent external communication help.[296]

Global Covenants and Strategic Alliances

The ratification of the Tampere Convention[297] in 2005 has helped expedite the deployment, cross border movement, installation and operation of telecommunication services during disasters. There are also numerous partnership arrangements among government, industry and NGOs seeking to address the standardisation, interoperability, data availability, and cost issues related to the use of ICTs in disaster management. Table 4 lists a few of these.

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[290] http://www.smartbridges.com/company/news/59-press-release-sb-and-itu-for-haiti
[291] Asplund et al. op.cit.; Bunker & Smith op.cit; Dawes et al. op.cit.; ECBP op.cit.; UN ESCAP 2008.
[292] Törnqvist et al. 2009: 1.
[293] The term *hastily formed* networks (HFN) was coined by the US Naval Postgraduate School in 2004 and refers to "multiple organisations with no common authority that must cooperate and collaborate" with each other to fulfil a large, urgent mission (Denning 2006).
[294] See for example Asplund et al. op.cit.; Denning 2006; Shklovski et al. op.cit.; Tornqvist et al. op.cit.
[295] Maitland and Tapia 2006: 341. Also Suparamaniam & Dekker 2003.
[296] NRC (2007a) appears to have reached a similar conclusion.
[297] The Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations allows for tariff-free movement of telecommunications equipment and personnel across national borders, and into disaster affected areas, and waives licensing requirements for the use of needed frequencies (Coyle & Meier op.cit.; IBRD op.cit.; Wattegama op.cit.).

Table 4: ICT-Related Collaborative Initiatives[298]

Institution - Initiative	Purpose
EU – JRC Global Disaster Alert and Coordination System (GDACS)	Produces near real-time situation reports and tools to help disaster response coordination, such as media monitoring and map catalogues.
Innovative Support to Emergencies, Diseases and Disasters - RIFF[299]	Leverages open source technology to improve information flow, cross-sector collaboration and more efficient collective action.
UN Global Impact and Vulnerability Alert System (GIVAS)	Maximises use of new media and digital technologies for information collection to provide decision-makers with real time alerts and analysis of impacts on the poorest and most vulnerable populations.
UN Operational Satellite Applications Programme (UNOSAT)	Provides satellite images and analysis to relief and development NGOs with field contacts to provide context.
WFP – Emergency Preparedness Integration Centre (EPIC)	Creates a platform to integrate operational information from multiple sources for use by humanitarian agencies.
World Vision – Last Mile Mobile Solutions	Combines mobile technologies with improved humanitarian agency practices to "promote greater efficiencies and accountability in food aid programming and delivery at the last mile"[300].
NGOs/Bill &Melinda Gates Foundation/Microsoft Corp – Emergency Capacity Building Project	Develops ICT skills among frontline NGO staff. Its toolkit – *Building Trust in Diverse Teams* – integrates trust tools in learning projects, embedding them into existing preparedness, individual operation plans, training and induction plans.

[298] Coyle & Meier op.cit.; ECBP 2008.
[299] RIFF is a platform developed for monitoring public health threats which can be adapted to natural disasters. It combines satellite imaging, data analysis, and vulnerability assessment for early warning system. It was developed by an NGO, InsTEDD (Innovative Support to Emergency Diseases and Disasters) which is supported by the Google Foundation. RIFF includes automated feature extraction and integrates several capabilities, such as data gathering and aggregation module, data classification and tagging modules, a prediction and alert output and field confirmation and feedback modules. It allows the user to collect data from SMS, RSS feeds, email distribution lists, databases and online discussion fora and facilitates collaboration by allowing users to comment, tag and rank sets of related information. The application of this platform to other disasters is being explored (Lewis 2009).
[300] IFRC 2009: 22.

4. ICT Use, Disasters and Developing Countries: Some Reflections

ICT applications in developing country disaster management did not begin in earnest until the mid 1980s: at least a decade after their introduction in industrialised countries, and even then confined mainly to administrative purposes. A Virginia-based NGO, Volunteers in Technical Assistance, pioneered the use of low earth-orbiting satellites and Internet-based messaging services in its relief and development operations in Chad, Djibouti, and Pakistan in the late 1980s.[301] In the early 1990s software for decision support was introduced by UN agencies in their relief and refugee operations. By the mid-1990s, bulletin board networks were starting to be used by agencies in developing countries for disaster management-related discussions.[302]

Today there may be less overt sense of technological lag. As described Section 3, the uses of ICTs in disaster management in developing countries are as sophisticated as those in industrialised countries. Yet this has largely been enabled by external agencies, specifically, the UN agencies, donors, and international NGOs. Very few developing countries have the resources to install, operate and maintain the necessary ICT infrastructure, notwithstanding well-intentioned policy statements to this effect.[303] And in general, we need to recognise some of the ongoing issues surrounding use of ICTs for climate change-related disaster management in developing countries.

4.1 Institutional and Cultural Barriers

The barriers to greater ICT use in disaster management go beyond cost. Governments which have the resources may not implement ICT-friendly policies or may not invest in more resilient electricity and telecommunication systems that decentralise information generation and sharing, and democratise decision-making.[304] In many countries with moderate or high levels of ICT penetration, access to ICTs continues to be restricted by economic factors as well as government policies, illiteracy, and cultural barriers of gender, ethnicity, religion and caste.[305] All of these must be recognised and coped with in seeking to expand ICT disaster-related applications.

4.2 Data Standardisation and Quality Issues

The lack of standardisation in data collection in developing countries is acute. It is not uncommon for census, cadastral registries and other housing data within a country to be maintained using different media, standards, and definitions. They are frequently held by different institutions. Local laws, security protocols or inter-organisational rivalries may prohibit or complicate the sharing of certain types of data. Historical data and local maps are frequently not available in digital format and/or lacks proper meta data. Available data may be out of date, or collected using different methodologies.[306] The initiatives listed in Table 4, being all reactive, will ameliorate *some* of these problems in some *future* disaster events in *some* countries.

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[301] Gariott 1991; Ruth & Ronkin 1992.
[302] Stephenson & Anderson 1997.
[303] Best op.cit.; Statskontoret 2002; TeleCommons Development Group 2000; Yonazi 2009.
[304] Purbo n.d.; Wattegama op.cit.
[305] See for example Apikul op.cit.; Hazarika et al. 2010; Wattegama op.cit.
[306] Laituri op.cit.

4.3 ICT Capacity Deficits

Meteorological data, forecasts and analyses are often inaccessible or incomprehensible to those who need the information most because of lack of the necessary skills to interpret, process and integrate the data..[307,308] ICT skills development has been the goal of ICT for development projects which have proliferated in the last 15 years. Relatively few are deemed successful or sustainable.[309] Many reasons are cited for the failure but lack of local capacities, such as skills, is a repeating element.[310]

One proposal has been the linking of relief and development through ICTs. The argument is that ICTs introduced for relief can and should be retained in the area for continuing use in terms of information collection, analysis and sharing by local NGOs. The disaster ICT infrastructure may thus help leapfrog an area to a competitive telecommunications market structure.[311] A more interesting outcome from a capacity development perspective is that such a transition would reinforce the ICT skills learned and enhance local ICT capacities, though of course there is some elements of chicken-and-egg, in that successful application of the disaster/relief information systems would only be possible if a certain level of capacities are already present and/or transferable during usage.

Such capacities can often be quite basic. For example, it is interesting to note that all the ICT-in-developing country policy documents reviewed for this paper focus on cost as the major issue and market-friendly policy instruments as the solution to the digital divide.[312] There is no mention of illiteracy as a significant barrier to access, and basic education as a necessary policy response to this barrier. Yet the digital divide affecting ICT usage in disaster management is partly a literacy divide.

4.4 Grounds for Optimism

There are several grounds for optimism.

One is the compelling evidence from Cuba and Mozambique that reaching and therefore saving lives in the 'last mile' can be achieved by maximising "the use of readily available, low-cost low-tech solutions…".[313] Another is the evidence of socially minded ICT-savvy professionals from both sides of the development divide who are giving their skills and time to make ICTs a global public good – the Kenyan bloggers who developed *Ushahidi*, the Sri Lankan ICT professionals who developed *Sahana*, the professionals who developed *Dumbo*, the Filipino web developer and cyber enthusiasts who developed the hub during the 2009 floods, and the volunteers with TSF, MapAction, GISCorps and others. Additionally, the development of new wireless technologies, the convergence of voice, data, computing and modelling capabilities of services, networks, products and

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[307] Coyle & Meier op.cit.
[308] Note that this is not unique to developing countries. Studies on the response to the attack on the World Trade Centre and Hurricane Katrina report exactly the same problem (Dawes et.al 2004; NRC 2007a).
[309] See for example Abbasi 2007; Maiye & McGrath 2010; Osama 2006; van Reijswoud 2009.
[310] See for example Heeks 2003; Maiye & McGrath op.cit.; Osama op.cit.
[311] Maitland et al. 2006.
[312] This specifically refers to: Best 2003; Statskontoret 2005; Telecom Dev Group 2004; van Riejswoud 2009; Yonazi 2007.
[313] IFRC 2009:28.

terminals are enabling the provision of user- and management-friendly information and communication services with a farther reach at a lower cost.

But the basis for hope rests not simply on a combination of bottom-up volunteering and exogenous technological change. It has also required coordinated efforts over many years by multiple national and international organisations.

For example, work on standardisation is progressing, facilitated by technology developers. Table 4 provided some details but another instance is *DesInventar*, a disaster management application first used in disaster preparedness in Latin America in 1994 to develop national-level disaster databases in 17 countries using up to 30 years of data from NGOs, universities, scientific organisations and government agencies. It ran up against the problem of data standardisation, but efforts to address the problem continued. Ten years later *DesInventar* was modified and applied successfully in developing India's Integrated Disaster Resource Network using data going back 30 years from governments and news media. *DesInventar* was further modified and adapted to South Africa's programme for Monitoring, Mapping and Analysis of Disaster Incidents, focusing on large urban 'non-drainage' floods, wildfires, extreme wind events, and highly frequent 'small' and 'medium' fires, effectively integrating socio-economic conditions and environmental risk factors.[314] *DesInventar* is now used to establish one of four international disaster databases, the others being EM-DAT, Nat Cat and Sigma.[315]

There also appears to be some progress on the problem of inter-agency cooperation and collaboration. As noted in Table 4, the impacts of coordination failure that surfaced during the 2004 Indian Ocean tsunami led to a grant to the Inter-Agency Working Group (IWG)[316] on Emergency Capacity Building (ECB) to find ways to address the problem.[317] Among the more than 20 work streams, the Building Trust in Diverse Teams Pilot Project focused on some of the softer, less well-recognised institutional and cultural barriers that can hamper effective ICT usage. Conclusions to date have been that, "Within the IWG, the substantially increased levels of trust, coordination, improved relationships, and willingness to share information and resources has been the ECB's most important outcome."[318]

Regional actions have also played their part. For instance, in the Asia Pacific there are initiatives aimed at establishing regional and subregional standby communications systems for disaster management purposes as well as arrangements for sharing information. These are enabling access at much reduced cost to countries with fewer resources and weaker infrastructure.[319]

Finally, national policies should not be forgotten. Governments may be criticised for the policy lag that continuous technological change often creates, but there is a flip-side of ongoing legislation. As one example, more and more countries are

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[314] Apikul op.cit; Wattegama op.cit.
[315] EM-DAT – emergency disasters database, managed by the Brussels-based Centre for Research on the Epidemiology of Disasters. Nat Cat and Sigma are managed by Munich Re and Swiss Re, respectively.
[316] IWG was formed in 2003 by the emergency directors from 7 of the world's largest humanitarian assistance agencies – CARE Intl, Catholic Relief Services (CRS), Mercy Corps, OXFAM GB, Save the Children and World Vision
[317] Maitland & Tapia 2008.
[318] ECBP 2008: 21.
[319] Examples include the Sentinel Asia initiative aimed at integrating space information and the products and services of earth observation satellites.(UN ESCAP 2008).

allowing the commercial utilisation of license-exempt radio frequencies and opening up markets for technology development.[320]

5. Strategic Recommendations

Large-scale, climate change-related disasters, regardless of the specific physical event involved, often result in similar scenarios: critical infrastructures destroyed or disabled for several days or weeks, and an influx of different organisations offering assistance. Generally more pronounced in developing countries, these scenarios pose tremendous challenges in communication, coordination and accountability, which have important consequences for the effectiveness of disaster response. They warrant strategic policy and programme responses.

5.1 Ensuring Continuity in Challenged Environments

Regulations should provide for priority access to communications for disaster responders, and priority repair of communication services to ensure continuity of ICT-enabled services and products. If the ICT infrastructure is in private hands such provisions should be included in licensing and concession contracts. Hardened data centres for archiving digital data and running of essential government services should be established. This is admittedly costly but has high development returns.

A forward looking government strategy would 'mainstream' wireless technologies more systematically, expediting the use of cheaper, energy-smart WSN in early warning systems, and the deployment of inexpensive ICT solutions when infrastructure is compromised.[321] Disaster conditions frequently demand extraordinary use of communication tools. ICT systems should be developed not with proprietary solutions but with diverse standard components and operational interfaces that accommodate interoperation. And when procuring ICT equipment, systems based more around routinely-used, familiar applications should be preferred over those requiring specialised training. Responding to disasters involves solving problems under high stress conditions. Skills used infrequently are often forgotten in such situations. Routine use builds confidence.[322]

5.2 Bringing about Inter-agency Coordination and Cooperation

Of the four acknowledged barriers to interoperability, only one is non technological – fragmented planning and poor coordination.[323] Interestingly, reviews of responses to several major disasters in the last fifteen years[324] share one conclusion, along the lines expressed by Denning: "the quality of the response depended not on response planning or on new equipment, but on the quality of the network that came together to provide relief".[325] Furthermore, the

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320 Best op.cit.

321 For example wireless sensor networks for monitoring environmental conditions in harsh environments (Karanasios 2010), or monitoring the integrity of buildings and bridges (Eisenberg 2011).

322 NRC 2007a.

323 The other three are: incompatible standards, aging equipment, limited and fragmented radio spectrum (NRC 2007a; UN ESCAP 2008; Wattegama 2007).

324 See for example, Bunker & Smith op.cit.; Denning op.cit.; Maitland et al. op.cit.; Sjöberg et al 2006; Suparamaniam & Dekker op.cit.; Törnqvist et al. op.cit.

325 Denning 2006: 15.

existence of a well established national disaster response plan does not appear to make a difference.[326]

Forming an executive committee on site, representing the different organisations, might be a non-threatening way to initiate coordination. Protocols for sharing information, equipment and resources and decision making would have to be agreed upon at the outset.[327] The experience in the 2001 Gujarat earthquake suggests that having ICT experts in the response teams hugely facilitates the coordination process.[328] Tools for labelling and filtering need to be developed so members can avoid being paralysed by information glut, and only access information relevant to their needs.

Donors could make standardised disaster data collection a condition for channelling funds through NGOs. A registry of participating NGOs could be put up in donor agency websites to inform potential donors.

For their part, national governments could make data sharing mandatory among public sector agencies for disaster management purposes.[329]

5.3 Maintaining Transparency and Accountability

Whether large or small, disaster response in developing countries often relies on external financing and assistance. ICTs have become very effective tools in raising funds for disaster assistance, but such financial assistance will only be continuously provided if donors – agencies, governments, individuals – are convinced that assistance was wisely used. Therefore the use of ICTs to create transparency and accountability of disaster response agencies should be more widely adopted. There are pioneer databases for this purpose, e.g., UNDP's DAD during the 2001 Gujarat earthquake[330, 331], Microsoft and Mercy Corps' FACTS (Food and Commodity Tracking System),[332] and *Sahana*.

5.4 Pursuing Combination, Not Specialisation

One continuous message from the case studies reviewed is the need to think broad rather than narrow. This applies to technology: almost all of the most valuable applications are those involving combinations of technologies. Sometimes, as in the Maldives EWS, these run in parallel. But often they run in combination within the same system – combining the Internet and mobile phones, combining satellites and GIS, and so on.

Very few, if any, of the ICT applications reviewed in this paper were climate change-specific. There is a strong argument to be made for combining disaster and development ICT uses into a single system – for example, generic weather

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[326] The problem is best illustrated by the chaos that reportedly characterised the work of the two hundred or so NGOs that went into Aceh Indonesia in response to the 2004 tsunami. Indonesia has a well-established emergency response plan that did not prevent this (The Economist 2010; IFRC 2005).
[327] This was proposed by Denning (2006) and something similar was reportedly adopted quite successfully by UNDP during the 2001 Gujarat earthquake (Maitland et al 2006).
[328] Maitland et al. op.cit.
[329] This was proposed by the National Research Council (2007a).
[330] Maitland et al. op.cit.
[331] UNDP's Development Assistance Database provides an interface that allows it to link to other accounting, financial and statistical systems (Synisys n.d.).
[332] The FACTS design team included the American Red Cross, Catholic Relief Services, Food Aid Management, Food for the Hungry International, Project CONCERN, and Save the Children. FACTS is already used in Bolivia, Guatemala, Indonesia and Kyrgyzstan operations of these NGOs (Sahu n.d.).

information systems; generic 'human sensor' reporting systems, generic mapping systems. Not only is this more efficient, it also helps to embed disaster management systems into the routine functioning of communities.

5.5 Areas for Future Research

More research is needed on the issue of using converged rather than specialised ICT systems. How great can the combination of systems be: just extending disaster management systems to incorporate climate-related events, or attempting the much broader task of integrating disaster and development systems? Technically, how could this type of convergence be made to work? Institutionally, what does it mean to seek to combine disaster and development applications? And institutionally how can the different actors that need to combine be brought together?

In addition, two of the problem areas discussed in this paper warrant more careful examination if we are to see significant improvements in the quality and efficiency in preparedness and response to climate-related disasters, as well as inform resource allocation decisions of developing country governments.

One is coordination and cooperation among hastily formed networks. Why is coordination and cooperation among response agencies immensely difficult? Are national NGOs better than international ones? Does organisational size make a difference? How about history of engagement in local development? Are development NGOs more amenable than humanitarian agencies to coordination? Are 'flat' organisations more willing to cooperate than hierarchical ones? Are decentralised or autonomous NGOs more cooperative than those with headquarters outside the country? Are field volunteers more willing than staff to cooperate with each other? Do donors care or are their reporting requirements partly responsible for the problem?

Examining these issues would entail interviews of key informants and review of reports and documents of government and non-governmental organisations that have been involved in major disasters in developing countries in the last five years.[333] This should be complemented by archival research (e.g., local newspapers), and interviews with local leaders in selected disaster sites.

The second area needing attention is performance evaluation and financial auditing of disaster preparedness and response programmes. Several million dollars are raised and spent in every major disaster but there is little public knowledge as to how the funds were spent, for what, who actually benefited, and how many.[334] How quickly were voice and data communication set up? How quickly was assistance delivered? Were the targets reached? Who were ignored or bypassed and why? How well did the group coordinate its activities with others? Did the organisation comply with relevant financial and legal requirements? Is the entity's internal financial control suitably designed and applied? Were their inefficiencies? What were the causes? What has been the contribution of ICT use on the quality of the outcomes?

The requirement for performance evaluation and financial audit could be embedded in the funding application process and budget allocated for the purpose. The evaluation and audit reports could become part of an organisation's file that would inform its next application for disaster relief funds.

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[333] Longer than five years would probably pose difficulties of recollection among those involved.
[334] Labadie 2008.

Global climate change models predict more frequent and severe climate related disasters. It is in the interest of those committed to ameliorating disaster impacts on the world's poor that the generous expressions of humanity and good citizenship that arise in the wake of disasters not be betrayed, and that public confidence in the integrity of humanitarian assistance systems be maintained.

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Glossary of Acronyms

AMARC	Association Mondiale de Radiodiffuseurs Communautaires
APCICT	Asian and Pacific Training Centre for Information and Communication Technology for Development
AREA	Addressable Radio for Emergency Alert
AVHRR	Advanced Very High Resolution Radiometer
CAP	Common Alert Protocol
FEWS NET	Famine Early Warning Systems Network
GEO	Group on Earth Observation
GIVAS	Global Impact and Vulnerability Alert System
IFRC	International Federation of the Red Cross /Red Crescent Societies
ICSMD	International Charter on Space and Major Disasters
InsTEDD	Innovative Support to Emergency Diseases and Disasters
ITU	International Telecommunication Union
OASIS	Organisation of Structured Information Standards
RAD	Remote Alarm Device
RANET	Radio and Internet Technology for Communication of Hydro-meteorological Information for Rural Development
TSF	TelecomSansFrontieres
UNESCAP	UN Economic and Social Commission for Asia-Pacific
UNOSAT	United Nations Institute for Training and Research Operational Satellite Applications Programme
WMO	World Meteorological Organisation

Chapter 6: Climate Change as a Strategic Priority for ICT4D Organisations:
Current Attitudes, Responses and Needs

ALAN FINLAY

Executive Summary

This paper considers the extent to which climate change has become a strategic priority for information and communications technology for development (ICT4D) organisations. Through a survey of 30 ICT4D organisations primarily from developing countries, as well as an overview of the thematic interests of authors participating in a recent publication on ICTs and environmental sustainability, it shows that there is a predominant interest in adaptation strategies in developing contexts. However, it also supports the argument that widespread, tangible ICT interventions at the local level are not yet being felt. This is due to many reasons, including capacity issues in organisations, the fact that many organisations are still positioning themselves appropriately in the field of ICTs and climate change, and unsupportive institutional contexts.

The paper argues that while ICT4D organisations can leverage past competencies in addressing climate change in developing countries, climate change presents an atypical advocacy scenario, which makes direct engagement in the field difficult for some and may affect decisions around strategic interventions. It goes on further to tentatively suggests that while adaptation strategies in the most vulnerable contexts are critical, interventions in the field that support ICT4D organisations should guard against overdetermining strategic engagement, given the heterogeneous nature of ICT4D organisations, and the fluidity of their engagement across different fora and platforms, from the local to the global level. In this regard, the most effective strategic response to climate change from ICT4D organisations is likely to be specific to their key competencies and organisational strategies and mandates generally, rather than geographically predetermined.

1. Introduction

The recent literature review of information and communications technologies (ICTs), climate change and development by Angelica Ospina and Richard Heeks[335] points to a clear role for civil society organisations at many levels of climate change response, including advocacy, information dissemination, helping local communities adapt, and providing a voice for affected people. Something of the 'communications response' by organisations that use ICT for development (ICT4D) specifically in the context of climate change has been documented in publications like *Planting the Knowledge Seed*.[336] This includes case stories that share the potential for interactive community radio to bridge the divide between scientific knowledge and local communities; using Web 2.0 tools to create 'knowledge systems' aimed to "increase community resilience through increased awareness";[337] using telecentres as information key points in the struggle for food security in Peru; online campaigns to raise awareness amongst media practitioners about climate change issues; and introducing ICTs to small-scale farmers. As Kalas points out,[338] many of the best practices learned in ICT4D interventions over the years can be applied to climate change, and this experience is seen as the main contribution of ICT4D practitioners to the complex and myriad responses to climate change currently being felt at most levels and across institutions and sectors.

Many ICT4D organisations have been active at the interstice of ICTs and environmental sustainability at least for the past three decades. The pioneering role organisations across the globe – such as GreenNet in the United Kingdom, Pegasus Networks in Australia, and SANGONeT in South Africa – played in the early Internet in those countries, meant that many served a critical historical function in linking up social and environmental activists, some as far back as the 1980s. Instituto Nupef offers this account of the development of the Internet in Brazil:

> Few people know that the origins of the Brazilian Internet are deeply connected to the environmental movement and that its use has played a key role contributing to the growth and strengthening of networks of NGOs working in the field of environmentalism and sustainable development. In fact, the access to the Internet was made possible to a wider public in the country during the preparatory process for the Earth Summit in 1992 – before that moment, Internet access was restricted to some academic centers or via Ibase's Alternex project, in both cases just for exchanging messages, as permanent links were not yet available.[339]

Over the years, other ICT4D engagements close to the field of environmental sustainability have included experiments with technologies such as solar panels or wind-up radios in communities that lacked infrastructure (lessons that now can be applied in energy-saving practices), and a groundbreaking role in the use of refurbished computers in education and community access. This in turn led to practitioners being amongst the first to advocate on the issue of e-waste dumping in developing countries in the 1990s, and to begin to call for multi-national vendors to take responsibility for the safe recycling of discarded computers in those countries. All of this was prior to the interest shown by programmes such as those financed by the Swiss government in setting up e-waste management

[335] Ospina and Heeks, 2010
[336] Kalas and Finlay, eds. 2009
[337] ibid. p25
[338] ibid. p10
[339] Instituto Nupef, 2010

frameworks in countries like South Africa, India and China,[340] and before vendors, such as Hewlett Packard and Nokia, launched their recycling responses in developing regions. The historical importance – and thematic significance – of environmental issues to the ICT4D sector is highlighted by the 2003 World Summit on the Information Plan of Action, where "e-environment" (C7, 20) is one of the activity areas alongside e-government, e-learning and e-health, amongst others.[341]

Yet while a number of ICT4D activists played a pioneering role in the field of ICTs and the environment, there is also a sense that for many this early relationship was not sustained. Over the years, with the growth and specialisation of the ICT4D sector, environmental issues have become less and less of a concern for practitioners. The urgency of climate change provokes the need for it to be mainstreamed in everyday discourse and activities – a mainstreaming which is now not necessarily in line with the function of ICT4D organisations, even though environmental activism, in one way or another, has been an important historical cousin to that function. Engagement in environmental causes is not systemic to ICT4D activities in the way that gender or advocating for open source have been, and in many contexts environmental issues have failed to impact on ICT4D organisations in practice. This perspective is made clear in a recent report by Frederic Sultan on ICTs and environmental sustainability in France, where he argues that "[t]he management of e-waste, and the environmental consequences of the use of ICTs is rarely singled out by French organisations combating the digital divide. Most activists of the information society ignore this face of ICTs".[342]

Not all ICT4D organisations feel that engaging on issues of ICTs and environmental sustainability is appropriate to their strategic imperative, which some believe is more generally about bringing about systemic socio-political change and transformation. In this context, environmental causes are seen to be ideologically embedded, and not seen as a way to leverage that systemic change. They are seen, rather, to ultimately confirm the status quo. A version of this argument is captured in an informal e-mail exchange between the author and Parminder Singh, a director of the Bangalore-based ICT4D organisation IT for Change,[343] on the topic of ICTs and environmental sustainability generally:

> ICT manufacturers, energy policy-makers etc. may need to be addressed on this issue much more than those in development policy and practice, which is the area we work in. We understand the major issue for environmental sustainability to be of unsustainable consumerism, and the increasing hold on our lives by, let me say the bad word, neo-liberal ideology – not only through our economic, but also, increasingly, social and political systems, which can only thrive with ever increasing rates of consumption, which we all know is unsustainable. The real issue *vis-à-vis* ICTs and environment then is the relationship between ICTs and consumerism, and ICTs and the spread of neo-liberal ideology. On the other hand, the counter-possibility is whether ICTs can help construct alternative social, economic and political paradigms – or at least possibly contribute towards these directions.

It is with this as background that this paper aims to better understand current attitudes, responses and needs in the context of climate change amongst a sample set of ICT4D organisations. It looks to better understand if climate change

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[340] http://www.ewaste.ch/
[341] WSIS, 2003
[342] Sultan, 2010
[343] http://www.itforchange.net

is, or will become, a strategic priority for ICT4D organisations working across the world, as well as understanding inhibitors to mainstreaming climate change responses in organisations.

There are two components to the paper. The first involves an overview of perspectives on climate change offered by authors who contributed to a publication called Global Information Society Watch (GISWatch) during 2010, published annually by the Association for Progressive Communications (APC) and Humanist Institute for Cooperation with Developing Countries (Hivos).[344] GISWatch 2010 sought to offer a civil society perspective on the growing global focus on ICTs and the environment as a way of entering the debates and of building capacity and interest amongst participating civil society organisations to engage in policy advocacy. The GISWatch report offers a useful sense, at this juncture, of ICT4D organisations' interest in ICT and environmental sustainability issues broadly, as well as advocacy areas that lie ahead.

The second component of this paper reports on a follow-up survey conducted amongst largely the same organisations specifically on the topic of climate change. The survey aimed to ask questions of the organisations using Ospina and Heeks' overview model of ICTs, climate change and development as a starting point.[345] In their review of literature on ICTs and climate change, Ospina and Heeks note that much of the technological exploration in connection with climate change has focused on the mitigation needs of developed countries, and there have been fewer concrete learning experiences on the "potentially innovative approaches to respond, prepare for, and adapt to climate change impacts"[346] in the most vulnerable contexts. Using this perspective as a starting point, and while trying to draw out issues such as the level of priority respondents give climate change in their organisations, how climate change issues are situated in organisations, as well as barriers to engagement in the climate change field, the survey tries to build on the Ospina and Heeks model by asking respondents to define their strategic interest in the areas – as defined by the model – of mitigation, adaptation, monitoring, and strategy.[347]

2. Overview of GISWatch Reports

2.1. Fields of Interest and Enquiry

53 authors responded to a call for country reports on ICTs and environmental sustainability for GISWatch 2010.[348] Of these, nine (17%) can be considered reports from developed countries,[349] with the remaining covering developing countries across the globe. Not all of the authors were civil society organisations: some were ICT4D consultants, and at least one was a journalist. However, the majority of the authors worked in the ICT4D sector. As a result, the perspective of the GISWatch authors can be said to strongly represent the perspective of ICT4D practitioners in developing countries, and their choice of topic suggestive of their expertise and interests in the broad field of ICTs and environmental sustainability.

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344 As editor of this publication, my perspectives and summary of the contents should be considered embedded.
345 Ospina and Heeks, 2010. p21
346 ibid. p3
347 ibid. pp 15-23
348 For a list of organisations, see Appendix 1.1.
349 The use of terms 'developing' versus 'developed' is based on the International Monetary Fund's (IMF) list of emerging and developing economies (2010). In this paper South Korea, an advanced economy according to the IMF, is considered a developed country.

A number of authors who had written authoritatively for previous reports felt that the specific focus of this year's report – "ICTs and environmental sustainability", which included but was not limited to issues to do with climate change and e-waste – was outside of their field of expertise. While some said they could not do the report, others sought partners with experience in the area to help them write on the issue. This is significant to the extent that it diverged from previous editions of GISWatch which focused on what may be seen as more 'traditional' ICT4D concerns, such as "participation", "access to infrastructure" and "access to online information and knowledge", and was an indication that the field of ICTs and environmental sustainability was one relatively new for the participating authors. Despite this, it is worth noting that the 53 reports is a higher number of reports than previous years, indicating that the topic is seen by ICT4D organisations as one that is important to their work.

As Table 1 below shows, of the 53 authors, 24 took e-waste as the primary focus of their discussion, 12 focused on ICTs and climate change, and 15 on both topics. This can be taken to reflect – but should not be taken to over-determine – areas of competency.

	No. of reports	%
E-waste (including issues of production)	24	45
Both	15	28
ICTs and climate change	12	23
Mixed/other	2	4
Total	**53**	

Table 1: Fields of Interest and Enquiry

2.2. Positioning and Perspectives

Reading across the reports, responses amongst authors on the issue of ICTs and the environment can be broken down into at least four categories, which suggest different ways of engaging (or not) and mandates. These are not absolute positions, and inevitably any one organisation might adopt more than one position at any given time. It does nevertheless offer useful insight into how ICT4D organisations frame the field of ICTs and environmental sustainability, and therefore are likely to frame the evolving field of ICTs and climate change specifically.

Non-engagement

Environmental issues are one of many development issues that require attention. However given basic development imperatives and the core focus areas of ICT4D organisations – poverty, disease, and rampant economic and other inequalities – it is not first on the list of issues that need immediate attention.

As mentioned in the Introduction, some organisations feel that environmental concerns are not specifically the mandate of ICT4D practitioners. A similar perspective is expressed in the opening remarks of the Iran country report, where authors Sohrab Razaghi and Hojatollah Modirain (who work for an organisation called Arseh Sevom) point to the immediacy of more urgent issues in that context:

> Without human rights, sustainable development cannot happen. It should be noted that human rights is not only confined to freedoms, such as freedom of speech and prohibiting torture, but also covers some basic rights such as water, health, food, eliminating poverty, education, as well as freedom of information and access to the internet …The political uncertainty in the country and harsh suppression of civil society has resulted in less attention being given to environmental issues and climate change.[350]

Political

Environmental issues are an opportunity to concretise historical concerns such as rampant consumerism, global economic inequalities, and exploitation of developing markets by powerful multi-national businesses and governments. They offer way of refocusing demands.

This is perhaps the mirror image of the first position, where concerns with consumerism and economic inequalities are also referred to. Here, addressing technology-driven consumerism is a critical aspect of addressing the interstice of ICTs and environmental sustainability, which can also be leveraged to address the ongoing political confrontation with power. This implies engaging big business and governments and decoding the marketing agendas of business ("green washing"):

> As "green" products are proving a successful model for marketing, ICT vendors stress the fact that their newest products are greener and that is why customers should buy them, even if their old equipment satisfies their needs. This is a business practice that eventually leads to a commodity-driven lifestyle that directly contradicts the logic of green ICTs: saving nature's resources.[351]

Mainstreaming

Environmental issues are cross-cutting concerns and need to be mainstreamed in the development process.

This is a broad position, which may include advocacy, awareness raising in different sectors, networking, and influencing consumer behaviour (such as "buying green"), amongst other activities. An advocacy imperative lies in conscientising ICT civil society organisations on the issues of ICTs and environmental sustainability, including climate change. As Rozália Klára Bakó (2010) suggests in her report on Romania, this position implies an awareness of an "environmental divide" where "key stakeholders in policy making – governmental agencies, business organisations and civil society activists – are not aware of the issues at stake; that is, the link between ICTs and environmental issues" (Bakó, 2010). This perspective is also alert to an apparent disconnect between environmental organisations and ICT4D organisations, and, within the ICT4D sector, a lack of awareness or even concern with environmental imperatives.

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[350] Razaghi and Modirain, 2010
[351] Staevska, 2010

Practical/opportunistic

Environmental issues can be used to attend to other development concerns, such as job creation and workers' rights.

"Opportunistic" here is used in its non-pejorative sense of seizing an opportunity as it presents itself for a public or other good. For example, the practical implication of ICTs and environmental concerns is expressed in the potential of e-waste to create employment for poor people. However, more generally, a focus on ICTs and the environment is also an opportunity to attend to issues such as the work conditions of waste-pickers, workers rights and safety in factories, as well as the skills and access to infrastructure in marginalised communities. Environmental causes offer an opportunity for practical interventions, and to mobilise funds around interventions that would be seen to be of benefit to development and rights imperatives more generally. In the context of climate change, interventions at the grassroots level, including economic and health and educational interventions, set up developmental channels that are of benefit to affected communities in the long-term and in other, sometimes unintended, ways.

2.3. Climate Change Advocacy Priorities for ICT4D Organisations

Separating out the reports that dealt with e-waste from those that looked at climate change, several advocacy priorities to do specifically with climate change are listed in the reports. These are summarised in Table 2.

	No. of mentions	%
Awareness raising and advocacy	16	31
Policy advocacy	12	23
Monitoring: data capture, indicators	6	11
Review of legislation	6	11
Building capacity in local communities	5	10
Co-operative actions	5	10
Developing infrastructure for interventions	2	4

Table 2: Advocacy Priorities

This summary should be taken as suggestive, given than the advocacy priorities were often discursive and not always so easily compartmentalised. They have also not been mapped onto the Ospina and Heeks model – which was used as a framework for the survey (see below). Rather they are to be taken to indicate the kinds of activities ICT4D organisations see themselves as most likely engaging in in the field of ICTs and climate change. It is also inevitable that many organisations would agree that interventions on several of these levels would be necessary, even if only one or two were highlighted.

Awareness-raising and advocacy concerns all sectors, and includes developing information programmes and projects, and engaging the media. In India, for instance, there is a need to expand knowledge platforms to build capacity in villages in "variability assessment and on adaptation to climate change".[352] In Japan there is a need to push for government leadership in the region on the issue of climate change, so that there is "the adoption and spread of environmental values in international trade and currency dealings",[353] and using ICTs to share methodologies for mitigating climate change regionally. *Policy advocacy* includes calling for policies dealing with mitigation interventions such as smart buildings and transport in a country like Ethiopia, where there is an "increasing energy use as a result of the expansion in ICT infrastructure, real estate development and transportation infrastructure, as well as the increase in the number of motor vehicles".[354]. In Venezuela there is a need to legislate the transition to e-government at all administrative levels, as well as the use of ICTs in environmental responses in order to ensure sustainable development.

Monitoring is different to 'information programmes' and should be taken to be a more technical and structural activity, including 'participatory sensing' using mobile phones (in the Democratic Republic of the Congo). In the case of Egypt, multi-lateral partnerships are proposed for sharing the costs of running expensive GIS data systems, given the regional implications of climate change on critical resources like the Nile. *Legislative review* (including regulations) is taken to be different to policy development, and in instances may include ensuring that current regulation is implemented properly (i.e. attending to accountability). In one case (Bulgaria) which has a bearing on the monitoring of climate change and accountability of institutions, there was a call that "[i]nnovative online action tools for green causes need to be formally recognised by state institutions, and NGO online alerts…to be treated as administrative documents, submitted by citizens".[355]

Capacity development includes developing skills in communities and the general public, amongst civil society organisations and in government (for instance, to strengthen engagement in regional and global climate negotiations). *Co-operative actions* defines the need for, amongst other things, cross-sectoral networking, and encouraging or facilitating inter-regional co-operation, as in the case of managing the Nile as a critical water resource in North Africa or in co-ordinating the adaptation interventions of civil society, the government and the private sector in order to prevent duplication and to "maximize the efficient use of limited resources".[356] *Infrastructure* refers specifically to access to the Internet in under-served communities (so that people can receive and share information), and, in one instance (Benin), the need to stabilise electricity supply in order to make climate change interventions using ICTs possible.

This overview of GISWatch country reports suggests a number of things: firstly, that climate change presents a new learning curve for many organisations, and that ICT4D organisations position themselves differently on the issue of environmental activism. Even though there may be shared concerns on issues such as consumerism and the global structures of socio-economic power, the political strategic imperative to attend to ICTs and environmental concerns is not necessary shared. The summary of advocacy priorities also conforms with the argument that ICT4D organisations are likely to draw on historical competencies and fields of engagement in addressing climate change (such as awareness raising, advocacy, and policy development, and at different levels – the community, national and global).

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[352] Manzar and Das, 2010
[353] Shiino and Aizu, 2010
[354] Chekol, 2010
[355] Staevska, 2010
[356] Habumuremyi, 2010

3. Survey Results

3.1. Overview of Survey Respondents

With this understanding as a basis, a survey was conducted primarily to further understand their interest and engagement specifically on ICTs and climate change issues. 30 organisations responded to the survey, mostly via GISWatch authors.[357] The respondents were diverse geographically, with organisations based in Asia, Central America, Latin America and the Caribbean, Africa and Europe. A number of the respondents worked in more than one country, and in this regard country-level experiences in more than 56 countries are accounted for here: several respondents working regionally, as in "CARICOM countries", "partly Europe", and "Southern Africa and East Africa".[358]

As Table 3 shows, despite the presence of respondents working in highly developed contexts such as Japan, the Netherlands, and the United Kingdom, the majority of the respondents (81%) are based, and work primarily in developing countries. The survey results can therefore be taken on the whole to reflect the perspectives and practices of ICT4D organisations working in contexts where the impact and implications of climate change are expected to be magnified.[359]

	No. of organisations	%
Developing countries	24	81
Developed countries	6	19

Table 3: Engagement in Developing versus Developed Countries

3.2. Climate Change as a Strategic Priority

A consideration of the individual survey responses does not suggest any firm pattern of why an organisation might consider climate change of more strategic importance than any other issue. There are several factors that contribute to any single issue being taken up by development organisations generally, which may include organisational focus and historical interest in the field, donor agendas, and capacity in an organisation, amongst them.

As Table 4 shows, half of the respondents give climate change a "medium" priority in their organisational work. The remaining respondents are roughly evenly split between a "high" priority and a "low" priority given to climate change.

	No. of organisations	%
High	7	23
Medium	15	50
Low	8	27

Table 4: Priority of Climate Change in Organisational Work

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357 See Appendix 1.2. Only one of the organisations that responded was not involved in producing a report for GISWatch (although it had been involved in previous years).

358 The breakdown of regions where the respondents have country-level experience is shown in Appendix 1.3.

359 Kalas, 2009. p9

Of the seven organisations that give climate change a high strategic priority, all of them work in developing contexts. Four of them work in Africa (Kenya, Uganda, Tanzania, Zimbabwe, Zambia, Nigeria and Egypt), one in Asia (its spread of countries being Nepal, India, Pakistan, Sri Lanka, Bangladesh, Bhutan and Afghanistan), and two in Latin America and the Caribbean (Venezuela, Colombia, Ecuador, Peru, Bolivia, Argentina, Chile, Jamaica, Trinidad and Tobago, and Barbados). Three of the respondents are still in the planning stages of interventions in the field, showing that at this point in time, climate change as a strategic concern is still new to many organisations, and has not necessarily translated into projects on the ground.[360]

Of the four organisations that are already involved in projects, these involve research, documentation and information dissemination at the local level. Some of these projects suggest a substantial engagement in the field. For example, one organisation is involved in documenting knowledge, practices and policy regarding climate change in the tropical Andes, an evaluation of land use and cover change in the Andes over the last 30 years, and a project that is assessing how rural communities perceive climate change. Another organisation is involved in making useful and practical information on climate change adaptation practices available to local communities using traditional publishing and Web 2.0 tools. A third respondent is involved in "sensitisation" initiatives on the causes of changes in rainfall patterns in Nigeria, as well as on the long-term consequences of farmland destruction and deforestation for domestic fuel. Six out of seven of the organisations that give a high strategic priority to climate change also consider it a cross-cutting concern in their organisation.

Five of the six respondents based in developed countries (Japan, UK and the Netherlands, Spain and Switzerland)[361] attach a "medium" strategic priority to climate change in their work. Again, the disconnect between the recognition of climate change as a strategically important area to engage and projects on the ground is felt. Four of the five respondents either were not involved in climate change work at all, described their engagement as "spontaneous involvement in some projects", or were indirectly involved in mitigation projects such as fuel-efficient transport and sustainable housing (in the latter case the organisation also worked in India and Ghana). This perhaps surprising lack of current engagement with projects in developed contexts may reflect the widespread concern with climate change as an issue in those countries, and a low incentive or even need to be engaged in projects when many other sectoral organisations already are. This can be contrasted to the range of opportunities for engagement in climate change in developing countries.

Of the remaining nine organisations that work in developing countries and give climate change a medium strategic priority in their work, only two are not involved in any projects at this point in time. Many of these projects involve the communications function, drawing on their historical competencies. Projects that the organisations are engaged in include running sustainable development networks and environmental observatories, preparing content on climate change for community radio, disseminating information about local climate change projects to the media, raising awareness amongst indigenous people in the Congo around environmental conservation and supporting income-generating activities for these communities, providing a platform for civil society activities involving the environment, and working as a content partner on climate change and health issues.

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[360] For examples of projects or work that organisations are involved in, see Appendix 1.4.
[361] The sixth, based in South Korea, attaches a low priority to climate change.

Nine out of the 15 respondents giving climate change a medium strategic priority consider it a cross-cutting concern in that organisation, rather than a discrete project.

Of the eight respondents who gave climate change a "low" priority, only one was involved in a climate change project, which involved "collaborating with other civil society initiatives". One respondent had submitted a funding proposal which was rejected, and other projects are in the pipeline. Another respondent described its engagement as "aspirational". All except one of the respondents (South Korea) are based in developing countries. Only one saw climate change as a cross-cutting concern.[362]

Table 5 below shows that all together 61% of the respondents consider climate change a cross-cutting concern in their organisation, rather than a issue particular to a single project. This suggests that even if an organisation gives climate change a "medium" priority in its work, it nevertheless is a concern that filters across different projects, and informs strategic discussions in the organisation generally. As the above analysis also suggests, although it will not be the case in all instances, there is a match between considering climate change a high strategic priority, and a cross-cutting concern in an organisation, and considering it a "low" priority and discrete project. This can be taken to indicate the extent to which climate change is mainstreamed in an organisation's work, even if the interest in the field is at the planning stage.

	No. of organisations	%
Cross-cutting	16	53
Single project	11	37
No response	3	10

Table 5: Influence of Climate Change in Organisation

It is clear from the above that the organisations that are engaged in climate change are engaged in several different kinds of projects, ranging from communications, to networking, education, monitoring and research, and in areas such as health at the local level. Some also appear to be engaged in technically-complex projects. However, the results also suggests that there is little common ground amongst organisations in developing countries as to the strategic priority that ought to be afforded to climate change.

In total 15 out of the 30 (50%) organisations surveyed are not currently involved in climate change initiatives, a percentage which is high and which can be contrasted with the observation that most respondents saw the need to be involved in climate change issues, some with a sense of clarity of commitment: "[I]n truth, it is now that we realise the issues, and day-to-day projects are born to address these issues". Only one organisation said it would not be involved in climate change issues "for the foreseeable future".

Overall this suggest the influence both the global focus on climate change is having on local strategic priorities – climate change is now firmly on the development agenda – as well as, possibly, the felt need to respond at the local level where the impact of climate change is most visible.

[362] As is to be expected, given the low strategic priority given to climate change, three did not answer the relevent question in this regard.

3.3. Specific Areas of Focus

The literature review conducted by Ospina and Heeks shows how the initial focus on ICTs and climate change in developed countries was on mitigation, with a gradual shift towards the potential of ICTs to play an important role in adaptation efforts in developing contexts. Their review also suggests how much of the experience of the potential for ICTs to play an adaptation role in developing contexts at this point is anecdotal, and that few "assessments [are] available in terms of their social and economic impacts" (p26).

Drawing on the Ospina and Heeks model of climate change engagement, respondents were asked what their specific areas of focus was in their climate change work. As Table 6 below suggests, although, as argued by Ospina and Heeks, the trend is towards focusing on adaptation efforts in developing countries, a number of respondents are involved – or see their strategy involving – mitigation efforts. As the results indicate, within the category of "mitigation", the majority of organisations focus on moving towards a knowledge economy generally, with a strong emphasis on using ICTs to modify consumption habits, and improve energy efficiency.

	No. of organisations	% of total orgs
Mitigation: Physical production (using ICTs to shift to the knowledge economy and reduce the impact of production on the environment)	11	37
Mitigation: Physical consumption (using ICTs to modify consumption habits)	8	27
Mitigation: Energy use (the role of ICTs in energy efficiency from a user's perspective – e.g. smart buildings; use of Green IT)	8	27
Mitigation: Energy generation and distribution (using ICTs for better energy management – e.g. smart grids)	2	7
TOTAL	**29**	

Table 6: Strategic Interest in Mitigation

All except one (South Korea) of the respondents based in developed countries have a strategic interest in mitigation efforts (in one notable instance this entails indirect involvement in fuel-efficient transport and sustainable housing). Three out of the six have an interest in adaptation interventions (based in South Korea, Netherlands and Switzerland), with the respondent based in South Korea exclusively interested in adaptation strategies. In the case of the organisation based in the Netherlands, its organisational work extends to India and Ghana, potentially accounting for its interest in adaptation. In the case of the organisation based and working in Switzerland (and partly in other countries in Europe), its interest in adaptation is specifically on socio-political inclusion and capacity building. This does begin to suggest that a framework which considers adaptation of interest primarily to developing countries, and mitigation an interest for developed countries, should be a tentative framework that helps to focus interventions but not necessarily limit them.

Table 7 suggests a number of respondents based and working in developing countries take monitoring as a key strategic focus area. Only one of the six organisations based in developed countries (Japan) saw monitoring as important, which could reflect the high level of monitoring and data capture already operational in those countries. The dearth of good climate data in the developing context has been widely noted, which could account for the interest in this field, including an interest in using technology such as mobile phones to develop community monitoring frameworks and projects. As has already been suggested, in some instances the monitoring projects undertaken appear substantial, as in the evaluation of land use and cover change in the Andes.

	No. of organisations	% of total orgs
Monitoring: Data capture (using ICTs to gather information on changes to the environment or climate)	9	30
Monitoring: Data presentation and dissemination (using ICTs to present, distribute or share the data that has been captured)	7	23
Monitoring: Data processing (using ICTs to record and analyse data that has been captured)	6	20
TOTAL	**22**	

Table 7: Strategic Interest in Monitoring

As Table 8 shows, respondents have a high strategic interest in adaptation interventions (in particular socio-political adaptation). This may be for several reasons, including the bias of this survey which would capture the perspectives of ICT4D organisations working in developing countries where adaptation efforts take primacy and where, in many instances, the tangible effects of climate change on local communities and the environment (e.g. the Andes) and unsustainable grassroots practices (e.g. the Congo) are apparent and more likely to provoke action.

It is also the case that adaptation issues – which include capacity building, awareness-raising, using community radio to share grassroots information, building inclusiveness, and so on – are traditional functions of many ICT4D organisations, as opposed to often more technical and specialised fields of monitoring and mitigation. This would suggest that climate change adaptation strategies, as with the communications function, can most readily be incorporated into current developmental interventions (e.g. an organisation working with local communities on sharing health information using mobile phones can easily begin to think about extending that to include issues of climate change and health). More specific, and technical interventions using ICTs to adapt to climate change, which may be specific to climate change, however, may prove more difficult for the ICT4D organisations to deliver, and would be dependent on external resources from donors or other partners.

	No. of organisations	% of total orgs
Adaptation: Socio-political (using ICTs for inclusiveness, and capacity building etc.)	17	57
Adaptation: ICTs, livelihoods and finance	5	17
Adaptation: ICTs and health	5	17
Adaptation: ICTs and water security	5	17
Adaptation: Habitat (e.g. using ICTs in dealing with human settlements, and population displacement)	3	10
Adaptation: ICTs and food security	3	10
TOTAL	**38**	

Table 8: Strategic Interest in Adaptation

Historically ICT4D organisations have played a supportive role in developmental processes that are already unfolding. Of the four areas of engagement identified by Ospina and Heeks, the strategic function – such as advocacy, awareness-raising and capacity development – of civil society actions is the easiest to identify. Table 9 shows that the majority of the respondents (77%) take their strategic focus area as awareness-raising and capacity building. A high number (60%) show an interest in policy advocacy and networking, with some already engaging in the field despite it being relatively new to them.[363] Few show an interest in carbon markets.

	No. of organisations	% of total orgs
Awareness and capacity building	23	77
Policy networks and advocacy	18	60
Technology transfer (including to communities)	10	33
Supporting or engaging in decision-making processes	9	30
Carbon markets	1	3

Table 9: Overview of Strategic Focus Areas

It is important to remember when considering the above results that a large number of the respondents (50%) are not currently involved in the implementation of climate change projects. The strategic interest of the organisations, in a number of instances, is therefore hypothetical.

[363] For a breakdown of policy advocacy activities, please see the Appendices.

3.4. Barriers to Engagement

Finally, respondents were asked what were the key barriers to their further engagement in climate changes issues. These have been summarised in Table 10.

Barriers	No. of mentions
Capacity strengthening	12
Unsupportive context	8
Funding	7
Access to relevant information	5
Strengthening of networks	1

Table 10: Barriers to Engagement

As the table shows, capacity strengthening was the most frequently mentioned need from respondents. This included training opportunities ("There are not enough training opportunities in the country on climate change and how to get involved"), the "skills for fundraising and research", and the need to engage volunteers to boost an organisation's capacity to engage on climate change issues.

The category of access to relevant information refers both to the need for information that can assist in making strategic decisions ("still a need for more information and orientation on the issues to see what could be our most strategic role in ICTs and climate change"), and the application of information at the local level ("There is not enough relevant information that can be shared with the majority of rural Nigerians.") This suggests a strong need for the translation of climate science and the role of ICT application at the local level.

The lack of a supportive context is an unexpected result in terms of a barrier to engagement. Clearly the context that the ICT4D organisations engage plays a strong part in determining the success of their advocacy efforts, and other needs, such as fundraising. The lack of a supportive context includes a low awareness amongst stakeholders about climate change issues ("Key stakeholders are not yet aware of the issues involved and how they can engage with the processes of climate change mitigation"/ "Limited number of professionals regard this as an important issue"), difficulty in securing funding for climate change projects, and a weak policy context that inhibits engagement. While serving as a cause for advocacy, the latter also points to an environment where the importance of ICTs and climate change is not recognised, which has the inverse effect of making policy advocacy difficult, and maybe even impossible in some countries. The challenge in implementing climate change projects in a 'weak' context was described by one respondent as a "conceptual barrier".

4. Conclusions

This paper began from the point of view that there is a practical need for ICT4D organisations in developing contexts to attend to climate change adaptation initiatives in the most vulnerable contexts. Through an overview of contributions to GISWatch on the theme of ICTs and environmental sustainability, and a survey of primarily GISWatch organisations, it sought to understand better how climate change is being taken up as a strategic priority in those organisations and what the barriers to engagement might be.

In doing so, a number of general findings are apparent. Firstly, there is a predominant strategic interest in adaptation strategies in ICT4D organisations working in developing contexts. In particular, there is an interest in using ICTs for inclusiveness and capacity building, which concurs with a general historical function of ICT4D organisations. However, this survey supports the reading offered by Ospina and Heeks that despite several significant interventions on the whole this interest is nascent and that a lot more concrete work needs to be done on the ground to fully realise the potential of ICTs to help with adaptation in communities.

Secondly, climate change is new to a notable number of ICT4D organisations surveyed here, which are still trying to properly understand how it fits into their organisational agendas. Although many have identified the broad areas of strategic engagement, and in doing so have a sense of their strategic priorities, this has not yet translated to projects on the ground. There are a number of reasons for this, including what appears to be an historical split between environmental concerns and ICT4D concerns (with some ICT4D organisations now playing catch-up), internal deliberations about whether or not environmental concerns are in fact important to the ICT activist's agenda, capacity in organisations, the new policy and technical terrain presented by the field, and a lack of an institutional context, including access to funding, to support innovative initiatives on the ground or to be receptive to advocacy drives.

As Kalas argues[364] the lessons and frameworks established in ICT4D communications practice (the "strategic tools")[365] can be applied to climate change. To the extent that traditional nodes and frameworks of engagement with institutions and other stakeholders can be leveraged in order to engage on issues of ICTs and climate change, climate change can be said to present a typical model of engagement for the ICT4D sector. Outside of the potential to implement adaptation strategies, this feels particularly important when it comes to policy advocacy, where, as far as climate change impacts the ICT4D sector at a policy level, the long-standing experience ICT4D advocates have developed in the policy arena can be leveraged in climate change causes. This experience in engaging in national and global fora in a crucial sense should prove invaluable. Kalas points out that climate change magnifies development inequalities; to the extent that these inequalities provoke political engagement and disagreement, political faultlines (such as North versus South; the plight of developed versus developing countries) are likely to be magnified too.

However, the climate change arena is atypical in at least the following respects:

Non-Traditional Partners

For many, and in a practical and concrete way, it involves 'non-traditional' partners such as environmental organisations and institutions, some of which have already engaged quite substantially in issues of ICTs in the context of climate change. Despite the historical engagement of ICT4D organisations in environmental issues, environmental causes have not necessarily continued to be systemic to ICT4D concerns. This is suggested in the process of editing the GISWatch report, where a number of organisations were either new to the issues being discussed, or partnered with other authors with experience. This relative

[364] Kalas, 2009. pp9-21
[365] ibid. p10

inexperience in the specific field of climate change has arguably created a disconnect between the agendas of environmentalists and key focus areas for ICT4D practitioners. This to the extent that environmental organisations (for example, the World Wildlife Fund) have in some instances engaged substantially in the potential of ICTs in the context of climate change – suggesting that there is something of an advocacy lag with the current status of ICT4D organisations playing 'catch-up' to the ICT policy imperatives that have already been developed by others. In this engagement with non-traditional partners, there is a need for clarity on the key learning experiences and expertise that ICT4D organisations bring to the partnership: their *usefulness*. This will, of course, differ from organisation to organisation and context to context. In some instances, ICT4D organisations can provide the technical expertise in these associations. Nevertheless, the argument provided by Kalas is one step in that direction, and there is a sense that this could be expanded on.

Unfamiliar Policy Contexts

Climate change is also atypical in that it engages unfamiliar policy contexts – that is, environmental policy, which has its own sets of actors, drivers, politics and institutions. One of the critical questions policy advocates around ICTs and climate change need to ask is where exactly to locate policy advocacy: in ICT policy, or environmental policy or elsewhere? This challenge is exacerbated when its comes to adaptation, given that the areas of focus are cross-cutting, and including things like local economics, health, education, agriculture, community safety (i.e. in the event of disasters) and the environment generally. At the level of mitigation, one might clearly see an advocacy strategy in working with traditional ICT policy partners – one can, for instance, clearly advocate for a policy on green ICT procurement – but when it comes to adaptation, it is more a case that ICT advocacy and awareness-raising needs to happen across a number of sectors. The strategic decision of where to locate advocacy drives may vary from country to country and may imply engaging with different stakeholders, in different fora – some of which require years of experience to engage fruitfully. In other words, in the absence of establishing strong cross-sectoral advocacy partnerships – where mutual agendas can be advocated for – questions of capacity in terms of time and resources can be raised in connection with the effectiveness of ICT4D organisations in engaging in policy advocacy generally in the environmental sphere.

In this regard, one can see how some organisations are ambivalent about engaging in the field of ICTs and environmental sustainability. The atypical nature of climate change suggests that a significant shift in advocacy behaviour is necessary in order to create a systemic response, at least at the policy level. This to the extent that one could argue that while associations with environmental agendas may be productive, a focus on climate change specifically may only happen on a superficial level (at the level of 'moral support' or 'support in principle') for some individual ICT4D organisations rather than at the detailed engagements seen in other policy advocacy drives, such as those at the Internet Governance Forum or World Summit on the Information Society. Given this, anything other than 'engagement in principle' (which one survey respondent called the "well-wisher level") might detract from current ICT4D agendas and strategies which still require attention unless an appropriate multi-stakeholder engagement forum can be created.

Thirdly, while there is a predominant strategic interest in adaptation in the developing context, the responses also highlight there is an interest *across* the field of climate change response, and at many levels: local, national, regional and global. This much is suggested by one respondent, whose survey comment is worth quoting in full to get an idea of the kind of textured response ICT4D organisations can offer in the field:

> ICTs and climate change is a junction with few impacts in Mexico. Even climate change advocacy is a new field for Mexican civil society groups. From the three traditional sectors talking about climate change (government, industry and civil society) I can identify groups with different perspectives and visions. In the civil sector there are three perspectives at least. The position of one initiative is about being independent of official governments at both levels, national and international. This initiative congregates several small collectives and groups in rural and urban areas. Its work is starting, and it is deeply intense. They try to deal with climate change through direct community actions. The second initiative groups NGOs and international organisations like Oxfam, Greenpeace etc. They are interested in public policy advocacy related to governments, but keep a critical position. They also develop community actions. And there is a third initiative, which is working in areas very related to governments and its projects. The strategy of [the respondent's organisation] is to keep and develop relationships with most of the civil society initiatives.

The heterogeneous nature of ICT4D organisations, and their relatively fluid framework of engagement suggests that an institutional agenda (e.g. donor or government) should not seek to overdetermine the strategic emphasis of ICT4D organisations in relation to climate change in the developing context. Rather, their role should be conceptualised as relatively fluid, operating at many levels, and engaging horizontally at many points, and that in this sense the strategic focus of ICT4D organisations should be self-determined, and shaped by interests and competencies. ICT4D actors themselves, who are intimately engaged in their own work, would most readily see these opportunities.

Similarly, it does seem that ICT4D organisations in general have a broad appreciation and interest in ICTs and environmental sustainability, and that interventions in different fields, like e-waste and climate change, overlap. While climate change interventions may be specific, there is a sense that there is value in encouraging (or at least better understanding) the growing broader environmental consciousness in the sector. There is a sense here where the *urgency* to mainstream climate change concerns, and the felt sense of a need to prioritise adaptation interventions in the developing context, needs to be balanced by the perhaps longer-term value of conceptualising the interstice of ICTs and the environment more broadly. For instance, it makes little sense to advocate for climate change response, but then to ignore waste practices in a project or organisation or even at a government policy level. And as has been well documented, besides the impact that production, 'disposable' technology, and waste incineration has on carbon emissions, in many instances vulnerable communities are equally vulnerable to improperly managed and recycled e-waste, and in some instances more so.

While this paper does not explore this point, it tentatively suggests that a sustainable long-term response to climate change by ICT4D organisations implies a broader conceptualisation of environmental sustainability, and a framework where strategies can be understood in a way that does not unnecessarily create a discrete compartamentalisation of concerns, whether this entails a strategic focus on climate change in line with the Ospina and Heeks model, or an emphasis across various fields of environmental sustainability.

It is important to stress that this is a sample survey and overview, and therefore should be taken to yield illustrative results. A more comprehensive survey clearly might show something different. At the same time, the field of ICTs and climate change is a rapidly changing one, with important drivers at play, including donors, and global institutions like the International Telecommunication Union and Organisation for Economic Co-operation and Development (OECD). This means that attitudes, and engagement in the issues at this point in time, may change in the medium or even short term.

Priorities for Future Research

The survey suggests a number of strands for interventions that are needed in order to support the engagement of ICT4D organisations on climate change issues. These include capacity building, knowledge sharing, and documenting innovative examples, resources and tools that will increase their understanding and ability to strategically engage in the area.

A number of these interventions might have research components. For instance, a possible research priority could include distilling, in a systematic way, the learning experiences of ICT4D organisations that have been involved in the monitoring and documenting of the experiences of local communities, so that a clear picture of methodologies and practices can begin to unfold. (Some best practices suggested by the survey are presented in Appendix 1.5.) Given the specificities and complexities of the different sectoral responses when it comes to adaptation, these experiences may need to be structured according to specific sectors, rather than from the perspective of ICTs generally. Systematic information collection on the topic of ICTs and climate change and the translation of concepts for the local level would be useful, as would an analysis of ICT tools and practices that can be used to mitigate or adapt to climate change, and their appropriateness given the limitations and possibilities of different contexts.

There does appear to be a general need for the development of capacity building and training modules suited to local contexts that can be used to raise awareness and change behaviour amongst communities and organisations. These would have an element of research to them given the relative newness of the field – they may, for instance, involve focus group studies in order to properly pitch training interventions, while considering issues such as skills levels and appropriate technology. There also appears to be a need to better understand donor agendas in the field of ICT adaptation to climate change more generally, and some forward-looking mapping of these agendas would be useful. Research into the specific country institutional contexts that enable (or disable) a climate change response would also help shape and sharpen ICT-related interventions.

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Appendix 1. List of GISWatch Country Report Authors

Country	Organisation
Argentina	Nodo TAU
Australia	EngageMedia
Bangladesh	Bytes for All
Benin	GOREeTIC
Bolivia	NETWORKS Foundation
Bosnia and Herzegovina	oneworld – platform for southeast europe (owpsee) foundation
Brazil	GPOPAI
Bulgaria	BlueLink
Cameroon	PROTEGE QV
Chile	Centro de Investigación de la Inclusión Digital y Sociedad del Conocimiento/Mujeres en Conexion; ONG Derechos Digitales
Colombia	Colnodo
Congo, Democratic Republic of (DRC)	Alternatives; University of Cape Town
Congo, Republic of	AZUR Développement
Costa Rica	Sulá Batsú
Croatia	ZaMirNET
Ecuador	IMAGINAR
Egypt	ArabDev
Ethiopia	Ethiopian Free & Open Source Software Network (EFOSSNet)
France	VECAM
India	Digital Empowerment Foundation
Iraq	Arab Knowledge and Management Society
Iran	Arseh Sevom
Jamaica	Telecommunications Policy and Management Programme (TPM), University of the West Indies, Mona
Japan	Institute for InfoSocionomics, Tama University; Nomura Research Institute (NRI)
Jordan	Alarab Alayawm
Kazakhstan	Andrew Beklemishev
Kenya	KICTANet
Korea, Republic of	Korean Progressive Network Jinbonet
Kyrgyzstan	Civil Initiative on Internet Policy (CIIP)
Mexico	LaNeta
Morocco	DiploFoundation
Nepal	Panos South Asia
Netherlands	Enviu
Nigeria	Fantsuam Foundation
Occupied Palestinian Territory	Applied Information Management
Pakistan	Bytes for All
Peru	Consorcio para el Desarrollo Sostenible de la Ecorregión

	Andina
Philippines	Foundation for Media Alternatives (FMA)
Romania	StrawberryNet
Rwanda	Media High Council
Saudi Arabia	Saudi Arabian Strategic Internet Consulting (SASIc)
Senegal	GOREeTIC
South Africa	groundwork
Spain	Pangea; Tecnologia per Tothom (TxT)
Sweden	APC
Switzerland	comunica-ch
Syria	Anas Tawileh
Uganda	Women of Uganda Network (WOUGNET)
United Kingdom	GreenNet
Uruguay	ObservaTIC, Universidad de la República
Uzbekistan	GIPI Uzbekistan
Venezuela	EsLaRed
Zimbabwe	e-Knowledge for Women in Southern Africa (EKOWISA)

Appendix 2. List of Survey Respondents

Respondent organisation	Countries in which the organisation works
Korean Progressive Network Jinbonet	South Korea
Bytes for All and Bangladesh Open Source Network	Bangladesh
UNECA	All of Africa
Telecommunications Policy and Management Programme, University of the West Indies, Mona Campus, Jamaica	Jamaica, Trinidada and Tobago, Barbados and other CARICOM countries
Foundation for Media Alternatives	Philippines mainly
ONG ORIDEV	Républic of BENIN
LaNeta	Mexico
Nodo TAU	Argentina
AZUR Development	Republic of Congo
Comunica-ch	Switzerland and partly Europe
ArabDev	Egypt
PROTEGE QV	Cameroon
Owpsee	Western Balkans
ZaMirNET	Croatia
Colnodo	Colombia
Centro de Investigación de la Inclusion Digital y Sociedad del Conocimiento Research Center for the Digital Inclusion and Knowledge Society	Chile
SANGONet	Southern Africa, East Africa
Pangea	Spain
Ekowisa	Zimbabwe, Zambia
StrawberryNet Foundation	Romania
Fantsuam Foundation	Nigeria
Enviu	Netherlands, India, Ghana
Digital Empowerment Foundation	India, Sri Lanka, Bangladesh
Women of Uganda Network (WOUGNET)	Uganda
GreenNet	UK
CONDESAN	Venezuela, Colombia, Ecuador, Perú, Bolivia, Argentina and Chile
NGO Derechos Digitales	Chile
ALIN	Kenya, Uganda and Tanzania
Panos South Asia	Nepal, India, Pakistan, Sri Lanka, Bangladesh, Bhutan and Afghanistan
Institute for InfoSocionomics, Tama University	Japan

Appendix 3. Geographic Areas of Work of Survey Respondents

Region	No. of organisations working in region
Africa	
Eastern Africa	8
Central and Western Africa	6
Northern Africa	2
Southern Africa	2
	18
Asia	
South-central and South-eastern Asia	13
Eastern Asia	2
Western Asia	0
	15
Europe	
Eastern and Southern Europe	4
Western and Northern Europe	3
	7
America	
Latin America and the Caribbean	15
Central America	1
North America	0
	16
Oceana	
Oceana	0
TOTAL	56

Appendix 4. ICTs and Climate Change Projects and Initiatives

Examples of awareness-raising projects/work surveyed organisations were involved in		Examples of policy advocacy work surveyed organisations were involved in
Desktop research and document review; interviews and report writing		Workshops (e.g. a post-Copenhagen workshop on climate change involving scientists and policy-makers; helping institutions like the ITU organise workshops on ICTs and climate change)
Industrial and academic research		Developing policy frameworks (e.g. the African Innovation Framework, which advocates for low-carbon growth and development strategies)
Content development and access to information and knowledge (e.g. one organisation is a content partner of a project called "Climate change and health"; projects in Africa using web 2.0 tools; printed briefings, accessible summaries of research and community case studies)		Engaging regional policy bodies/institutions (e.g. National Information and Communication Infrastructure (NICI) in Africa)
Working with the youth (e.g. one organisation was involved in a high-school essay competition on ICTs and climate change and a young researchers competition on the same topic)		Engaging telecoms providers (e.g. trying to get telecoms operations in the Caribbean to consider mitigation and reduction in non-renewable energy consumption)
Collaborations with other initiatives (such as www.dialogoclimatico.org)		Engaging the academic community
Engaging the media (e.g. distributing information to the media)		Engaging governments (e.g. looking to get non-renewable energy consumption on the national policy agenda in the Caribbean)
Working with local communities (including indigenous communities around forest preservation, income generation, water security, the destruction of farmland by illegal miners, and assessments of perceptions in rural communities around climate change)		Support of initiatives that focus on the reduction of energy consumption and the adoption of green ICTs
Working with community radio (content development);		Conducting research to highlight policy gaps
Running environmental initiatives (such as the Sustainable Development Network in Colombia)		Engaging in policies focused on the prevention of violent conflict (e.g. that might occur as a result of water shortages caused by climate change)
Projects that involve fuel-efficient transport and sustainable housing		Technological policy (e.g. advocating the use of open source software, and refurbished computers)
Documentation of knowledge, practices and policy regarding climate change (e.g. in the Andes)		Participating in policy advocacy networks (e.g. GreeningIT network started by APC)
Long-term evaluations of land use and cover change (e.g. in Andes)		Advocating for the inclusion of climate change as a topic in school curricula (e.g. primary schools and rural schools)
Running online information nodes		Information dissemination and developing "accurate" information (as one respondent put it, "policies on climate change are mostly based on inaccurate information.")
		To promote the application of technology (e.g. in Nepal, encouraging villagers to use technology to get connected, and to monitor the glacier lake level at Imja Lake)
		Promoting research (e.g. on smart grids)

Chapter 7: Informational Governance of Climate Change Organisations

LAURENCE L. DELINA

Executive Summary

Climate change has emerged as a key global issue, and increasing numbers of organisations are seeking to address this issue in various ways. These "climate change organisations" are found at different levels, from the international organisations of the UN system through national ministries and down to local government and community organisations.

There is recent and growing recognition that information and communication technologies (ICTs) play an important role in climate change monitoring, mitigation and adaptation. This presents a strategic challenge to climate change organisations; the more so since – to date – there has been little analysis of how these organisations should build ICTs into their strategic thinking.

This paper therefore provides guidance for local, national and international organisations responding to climate change on how to build "informational governance": the effective response that both incorporates ICTs into a strategy for external climate change action, and which utilises ICTs as a tool for the internal planning and implementation of organisational climate change strategy.

It does this by identifying the key factors required for effective informational governance, i.e. for effective strategic use of ICTs by climate change organisations. Those factors are categorised as arrangements (organisational presence and structure, and climate-ICT initiatives); frameworks (focus, strategy and resources); coordination (horizontally/vertically, internationally, and with other stakeholders); and accountability. These are presented in the form of questions that climate change organisations can ask themselves in order to identify current challenges and opportunities, to build a firmer foundation for effective informational governance, and to thus enable a better climate change response.

1. Introduction

Damage to the environment has crossed national borders and generations at the same time that the world becomes interconnected because of globalisation[366]. Climate change is among those problems whose effects know no boundaries. It affects developed and developing countries alike. However, the ability to adapt to these changes is not uniform across countries. While London may be able to construct sophisticated mechanisms to save the city from a projected sea level rise, more vulnerable Dhaka could apparently not given its current level of development. Human settlement patterns are seen to be potentially disrupted by climate and weather pressures with the poorest communities likely to be the most vulnerable since they are the most directly dependent on natural resource systems and have the least resources to adjust to change[367]. Climate change is indeed one of the defining development issues of our time.

An unprecedented transformation of economic and social development is required for effective response to the global climate challenge. Climate change is a problem that is tied to a wide array of policy areas – transportation, energy, water, technology, etc. It is an issue that requires integrated action – monitoring, mitigation, and adaptation – at multiple levels of governance (local to national and international) within the spheres of politics, economics, and society. This suggests the paramount importance of understanding climate change governance from the perspective of organisations and their roles at different levels of governance.

In this paper, we refer to these organisations as "climate change organisations" to mean the entities whose activities are in one way or another aimed at monitoring climate data (such as the work of the World Meteorological Organisation (WMO) and national meteorology agencies), mitigating the effects of climate change (such as electricity suppliers investing in renewable energy technology and smart grid distribution), and adapting to the effects of the changing climate (such as disaster management agencies). In practice, organisations may combine these activities, e.g. the National Board on Climate Change which acts as a collegial body for climate monitoring, mitigation and adaptation in Indonesia. The Indonesian Board, like other country committees and ministries, operates at the national, macro level. At the supra-macro – regional and international – level, are bodies like WMO and other agencies of the UN. At the micro level are community-based organisations (often focused on adaptation) such as Barotseland.com in Western Zambia, which operates the Lyambai Vulnerability and Adaptation Project.

Regardless of governance location and climate action, the struggle to keep up with the complex, diffuse impacts of modern technologies[368], especially information and communication technologies (ICTs)[369] has always confronted climate change organisations. The role ICT plays in the wide gamut of the climate change agenda has been apparent. ICTs can function as an efficient means of knowledge collection and sharing. These new technologies provide a dynamic way

[366] Mason, 2008; Esty, 2008; Haas, 1999.
[367] Meadowcroft, 2009.
[368] Mason, 2008:8.
[369] ICT, in this paper, primarily refers to digital computer technology, the protocols used to connect these together and the software which enables human interaction with these tools. It encompasses the familiar desktop and laptop computer, mobile telephony, digital photography, and wired and wireless networks, including the Internet (Kennedy, 2010; FAO, 2010:39; Kalas & Finlay, 2009). In the particular context of climate change institutional governance, ICT also spans radio, television and other traditional media, as well as new media and satellite-based technologies, remote sensors connected to a central monitoring service, and mobile sensing devices.

for knowledge development and instant sharing of various perspectives[370]. Use of ICTs is rapidly spreading thereby creating new spaces, opportunities and challenges for developing countries that are most vulnerable to climate change impacts. Institutions[371] and organisations, as expected, play an important role in mediating climate action. Yet, a review of available literature in the field of ICTs, climate change and development[372] suggests that governance of climate change organisations and their usage of ICTs in practice is still one of the least explored areas for analysis.

With the emergence of climate change as a key policy issue and the implied significance of ICTs in climate change action, climate change organisations at different levels of governance need to adjust in order to incorporate the potential of ICTs into their strategies to meet climate-related goals and objectives. These organisations possess distinct and complementary roles in developing strategies for climate action[373]. Yet, given the diffusion of environmental governance practice in various organisations, limited analysis has taken place to date on how these organisations implement policy processes to address climate change and recognise the major potential and role of ICTs.

Despite the world becoming increasingly interconnected by flows of information, trade and technology, many perceive organisation-building to be fragmented, poorly coordinated, and inapt in dealing with the escalating speed of informational and climatic changes. Governance for climate change is increasingly non-optional as adopting appropriate responses to climate change increasingly becomes a norm for 'good governance' at all levels[374]. Yet those responses must now also include an understanding of ICTs.

Recognising the close links that exist between governance in climate change organisations and the achievement of development outcomes, alongside the increasing use of ICTs within climate and development contexts, this paper seeks to review existing literature on environmental governance across developing countries and international organisations focusing on the use of ICTs in climate change action within and outside their organisations. Particularly, focus will be on understanding the roles, procedures and mechanisms of these organisations. ICTs will be introduced as strategic tools that have the potential and role of contributing towards effective governance and therefore, helping to enable strategies for climate change action. Specifically, this paper aims to take stock of existing knowledge and practical applications on the potential and role of ICTs in climate change action by climate change organisations; identify the elements necessary for effective governance for climate change action at different levels; identify challenges; and recommend policy actions to advance the emerging notion of "informational governance".

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[370] FAO, 2009; Kalas & Finlay, 2009.

[371] Institutions include both the legal entities and informal organisations for climate change monitoring, mitigation, and adaptation including the rules and processes within which they operate. Although 'organisations' are theoretically different from 'institutions', most international relations writers treat both terms as synonyms (Haas & Haas, 2002). They are used interchangeably in this paper.

[372] Ospina and Heeks, 2010a.

[373] Schreurs, 2010.

[374] Meadowcroft,2009.

2. Review of Literature and Model for Analysis

In this section, we take a quick look at our understanding of organisations and governance in general. Then, we try to associate these concepts with the potential and role of ICTs on climate change action and identify elements that make up the notion of informational governance.

Recognising that organisations have a key role in both the selection and implementation of policy for climate change action, it is also appropriate to understand the process of their formation including the frameworks that define their arrangements[375]. Institutions[376] are organised by both informal organisations (such as family groupings and power relations) and formal organisations (such as those of the government, private and NGO sectors) [377]. The process of organisation often required complex and long term sub-processes of institutional evolution, cross national imitation and learning, and iterative lesson drawing and design[378]. Today, governance institutions are identified with their well known legislative mechanisms, representative organisations, federal structures, functional differentiation of ministries, professional bureaucracies, policy frameworks and so on[379].

Through the decades, attention on the focus of governance, especially in developing countries, has been about 'accelerating' development – a multi dimensional process involving economic, social, and political advance. Modern organisations came into being across the developed world, spreading later to developing countries since the late 1960s[380]. At the multilateral level, international environmental governance has been evolving for more than thirty five years as the international community attempted to address ecological externalities brought about by economic globalisation[381].

Nevertheless, environmental governance institutions (including obviously those involved with climate change action) are perceived as weak compared to more established areas of government competence[382]. Thus, a further phase of better governance practices in these organisations is apparently required on the basis of its importance, development imperative, and immediate necessity for action. This further extends to the use of ICTs in creating, harnessing and delivering effective climate change governance. The next section attempts to merge these elements and conceptualise the notion of informational governance of climate change organisations.

2.1. Conceptualising and Modelling Informational Governance of Climate Change Organisations

This paper is developed based on the recognition of a seemingly complex set of relationships existing between organisations, environmental governance, climate change and tools without removing development goals from the picture. We put a premium on the use of ICTs as strategic tools for meeting these goals. The

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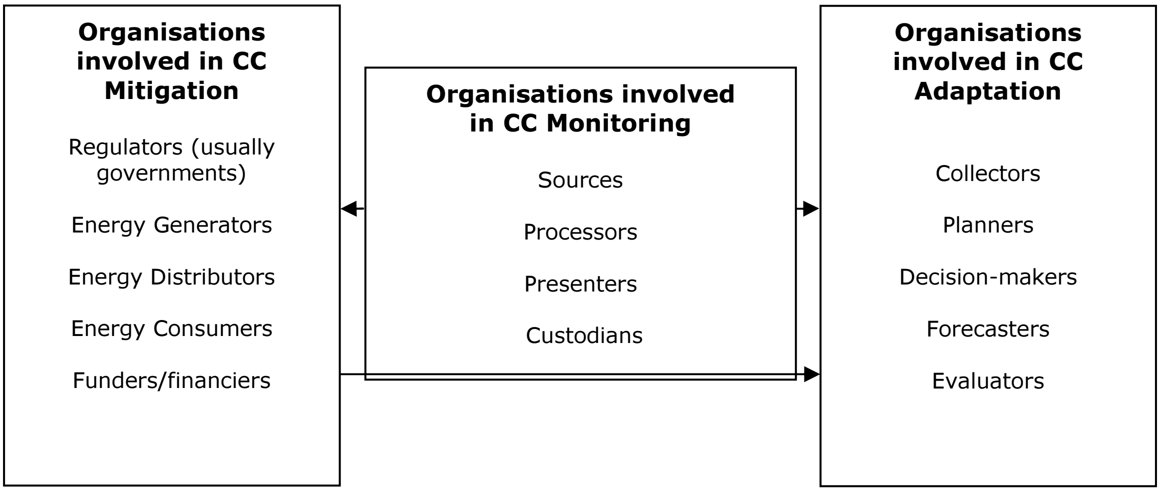
[375] The concept of "arrangements" and "frameworks" are described in the latter part of the paper.
[376] In this paper, we focus on established formal organisations.
[377] Lowndes,1996 in Ospina & Heeks, 2010a.
[378] Meadowcroft,2009.
[379] Ibid.
[380] Ibid.
[381] Haas, 1999:103; Pelletier, 2010.
[382] Esty, 2008.

linkages that exist between these concepts will be illustrated in Figures 1 to 6, building an overall picture of informational governance[383].

Climate change organisations are currently typified as having three distinct "personalities" based on their functions in climate change action – monitoring, mitigation and adaptation. The chain affecting the various dimensions of these actions relative to the utilisation of ICTs is reflected in Figure 1.



Source: Kalas & Finlay 2009, Ospina & Heeks 2010

Figure 1: Linkages between Climate Change Organisations, their Functions in different Climate Change Actions, and the their Functional Relations to ICT Tools

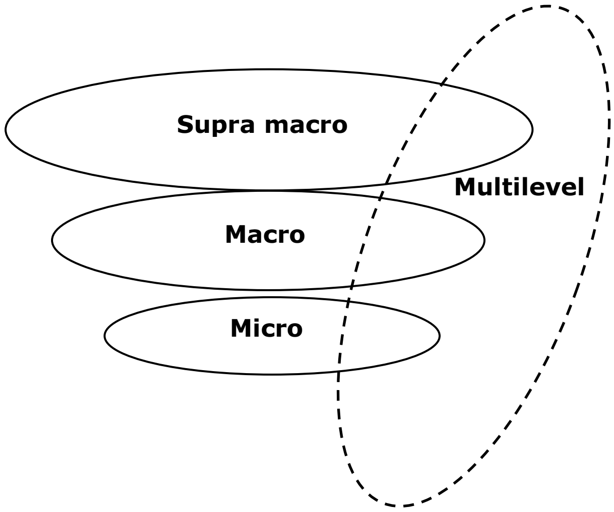
It follows from Figure 1 that although the three areas for climate action are distinct from each other, they are intertwined such that the activities in one sphere affect those of the others. This may affect individual organisations, some of which work in more than one field of climate change action. It may also affect multiple organisations. For instance, organisations involved in monitoring activities are expected to share their data to organisations involved in mitigation and adaptation to ensure that relevant actions are carried out, and vice versa.

Porosity across these organisations not only exists in terms of varied actions but also in relation to their locations in the various jurisdictional scales and different levels of governance. Since the pathways of actual and potential harm that climate change brings have provoked responses at these levels, a multi-sectoral and multi-level approach is imperative.

This approach has been succinctly described by neoinstitutionalism as a movement involving coordination among networks and actors from different types and level of organisations. Multi-level governance emerges as a conceptual approach that steps away from the assumptions that national government at the macro level is the dominant policy making unit towards policy making that involves actors within a 'nested hierarchical set of government levels'[384]. Actors of multilevel governance may come from community organisations, NGOs, and people's organisations, private organisations, local governments, national governments, and international organisations.

[383] Aside from this author, Kennedy (2010) has also recently provided a general description of this notion albeit in the context of law.
[384] Marsden & Rye, 2010

Recognising this approach to climate change action, climate change governance must thus be seen as multi-level, spanning three principal units of analysis: the micro (community or local level), macro (national level), and supra macro (international level).



Source: Author

Figure 2: Location of Climate Change Organisations at the Three Levels of Governance

Regardless of their locations and actions, however, the functions of climate change organisations are related with how, when and where they use ICT tools. The following sections describe this; albeit briefly since these roles have been described in greater detail elsewhere, and the intention here is just to illustrate the ways in which ICTs can participate in climate change action. The focus of these sections is on this "external" role of ICTs, but we also note and will incorporate their more "internal" role as a tool that can generically assist organisations in the planning and implementation of their organisational strategies.

2.1.1. Climate Change Monitoring Organisations: Activities and ICT Tools

Generally, this type of organisation gathers and distributes key data. With this information, organisations stress the potential and use of accurate indicators to increase the possibilities of mitigating climate change and of helping developing countries in particular to adapt to weather events. Access to high quality, timely data is central to facing the challenges of climate change and ICT has been considered as key to achieving this. At the moment, ICTs are used in monitoring systems for forecasting weather, predicting climate changes, and mitigating the effects of natural disasters[385].

Figure 3 shows how ICTs could be specifically utilised by organisations in climate data monitoring. It breaks this down by stages in the information system process; identifying that climate change monitoring organisations basically function as data sources, processors, presenters and storekeepers. Across these four activities, specific tasks are involved and ICT tools are utilised.

[385] ITU, 2009

	Sourcing	Processing	Presenting	Storing
Organisations use ICTs to	…collect data from all available sources	…convert raw data into useful information (either for adaptation or mitigation)	…provide appropriate information to all stakeholders at the right time	…store information for future retrieval and sharing with networks
Examples of ICT tools	Remote sensing techniques; sensor-based networks	Software-based systems	Media, including internet, SMS and broadcast (especially radio); telecentres	Digital databases and repositories
Examples of organisations	Supra macro (World Meteorological Organisation through the Global Climate Observing System (GCOS))	Supra macro (World Meteorological Organisation; World Bank Group[386]) Macro (national government agencies)	Supra macro (World Meteorological Organisation; World Bank Group) Macro (national government agencies)	Supra macro (World Meteorological Organisation; World Bank Group) Macro (national government agencies)

Source: Author's compilation from Kalas & Finlay 2009:16 and Ospina & Heeks 2010:16-17

Figure 3: Organisations for Climate Change Monitoring: Activities and ICT Tools

2.1.2. Climate Change Mitigation Organisations: Activities and ICT Tools

Climate change organisations involved in mitigation activities need to understand emission sources, cost-effective abatement procedures, and policy approaches allowing ICTs to be used in identifying 'no regrets' policies which can encourage mitigation at little or negative economic cost[387]. Exploring environmentally-sustainable business practices and models to transition towards a less carbon-intensive society is particularly relevant for developing countries[388]. Among these practices is the promising use of ICTs especially in energy efficiency. Within this strand, the potential of ICTs includes a variety of highly innovative applications aimed at improving energy efficiency in building, transport, communication and other sectors. Figure 4 shows how mitigation organisations could employ ICTs in their activities.

[386] The World Bank Group assembles and shares data to help set baselines for climate change, to identify effective public and private actions in adaptation and mitigation, to monitor progress on goals and targets, and to evaluate impacts. It provides and conducts research and shares findings which are mostly available online to help developing countries understand and address the impact of climate change (World Bank, n.d.)

[387] Meadowcroft, 2009.

[388] Ospina & Heeks, 2010:13.

	Consumption and Production	Energy Generation and Distribution	Energy Consumption
Organisations use ICTs to	…dematerialise goods and services	…ensure monitoring and minimum to zero losses	…advance energy efficiency at homes, offices, buildings, transport systems and industries
Examples of ICT tools	Journey substituting through online collaboration (VOIP, social networking); web-based applications; interactive media; satellite imagery	'Smart' grids; web-based applications	Green ICT, smart building design, green buildings, smart transport systems
Examples of organisations	All levels (organisational mitigation efforts))	Macro to micro (electricity companies - generators and distributors alike)	All levels (organisational mitigation efforts)

Source: Author's compilation from Kalas & Finlay 2009:16-17 and Ospina & Heeks 2010:15-16, 24-25

Figure 4: Organisations for Climate Change Mitigation: Activities and ICT Tools

The activities of climate change organisations involved in mitigation range from reducing emissions in material consumption and production to energy generation, distribution and consumption. Within the organisation itself, standards and procedures may be checked against energy efficiency (see, for example, the activities of the International Telecommunication Union (ITU) [389]). Carbon audits within the premises of organisations may also be undertaken to intensify the use of ICT tools in carbon footprint reduction. Several dematerialisation activities utilising ICT tools may be employed including virtual meetings and other online collaboration. The use of ICT in smart building design is also emerging in the construction and building sectors. These among others are bright prospects for many developing countries.

2.1.3. Climate Change Adaptation Organisations: Activities and ICT Tools

In developing countries, most organisational and programmatic focus has shifted from mitigation towards adaptation within the context of increasing international awareness over the magnitude of climate change and the impacts of extreme natural events to society and the economy. The organisational role of ICTs in the process of adaptation is presented in Figure 5.

[389] Johnson, 2010.

	Data collection	Analysis & Planning	Decision-making	Implementation & Management	Monitoring & Evaluation
Organisations use ICTs to	…collect, store and share data and information for developing appropriate adaptation strategies	…predict events (risk and early warning) and design appropriate adaptation strategies	…get the right information to the right people at the right time	…forecast, warn, and disseminate information and cope with short and long-term disaster	…provide an effective way to analyse, store and communicate the impact of adaptation strategies
Examples of ICT tools	Remote sensing techniques; sensor-based networks	Software-based modelling systems for scenario analysis	Media, including internet, SMS and broadcast (especially community radio); telecentres	Early warning systems and devices; emergency response systems	Software-based systems, digital databases, and repositories
Examples of organisations	Supra macro (World Meteorological Organisation through the Global Climate Observing System (GCOS); UN ESCAP[390]) Macro (national government agencies) Micro (local governments)	Supra macro (UN ESCAP[391]) Macro (national government agencies) Micro (local governments)	Macro (national government agencies) Micro (local governments)	Macro (national government agencies) Micro (local governments; community organisations, civil society)	Macro (national government agencies) Micro (local governments; community organisations, civil society)

Source: Author's compilation from Kalas & Finlay 2009:16, 18 and Ospina & Heeks 2010:17-20, 25

Figure 5: Organisations for Climate Change Adaptation: Activities and ICT Tools

The international community – realising that extreme weather conditions and natural disasters result from climate change – adopted the Hyogo Framework for Action in 2005 to strengthen disaster preparedness, enhance early warning systems, and identify, assess and monitor disaster risks[392]. The potential and use of ICTs in climate organisations with activities focused on adaptation have started

[390] ESCAP (2010) has recognised ICT as a major player in this field learning from the frequency and severity of disasters in the Asia Pacific region as exampled by the 2004 Indian Ocean tsunami and 2008 Cyclone Nargis in Myanmar.

[391] ESCAP launched in September 2010 the Drought Monitoring and Early Warning Cooperative Mechanism which provides satellite products for general drought monitoring and higher resolution products for identified high drought areas and assists members in developing localised products and services for relevant decision-making.

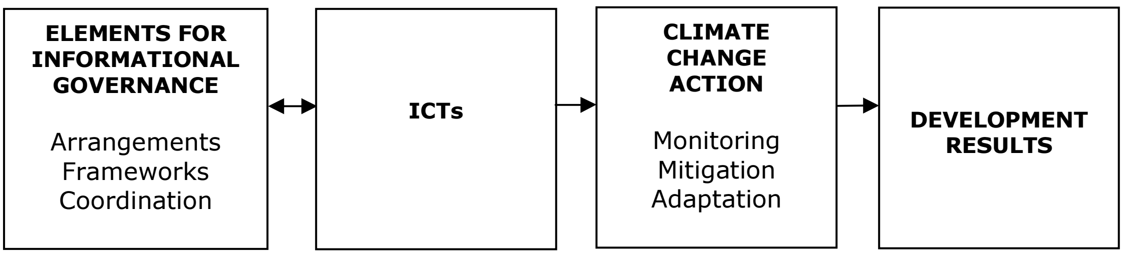
[392] ESCAP, 2009. Although "disaster risk reduction" and "climate change adaptation" have different origins, they overlap a great deal through common factor of weather and climate and the similar tools used. It makes sense therefore to consider them and implement them in a systematic and integrated manner (ISDR, 2009).

to emerge in the literature with examples such as the use of mobile phones in adaptation strategies[393]. Others include improving farmers' market information, raising agricultural production, and providing early warning during hydro-meteorological fluctuations to enable farmers to change cropping patterns[394]. In Figure 5, five adaptation activities are listed that – as for climate change monitoring – approximate to the stages of information systems operation: data collection, analysis and planning, decision making, implementation and management, and monitoring and evaluation. This series of activities could be taken as the procedural path of action for risk management. There are, of course, obvious activities that cross both adaptation and monitoring (as in 2.1.1).

2.2. Model for Informational Governance of Climate Change Organisations

The added value ICTs contribute as strategic tools for climate change action is well-known from other literature, and has only been briefly reprised here. As shown in Figures 3 to 5, the potential for ICTs in climate change activities is mostly accomplished through awareness raising, knowledge sharing and capacity development when viewed from an information systems perspective. The potential to use them as technologies for mitigation is also important. To dig deeper into this vast potential, we turn to the concept of "informational governance".

"Information governance" is the term we can apply to the use of ICTs as strategic tools in climate change governance. This concept integrates the key factors that help determine the role of ICTs in effective organisational governance for climate change action. This in turn, is intended to achieve development results amidst an uncertain climatic future. The concept could be best defined by using a model in which ICTs interact with a group of organisational properties that would enable organisations to monitor, mitigate, and adapt to climate change (see Figure 6).



Source: Author

Figure 6: Model for Informational Governance

The model allows us to analyse the dynamic interactions between organisational processes that play a role in the achievement of mitigation, adaptation and development at the three levels of analysis: supra macro, macro, and micro. The use of ICTs as strategic tools across these three levels implies that the tools must be an "integrated component of a development programme"[395]. The integration of ICT tools to development programmes is, therefore, contributory to the effectiveness of climate programmes in particular and climate organisations in general. The hypothesis and working assumption for this paper could then be stated as follows: good informational governance determines the effectiveness of ICT utilisation and development policy implementation in climate change

[393] Ospina and Heeks, 2010a.
[394] UNDG, n.d.
[395] Kalas & Finlay, 2009:14.

organisations in order to achieve development results. One fundamental organisational virtue that is required to respond to climate change and development is "effectiveness." Unless there is a promise that a policy mechanism will produce net benefits, there is little reason to invest in governance[396]. We posit the same argument for climate-ICT policy. Effectiveness, being the sine qua non of organisational design, could be realised in climate change organisations through informational governance.

Informational governance of climate change organisations covers the use of political authority, organisations, and resources (with special focus on ICTs as strategic tools) at all levels. This elucidates the number of spatial dimensions and issues that crosses the concept which generally include: structures[397], resources (people and ICTs, oftentimes finance), human capacity (including training), strategies[398] (such as direction-setting), climate policy development processes (including integrating organisational activities and interventions with related development programmes), funding mechanisms, the use and role of monitoring (standards, evaluation, and indicators)[399], compliance and enforcement to ensure accountability, research and innovation (for strategy delivery, review and organisational evolution), and interventions (including projects and programmes).

The scope of informational governance is indeed broad. At the same time, it is a relatively complex concept and not much has been written about it even in developed countries. This paper therefore seeks to provide a modest contribution in this emerging field by drawing upon experiences across countries and international organisations to better understand its key elements. As a caveat however, this approach should be seen as illustrative rather than comprehensive.

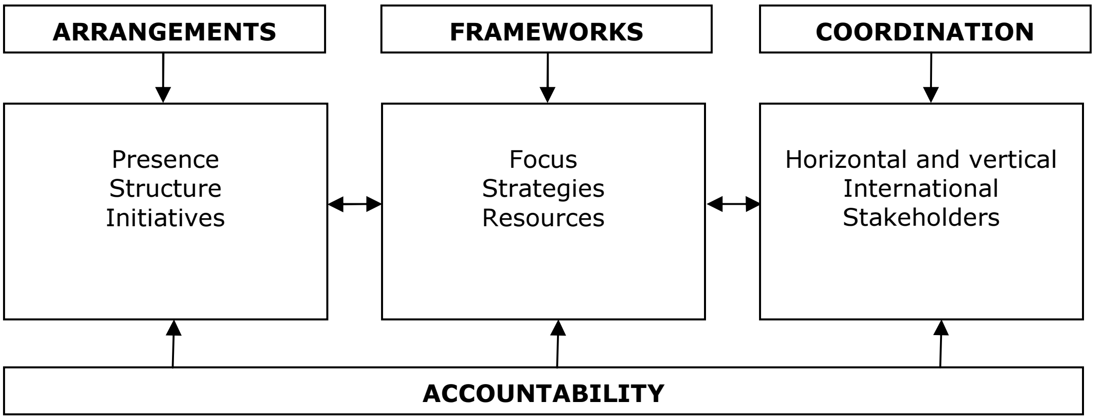
3. Informational Governance of Climate Change Organisations

To grasp the concept of informational governance, it is essential to start by identifying essential elements in organisations favourable in achieving optimal performance. We can identify four elements of informational governance: arrangements, frameworks, coordination, and accountability. These elements could be understood as the "means" for achieving an "end." We can posit that the "end" is best understood as something that defines an "effective organisation." Each of the first three elements, in turn, has underlying identifiers (see Figure 7) which are described in detail in 3.1, 3.2, and 3.3 respectively. Accountability, the fourth element for organisational effectiveness, is shown encompassing the first three elements. In order to provide a corresponding framework for these extended concepts, the model in Figure 6 is now supplemented by Figure 7 which lists the elements for ensuring effectiveness of informational governance.

To check whether these elements are present, at work, and responsive to climate change action, this paper suggests an assessment that could be done internally by organisations. A series of questions were identified at various levels of governance that need to be asked. As a caveat, it should be noted that this approach is by no means exhaustive, but does capture a substantial amount of practical information that would define effective informational governance at the micro, macro and supra macro level. Overall, this chain provides the support to

[396] Esty, 2008.
[397] Meadowcroft, 2009.
[398] Schreurs, 2010.
[399] FAO, 2009; FAO, 2010.

our assumption that effective ICT utilisation in climate change organisations enables the achievement of development results.



Source: Author

Figure 7: Elements for Effective Informational Governance for Climate Change Organisations

3.1. Arrangements of Climate Change Organisations

The first leg of effective informational governance involves organisational arrangements, which include the typologies and broad range of organisations involved in climate-ICT policy as well as their structures and initiatives. Overall, the typologies and structures of climate change organisations should be appropriate and congruent to the level of ICT resources allocated in order to produce and sustain climate change action. Their design and structure should be reflective of their desired results. Although a number of organisational designs exist such as those for energy efficiency institutions[400], it should be noted that there is no single universal model that fits all. With regards to organisational initiatives for climate action, any approach, strategy and procedure adopted to support ICT tools in climate action should, in general terms, be easily understood, written in simple terms, and well-communicated to stakeholders[401].

3.1.1. Presence

Organisational arrangements for climate-ICT policy exist variably across the three levels of governance. At the supra macro level, these arrangements take the form of international agencies (mostly attached to the United Nations), international NGOs, multilateral development banks, and private enterprises. At the macro level, these are usually in the form of ministries (oftentimes environment and energy ministries), specialist technical agencies (such as weather bureaus), energy generators and distributors, NGOs and private enterprises. At the micro level, climate change organisations may be seen as a division or a department of local governments, a community-based or civil society organisation. Their presence at each level is an important element in ensuring that appropriate climate change policies and actions are made, developed and implemented.

At the supra macro level, transboundary environmental issues through international regimes are a key issue[402]. At the macro and micro level, however,

[400] World Bank, 2008.
[401] Kalas & Finlay, 2009:44.
[402] See for example, Bulkeley, 2005; Siebenhuner, 2008; Ivanova, 2010.

specific governance measures are required[403]. Above all, though, there is a need for nation states to put up organisations capable of undertaking climate change governance.

Thus, it is important that at the national level, governments are able to respond to questions such as:

- Are there organisations at the level of the nation state that are primarily tasked to deal with climate change?
- If there are, what are these organisations?
- How do they exist? Is it at the level of a ministry, a specialised technical body, or as a committee consisting of multiple agencies?
- What are the constraints for establishing a primary climate change organisation in developing countries? How could these challenges be overcome?
- Does the nation state participate in the international climate change regime? How and in what capacity?

The responses to these questions signal whether at a baseline point, appropriate organisations have been put up to address climate change and involve themselves in a larger process at the supra macro level. A negative response to any of these questions provides the opportunity to create a primary organisation. Building an appropriate organisation at the macro level may be easy for some countries but may be difficult and take time especially in developing countries. Low-income countries should at least aim to develop a competent basic climate administration[404]. In summary, presence of a particular organisation established especially for climate change issues is a first signal of effective informational governance.

Local governments, especially in the most vulnerable developing countries have an important role in local adaptation and response, generally because they have the primary responsibility for a wide range of infrastructure and service provision, for implementation of regulatory frameworks, and because of their spatial proximity to the consequences of climate change. ETekwinin Municipality (previously a part of Durban Municipality in South Africa), for instance, through its own Environment Management Department developed the 'Headline Climate Change Adaptation Strategy' highlighting how key sectors should respond to climate change[405].

However, good local governance and management depends on the active engagement of other local stakeholders and a supportive national government[406]. The former is oftentimes represented by civil society groups facilitating effective climate change action, especially in evacuation and distribution of emergency supplies in the case of extreme events. National governments, on the other hand, have the key role in providing the legislative, financial and institutional basis within which micro-level organisations respond to climate change. It is therefore necessary that at the micro level of governance, the following questions are answered:

[403] Meadowcroft, 2008.
[404] Ibid.
[405] Dodman & Satterhwaite, 2008.
[406] Dodman & Satterhwaite, 2008.

- Does the local government have a lead division to identify and spearhead local initiatives on climate change issues especially in most vulnerable places in developing countries? How does this exist? Is this through some form of legislation or as an initiative of the local government?

- What kind of support does this division get from other levels of governance (such as national government, international organisations, and community stakeholders)?

- What types of non-governmental climate change organisations typically work at the micro level? How do they exist?

- How can local governments tap the capacity of civil society groups in climate change action?

3.1.2. Structures

An administrative structure is required to implement any kind of climate-ICT policy. While climate change organisations can perform any type of climate-ICT activity, there are situations when some of these functions could only be performed by governmental organisations, by the private sector, or through collaboration among organisations[407]. Whatever the case is, an appropriate structure is needed.

At the supra-macro setting, structures of international organisations are often defined by multilateral agreements involving different governments such as the case of many agencies of the United Nations[408]. However, there is widespread agreement that the international environmental regime suffers from significant design flaws and does not provide a functioning institutional structure[409]. This, in itself, is a big challenge especially since structure has direct implications for organisational effectiveness and legitimacy. At the macro level, governments are primarily responsible for designing the structures of climate organisations, whereas structures at the micro level may be defined by both the government and civil society.

Appropriate response can only be defined through appropriate organisational structuring, which in turn determines organisational needs and their set up at appropriate levels. Given these realities, it is important that structural frameworks for monitoring, addressing, and adapting to climate change are laid out by answering:

- What are the existing structural designs of climate change organisations at the supra macro, macro and micro level?

- How does the current organisational structure facilitate the need for effective climate-ICT policy?

- Does the current structure impede the organisation in programme delivery? What are these structural challenges?

Responses to climate-related emergencies also take a multilevel approach which involves collaboration among various organisations across the three levels. Nevertheless, the placement of local communities existing at the micro level is an important consideration for organisational structuring. Their role in climate

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407 Meadowcroft, 2009.
408 Pelletier, 2010.
409 Esty, 2008; Young, 2008

change action is understandably critical due to their familiarity with local circumstances that macro and supra macro organisations often do not have[410]. Citizen engagement through the use of ICT tools offers an opportunity given the scale of climate impacts[411]. This has important implications especially for adaptation activities.

3.1.3. Initiatives

Climate-ICT initiatives are programmes and activities involving ICT deployment for climate change actions. They represent another organisational condition for effective informational governance. There are a number of sound examples of initiatives across the three levels of governance in the form of symposia, seminars, development of e-toolkits, community-enabled models resulting from GIS, mobile applications, and others.

The scope of such initiatives was outlined above in Figures 3 to 5, and there and in the broader literature, examples are provided. One example of a climate-ICT initiative at the supra macro level is the ITU-developed e-Environment Toolkit and Readiness Index which responds to the need for a strategic planning framework to enhance the capacity of countries to use ICTs for environmental management. The Index is a practical tool for rapid assessment of a country's potential for using ICTs to help mitigate and adapt to environmental and climate change[412].

Awareness raising and knowledge sharing could be accomplished through symposia such as the ITU-sponsored international symposium on climate change in 2009[413]. UNESCO had also held a seminar in 2009 to identify learning materials and good practices on climate change education, and how to enhance their dissemination via suitable ICT tools[414]. UN ESCAP is also involved with training on the use of ICTs in adapting to climate change[415]. A final supra macro example is the use of the online Climate and Tourism Information Exchange Service in the activities of the World Tourism Organisation which have direct relevance for many highly vulnerable developing island states where tourism is a principal economic resource[416].

At the macro to the micro level, a number of climate-ICT initiatives could be listed. One is the agricultural clinics in India and online advisory service in Chile where rural communities, mostly farmers, get access to relevant information[417]. In addition to improving the links between micro systems and macro-level organisations in providing enabling conditions for climate adaptation, these kinds of initiatives have increased the information assets available and the capacity of human capital at the micro level, which obviously can be tapped during climate-related events[418].

Both traditional and emerging technologies have the potential for awareness raising and knowledge sharing[419]. Recognising this, climate change organisations in developing countries may exploit the potential of community radio, for instance, to help in informing and involving communities in local climate

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410 Schreurs, 2010
411 Ospina & Heeks, 2010:13
412 ITU, 2009
413 ITU, n.d.b
414 UNESCO, n.d.
415 ESCAP, 2009
416 World Tourism Organisation, n.d.
417 Stienen, Bruinsma & Neuman, 2007.
418 ESCAP, 2009.
419 ESCAP, 2009:3.

actions[420]. In the Caribbean, for example, collaboration among various organisations resulted to the launching of *My Island – My Community,* a regional drama serial aimed at building public awareness on climate change adaptation[421]. Evidence on other uses of ICT tools in climate action in developing countries is present in the literature[422].

However, informational governance does not end at simply having climate-ICT initiatives but in reflecting on the effectiveness of such initiatives, and in learning which performed well and which did not[423]. Thus it is important to ask:

- What are the good and bad practices in planning, implementing and monitoring climate-ICT initiatives that are similar to the initiative of the focal organisation, especially in developing countries?

- Where could the organisation find resources on climate-ICT initiatives? Are their repositories of good practices available?
- Upon identification of climate-ICT initiatives, how could macro and micro climate organisations in developing countries adopt and replicate the good ones while trying to avoid the bad ones?

- Where could ICT tools be best positioned to make these lessons available for other climate change organisations?

Responses to these questions allow climate change organisations to learn from each other and to replicate or adapt climate-ICT initiatives in their own situation. It also allows them to classify initiatives, procedures and actions which are working and which are not.

3.2. Frameworks of Climate Change Organisations

This organisational element confers authority, attracts attention and provides resources for the utilisation of ICTs in climate change and development policy implementation. The organisation must possess focus, establish strategies, and allocate (or be allocated with) funds, which in most cases could be enabled by an appropriate piece of legislation. At the macro level, such legislative frameworks oftentimes include: an articulation of government policy's purpose and intent, and the justification for government intervention. Across all levels, frameworks usually involve the inclusion of specific, quantitative, time-bound goals or targets, and provision of funding and other necessary resources.

Focus is inevitable to ensure organisational effectiveness and could be realised only if strategies for ICT mobilisation and utilisation are made available. The functions of ICTs as part of climate change action are incorporated into longer term development planning and practice in the organisation. Targets and goals often provide the solid basis for organising successful initiatives. In many cases, funding mechanisms to enable ICT use in informational governance are a serious challenge, especially in developing countries.

3.2.1. Focus

Organisational focus is an important indicator for the frameworks of climate change organisations to achieve effective informational governance since it

[420] Ospina & Heeks, 2010:25; Kalas & Finlay, 2009:22-24.
[421] PCI-Media Impact, 2010.
[422] See Ospina and Heeks, 2010:25-26; Kalas & Finlay, 2009:22-45 for examples.
[423] Ospina & Heeks, 2010:14; Kalas & Finlay, 2009:20.

provides the statement about how the organisation utilised (and will utilise) ICT tools and where it is headed. Organisational focus manifests in the context of responses that are made appropriate to the scope of the problem[424]. At each level, it is therefore helpful to ask:

- What is the primary focus of the organisation in the utilisation of ICT tools in climate change action? Is it specific to monitoring, mitigation or adaptation? Or does it cross these three?
- How has the focus evolved? What processes were involved in arriving at this statement?
- How is the focus conveyed? Is this written as a part of an important document such as the organisational mission?
- Does the organisational focus manifest itself in the current climate-ICT initiatives and future directions of the organisation?
- How does the organisation communicate its focus internally and externally?
- How are ICT tools placed in achieving organisational focus, and which ICT tools are included? Are they also utilised in the process of communicating the organisational focus?

Different problems warrant different responses. Whatever the case, the kind of organisational focusing should generally respond to the problem at hand. The potential and role of ICT tools in determining the problem is therefore significant in defining the primary focus of the organisation, the mode of conveying this focus to relevant stakeholders, and role of the tools in the process.

3.2.2. Strategies

In order to materialise organisational focus on the use of ICTs in climate action, strategies and plans are made to effectively implement climate initiatives[425]. Targeting and goal setting – from organising programmes to justifying funding, and obtaining resources – are necessary elements for strategy formulation since targets and goals provide the basis for initiatives. A common tool for measuring policy implementation is to compare actual data against targets. This measure determines whether strategies are effective or not. Whether the initiative is for monitoring, mitigation or adaptation, it is important that organisations lay out their targets at the beginning of their intervention and continually check their progress against these baselines. Throughout this process, ICT tools play important role.

- How does the organisation lay down its targets and goals in the effective utilisation of ICT tools in climate action? What are its strategies? Are these clearly worded and communicated to stakeholders?
- How does the organisation utilise ICT tools in the process of strategic implementation? Do ICTs also play a role in checking actual data against targets?

[424] See Schreurs, 2010 for examples.
[425] Ibid.

- How does the organisation utilise this information to strengthen climate-ICT initiatives?

- What are the barriers and challenges that developing countries face regarding access and capacity in adopting ICT tools in climate change action?

3.2.3. Resources

At different levels of governance, climate-ICT initiatives need to be assigned with adequate resources available to maximise the potential and role of ICTs. At this point however, no one has yet attempted to estimate the overall ICT requirements at any level. Incorporating ICTs into the functions of climate change organisations must take into account numerous resource issues – personnel, technical and financial especially. Funding provisions are critical when determining the framework of the organisation. The level of funding usually determines the scale of governance (as in the case of governance of energy efficiency institutions[426]). Nevertheless, funding should not always be seen as an external intervention rather it should also be considered as potentially emerging from within. It is important then that organisations are ready to respond to questions such as:

- What are the necessary ICT tools to be procured in the short and the long term? Does the organisation conduct an appropriate inventory to identify these?

- What skill sets are required and where do they currently exist? How should the organisation prepare its people to the influx of new technology in climate monitoring, mitigation and adaptation?

- What actions should the climate change organisation take to ensure it has appropriate tools?

- What are the available mechanisms for ensuring that developing countries have access to these tools?

- Where should funding come from? How could the organisation design its framework to be more independent of external funding, if possible?

The responses to these questions are related to choices about resources which need to be reflected in designing appropriate strategies. Although capacity building can take a long time, especially in developing countries where other development objectives are the priority, there are options available for countries to upgrade their equipment[427]. Possibilities range from applying for grants to approaching multilateral funders to collaborating with neighbouring countries at the sub regional level.

3.3. Coordination among Climate Change Organisations

The creation of coordination mechanisms both within and across the three levels of governance directly impacts the effectiveness of climate change policy, action and development results. The necessity for coordination is directly related to ensuring mobilisation of the complex network of organisations required for

[426] See Jollands, Gasc & Pasquier, 2009:35-36.
[427] ESCAP, 2009:4.

successful and effective informational governance. FAO further reports the necessity for alliances stressing that effective social change on any development issue emerges from alliances of social interests rather than from one specific programme[428]. Similarly, work on neoinstitutionalism trace the shift of governance away from the conventional process of public administration to a process involving actors from within and outside the aegis of public office[429].

In the neoinstitutionalism sense, capacity building, balancing structures, and maintaining flexibility are necessary for effective coordination[430]. These can lead to more comprehensive policies, improvements in climate-ICT implementation, efficiency in the utilisation of resources, and improved stakeholder participation. Although organisations may exhibit coordination either horizontally or vertically or both directions at the same time, coordination mechanisms always vary according to the inherent complexity of their arrangements. In sum, coordination is the mesh that ties the many elements of informational governance altogether.

3.3.1. Horizontal and Vertical Coordination

Coordination within and among climate organisations happens either horizontally or vertically where state and non-state actors play a variety of roles[431]. Horizontal coordination is especially recognised in the form of intra-agency cooperation at the macro level to address overlaps and duplication. This type of coordination allows for informed discussions among organisations at the same level of governance to ensure effective decision-making and good policy implementation. In informational governance, coordination provides opportunities for new ideas and allows efforts and ICT tools that are proven effective to be replicated at other levels. Moreover, coordination improves implementation, and helps identify and resolve policy gaps between micro, macro and supra macro strategies and policies.
Examples of coordination abound across the three level of governance. In China, for example, there is growing awareness that climate mitigation must involve a multilevel governance approach[432]. These approaches usually involve energy conservation and improved energy efficiency in action plans[433]. Climate change policies are coordinated vertically from China's 27 central government ministries and agencies all the way down through provinces and autonomous regions to individual cities. The same set-up could be observed in many developing countries.

Many of the governance structures necessary to assure effective vertical and horizontal collaboration among organisations, however, remain underdeveloped[434]; thus presenting a number of opportunities. In ensuring that organisations get optimal results out of coordination, it is important to ask these questions:

- What are the mechanisms adopted by governments to facilitate effective coordination in the horizontal (across agencies) and vertical (addressing porosity of the three levels of governance) directions?

- What are the existing coordination mechanisms at the level of the organisation? How about with other levels?

[428] FAO, 2009:7, 23-25.
[429] Paavola, 2007.
[430] Ibid.
[431] Bulkeley, 2005.
[432] Koehn, 2008 in Schreurs, 2010.
[433] Qi et al., 2008 in Schreurs, 2010.
[434] Corfee-Morlot et al., 2009 in Schreurs, 2010.

- How are the current coordination arrangements affecting the delivery of climate-ICT initiatives? What are the pros and cons?
- How should the organisation maximise the potential of coordination in the horizontal and vertical directions?
- What are the necessary and critical factors for ensuring effective coordination?
- What are the lessons learned from coordination that worked, is working, and did not work?
- How could the climate change organisation utilise the potential of ICTs for effective coordination and in building strategic and operational partnerships? What are the examples of mutual support in the field?
- Where are the gaps and what are the challenges for coordination and forging new alliances?

3.3.2. International Cooperation

The importance of international cooperation in approaching transboundary environmental problems has long been acknowledged through multilateral environmental treaties and regimes[435]. Over time, informational governance of climate change organisations especially at the supra macro level would be commonplace. The literature is rich in emphasising the potential of ICT tools in international cooperation driven by the need to scale-up the utilisation of ICTs in response to climate change and development concerns where international support and cooperation are instrumental in the establishment of a number of programmes around the world[436].

At the supra-macro level, the World Meteorological Organisation promotes cooperation in the establishment of networks for making weather observations, as well as the exchange, processing and standardisation of related data, and assisting in technology transfer, training and research[437]. One of its initiatives, the WMO Information System is built upon the global telecommunication system of the WMO World Weather Watch encompassing three types of centres: global information system centres (for regional and global connectivity), data collection or production centres (for data generation, processing and archiving), and national centres (for collecting and distributing data on a national basis)[438].

The Global Climate Observing System (GCOS) jointly undertaken by WMO, the Intergovernmental Oceanographic Commission of UNESCO, UNEP, and the International Council for Science is another example of a coordinated system of methods and facilities for making environmental observations on a global scale[439]. These facilities provide observations of the atmosphere and ocean surface for the preparation not only of weather forecasts and warnings, but also for national and international climate-related observations[440].

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[435] Haas, 1999.
[436] FAO, 2009:11-12
[437] WMO, n.d.
[438] WMO, n.d.c
[439] WMO, n.d.b
[440] WMO, n.d.

Regional examples include the UN ESCAP Regional Cooperative Mechanism on Drought Monitoring and Early Warning created to help its member states across the Asia-Pacific Gateway on Disaster Risk Reduction and Development in the context of climate change adaptation. This Gateway consists of a one-stop information portal where member states exchange knowledge, and obtain ESCAP expertise in areas such as the development of policies, and post-disaster assessments of damage and losses[441].

At the micro level, the growth of awareness and concern with climate change has initiated networking among cities[442]. Activities in these networks range from sharing information about best practices for energy efficiency improvements, air and water pollution control, and GHG mitigation where the use of ICTs in information sharing has been proven valuable.

Given these examples, it is helpful for climate change organisations to explore possibilities for cooperation at the supra macro level especially at times when micro and macro organisations do not have the necessary resources to monitor, mitigate and adapt to climate change on their own. The challenge for developing countries, however, relates to the inaccessibility of appropriate and timely information in those vulnerable environments which need this information most, due to the lack of infrastructure and skilled human resources[443]. But this could be addressed by collaborating with other nation states at the supra macro level such as via the above-mentioned WMO information system.

At the country level, macro and micro organisations could utilise these data to design an appropriate action, either in mitigation or adaptation. Important questions such as the following could help organisations at these levels in accessing the rich resources available at the supra macro level:

- Which existing cooperation mechanisms at the international level do macro and micro organisations involve themselves in, especially on the utilisation of ICT tools in climate action?

- What mechanisms and arrangements at the supra macro level allow micro and macro organisations to cooperate? How could micro and macro organisations participate in these cooperation mechanisms?

- What are the preconditions for joining these international cooperation mechanisms? How could micro and macro organisations prepare themselves to meet these preconditions?

3.3.3. Stakeholder Engagement

Stakeholder engagement in policy initiatives has been increasingly utilised across different levels. This has been a trend in development programmes where active participation in decision-making is a norm. Designing a climate change and development policy is a complex process; thus making it a challenging task. This complexity requires consideration of different perspectives, and this consideration applies equally to climate-ICT initiatives[444]. Here, stakeholder engagement is seen as a way to capture this diversity in order to develop more effective ICT-based solutions.

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[441] ESCAP, 2010
[442] Schreurs, 2010 lists a handful of local government networks that adopted climate change action in their activities.
[443] Ospina & Heeks, 2010:12.
[444] Santos et al., 2006.

Multistakeholder mechanisms are important to make relevant information accessible to end users[445]. For example, intermediary organisations have to connect rural communities to available knowledge. Users will increasingly want tailor-made, quality answers to their questions. Examples where communities engage themselves range from mobile Q&A services in India to the extensive use of mobile telephones in rural South-East Asia and Africa.

In ensuring that stakeholders are engaged in climate change actions and that they participate actively, the following questions would be helpful to organisations:

- What are the existing practices at the micro, macro and supra macro level in ensuring that stakeholders are engaged in the important processes of climate change action?
- What are the challenges encountered so far?
- How could organisations utilise ICT tools to ensure effective stakeholder engagement for climate action?
- What are the challenges for realising this? How could these barriers be hurdled?

3.4. Accountability

Accountability arrangements, such as oversight and evaluation in strategy implementation of ICT-based climate change action are an important element for ensuring effectiveness in informational governance. Accountability is at the core of any organisation and this could be ensured with proper evaluation procedures and techniques[446]. As in other case, there is a dual role for ICT here. It is a component of climate action strategy for which organisations must be held accountable. But ICT can also serve as a strategic tool for increasing accountability by providing better access to information[447]. Evaluation and monitoring have critical roles to play in ensuring that climate change organisations are developing and implementing climate-ICT initiatives and that these actions are accomplished as originally planned. It makes them accountable for results, and this can be improved by addressing the following questions:

- In the current arrangements, who is providing oversight? In case there is none, who may be able to provide it?
- What are the evaluation mechanisms available for organisations to assess their performance?
- What is the frequency of evaluation? Where it is situated? Is it during or after the process? Or both?
- Who conducts the evaluation? Who is involved in the evaluation process?
- What are the mechanisms adopted by organisations to ensure that the evaluation yields credible results?

[445] Ospina & Heeks, 2010:14.
[446] Backstrand, 2008.
[447] Kalas & Finlay, 2009.

- How does the organisation utilise the results of the evaluation?
- Does the presence of ICT within strategic plans present any specific accountability issues?
- How does the organisation position and use ICT tools during the evaluation process of climate-related activities?
- What challenges do organisations face during the evaluation process?

Whether the climate change organisation is created by an international agreement, a national institution, an NGO, or a private entity, evaluation results provide the measure of outcomes against targets consequently providing an overall barometer for organisational performance.

4. Conclusions and Recommendations

Effective governance is the key to effective action for climate change organisations, and it demands strategic planning and implementation. The increasing insertion of ICTs as both a component of external strategic action, and a tool for internal planning and implementation presents both challenges and opportunities for these organisations. This paper has sought to identify the factors which underpin the "informational governance" that is necessary to make the most of ICTs for climate change. However, this only starts the debate on the emerging notion of informational governance signalling a larger opportunity to conduct research on the topic.

After listing some illustrative climate-ICT initiatives and asking organisations important informational governance questions in the preceding sections, this section wraps up the paper by determining the challenges and opportunities to enhance informational governance.

Acknowledging the fact that much remains to be explored in terms of the role and potential of ICTs within the climate change field, the analysis in this paper sheds light on key concepts and practical experience that help better understand the complex linkages that exist within the context of informational governance of climate change organisations. As with other branches of the emerging literature on the nexus of ICTs, development and climate change, emerging evidence is often anecdotal with regards to climate change organisations and the ways they employ ICTs as a tool for climate change action[448]. Overall, the analysis undertaken above of the potential contribution and role of ICTs in climate change organisational governance is not easy. However, international and national experience as shown in this paper demonstrates the existing and varying challenges to coordinate, communicate, and share vital climate change information for monitoring, mitigation and adaptation among various actors and stakeholders.

The impact of ICT on the governance of climate change organisations could be far and wide. This could be done through creating new possibilities for linking regimes and creating networks that bypass blockages in existing organisational arrangements. ICTs in organisations are expected to enable small-scale climate change actions to be effective, facilitate more responsive and appropriate national and local governance, and help climate change organisations to exist and connect more easily. Although ICT provides the necessary tools and implements to better

[448] Ospina & Heeks, 2010: 25-26.

understand, manage and adapt to the varying effects of climate change and extreme weather events, it also has important limitations that need to be considered. We then turn now to discussing some of these challenges, and their possible solutions.

Before looking at these specific components though, mention must be made of the cross-cutting issues that face informational governance in developing countries, and of the need to take into account the broader development picture within which developing country governments, institutions and agencies operate. These may further challenge climate change organisations in those countries and/or may limit their ability to take up some of the recommendations provided here. Space prevents a full consideration of these challenges but the most obvious would be resource constraints: the limitations of ICT infrastructure, human resources and finance that were seen as important to various parts of informational governance. These knock-on into constraints on organisational capacity including governance deficits and hindrances to strategic planning. And yet, simultaneously, we have noted that developing countries are most in need of climate change action; most in need of the support to climate change response that ICTs can provide. It is thus to be hoped that priority is given to overcoming and/or working around the specific informational governance challenges that developing countries face in order to make effective use of ICTs for climate change action.

4.1. Arrangements

Ultimately, all countries will require systems to govern climate change monitoring, adaptation, and mitigation. At the macro level, the extent of national socio-economic development and the effectiveness of existing climate change organisational arrangements have direct relevance for informational governance as well as for the priorities that governments are adopting in relation to climate change. Developing countries should therefore aim to create or identify and sustain a competent climate change organisation at the macro level. This is basic. The strengthening of informational governance for climate change organisations at all levels should be a national agenda in the long run. At the national level involving macro and micro governance, this could be accomplished by creating and passing policy and legislation on the role of ICTs in climate change action. ICT tools should also be included into national development plans and successfully integrated into local plans. The important factor for strengthening human and organisational capacity however does not end with legislation and policy but with their sustainability. To achieve this, the development of ICT and its integration in climate change action should receive continued support.

Organisations should avoid complexity, overlaps and duplication by simplifying procedures as much as possible. Developing and implementing effective procedures and programmes is not an easy task but ICTs could in their internal role provide a means to do this.

A fully-developed system for mobilising ICT resources in support of climate change actions and goals means moving a number of parts that need to be interconnected. Developing such organisational arrangements and structures could take years and incur significant resource costs, especially for developing countries. However, it is important to take into account existing organisational resources and capacity in apportioning organisational responsibilities which in some cases may mean creating an entirely new organisation.

4.2. Frameworks

In order to effectively implement ICT applications for climate change action, an enabling environment that fosters ICT infrastructure development along with strengthened human and organisational capacity is required. Although awareness on the use of ICTs in climate change action has increased in parallel with the increasing affordability and reach of ICT tools, the current situation in many developing countries renders it unrealistic to put everything in place soon. The lack of skilled staff to analyse and interpret data gathered by ICT tools for decision making is another organisational challenge in many developing countries which comes mostly along with the absence of effective organisational frameworks for data handling.

Effective informational governance depends on strong human resources, ICT tools that work, and well-developed organisations. Gaps and deficiencies in staffing and equipment of technical agencies responsible for climate change action should be addressed. Developing countries whose personnel and organisational faculties are weak may join cooperative mechanisms available at the regional and international level such as those mentioned in 3.3.2.

4.3. Coordination

Considering the impact of lower transaction costs and higher speed of iteration, it becomes clear that ICT allows the easy creation of cross-border organisations and collaborations[449]. This extends across the three level of governance to demonstrate the role of digital technology in supporting general climate governance. For supra macro organisations, whose basic mission is to encourage collaborative work among its global members, remote collaboration is a bright prospect. This may include audio and video conferencing, instant messaging and chat, etc. Workshops held online can also address a wider audience, notably reaching participants from developing countries. Organisations need to identify the opportunities for cooperation through networking. Organisational mechanisms need to be in place to ensure learning and information sharing. At the supra macro level for instance, "commitment to robust programs of data collection, problem identification, risk assessment, trend tracking, comparative metrics on policy performance, and other elements of cross country benchmarking" is critical for international institutions[450]. Regional and international organisations should therefore establish cooperation across specific clusters of countries to achieve greater possibilities for collaboration and data sharing.

In many cases too, climate change policy at the national level falls within the purview of the Environment ministry while ICT policy is the responsibility of a different ministry such as Information or Telecommunications. This division demands increased coordination among organisations by establishing inter-agency coordination mechanisms. Organisations also need to identify and engage stakeholders to create a community of interest. Stakeholders include those who are affected by climate change and extreme weather events and those who are doing something about it; thus their involvement in policy development can improve quality and help build consensus. Again, there is a dual role here: stakeholder engagement is a necessity for effective strategic use of ICTs in climate change, but also ICTs can enable the stakeholder engagement that underpins effective climate change strategy planning and implementation.

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[449] Kennedy, 2010.
[450] Esty, 2008

4.4. Accountability

Across countries and regions, perspectives on the role of evaluation vary but its importance is recognised everywhere. The data gained from a good evaluation are vital for improving organisational policy, initiatives and climate-related actions, and for communicating results to stakeholders. The process of evaluation, therefore, fosters innovation, increases credibility, and helps build consensus for future undertakings.

The process of designing evaluation materials starts with identifying the objectives. It is therefore necessary that at the beginning of the programme development process, evaluation needs are taken care for[451]. If applicable, the evaluation plan should involve programme designers, implementers and other stakeholders. What is actually needed is an evaluation process that yields credible information, objective analysis, and transparency of programme results.

4.5. Future Research

This paper provides only a preliminary attempt to elucidate some of the concepts that could be built upon the notion of "informational governance" for climate change organisations especially in developing countries. Owing to the novelty of this notion, a number of opportunities arise for further investigation. These could include:

- A larger study across climate change organisations hinged on the informational governance framework presented in Section 2 that would enrich the elements discussed in Section 3. This would not only provide the necessary evidence on the obvious importance of ICT tools in climate change governance but also allow for the determination of gaps, barriers and challenges.

- A study on the successful (and less successful) application of ICT tools in general environmental and climate change governance in different contexts in the developing world would provide specific and important guidance.

- The development of toolkits, guidelines, or similar instruments for climate change organisations would outline the elements and factors for effective informational governance based on the results of these studies.

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[451] FAO, 2009; FAO, 2010

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WMO (n.d.c) *World Information System*, World Meteorological Organisation [Online], Available: http://www.wmo.int/pages/prog/www/WIS/ [Accessed September 6 2010].

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Chapter 8: New & Emergent ICTs and Climate Change in Developing Countries

STAN KARANASIOS

Executive Summary

Climate change impacts both the biophysical environment and human activity, and imposes a range of new challenges for research, technology development, and knowledge and information exchange. Over the last decade advances in ICT have emerged as a critical ingredient in the development process and can equally play a role in the climate change challenge. Based on a comprehensive review of the extant literature this paper outlines the range of new and emergent ICTs (e.g. wireless broadband and wireless sensor networks, geographic information systems and Web-based tools) being applied to climate change issues and investigates their use in developing countries. It also discusses innovative uses of established technologies such as mobile phones, but the main contribution will be to give those working on climate change an understanding of the technologies that will increasingly be used in their field: not just the identity of the technologies but their potential benefits and application areas.

The paper discusses three major application areas: (1) monitoring of climate change and the environment, (2) disaster management, and (3) climate change adaptation. A range of examples of the use of new and emergent ICTs in these areas in developing countries is described in order to demonstrate their utility and importance in assisting vulnerable communities to meet the climate change challenge. The review shows these technologies are predominately being deployed for disaster management and for localised monitoring activities. The technologies are not yet being employed much for adaptation purposes. A series of recommendations for researchers, NGOs and governments is provided in order to facilitate the widespread and effective application of new ICTs for climate change in developing countries.

1. Introduction

Climate change impacts both the biophysical environment and human activity, and imposes a range of new challenges for research, technology development, and knowledge and information exchange[452]. Over the last decade advances in ICT have led to widespread changes in human and economic activity, and emerged as a critical ingredient in the development process. Similarly, ICTs can play a catalytic role in adapting to climate change through collecting, analysing and disseminating information[453]. Advances, in particular, in space-based systems, geographical information systems (GIS), wireless broadband technologies, wireless sensor networks (WSN), mobile (cellular) technology and soft technologies such as Web-based tools (i.e. Web 2.0) and information systems have resulted in technologies that are well-suited to the climate change challenge.

Within the climate change domain there are a number of overall areas where ICTs can be useful to governments, vulnerable communities, scientists and other relevant actors in developing countries. This paper concentrates on the adoption of new and emergent technologies in three broad and interrelated activities: (1) monitoring of climate change and the environment, (2) disaster management, accounting for preparation, early warning systems (EWS), and response and recovery, and (3) climate change adaptation. Other pertinent activities such as mitigation, resource management, education and capacity building, networking, monitoring and evaluation, and climate modelling[454] are beyond the exposition of this paper. The frame of reference for this paper is graphically represented in Figure 1.

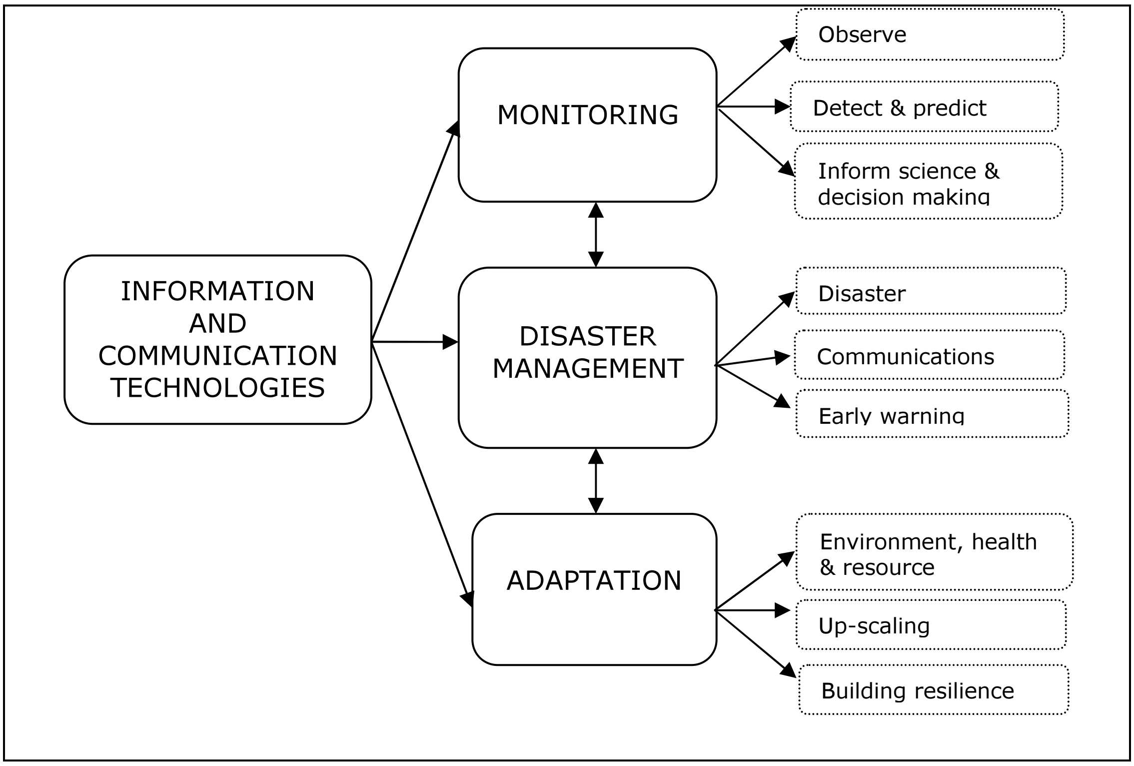

Figure 1: Conceptual Framework

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[452] FAO (2010 p.282)
[453] ITU (2009b), FAO (2010)
[454] See FAO (2010), ITU (2008b), Sala (2009)

Within this frame of reference, the focus in this paper is on new and emergent ICTs. Primarily, it will focus on terrestrial technologies (wireless broadband and WSNs), geographical information systems and Web-based tools, and innovative use of mobile phone technology, providing a localised technological perspective on climate-related applications. Satellite/remote sensing technologies[455], while forming some of the underlying foundation of some of the technologies discussed, will not be addressed in detail and can be reviewed elsewhere[456].

This paper is one of few that examine new and emergent technologies in the context of developing countries and climate change. It draws on practical examples from developing countries but also developed countries (given the novelty of many of the applications), and it discusses some of the key issues in the field of ICT and climate change in developing countries. By doing so, this paper brings together literature from the fields of climate change, environment, development and ICT. Other authors have allocated importance to the role of ICT in climate change primarily in general statements, resulting in limited understanding of the mix of ICTs available, particularly new ICTs, and of the ICTs best suited to developing regions and climate change-specific scenarios. It is the intention of the paper to fill this gap.

The remainder of the paper is organised as follows. It begins with a discussion on monitoring activities and introduces emergent WSNs and wireless broadband technologies and presents a spectrum of climate change-related examples. A review of disaster management activities in the context of climate change and new ICT is then presented. Following this, a discussion on the scope of adaptation initiatives using emergent ICT in developing countries is provided. The final section looks at emerging patterns in the ICT, climate change and developing country domain and outlines a number of recommendations.

2. Monitoring Climate Change and Impacts

For developing countries to better understand their local climate and be able to anticipate climate change impacts, they must have adequate local and national observation networks, and access to the data captured from other global and regional networks. Systematic observations of the climate system are usually carried out by national meteorological centres and other specialised centres, which monitor atmosphere, ocean and terrestrial systems[457], typically using satellite technology. At the global level a number of established systems capture meteorological data using ICT, such as the World Meteorological Organisation's (WMO) World Weather Watch (WWW)[458], which predominately makes use of satellite-based systems[459]. While, satellite technology is useful for large-scale phenomenon, it is limited in complex, cluttered environments where line of sight (LOS) paths are short[460]. Further, remote sensing is not ideal for a real-time continuous monitoring as the data is less accurate than ground sensors and the frequency and delay of the data depend on the satellite's orbit[461]. The cost of accessing this technology and procuring certain types of imagery is also typically

[455] Earth observation satellites and remote sensing systems (sensors mounted on satellites or aircraft) are used to view areas over extended periods making it possible to monitor environmental change, human impact and natural processes, allowing for future projections. See www.un-spider.org
[456] Sammonds and Thompson (2007), Olla (2009b), ITU (2010b)
[457] UNFCCC (2007)
[458] See World Meteorological Organisation www.wmo.int
[459] ITU (2009b)
[460] Elson and Estrin (2004)
[461] Panchard et al. (2007)

beyond the financial capacity of many developing countries[462], necessitating the need for complementary technologies[463].

Beyond these satellite systems, then, a range of new and emergent technologies for monitoring localised climate change phenomenon exist that include ubiquitous wireless sensor networks, advanced next-generation wireless network technologies, and a mixture of existing and novel devices, such as mobile phones and other hand-held devices[464]. For instance, climate stations and small-scale WSNs can be set up in tropical forests, by following online instructions, in order to measure climate change and understand the effects on biodiversity and the ecosystem[465], allowing for inexpensive and bottom-up monitoring initiatives to take place.

As yet, much of the priority for wireless and WSN technologies has been in the area of volcanic and seismic activity[466] and pollution monitoring[467]. However, this has demonstrated the applicability of the technology to monitoring environmental phenomena in the developing country context. At the more advanced stage, many relevant state-of-the-art applications based on hybrid wireless mobile/broadband, space-based and WSN technologies are being developed and implemented in Europe[468].

These technologies and their relevance to climate change in developing countries are discussed next.

2.1. Wireless Broadband Technologies

Before discussing the application of wireless broadband technologies to climate change in developing countries, it is useful to establish the case for short-range (such as Wi-Fi) and long-range (such as WiMAX[469]) wireless broadband technology in developing countries as the technical infrastructure that would underpin such applications. Where traditional wired infrastructure has been avoided because of the prohibitive costs and unsympathetic geography, wireless technologies are attractive to governments, NGOs and operators in developing

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462 ITU (2008b)
463 Libatique et al. (2009)
464 ITU (2008b)
465 TEAM (2009)
466 Mignanti et al. (2008), Linsey et al. (2010), Neves et al. (2009b), Musavi et al. (2010a, 2010b), Werner-Allen et al. (2006)
467 Khedo et al. (2010)
468 See the following examples:

- WIDENS http://www.chorist.eu/index.php?page=51&sel=51: Rapidly deployable and scalable wireless ad-hoc communication system, based on Wi-Fi (IEEE 802.11) for future public safety, emergency and disaster applications.
- ARMONIA http://www.eu-medin.org/%28S%28jihy52ycnre1pdy2macd5x55%29%29/EUMEDIN/StaticPage2.aspx?pagenb=20268: Spatial planning in environmentally prone areas .
- WIERD www.ist-weird.eu: Uses WiMAX to support novel application scenarios, such as environmental monitoring, telemedicine and fire prevention, making efficient use of WiMAX technology for the fixed/portable (IEEE 802.16d) and mobile (IEEE 802.16e) systems.

469 IEEE 802.16d/e/m Worldwide Interoperability for Microwave Access (WiMAX). Based on the IEEE 802.16 standard WiMAX offers wireless transmission of data using a variety of modes supporting speeds as high as 40-70 Mbit/s, (however, the likelihood is that most users will experience speeds of one to five Mbit/s) and a range of up to 50 kilometres in LOS conditions and shorter ranges in non-line of sight (NLOS) conditions (although most WiMAX networks will have a 16 kilometre LOS range and eight kilometre NLOS range) (Etemad, 2008, Neves et al. 2009b). By contrast the Wi-Fi (IEEE 802.11) standard operates at somewhat slower data transmission speeds, typically over a few tens of metres, and at much lower cost.

countries because they can be deployed in an inexpensive, decentralised and effective manner, compared to other solutions[470].

Technologies such as WiMAX in particular have emerged as well suited to developing countries[471]. In 2008, Alvarion announced that it had 60 WiMAX networks deployed in 30 African countries and expected to reach more than 10 million subscribers over the next several years[472]. As an example of its utility, a hybrid WiMAX and satellite link was used to provide Internet access to Parintins, a small city located in the far east of the Amazonas state in Brazil, which has no roads and limited electricity[473]. Beyond development motivations, wireless broadband technology is essential for climate change applications such as climate scenario maps and images, which require high bandwidth[474]. Wireless broadband technologies also offer advantages for WSNs, especially when there is need for considerable bandwidth or mobile services such as GPRS[475] or GSM[476] coverage are not available[477]. Further, compared to other fixed technologies, it works better in remote locations, severe climates and difficult terrain[478].

Box 1: A Note on Mobile Broadband

Mobile broadband (such as the standard IEEE 802.16m[479]) will further change the wireless communication landscape and has been applied and projected for future growth in disaster communications[480] and environmental monitoring[481]. HSPA[482] is forecast to remain the dominant technology in the short-term for mobile broadband, accounting for nearly 70 percent of total subscribers by 2012, while substantial growth in mobile WiMAX is expected after 2012 with developing markets projected to lead to way[483]. Given these projections, there is significant scope for development organisations to begin considering this technology as part of the climate change adaptation armoury.

2.2. Wireless Sensor Networks

WSNs are systems of intelligent sensor nodes deployed to monitor particular environmental cues, such as temperature, light intensity, water levels, local

[470] Dhawan (2007), WiMAX Forum (2005), Ibikunle and John (2008), Proenza (2006), Rao and Radhamani (2007), Galperin (2005)
[471] Frost & Sullivan (2008), Karanasios and Allen (2010), Rao and Radhamani (2007), Juniper Research (2007), EIU (2006), Pareek (2006)
[472] Alvarion (2008)
[473] Clendenning (2006)
[474] Apikul (2010)
[475] General Packet Radio Service, a 2G/GSM/3G mobile service that transmits data in packets
[476] Global System for Mobile Communications -the most popular standard for mobile telephone systems in the world
[477] Nissilä et al. (2008), Neves et al. (2009a). The capacity of GPRS and GSM for WSN is limited, GPRS communications costs are also high
[478] Sedoyeka and Hunaiti (2008), Rao and Radhamani (2007)
[479] Little distinction is made between fixed/mobile/true mobile broadband (for instance IEEE 802.16d, IEEE 802.16e, IEEE 802.16m) in this paper. For in depth discussion see Ergen (2009), Dahlman et al. (2007), Chen and de Marca (2008)
[480] Riegel et al. (2009)
[481] Ibikunle and John (2008), Linsey et al. (2010)
[482] High Speed Packet Access (HSPA), is a part of the group of high-speed 3G digital data services provided by mobile carriers worldwide that use GSM
[483] Juniper Research (2007)

meteorological data and pollutant level[484]. They are well-suited to the application of collecting environmental data that will facilitate the study of the climate[485].

A WSN typically consists of large collections of nodes performing local processing, communicating wirelessly to form networks. Individually, each node is autonomous and has a short-range; collectively, they are cooperative and effective over a large area[486]. The typical elements are[487]:

- **Sensors:** Sensors with harvested or stored power sources for collecting and transmitting information about the surrounding environment
- **Access Network:** Sink nodes collecting information from a group of sensors and facilitating communication with a control centre or external entities
- **Network Infrastructure:** Typically based on 2G, GPRS, 3G or WiMAX/Zigbee[488]
- **Middleware:** Software for the collection and processing of the data
- **Applications Platform:** A technology platform for effective use of a WSN for a particular application

One of the main advantages of WSNs is that they can be deployed in almost any kind of terrain where it might be impossible to use traditional wired networks, require little human interaction, are scalable[489] and offer many advantages over long-range remote sensing technologies. Developing countries have been identified as major beneficiaries of WSNs in the field of environmental monitoring as they are most at risk from climate change[490].

2.3. Climate Change Applications in Developing Countries

2.3.1. Rainfall and Landslide Monitoring

Countries in temperate and tropical zones are likely to experience increased and increasingly-variable rainfall and exposure to extreme landslide events due to global warming[491]. Typical examples of existing landslide solutions involve a trip wire and alarm installed along landslide-prone areas, triggered by falling rocks[492]; but these are unreliable due to their margin for error.

In order to monitor rainfall and detect landslides a number of WSN initiatives have been deployed in developing countries. Amrita University deployed a landslide detection system using a WSN in Munnar, Idukki and Kerala in India; areas which are highly prone to landslides due to systemic monsoon-induced rainfall. The rainfall-induced landslide detection system used a WSN with Wi-Fi network and satellite technology. The deployment included 15 wireless sensor nodes and a total of 50 geophysical sensors (piezometers, tiltmeters, strain gauges, rain gauges, dielectric moisture sensors, geophones), which automatically collect and forward data via the WSN[493]. The real-time data from the deployment field is streamed to a central repository, providing a better

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[484] Elson and Estrin (2004)
[485] Morshid (2009), Polastre (2003), ITU (2008d)
[486] Elson and Estrin (2004)
[487] ITU (2008d), Vassilaras and Yovanof (2010), Ganguly (2008), Townsend and Arms (2005), OECD (2009b)
[488] IEEE 802.15.4 A low-cost, low-power, wireless mesh networking standard
[489] Suri et al. (2006), Li et al. (2006), Pathan et al. (2006), ITU (2008d)
[490] ITU (2008d)
[491] Cruz et al. (2007)
[492] Sheth et al. (2007, 2005)
[493] Ramesh et al. (2009b, 2009a)

understanding of landslides in the region than was previously possible and thus helping prevent the loss of human life[494].

Moving away from detection, SenSlide[495] - a distributed sensor system - predicts, rather than just detects landslides, in the hilly regions of western India, which occur frequently during the monsoon, rains causing significant damage. SenSlide makes use of a WSN and 2-axis strain gauges to predict landslides. The low maintenance WSN architecture consists of small sized, low cost, and wireless battery operated nodes deployed over a Wide Area Network with data sent to a base-station using Wi-Fi or GPRS[496]. Similar setups have been proposed in developing countries for tropical-rain monitoring using hybrid wireless broadband networks in conjunction with real-time acoustic rain rate point sensors and complementary rain gauges to monitor rain and rain-induced hazards. This approach leverages recent wireless communications infrastructure deployments in developing countries, even in regions where remote weather radar and climate monitoring systems are sparsely deployed, and will be critical for regions with undeveloped sensor systems[497].

2.3.2. Fire Monitoring

With global temperatures expected to rise, a major concern is the increased frequency of forest fires[498], which contribute 25 to 30 percent of carbon emissions[499]. Typical approaches to fire detection involve human spotters in towers or aircraft searching for smoke. These are costly: for instance, in Portugal a network of over 200 surveillance towers observes fire-sensitive areas[500]. But they are also relatively ineffective given the difficulties of providing total coverage and accurate location.

Wireless sensors or wireless broadband-supported video surveillance with automatic detection of smoke or heat sources can be used to monitor fires. These approaches can still require human interaction for confirmation, however they greatly enhance the efficiency of monitoring networks by reducing costs (only centrally-located operators would be required), provide more accurate location data, effective management of false alarms and 24/7 operation[501]. Technologies such as fixed broadband, mobile and radio links (e.g. ADSL or 3G/UMTS, GSM, GPRS) are not typically available in remote forests or cannot provide the bandwidth required for more automated fire detection[502]. Wireless broadband technologies can fill this gap by providing connectivity to remote sensors and monitoring systems, capable of effectively providing early detection of fire in an efficient and cost effective manner. In China, a forest WSN using the ZigBee wireless mesh standard was implemented to monitor temperature, humidity and fire, and was found to have technical advantages in terms of safety in data transmission, flexibility in the network build and low cost energy requirements[503].

A different approach can be to have cameras mounted in surveillance towers that can automatically scan a 360-degree area, within a 2,000 km^2 area, and send collected data (location data, meteorological data etc) to control centres, where prospective fires are further investigated (for instance remotely pointing and

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494 WINSOC (2007)
495 http://www.cse.iitk.ac.in/users/cs725/lec_notes/senslide.html
496 Sheth et al. (2007, 2005)
497 Libatique et al. (2009)
498 IPCC (2001)
499 FAO (2010)
500 Neves et al. (2009b)
501 Neves et al. (2009b), Mignanti et al. (2008)
502 Mignanti et al. (2008)
503 Zhang et al. (2008)

zooming the cameras to the suspect area)[504]. A similar forest fire system (FireHawk) of cameras with zoom lenses and microwave transmitters and receivers was implemented in mountainous and extreme temperate locations in South Africa. The system detected 153 fires, even at night, limiting the impact of damage[505], demonstrating the efficacy of ICT automation.

2.3.3. Flood Monitoring

Climate change is predicted to increase flooding frequency causing significant problems for vulnerable communities in developing countries[506]. The normal practice of flood monitoring typically involves taking readings from painted markers at certain points or water gauges[507]. There is a great deal of potential for WSNs to be deployed for flood and water level monitoring systems[508]. Figure 2 provides a simple graphical representation of a riverbank WSN for monitoring floods. In this example, sensors form clusters at certain points along a river bank to communicate with local base stations, which communicate with each other and the processing centre wirelessly.

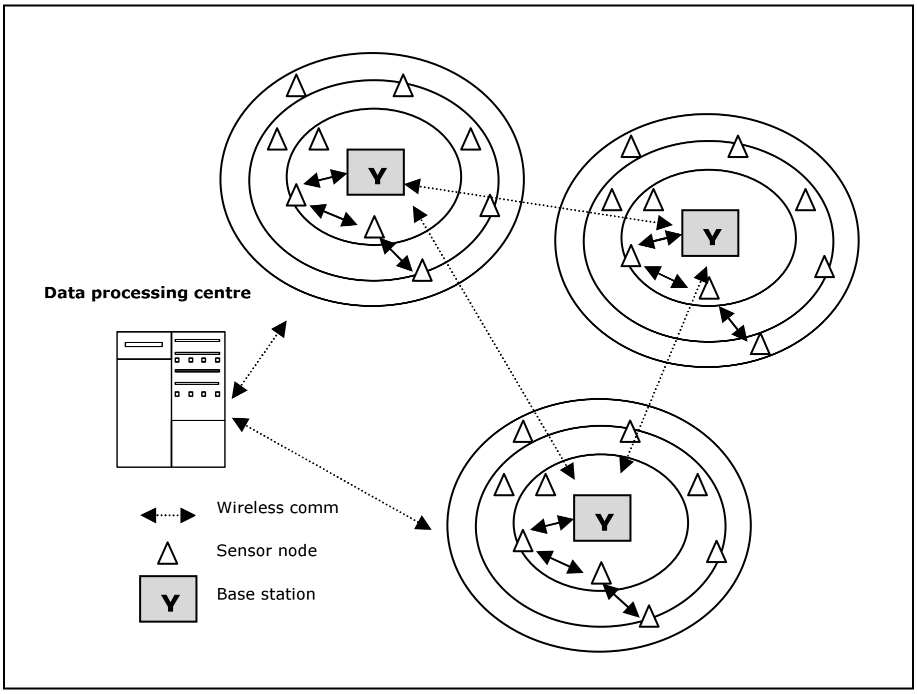

Figure 2: Simple Riverside Flood Monitoring WSN[509]

In Mérida, Venezuela, a WSN for flash flooding was designed in this way using hydrological nodes located along the river shore to monitor water level and water flow. In this design a geographic information system (GIS) constituted the basis for a data-collection and alarm generation station in the urban area. An Internet server published information about the current state of the environment[510], showing that these systems play a role in the path from data capture to information dissemination.

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504 Mignanti et al. (2008), Linsey et al. (2010), Neves et al. (2009b)
505 FireHawk (2004)
506 Cruz et al. (2007), Magrin et al. (2007)
507 Basha et al. (2008), Basha and Rus (2007)
508 Pathan et al. (2006)
509 Adapted from Pathan et al. (2006 p.708)
510 Castillo-Effer et al. (2004)

In Honduras, a WSN for flood monitoring was developed that was able to withstand river flooding and the severe storms causing the floods, communicate over a 10,000 km^2 river basin, predict flooding autonomously, and limit cost, allowing feasible implementation of the system in a developing country. A simplified version of the 9-node sensor network was deployed on the Aguán River basin in northern Honduras Experiments with the system confirmed the technical feasibility of a scalable, sensor network for use in a developing country[511].

2.3.4. Monitoring Impacts on Agriculture

In developing countries climate change is likely to affect agriculture, increasing risk of hunger and water and resource scarcity[512]. Existing systems have involved informing farmers of climate variability and better practices through radio and word of mouth and more recently mobile phones or telecentres. WSNs can provide risk assessment data such as alerting farmers at the onset of frost damage and provide better microclimate awareness[513] and inform climate science.

A number of examples demonstrate the use of ICTs for monitoring climate change and agriculture, such as wireless telemetric rain gauges, use of SMS to monitor rainfall and manage water in semi-arid areas[514], and strengthening drought preparation by using GIS for water allocation and contributing to improving micro-level drought preparedness[515]. In India a WSN-based agriculture management system, named COMMON-Sense Net[516], was deployed to support rain-fed agriculture and provide farmers with environmental data. Wireless sensors were deployed in geographical clusters, each with one base-station that was connected to a local server via a Wi-Fi link and organised in groups, each corresponding to a particular application, such as crop modelling, water conservation measures, or deficit irrigation management.

However, the monitoring system did not encourage the expected participation of the farmer population, making it difficult to develop the intended decision-support system. Based on the experience of this project it was proposed that the deployment of WSN technology in developing regions is more likely to be effective if targeted towards scientists and technical personnel, rather than farmers[517]. This suggests that although the technical feasibility of the solution is clear greater investigation into the needs and requirements of targeted communities is required.

2.3.5. Participatory Monitoring via Mobile

The previous examples relied on a high-level of automation and new and emergent ICTs. However, there are a number of localised monitoring techniques that involve a new type of convergence between mobile phones and human involvement, enabling 'citizen science', scaling up the monitoring process of climate change[518]. 'Mobile sensing', an emergent paradigm, enables data collection from large numbers of people by affixing sensory devices to a mobile phone allowing dynamic information to be collected about environmental

[511] Basha et al. (2008), Basha and Rus (2007)
[512] Cruz et al. (2007), Boko et al. (2007)
[513] Edordu and Sacks (2006), Srivastava (2010)
[514] Pradeep (2004)
[515] Sreedhar et al. (2009)
[516] http://commonsense.epfl.ch
[517] Panchard et al. (2007)
[518] OECD (2009a)

trends[519]. Such a system was employed in Accra, Ghana to monitor pollution and air quality, leading to the adaptation of behaviours of people involved in the data collection[520] and presents an interesting means of monitoring and adapting to climate change in developing countries.

3. Disaster Management

Responding to natural disasters in a timely and effective manner has emerged as an important climate change theme particularly in developing countries; where in addition to the immediate crisis vulnerable communities suffer excessively from the secondary post-disaster effects that compound the tragedy. Disaster response in developing countries typically involves the military to stabilise the situation, medical staff, emergency services, officials, the media, a range of international and local NGOs, and other specialised agencies working together to manage particular situations. Coordination and communication becomes particularly imperative where contingencies cover expansive geographical areas, cross borders and require trans-border intra-agency cooperation[521].

In many cases, the existing telecommunication infrastructure will be significantly or completely destroyed by an extreme weather event, and hence rapidly deployable networks and other communication services need to be employed for disaster relief operations[522]. Communication technologies in such events typically have been limited to satellite communications, which are expensive to use, not sustainable beyond short-term use, and suffer from limited capacity for handling simultaneous calls, (although new satellite phones capable of terrestrial GSM wireless service are available)[523]. Wireless broadband technologies have filled this gap, allowing for rapidly deployable and flexible networks.

3.1. Preparation and Response: Emergency Communication Systems

Driven by the occurrence of large-scale disasters over the last decade, investment in rapidly deployable wireless communications is an area where there has been substantial allocation of resources by governments and international bodies in order to enhance response to disasters, signifying a commitment towards one element of climate change adaptation. During environmental contingencies wireless broadband can support better communication between actors, allowing for instant data exchange between responders and the control centre (location of the event, meteorological data, instructions from the control centre etc)[524]. In Bangladesh an Integrated Information and Communication System is underway which will use satellite, wireless broadband, mobile phones and community radio services strengthening communication links between rescue and relief units and Emergency Operation Centres (EOC)[525]. In other parts of Asia and the Pacific it has been suggested that EOC's employ similar hybrid approaches[526] (converging satellite with terrestrial communication technologies),

[519] Chaudhri et al. (2010)
[520] Kinkade and Verclas (2008)
[521] Paul-Morandini (2008)
[522] ITU (2008c)
[523] UN ESCAP (2008)
[524] Mignanti et al. (2010)
[525] Hazarika et al. (2010)
[526] Apikul (2010)

maximising the advantages of each technology[527]. It is realised that part of the disaster preparation approach involves establishing robust and reliable systems that will continue to allow for voice and data communication during and after disasters[528].

3.1.1. Rapidly Deployable Communications

One key portable infrastructure solution is Very Small Aperture Terminals (VSAT)[529], the only requirement being a direct line of sight to the satellite. VSAT networks can also support basic telecommunications infrastructure restoration requirements including the Public Switched Telephone Network (PSTN) and mobile and broadband wide area networks[530]. However, VSAT technology is known to be interference-prone especially in bad weather, expensive and have low bandwidth[531].

An alternative to satellite communications are wireless/mobile temporary/ad-hoc communication infrastructures[532]. Using wireless broadband technologies "nomadic" Relay Stations can be deployed temporarily to provide additional coverage or capacity where required[533]. Temporary-coverage WiMAX networks supported telecommunications destroyed in the 2004 tsunami in Indonesia and after hurricane Katrina in the Gulf Coast in 2005[534]. More recently, after the Haiti earthquake the ITU led a project that used WiMAX and Wi-Fi technology to rapidly set up wireless phone and Internet connectivity at 100 holding centres for displaced people[535].

A particularly interesting type of ad-hoc wireless typology in the context of developing counties is the fixed-mesh or mobile-ad hoc network (MANET)[536]. This is a network of mobile devices (subscriber stations) which interconnect in an ad-hoc manner to share data in a mesh network. Data is shared in a multi-hop manner by being passed between devices, with each device having the potential of routing data to another device. The devices in the network are self-configuring as the network automatically reconfigures when devices move in and out of range. Access to the Internet can be provided by just a single device in the network, which has Internet access on a wired or wireless basis. Mesh applications have been identified in developing countries as having important

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527 UN ESCAP (2008)
528 Apikul (2010), ITU (2008a)
529 A small antenna on the ground that allows two-way communication with a satellite-based communications system
530 ITU (2008b)
531 OECD (2009b)
532 Jiang et al. (2008), Soldani and Dixit (2008), Abichar et al. (2006), Sithirasenan and Almahdouri (2010)
533 Soldani and Dixit (2008). For state-of-the-art advances in rapid deployable networks see:

- WISECOM, http://www.wisecom-fp6.eu: Rapidly deployable communication infrastructures for emergency situations, involving a mixture of terrestrial mobile radio networks such as GSM, UMTS, Wi-Fi, WiMAX and TETRA over satellite.
- U-2010 www.efipsans.eu: provides the most capable means of communication and the most effective access to information to everybody required to act in case of an emergency.
- WIDENS, www.comlab.hut.fi/projects/WIDENS: a high-data rate, rapidly deployable and scalable wireless ad-hoc communication system for future emergency and disaster applications.
- CHORIST,http://www.ist-world.org/ProjectDetails.aspx?ProjectId=7374640a32574e15bedf55fb2d739195: Proposes a solution to increase rapidity and effectiveness of interventions following natural hazards

534 Fitzgerald (2006)
535 www.dailywireless.org (2010)
536 Karanasios and Allen (2010), Sedoyeka et al. (2008), Kanchanasut et al. (2007b), Martikainen (2006)

potential to bridge the digital divide[537] and deliver development outcomes including those that are climate change-related[538].

> **Box 2: Project DUMBO**
> **Mesh Networks and Disaster Response in Thailand**
>
> DUMBO, a project initiated by the Asian Institute of Technology Internet Education and Research Laboratory, developed and tested a system for response to emergency scenarios in Thailand[539].
>
> Making use of the concept of wireless mesh networks, DUMBO uses lightweight portable mobile nodes to broaden coverage and penetrate deep into areas not accessible by roads or where the telecommunication infrastructure has been destroyed. During the trials in Thailand, laptops were carried on elephants to extend the wireless mesh network coverage. On the networking side, the solution utilised hybrid Wi-Fi and satellite connectivity. The second application component involved sensors, which allowed for readings of environmental data such as temperature, humidity, pressure, wind-speed, wind-direction, rainfall and CO_2. The third application component involved facial recognition software that allowed rescuers to compare facial images captured from the site to the collection of known faces[540]. This is one of a few systems in developing countries that make use of emergent technologies and combine communications with integrated disaster applications.

3.1.2. The Role of Social Networking Media in Disaster Management

In addition to the communications infrastructure, information dissemination media, such as social network platforms have emerged as playing the multifaceted role of informing various actors and communities, often being used by locals who are at the site of the disaster. Radio remains the main channel for providing information to large sections of the population[541], however, Web 2.0 technologies such as social networking provide the added advantage of allowing direct community involvement.

During Typhoon Ondoy in the Philippines in 2009, local volunteers organised and disseminated information online through Web sites such as Facebook and Twitter. Organisations and affected people used these sites for timely reports concerning the extent of damage, to provide information on the resources required and to allocate relief resources[542]. Likewise, during hurricanes Gustav and Ike, in the USA and Caribbean in 2008, volunteers used social network sites such as Ning to provide information on the hurricane. Newsfeeds were built in from other social networking media such as Twitter and Facebook and maps were created with information on shelters, evacuation routes and other relevant resources. Importantly, there is some emergent research that suggests local participation

[537] Karanasios and Allen (2010), Sedoyeka et al. (2008), Damsgaard (2006)
[538] Kanchanasut et al. (2007b)
[539] Kanchanasut et al. (2007b, 2007a) , Nouali et al. (2009), Myanmar Egress and MCPA (2008). DUMBO stands for Digital Ubiquitous Mobile Broadband Optimised link state routing (OLSR)
[540] Kanchanasut et al. (2007b, 2007a)
[541] UN ESCAP (2008), Chinese Radio Sports Association (2008), Coyle and Meier (2009)
[542] Apikul (2010), See http://www.abs-cbnnews.com/nation/09/27/09/ondoy-situation-map-metro-manila-google-maps#Map

through these social media was beneficial to the hurricane victims, empowering them to play some role in the response[543].

3.1.3.The Role of GIS & Other Information Systems in Disaster Management

For managing disaster situations, which usually involve a large number of different agencies working in different but overlapping areas, geographic information systems have proven to be powerful visualisation and management tools. For mitigation GIS can visualise high risk zones; for preparedness they can visualise evacuation routes, shelters and the catalogue of available resources and their proximity; for response they facilitate the identification of priority search and rescue zones, delivery of supplies and medical help; and in recovery they can be used in reconstruction efforts[544]. GIS have been used in a number of countries to visualise critical data by location, for use in the coordination and implementation of relief efforts[545].

In conjunction with GIS, disaster management information systems that provide the basis for organising the response and relief effort are critical and there has been developing country-relevant innovation in this area. For instance, Sahana[546], which was used in the recent Pakistan flood disaster, can facilitate rapid and effective response efforts. Sahana has also been deployed for cyclone and earthquake management in Myanmar, Peru, Pakistan, Indonesia and Haiti[547]. It is a free and open source software-(FOSS-)based disaster management system consisting of a missing person registry, organisation registry, camp and shelter registry and request management system.

The downloadable software serves the needs of government agencies at the federal or local levels, NGOs, global agencies, communities and victims, and technology developers. From a technology standpoint it functions networked or standalone and can be installed on different platforms (Windows, Mac, Linux etc) and on a laptop for workers in the field or at a central command centre for overall coordination. This is one of a few examples of a new successfully-applied-in-practice information system made readily available for a range of actors in the response effort in developing countries.

3.2. Early Warning Systems

Using ICT and traditional observation mechanisms coupled with climate data analysis, immediate and short/medium/long-term warnings can be made in order to minimise harm to vulnerable communities. Traditionally, most people in developing countries obtain climate contingency-related information through combined word-of-mouth, traditional knowledge and local media sources. However, the first two are often inefficient and arbitrary, whereas local media reports can be difficult for people to understand[548]. Radio and television are considered the most effective traditional media and are still being widely used for disaster warning in developing countries[549]. While they are effective for spreading a warning quickly to a broad population (even in rural environments where the teledensity is relatively low) the drawback is that their effectiveness is

543 Sutton (2009)
544 Apikul (2010), Chanawongse (2009)
545 Apikul (2010), Wattegama (2007)
546 www.sahana.lk
547 UN ESCAP (2008), Iglesias et al. (2010), n.a. (2009)
548 UNFCCC (2006)
549 AMARC (2008), t4cd (2006)

significantly reduced at night when they are normally switched off[550]. Proliferation of channels, and extension of warnings to those not listening/viewing are also issues.

Developing and implementing an effective EWS requires the contribution and coordination of a wide range of individuals and groups encompassing affected communities, national and local governments, regional institutions and organisations, international bodies, NGOs, the private sector and the scientific community. Each has a set of overlapping functions for which it is responsible[551]. In between these layers of actors ICT plays the crucial role of providing support to ensure the collection and dissemination of information and delivery of early warnings. In order to improve EWS at these levels there has been increasing focus on new ICTs for analysing and processing information and providing automated alerts to vulnerable populations. This involves the convergence of different information, risk assessment and disaster modelling and analysis systems, combined with multiple communication channels to send the alert[552].

3.2.1. Early Warning System Technologies

There is a wide range of new and emergent ICTs that can be used for receiving and disseminating alert messages to the public or central command posts[553]. For instance, trials are underway in 63 developing countries on a small two-way emergency messaging system named RANET Chatty Beetle, which can also be used to collect weather observations[554]. Many of its ICTs are subsets of the technologies already discussed and in some cases are already deployed and proven as well-suited to the developing country context, often in conjunction with non-ICT systems such as public address systems[555]. However, the range of technological EWS solutions introduces a tangle of conflicting requirements including cost and reliability, and raises several technological, social, and political problems[556].

Furthermore, no single technology has emerged as a fail-safe solution and little inquiry has been undertaken concerning the best channels to effectively warn vulnerable communities. In the context of cyclones on the East coast of India, a study of the public response to cyclone warning indicated that evacuation behaviour was not strongly related to the channel through which the warning was received or the timing and frequency of the warnings. Rather, evacuation behaviour was significantly related to prior warning experience, environmental cues, perception of safety during evacuation and perception of quality of stay at the relief camps, and the number of channels through which a person received the warning message[557]. This suggests that a multi-channel approach is the best strategy and that effective reliable systems are needed in order to develop a positive response pattern of behaviour among vulnerable communities.

550 Chanawongse (2009), Wattegama (2007)
551 UN/ISDR (2006)
552 UN ESCAP (2008), Wattegama (2007)
553 ITU (2010a)
554 RANET (2009)
555 Subramanian (2005)
556 Basha and Rus (2007)
557 Sharma et al. (2009)

Examples of key technologies are discussed next.

(a) Satellite Radio

A satellite radio is a digital radio that receives signals broadcast by a satellite, which covers a much larger geographical area than the traditional terrestrial radio antenna. Satellite radio can play a key role during both disaster warning and the recovery phase. Satellite audiences follow a single channel regardless of location within a given range, usually in areas not covered by terrestrial radio channels[558]. Bangladesh, India, Indonesia, Sri Lanka and Thailand have tested a Satellite Radios for Emergency Alerting (AREA) system that can be used to disseminate warnings to vulnerable communities. A GPS-enabled radio receiver set allows for warnings to be issued, in text and audio formats to specific areas[559].

(b) Mobile Phones

Fixed telephone lines suffer from congestion during disaster situations, exacerbated by the low penetration rate in developing countries. By contrast, mobile phone penetration rates are high in developing countries and there are many examples of how simple mobile phone warnings saved lives in environmental disasters[560]. SMS in particular are useful as an alert mechanism amongst family and friends[561] and are considered faster than conventional mass media[562]. In Wenling City in China, a sophisticated system to identify vulnerable buildings that could not withstand cyclone winds was implemented in order to warn residents. After identifying at risk buildings, residents were sent individual warning SMSs and relocated to safer places before a cyclone hit[563]. This acts as an example of not only an EWS, but also one of a few cases of understanding relevant infrastructural limitations and using ICT to adapt to it.

(c) Cell Broadcasting System

Cell broadcasting, which is being used increasingly in developing countries[564], is a geographically-specific public warning text message that can be sent to all mobile devices with such capability in any group of cells of any size, ranging from one single cell (about 8 kilometres across) to a collection of cells covering a region or country. Different mobile phone system standards have this capability[565]. It has been examined as a coastal warning mechanism for fishing sites, to warn fishermen/women of impending extreme weather events[566] and village communities[567]. In Bangladesh, the Disaster Management Information Centre is piloting CBS-based early warnings for floods in Sirajgonj and cyclones in Cox's Bazar[568].

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558 Chanawongse (2009), Wattegama (2007)
559 Apikul (2010)
560 Chanawongse (2009), Wattegama (2007)
561 Chanawongse (2009)
562 Samarajiva (2005)
563 UN/ISDR (2008)
564 Halder and Ahmed (2010), Wattegama (2007)
565 Wattegama (2007), CDMA, D-AMPS, GSM and UMTS are popular mobile phone system standards used around the world. CDMA, D-AMPS and GSM are considered second-generation technologies, while UMTS is a newer third-generation system designed to replace GSM. Towards 4G (such as WiMAX and LTE/3GPP) Multicast Broadcast Services usage scenarios will be possible and include streaming of multimedia, file downloading, real-time monitoring amongst other applications (UN ESCAP., 2008).
566 Torii et al. (2010)
567 Waidyanatha et al. (2007a)
568 Apikul (2010)

A critical issue with CBS is that it requires the use of private networks[569], which raises questions concerning the early warning as 'public good' and the private infrastructure required for its operation[570]. For instance, of concern, some network operators in developing countries have the CBS feature switched-off because they would have to pay a license fee to have it on[571].

(d) The Web

The effectiveness of the Web depends on the Internet penetration rate within the particular community, which is typically not high enough to expect it to play any critical role, particular for immediate EWS, in developing countries. Nonetheless, many new and continuously evolving Web-based EWS initiatives have been developed which can feed into immediate EWS and non-immediate EWS. For example, the Sharing Earth Observation Resources Website[572] provides a single access point for earth observation information and services including satellite imagery. Likewise, the Global Disaster Alert and Coordination System (GDACS)[573] a joint initiative of the United Nations and the European Commission provides real-time alerts about natural disasters around the world. The difference with this tool is that it enables the provision of warning messages (e-mail and SMS) and a secure virtual space for coordination efforts and maps and reports, and is directed more at disaster managers. These innovative systems are likely to inform part of the early warning decision-making process amongst politicians, scientists, and other local and international bodies. Amongst vulnerable communities Web 2.0 tools (Twitter, Facebook, etc) are likely to play some role[574], however they are better suited to coordinating relief and reporting casualties, damage, etc.

(e) Wireless Sensor Networks and Wireless Broadband

Many of the monitoring scenarios discussed above using WSN and wireless broadband can be used as a core element of an automated EWS. For instance, the infrastructure setup for monitoring can be used with other EWS tools to alert citizens and authorities to a particular contingency and allow for quicker response times and accurate data to be relayed[575]. However, the best method for using information gathering related to warnings from these systems to vulnerable communities has not been explored.

(f) The Common Alerting Protocol (CAP)

The Common Alerting Protocol (CAP) is an International Telecommunication Union (ITU) recommended international standard for public warnings. It is an XML-based data format for exchanging public warnings and emergency messages between alerting technologies. CAP allows a warning message to be consistently disseminated simultaneously over many warning systems to many applications, increasing warning effectiveness and simplifying the task of activating a warning for responsible officials[576]. CAP is useful for sharing alert information across multiple and dissimilar emergency information systems[577] and its benefits include cost reduction, reduced complexity, and the ability to convert messages to and from the native formats of all kinds of sensor and alerting technologies, forming a

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569 Goswami (2005), Wattegama (2007)
570 Goswami (2005)
571 Mongi (2007)
572 www.eoportal.org
573 www.gdacs.org
574 Wattegama (2007), Apikul (2010), Coyle and Meier (2009)
575 Khadivi et al. (2009), Linsey et al. (2010)
576 ITU (2007)
577 OASIS (2006)

basis for a technology-independent national and international "warning Internet"[578]. It has been applied in the USA, Europe and developing countries in initiatives related to climate change such as the state-of-the-art OASIS project[579] and other EWS[580].

HazInfo - a project on last-mile hazard notification in Sri-Lanka involving 32 coastal villages - implemented the CAP content standard in order to provide a semantic structure for composing warning messages, which could then be relayed rapidly and accurately across multiple technology platforms in English, Tamil and Sinhalese (see Figure 3). The project also incorporated a cross-section of communication technologies and assessed their potential to distribute hazard information to rural and remote communities. The network consisted of mobile and fixed telephones (including a specialised remote alarm system based on GSM), addressable satellite radios, and a small number of Internet terminals[581].

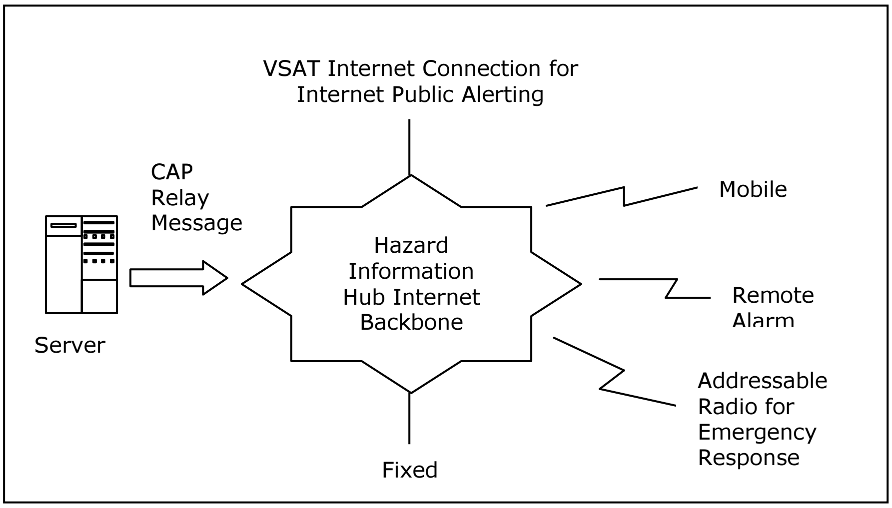

Figure 3: CAP Message Relay and the ICTs that Receive Alerts[582]

During a trial of the HazInfo EWS, misinformation was received by the target group and as a result instead of reacting to a Category 4 Cyclone the target group executed tsunami evacuation plans, which involved running to higher grounds, when critically the community were meant to seek shelter at lower ground[583]. This demonstrates the importance of the ensuring accuracy of the technology each time it is used in order to build trust.

4. Climate Change Adaptation

To cope with current and future climate stress, communities - particularly those most vulnerable in developing countries - must build their resilience, including adopting appropriate technologies, while making the most of traditional knowledge, and diversifying their livelihoods[584].

578 OASIS (2005)
579 Open Advanced System for Disaster & Emergency Management. See www.oasis-open.org and www.oasis-fp6.org
580 RANET (2009)
581 ITU (2009a)
582 Adapted from Waidyanatha et al. (2007b p.282)
583 Waidyanatha (2008)
584 UNFCCC (2007)

The choice of adaptation interventions and ICT applications is dependent on the circumstance of each community or region. Bottom-up, local coping strategies are an important element of planning for adaptation[585] and ICTs can be used in a number of productive ways, particularly by leveraging existing ICT successes in developing countries such as telecentres and mobile phones, as well as introducing emergent ICTs in conjunction with existing sectoral policies, planning and budgeting[586].

While a review of the extant literature reveals relatively little to date in the field of adaptation in the context of new/emerging ICTs and developing countries, there are a number of positive examples of innovative uses of existing technologies and large potential for the application of the emergent technologies discussed in this paper.

Experience has shown that those best placed to prepare for and respond to climate change are local populations. Therefore, a key aim is obtaining community participation and providing relevant information to stakeholders. To date, such approaches have involved word of mouth and radio, primarily for disseminating information to vulnerable communities[587]. Participatory GIS (PGIS), which involve local people during data collection and in the verification of data has shown to have direct community benefits[588] and demonstrates how communities can be integrated with the use of newer ICTs.

Telecentres have featured heavily in ICT for development programmes and have emerged as important in climate change adaptation and resilience building[589]. Beyond their traditional use as an information and computer access centre, emergent examples of information to be made available through telecentres include digitised hazard maps that track the hazards to which the communities are vulnerable (for instance, propensity for heavy rainfall to cause flooding in a densely inhabited area), digitised resource maps that indicate the locations of the resources available to deal with the risks, and chronological logs of disasters that had previously taken place in the area. These information bases can be created with input and involvement from the local community with technical support from disaster management authorities[590]. Therefore, telecentres can be a proxy to access new Web-based technologies, new information repositories, and information collected from advanced monitoring WSNs.

New technologies are increasingly being linked to telecentres. For instance, in addition to a telecentre based agrarian information system for use by farmers in Huaral Valley, Peru, portable terminals are also projected to be used in order to allow access to information outside of the telecentres[591]. Wireless broadband in particular has the potential to change the landscape of telecentres by connecting more remote locations, providing increased bandwidth[592] and therefore access to a range of new digital applications and new portable devices that can thereby be connected to telecentres.

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585 *ibid*
586 *ibid*
587 Solervicens (2009)
588 Shrestha (2006), Aynekulu et al. (2006)
589 Kumar et al. (2005), UN ESCAP (2009)
590 UN ESCAP (2009)
591 Novotný, (2009), APC (2007)
592 Rao and Radhamani (2007), Sibanda et al. (2008), Clendenning (2006)

4.1. Emergent Technologies and Adaptation

A number of ICTs have been described in this paper which can inform adaptation. For instance, monitoring networks can inform habitat location (provide information to house communities away from flood- or landslide-prone areas), better agriculture (based on informed climate information or water allocation) and provide early warnings, amongst other applications. Therefore, a key advantage of the wireless broadband and WSN examples provided in this paper is that they can span a range of activities. Further, as climate monitoring is an ongoing process many of the localised examples that have been described will over time provide longitudinal data that can inform global and local climate change science and adaptation.

A range of innovative Web-based tools and climate-related Web sites have also emerged as useful for informing the adaptation process. For instance, a range of online tools exist which can be used to present monitoring and prediction data[593] and inform communities on emergencies and disease outbreaks[594]. These are driven by NGOs, for instance, USAID's Famine Early Warning Systems Network[595] provides real-time updates on global weather hazards, food security and remote sensing data for a number of developing countries (Burundi, El Salvador, Nicaragua and Yemen).

By and large however, the main form of ICT applied in the adaptation process is mobile technology. The use of mobile technology in innovative ways in the context of adaptation is discussed next, covering topics such as health, environmental management and agriculture. A key focus is the expected diffusion of mobile broadband and its opening of a range of possibilities for climate change adaptation.

4.1.1. Scaling–up Mobile Technology for Adaptation

Mobile phones are increasingly being examined as a means of transitioning citizens from mainly voice to more advanced applications, including agriculture, government, capacity building[596] and relevant monitoring[597] and climate change adaptation information/applications through connection to mobile broadband technology. For instance, it can also allow for e-health/telemedicine applications (discussed below) and Multicast Broadcast Services[598]. The latter would be particularly useful for NGOs for broadcasts on local climate related events, downloading climate relevant data, alert services, weather information and real-time monitoring. To date, such services have only begun to be realised in the developed world.

In the context of ICT and agriculture, environment related information ranks high in the needs of the rural populations in developing countries[599] and at the farmer/village level mobile phones are likely to remain the key information medium[600]. Mobile phones have been used to provide agricultural advice in the form of voice and text messages[601]. In India it was demonstrated that mKRISHI, a mobile based agro-advisory system, provided up-to-date weather and pricing

[593]See http://climateprediction.net/, http://www.eoportal.org/, http://www.eoportal.org/
[594] www.alertnet.org, http://medusa.jrc.it
[595] www.fews.net
[596] Hopeton (2009)
[597] Linsey et al. (2010), Ibikunle and John (2008)
[598] Ergen (2009), Gur et al. (2008), Dahlman et al. (2007)
[599] Panchard et al. (2007)
[600] Kinkade and Verclas (2008), Dongtotsang and Sagun (2006), Tandon (2009)
[601] Ramey (2009), Kinkade and Verclas (2008)

information through text-messaging on mobile phones using sensors and GPS. The application can be prompted by text in farmers' local languages or via voice functions[602]. The pilot supported 20,000 farmers and was expected to reach 200,000 farmers[603]. The success of mobile phone innovations in the sphere of agriculture and adaptation suggest that they can be used to overcome some of the issues of farmer participation in the use of WSNs.

Mobile Health Application

Along with climate variability and extreme weather events, climate change is expected to increase the risk of disease, such as vector borne infectious diseases, to vulnerable communities[604]. In the process of adaptation and building resilience it is unequivocal that strengthening of health monitoring and information systems using ICT is required. As an example of mobile technology used for health purposes, TNokia launched a new software solution called Nokia Data Gathering to help the public sector and NGOs quickly and accurately collect data on critical issues such as disease outbreaks or disaster relief via mobile devices free of charge.

The Amazonas State Health Department in Brazil will be the first to use the solution as part of its fight against dengue fever in the city of Manaus in Northern Brazil. With the use of a regular mobile network, it can create tailored questionnaires and distribute them to multiple mobile phones. Field personnel surveying local conditions are able to quickly complete the questionnaires and immediately transmit findings to a central database. The system also allows organisations to geo-tag data with GPS location information to build a more detailed picture of local conditions[605].

Other health monitoring/reporting systems such as EpiSurveyor[606] and OpenMRS[607] have successfully been implemented in a number of African countries and will be critical in the adaptation process as the impacts of global warming manifest in developing countries. This method of surveying and emergency reporting could also be extended to monitor environmental, disaster management or global warming-related issues[608].

This is another area where wireless and mobile broadband technologies in particular can play a role in the adaptation process and enhance e-health/telemedicine activities. Such technologies allow for remote diagnosis, where there is a need to transmit urgent data in order to make immediate basic diagnosis, a need to intervene on non-transportable patients, providing in-situ treatment and remote monitoring[609]. This would allow high-resolution video footage to complement the diagnosis and treatment of persons[610].

In the climate change adaptation process such technologies can be used when temporary medical sites/displacement sites are setup for responding to disease breakouts, when large numbers of displaced persons due to climate change lead to temporary location sites, and for responding to emergency disasters where there is a large number of distributed casualties and limited medical personal.

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[602] Joshi et al. (2008)
[603] n.a., (2008)
[604] IPCC (2001), Watson et al. (1997)
[605] i4donline (2008)
[606] www.episurveyor.org
[607] www.openmrs.org
[608] Webersik and Wilson (2009)
[609] Neves et al. (2009a, 2009b)
[610] Mignanti et al. (2008)

Figure 4 illustrates some potential scenarios where this technology could be applied, particularly by NGOs.

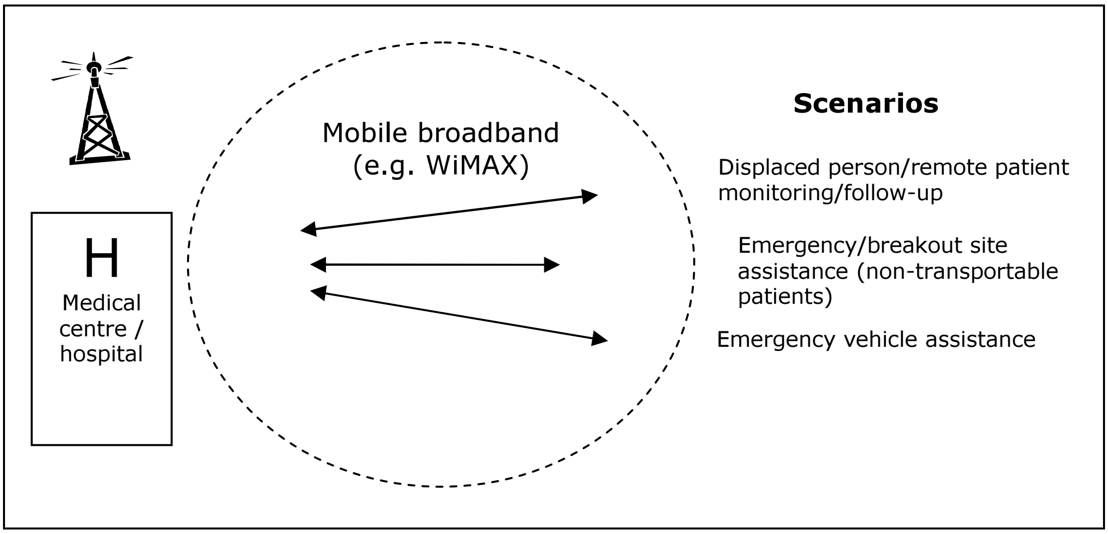

Figure 4: Examples of Telemedicine Application of Mobile Broadband[611]

5. Discussion

Several themes emerge from this review of the application of new and emergent ICTs to climate change in developing countries. The areas gaining the most currency are disaster management and early warning systems (EWS). This is linked to global and local level commitments to address environmental contingencies in the wake of recent large-scale environmental disasters. National disaster management systems and bodies and bottom-up initiatives have been established that have aligned their approaches with the use of new ICTs including Common Alerting Protocol (CAP)-based EWS, wireless broadband systems, wireless sensor networks (WSN), geographic information systems (GIS), disaster management information systems and even mobile ad-hoc networks (MANETs). The Sahana disaster response information system in particular is an instructive example of innovative use of ICTs in response to climate/environmental phenomena. On a global scale however, this is fragmented with many policymakers yet to acquire the knowledge needed to effectively plan for and operationalise new ICTs[612], and there appears to be little coordinated activity. As a point of reference, in the developed world there is a range of advanced environmental applications and coordinated regional activity[613], which has not been replicated to any significant extent in developing countries.

Unlike disaster management, the application of new ICTs to adaptation, particularly for longer-term climate change impacts, has not been addressed in a serious way and is mentioned as a priority in general statements, receiving low priority in terms of practical action. To this end, it is important that more funding is committed to making use of new and emergent ICTs for climate change adaptation and more attention is devoted to practical solutions, rather than broad-brush statements concerning the utility of ICT.

[611] Adapted from Neves et al. (2009b p. 59)
[612] Zengpei and Rhee (2010)
[613] For instance see http://ec.europa.eu/information_society/activities/sustainable_growth/funding/prj_climate/index_en.htm

While research on new technologies to effectively deal with climate change in developing countries is beginning to take shape, many of the examples of new ICTs were embryonic, making it difficult to assign definitive benefits. This paper alluded to the technical feasibility of the solutions discussed as well as greater automation, accuracy, reduced cost, better response and information exchange made possible through the ICTs examined. Importantly, this level of automation and scalability allows for use of the technology across more than one application area. For instance, a tropical rain monitoring WSN can be used for observation, data capture, early warning and informing adaptation. Examples were also given on predicting, rather than just detecting certain climate change related events through monitoring networks[614].

These examples provide lessons for NGOs and governments interested in building effective resilience solutions for vulnerable communities. Of course the picture is not just skewed to benefits. Along with level of technical sophistication demanded by new ICTs a number of challenges are raised such as gaining community involvement and identifying solutions that are specifically relevant to vulnerable communities.

While local level monitoring systems are beginning to be developed and deployed, greater attention is needed concerning management of monitoring data. This involves mechanisms to use captured data to inform livelihood, resource management and other relevant decisions that affect vulnerable communities. This will require building interoperability and open standards, which is essential so that data that has been captured at one point can be shared with other platforms to ensure complete data is used to inform decision making. That is, can sensor networks, remote sensing, GIS, Web systems etc talk to each other in an effective manner? This will become an important issue with the scaling-up of the mix of new and established technologies used for climate change scenarios. At the Web level the Global Earth Observation System of Systems[615] will allow interoperability amongst hundreds of web portals[616], however at the infrastructure level few initiatives are taking place (an instructive exception being CAP). With the increasing use of sensor networks and rich data captured through wireless broadband monitoring systems and other hybrid systems a complex issue that emerges is ownership of the data. For instance, many of the examples described in this paper were small-scale and localised and it is unclear how data captured feeds into broader climate change data collection and then dissemination that would inform local communities. A fundamental question is: who owns the data[617]?

The potential of WSNs for climate change has only recently begun to be examined. There have been calls for WSNs to be deployed in developing countries on a community shared-model basis[618] (i.e. sharing the WSN across multiple application areas rather than rolling out one for rainfall, one for landslides, one for fire detection, etc), which would offer some benefits for grassroots applications. A number of relevant WSN applications have been discussed in this paper which should be leveraged as successful exemplars for governments, NGOs and other relevant bodies. These were predominately localised examples and a gap still exists between local and national/global monitoring. As an emergent technology a number of technical challenges remain that need to be addressed, such as being able to withstand extreme weather events, deployments in remote

[614] Sheth et al. (2007, 2005), Basha et al. (2008)
[615] www.earthobservations.org
[616] ITU (2008b)
[617] Houghton (2009)
[618] Ramanathan et al. (2006)

areas and power[619]. Another gap in understanding is how data that is captured by monitoring WSNs and other ICTs is presented, disseminated and acted upon.

As the impacts of global warming continue to mount, more robust communication networks will be required[620]. This paper presented the case for wireless broadband communications for climate observation systems, rapidly deployable communications and the underlying network infrastructure for WSNs. The implication of hybrid networks such as satellite with mobile WiMAX (and in the future other 4G technologies), will allow for more flexible architectures leading to improved climate, environmental and health forecasting and monitoring whilst reducing the digital divide[621].

Countries that have suffered from a lack of broadband connectivity should therefore continue to examine wireless communications in order to provide enhanced connectivity and a more climate resilient infrastructure for future climate related applications. This is a key consideration for telecommunications policymakers in developing countries when deciding upon improving or implementing new infrastructure.

The use of the range of established low-tech ICTs (radio, television, mobile phone etc) and the convergence with new ICTs show the contextual compatibility of these technologies to vulnerable communities. Mobile phones and advances in mobile technology are likely to continue to play a large role in climate change adaptation. However, at present there is a clear disconnect between mobile phone uses (i.e. for agriculture, monitoring, and health) and the data captured through monitoring networks using new ICTs. A key question therefore is what is the potential for the convergence of mobile phones with advanced monitoring systems? The introduction of mobile broadband networks and the proliferation of smartphones present interesting avenues for future climate change applications. It is important that NGOs and governments begin to consider the range of climate change applications that can be made available with the projected increase of mobile broadband and devices.

The Web has also emerged as a promising climate change relevant technology, particularly for information dissemination and disaster management, and should continue to be researched and developed in order to understand and enhance its role in the climate change adaptation process. NGOs should embed these into their range of climate change activities to allow for greater community participation and additional information dissemination and collection channels.

A notable theme is that many of the examples in this paper have stemmed from South and South-East Asia and Latin America. Little application of ICT, new or otherwise, in Africa or Small Island Developing States (SIDS) in the context of climate change appears to have taken place, even though these countries are inhabited by the most vulnerable populations. This follows the broader pattern of ICT for development. There is a need for greater emphasis on ICT climate applications in Africa and the SIDS in order to prepare vulnerable communities.

5.1. Priorities for Future Research

This paper highlighted a number of gaps in the extant research and identified fruitful areas for further inquiry. Focusing on the impacts and outcomes of the use

[619] Basha et al. (2008), Khadivi et al. (2009), Vassilaras and Yovanof (2010)
[620] Ghosh (2007)
[621] Olla (2009a)

of new and emerging ICTs will augment understanding of the benefits and provide greater basis for advocating their diffusion.

From a technological position, looking ahead, the introduction of mobile broadband networks and the proliferation of smartphones present interesting avenues for research especially in the context of preparing for future climate change applications. There also needs to be a focus on researching the opportunities arising from the convergence of older and newer ICTs. Along with the mix of ICTs emerging for climate change applications a number of peripheral issues also need investigation, particularly, the ownership of data and information sharing across multiple technology platforms. The consequences of these issues particularly where a mix of public actors and private infrastructure is involved have barely been examined. Finally, and moving further from the technology, a critically under-researched area is the information requirements of vulnerable communities. Concentrating on community needs, rather than just technical issues, will ensure greater community participation and therefore improve the success of adaptation initiatives using new and emergent ICTs.

5.2. Recommendations

Based on the review of new and emergent ICTs and climate change in developing countries a number of recommendations are formed in order to facilitate greater understanding of how they may be applied. This will encompass expanding their application across climate change areas, building the underlying infrastructure that is required for the technology, and ensuring that communities, NGOs and governments can maximise the benefits of the ICTs available in order to meet the climate change challenge.

Recommendation 1

Demonstrate the success and feasibility of new and emergent ICTs in relation to climate change in developing countries:

- Review the benefits and outcomes of the use of new and emergent ICTs for climate change.
- Develop a knowledge base of the lessons learnt in the deployment of new and emergent ICTs.
- Leverage examples of successful deployments of new and emergent ICTs.
- Deploy new ICTs in Africa and SIDS in order to demonstrate their success and feasibility even in the least developed countries and most demanding environments.

Recommendation 2

Focus more on adaptation activities:

- Using the technologies outlined for monitoring and disaster response, focus on longer-term adaptation activities. Possible initiatives involve bottom-up and participatory approaches facilitated by the use of new and emergent ICTs.

Recommendation 3

Invest in wireless infrastructure:

- Use wireless infrastructure as a backbone for future climate applications.
- Examine the role of mobile broadband for use by NGOs, responders and other stakeholders.
- Research future wireless/mobile broadband climate change applications.

Recommendation 4

Build advanced terrestrial monitoring networks:

- Continue technical development of monitoring networks for climate change scenarios that would improve precision of climate monitoring. and prediction of climate change impacts.
- Establish how captured monitoring and prediction data can feed into local level information channels.
- Research the best-suited technologies for communicating early warnings.

Recommendation 5

Build upon established and successful technologies:

- Use wireless broadband as a means to up-scale existing initiatives
- Use mobile phones and telecentres to complement data captured by advanced monitoring systems and to act as dissemination channels.
- Use FOSS for climate change relevant information systems deployment.
- Research the role of the Web 2.0 for climate change action and its use as part of outreach, empowerment and adaptation strategies.

Recommendation 6

Understand information requirements and build cross-platform interoperability:

- Research how data gathered from observation systems using new and emergent ICTs can be integrated into broader climate change science.
- Investigate and understand data ownership at the local, regional and national level.
- Research the information needs of vulnerable communities and how these can be met by new ICTs.
- Develop and promote interoperable standards for data exchange across multiple platforms.

6. Conclusions

This paper has reviewed new and emergent ICTs and developed an understanding of the new technologies relevant to developing countries and climate change. It augments understanding of the ways in which ICTs can be deployed to specific climate change issues and presents a number of recommendations to better allow for the effective use of ICTs. Within the frame of reference of development, climate change and ICTs it is impossible to escape the reality of related factors such as limited infrastructure, and technology, illiteracy, poverty and so forth, which complicate climate change adaptation. The challenge is building on the current momentum and using the appropriate and best mix of new and established ICTs to address climate change in developing counties, while balancing sustainable development, the digital divide, financial scarcity and the short-term well-being of citizens.

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Glossary

2G: Second generation wireless telephone technology.
3G: Third generation mobile telephone services.
4G: Fourth Generation technology.
ADSL: Asymmetric Digital Subscriber Line.
CAP: Common Alerting Protocol.
CBS: Cell Broadcasting System.
CDMA: Code Division Multiple Access.
EWS: Early Warning System.
FOSS: Free and Open Source Software.
GIS: Geographic Information System.
GPRS: General Packet Radio Service.
GPS: Global Positioning System.
GSM: Global System for Mobile Communications.
HSPA: High Speed Packet Access.
ITU: International Telecommunication Union.
LOS: Line of Sight.
MANET: Mobile ad-hoc network.
NLOS: Non Line of Sight.
PSTN: Public Switched Telephone Network.
SMS: Short Message Service.
Wi-Fi: Wireless Fidelity.
WiMAX: Worldwide Interoperability for Microwave Access.
WSN: Wireless Sensor Network.
WMO: World Meteorological Organisation.
WWW: World Weather Watch.
UMTS: Universal Mobile Telecommunications System.
VSAT: Very Small Aperture Terminals.
ZigBee: IEEE 802.15.4 wireless mesh networking standard.

Chapter 9: Exploring the 'Gender-ICT-Climate Change' Nexus in Development:
From Digital Divide to Digital Empowerment

SAM WONG

Executive Summary

How gender influences the effectiveness of information and communication technologies (ICTs) in tackling climate change is under-researched. Gender is social expectations and stereotypes of how men, women, boys and girls, should behave in society. Gender enables some groups of men and women to get access to ICTs, whilst constraining others from doing so. Different control over ICTs, built on unequal power relationships, affects how poor people adapt to the changing climate and respond to climate-related disasters.

Conceptually, this paper explains why, and how, women are more constrained than men from using ICTs in tackling climate change. In term of assets, compared to men, women have less access to technology, to information, to finance, and are more deprived of land rights. Women are more institutionally-constrained than men. With regard to social structures, women are excluded from decision-making in policy design and resource allocation. They are less represented in formal decision-making bodies, such as the Clean Development Mechanism (CDM) and the Reducing Emissions from Deforestation and Forest Degradation (REDD) initiative.

In addressing these limitations, this paper makes four digital empowerment proposals in an attempt to make 'ICT-climate change' interventions more gender-sensitive:

(1) ***Contextualise gender mainstreaming***: gender mainstreaming helps integrate gender analysis into ICT policies. It acknowledges that men and women perceive and receive information differently, and that this requires diverse approaches to adaptation. However, the attempt to re-position women and girls as 'eco-carers' is problematic because this fails to capture their protective, as well as their destructive, role in relation to natural resources. Without addressing the unequal power relations between women and girls, e-adaptive practices can also help reproduce the inter-generational equalities.

(2) ***Strengthen governance***: crafting new and reforming old, institutional arrangements is essential to improve gender inclusion. Women-only interventions are sometimes necessary to empower previously-excluded women to engage in ICT-related decisions. However, poor and powerless men should also have their say in climate change policies.

(3) ***Develop gender-sensitive funding mechanisms***: securing adequate funding to support ICT interventions is crucial to gender empowerment. Yet, targeting women by micro-credit projects risk putting an additional financial burden on them, and that needs serious re-consideration.

(4) ***Recognise agency-structure dynamics***: women are active agents, but they are socially constrained from engaging in ICT-related decisions. Women's preferences, institutional arrangements and politics need to be taken into account in order to tackle digital exclusion.

These four proposals will be useful for development agencies, governments and NGOs seeking to improve the gendered outcomes from use of ICTs in response to climate change.

1. Introduction

Information and communication technology (ICT) seems to offer a partial solution to the problems of climate change. Kalas and Finlay (2009) suggest that ICTs help 'demystify climate change and improve climate literacy at all levels of society' (p19).

One positive part of the picture is that ICT facilities and subscriptions have seen fast expansion in developing countries over the past decade. The number of internet users has increased ten-fold (World Bank, 2011b). Growth rates of 40-50% per annum have been typical for mobile phone subscriptions (ITU, 2011). Institutionalisation of ICT strategies in national plans also shows a strong determination towards bringing ICTs to full capacity (Hussain, 2010).

Despite these positive signs, the digital divide, defined as 'between those with ICT capacity and access and those without' (UNDP, n.d.: 1), has been widening, not only between developed and developing countries, but also between developing countries, as well as between rural and urban areas (Nsibirano, 2008). According to the World Bank's World Development Report, the gender digital divide remains acute. Men, on the whole, are still better connected than women. In general, women in low-income countries are 21% less likely than men to own a mobile phone (World Bank, 2012). South Asia has the widest gender gap in mobile phone ownership, a record 37%[622].

While we are gaining a deeper understanding of the relationships between ICT and climate change (Heeks and Ospina, 2010; IISD, 2011; UNDP, 2011)[623], ICT and gender (Nsibirano, 2008; World Bank, 2007)[624], climate change and gender (IDS, 2008; UNDP, 2010b)[625]. The interactions between gender, ICT, and climate change are, however, under-researched[626].

One of the challenges in unpacking the 'gender-ICT-climate change' nexus is that there is a great deal of faith in ICTs in addressing climate change and, simultaneously, achieving gender empowerment (Etta, 2005)[627]. In reality,

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622 Although the World Bank has invested US$4.3bn in ICTs between 2003 and 2010, its internal evaluation reports show that only 30% of the investments have achieved the objective of increasing ICT access for poor or under-served areas (Independent Evaluation Group, 2011).

623 MacLean (2008) conceptualises the functions of ICTs in climate change in three aspects: monitoring and measuring the impact of climate change, raising awareness and facilitating dialogue, and fostering 'networked governance' (p4). The International Telecommunication Union (2009) suggests that ICTs can be an 'effective tool to combat climate change', but the effectiveness hinges on whether countries 'have affordable, widespread and accessible ICT infrastructure' (p2). Heeks and Ospina (2010) argue that the relationships between ICTs and climate change need to 'acknowledge the complex set of elements, relationships and vulnerabilities that prevail in developing settings, and that further constrain the ability of developing countries to withstand, recover from and adapt to the effects of climate change' (p4).

624 Thas et al. (2007) accuse the ICT industry of imposing stereotypes on women, considering them as merely 'consumers', rather than 'creators', of ICTs (p8). Gurumurthy (2004) criticises ICTs for focusing too much on technical solutions, and too little on social dimensions of the problems (p1).

625 UNDP (2010) warns that climate change can magnify gendered and other forms of inequalities when 'resources and access to goods and services become constrained in a changing climate' (p3). Rising inequalities, IDS (2008) suggests, would also 'intensify the impacts of climate change for all individuals and communities' (p2).

626 More funders are now aware of the research gaps. The International Institute for Communication and Development (IICD) and the International Development Research Centre (IDRC), for example, have offered grants to carry out research and projects to address the nexus.

627 MacLean (2008) considers ICTs as 'transformative technologies' (p1). The European Parliament (2011) regards ICTs as a 'revolution' for developing countries (p1). Hakfin and Taggart (2001) make a bold claim that: 'information technology can offer significant opportunities for virtually all girls and women in developing countries' (p4, our emphasis). UNDP (2011) also suggests that increasing access to information and education is 'essential for reducing the unequal vulnerability of women to climate change' (p8).

however, the report by the United Nations (2002) indicates that gender issues 'have yet to be introduced into ICT policy-making in Africa' (p17) and little has changed since that report. Many ICT projects do not properly analyse gender and social impact before, or during, the interventions (Castren and Pillai, 2011). In evaluating the impact of the World Bank's ICT projects, the Independent Evaluation Group (2011) suggests that evidence to demonstrate the actual impact of ICT interventions is 'more often anecdotal', and 'systematic monitoring of impact is lacking' (p.xv). Another challenge is methodological: it is quite difficult for researchers to 'uncover the context-specific social processes' of the subtle negotiation between men and women, especially at the household level (Banda and Mehlwana, 2005:iv).

1.1 Objectives of this Paper

This paper intends to offer a systematic review of the complex relationships of this three-way nexus. Drawing on examples and case studies in developing countries, it aims to explore the mechanisms by which gender influences, and is influenced by, the interaction of ICTs and climate change. It intends to highlight the positive and negative gendered outcomes of mitigation, adaptation and disaster planning policies across sectors, such as forestry, agriculture and water. This paper will also identify the gaps in literature and make suggestions for future research.

We want to stress that the focus of this study is not women-specific; instead, it examines the dynamic power relationships between, and within, women and men, along with other social and geographical factors, such as class, age, ethnicity and location, which affect access to power and resources. This paper focuses only on developing countries and draws materials largely from development literature and reports by development agencies. We adopt a content analysis method to unpack the complex meanings of the nexus.

The structure of this paper is as follows: we will first discuss the conceptual framework of the 'gender-ICT-climate change' nexus. We will then make our analysis by focusing on mitigation, adaptation and disaster management. Under each of these three themes, we will examine the role of gender in ICT-climate change interactions. We will conclude by making suggestions for future research.

2. Conceptualising the 'Gender-ICT-Climate Change' Nexus

Before we explain how the conceptual framework is developed and used, we want to unpack the meanings of ICTs and gender.

2.1 A New Generation of ICTs

ICTs are 'complex and heterogeneous sets of goods, application and services used to produce, distribute, process and transform information' (Marcelle, 2000:5, quoted in Gurumurthy, 2004:6). They include the 'hardware, software, networks, and media' that are characterised 'in the form of voice, data, text and images' (World Bank, 2011c:1).

Coyle and Meier (2009) point out that ICTs are not a new phenomenon in developing countries. Many not-so-poor communities already have televisions, telephones and radios for communication and entertainment. That said, the latest ICTs, such as mobile phones, community radio, email, blogs and other Web 2.0 applications, are potentially interactive and participatory. Information can be shared faster and more efficiently between individuals and communities. They reach a wider range of audience and help develop wider networks. In light of this, Kalas and Finlay (2009) suggest these new ICT developments can improve governance by 'empowering the poor and marginalised to raise their voice for political accountability and concrete action' (p9). The new generation of ICTs that has diffused into developing country communities since the turn of the century may therefore be changing the development landscape and development possibilities.

2.2 Gender Matters

The rosy picture has, however, been under challenge[628]. ICTs have been criticised for being gender-blind and their implementers criticised for failing to 'consider gender an important part of project design' (Jolly *et al*. 2004: 9). UNDP (2008) argues that 'ICTs are not gender-neutral – they are not accessed, managed and controlled by all men and women equally' (p5).

Gender is defined as the 'socially constructed roles and socially learned behaviours and expectations of women and men in a particular society' (World Bank, 2001:34). Gendered relations involve 'difference, inequality and power', and that shapes 'access to, and control over, material and symbolic resources' (Wilson, 2004:8). Gendered relations are 'contextually specific and often changing in response to altering circumstances' (Moser, 1993:230).

Gender matters in ICT and climate change research and practice because it highlights the differential access to information. It questions fundamental questions about the nature of information - what is information, who produces information, and how information is used (Coyle and Meier, 2009). Resurreccion (2011) stresses that the access to, and the use of, ICTs is gender-shaped. Gender influences how the benefits, costs and risks of ICTs are distributed between, and within, women and men. For instance, in some Ugandan schools, girls are expected to be discreet and should not run like boys. Influenced by this

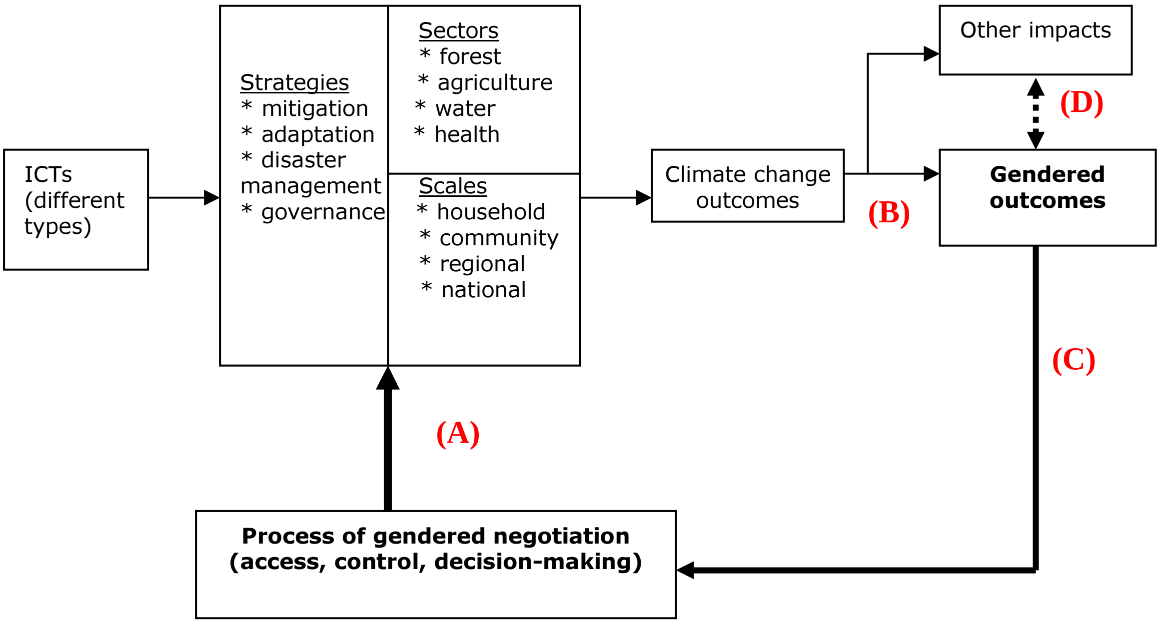
[628] The general criticisms of ICTs underline the obstacles in maximising the impact of ICTs in developing countries. For example, Gurumurthy (2004) highlights five key challenges: absence of basic infrastructure, high costs of ICT deployment, unfamiliarity with ICTs, dominance of English language in internet content, and lack of demonstrated benefits from ICTs (p1).

specific gender norm, along with limited supplies of computers in school, boys gain access to computers and girls are left out (UN, 2002: 5). Gender also influences people to make responses to a changing climate. For example, IDS (2008) suggests that it is often men, not women, who decide what investments are made on their farms – such as investments relevant to climate adaptation – since laws and social practices enable men to have control over land, money, credit and tools.

2.3 Conceptual Framework

Figure 1 shows the interactions between ICTs, climate change and gender[629]. It takes an instrumental perspective to consider that ICTs offer a 'technical fix' to climate change (MacGregor, 2010:8). They are tools that 'facilitate systematic awareness raising and knowledge sharing about the effects of climate change and possible coping strategies at all levels of society' (Kalas and Finlay, 2009:17).

Figure 1. Gendered Processes and Impacts on ICT-Climate Change Interactions



(Source: author's own diagram, inspired by Dankelman *et al.*, 2008 and Nelson *et al.*, 2008)

The influences of ICTs in climate change are discussed here in relation to three areas for strategic action: mitigation, adaptation and disaster management. The interactions are cross-sectoral and cross-level. Governance – sometimes separated as a fourth area – is here seen as embedded in these three strategies. It underlines the rules and institutional arrangements of how different stakeholders interact in different strategies, sectors and levels.

[629] Gurumurthy (2004), Wong and Sharp (2009), and Ospina and Heeks (2011) offer three other approaches to conceptualising the relationships between gender and technology. Gurumurthy compares and contrasts five different theories: Liberal, Marxist, Eco-feminist, Third World, and Culture. Wong and Sharp use the 'agency-institution-structure' framework to analyse how elderly women negotiate access to cutting-edge water innovations. Ospina and Heeks, in contrast, draw on vulnerability and the livelihoods framework to assess the ICT-gender relationship.

(A), (B), (C) and (D), in Figure 1, indicate the four particular mechanisms by which gender influences, and is influenced by, ICT-climate change interactions[630]:

(A) Process of gendered negotiation: The process explores what, and how, information is created and communicated, and how men and women understand the meanings, expectations and experiences of their gendered roles. Gendered relations are constantly negotiated and contested. They enable some groups of men and women to obtain access to information and to influence the outcomes of climate change, while denying others the facility to do so.

(B) Gendered outcomes: Men and women experience the benefits, costs and impact of the ICT-climate change interplay differently because of their differential power positions and social capabilities. The gendered outcomes can be positive, negative and also unpredictable. They are assessed on the basis of if, and how, people's practical and strategic needs are met, and if gender inequalities are challenged or reproduced.

(C) Feedback: The gendered outcomes of ICT-climate change interactions provide feedback to existing gender relations. They allow men and women to re-negotiate their gendered roles and expectations.

(D) Indirect influence: Some ICT-climate change interventions make an indirect impact on gender relations. Changing income distribution between men and women as a result of introduction of new ICTs, for example, can affect their decision-making power.

These four mechanisms provide an analytical lens for us to examine the case materials of mitigation, adaptation and disaster management policies, as discussed below in Section 3.

2.4 Discourses for Gender Inclusion in ICT-Climate Change Strategies

Arguments for including gender analysis in ICT-climate change interventions are diverse in the literature. We summarise them as four discourses: efficiency, effectiveness, equity and rights-based empowerment.

Efficiency: This perspective focuses on the cost-effectiveness of including men and women in projects. Owing to their frequent interactions with natural environments, poor men and women in rural areas are considered as 'resource managers'. Involving them in using hand-held ICT devices to monitor local forests, for example, helps lower monitoring costs and, simultaneously gain project legitimacy (IISD, 2011). This approach is, however, criticised for regarding poor people, especially women, as cheap labour. It pays insufficient attention to the triple roles of women (productive, reproductive and community) and risks increasing their already heavy workload. Defining poor people as 'eco-carers' also ignores their mixed role in environment conservation (Haynes *et al.*, 2010).

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[630] Another possible influence is the gendered nature of the ICT industry itself. Wilson (2004) criticises the masculine culture of ICTs for causing an under-representation of women in the ICT workforce. Light (2006) also suggests that, without adequate female participation in the process of design, development and diffusion of ICTs, ICT products are rarely 'women-friendly'. Despite the significance, we, however, decide not to include this influence in our analysis because the design and production processes of most ICTs are controlled in developed countries, not in developing countries, even while actual production is itself often located in the latter.

Effectiveness: This approach acknowledges the differences of men and women in experiencing vulnerability to climate change and possessing skills in adopting ICTs (Leduc, 2009). Understanding the differences offers better strategies, and thus enhances the chance of achieving the goals of the interventions (UNDP, 2011). This approach stresses participation of men and women in voicing their concerns. However, IDS (2008) is concerned that participation could increase women's workload, without successfully meeting their strategic needs and challenging power inequalities.

Equity: Similar to the discourse of effectiveness, this perspective recognises the diverse interests, needs and priorities of women and men, but it goes further and explains how underlying power inequalities widen the differences (Thas *et al*., 2007). The advocates of this perspective define both the digital divide and climate change as social justice issues. Challenging the fundamental power asymmetries helps remove gender disparities in the access to, and use of, ICTs (Banda and Mehlwana, 2005).

Rights-based empowerment: This perspective points out that poor women and men are deprived of 'their rights to information, knowledge, skills, resources and participation in decision-making' (Economic Commission for Africa, 2009:3). It stresses that rights to information are a basic human right, and that right can only be achieved by true empowerment.

On the one hand, these multiple rationales for gender inclusion can be seen as an incremental change for deprived women, and men, from being powerless to getting involved in the decision-making process. The changes are made possible by moving away from individual actions to collective mobilisation. On the other hand, the complex process of gender inclusion also highlights the tension between different goals of gender inclusion. While an increasing number of powerless women, and men, gain recognition in public participation in the discourse of efficiency, the rights-based activists lay emphasis on the quality of that participation as well as on the long-term impacts of the changes (*Cornwall et al*., 2007).

3. ICT-Climate Change Interventions and Gender

The conceptual framework suggests an inter-relation between 'e-climate change' interventions and gender. But what is the nature of that inter-relation? How do ICT-climate change interventions affect gender equalities; and how does gender, as a social factor, influences the effectiveness of such interventions. Three aspects, i.e. mitigation, adaptation and disaster management, are selected for the discussion below because they are the common policy arenas for interaction of ICTs and climate change strategies. In this section, the notion of governance is crucial to the understanding of the 'gender-ICTs-climate change' nexus. Defined as the ways in which policies are introduced and implemented (Wong and Sharp, 2009), governance plays a key role in affecting digital equalities. However, since governance is strongly embedded within mitigation, adaptation and disaster management interventions, its role will be discussed in each policy arena.

3.1 Mitigation

The conventional view of ICTs and climate change mitigation recognises that ICTs mainly help reduce CO_2 emissions through their application in key emissions sectors, and that will be the focus here; incorporating what 'gender-sensitive mitigation' is, as defined by IDS (2008). However, in doing this, we also note that there needs to be a more critical – and gender-sensitised – examination of the ICT industry itself, given it produces considerable CO_2 in its manufacturing and implementation processes (OECD, 2009).

3.1.1 Clean Development Mechanism

IDS (2008) suggests that existing mitigation policies are over-technical and over-scientific, and leave little room for gender-focused work (p14). The set-up of the Clean Development Mechanism (CDM), for instance, was intended to ensure technology transfers from developed to developing countries, in order to limit or prevent the occurrence of climate change. CDM is the largest source of mitigation finance to developing countries. ICTs, in the form of hardware, software and information, and incorporated into a wide range of new technologies in household energy, agriculture and food processing, forest management, and water pumping in rural areas, are part of the CDM programmes, although there is no statistical breakdown to indicate the actual proportion of ICTs in the CDM projects (Schalatek, 2009).

CDM as a whole, has, however, been criticised for being 'top-down' in nature. The limited consultation with local communities fails to 'give women and men an opportunity to define and have power over their livelihoods' (UNDP, 2010a:2). CDM is also accused of taking an implicit assumption of gender neutrality. UNDP (2010b) suggests that 'little research has been done on the gendered impacts of the CDM, making it impossible to discern the precise degree to which current projects have impacted women and men differently' (p3). Wamukonya and Skutsch (2002) explain that technology transfer in CDM is usually directed towards men, which reproduces the gendered norms that 'men are considered the decision-makers and the eventual managers of technology' (p121). A lack of recognition of women's contribution is also reflected in CDM governance. Of the 61 people who have served as Executive Board members, UNDP (2010b) shows that only 14 were women (p3).

3.1.2 Deforestation and REDD

Deforestation is the second most important human-induced source of greenhouse gases (GTZ, 2007). Tropical deforestation annually releases 1.5 billion tonnes of CO_2 into the atmosphere and this accounts for 17% of total greenhouse gas emissions (ITU and GeSI, 2007). Illegal logging, overgrazing, farming encroachment, rising population pressure, and exploitation of forest products by local communities for subsistence purposes are all responsible for forest degradation and a rapid reduction of tropical forest cover.

ICTs, supporting forest management and avoiding forest degradation, play a significant role in one of the main climate mitigation mechanisms, known as Reducing Emissions from Deforestation and Forest Degradation (REDD). Geographical information systems (GIS) and remote sensing images are used to monitor the geographical changes of forest cover over time. ICTs also help examine the change in quality of forests, helping avoid degradation on the ground. They help acquire information, such as soil type, topography, wildlife, growth and yield, to measure the changing stock (Nsita, 2010). Skutsch *et al*. (2009) also suggest that ICTs can be used to promote community participation in forest management. By providing community members with hand-held ICTs, they can help count species in their forests, thus allowing 'inexpensive and bottom up monitoring initiatives to take place' (IISD, 2011:28)

GPS and mobile phones provide efficient communication to track illegal activities which then facilitates law enforcement. However, if ICTs are in the hands of illegal traders, they can also make illegal logging easier. To avoid being caught, they might also use calls and messaging to identify and avoid law enforcement agency activity. Illegal loggers and wildlife poachers might also intercept communications between forest authorities and informants and take revenge on the involved communities and individuals. Castren and Pillai (2011) warn that this may put local communities at risk.

The perception of danger, associated with forest monitoring, has some gender implications for local ICT forest surveillance. Drawing on examples in Usangu, Tanzania, Cleaver (2001) suggested that people form village defence committees to protect their community resources. The youth are recruited as foot-soldiers and the elders act as advisors on tactics. While women and girls are excluded from the forest policing teams, because the tasks are seen as dangerous and physically-demanding, the full responsibilities fall on the shoulders of men and boys.

While some groups of men take up the role to protect their forests, others can collude with illegal loggers, and that undermines the prosecution efforts. Studies by Nsita (2010) show that corrupt politicians, mainly men, take bribes from forest encroachers. Driven not only by financial incentives, but also by winning votes, especially during elections, the political leaders give the illegal dealers cover, such as altering forest reserve boundaries. All these would reduce the effectiveness of the ICTs in arresting illegal loggers, and it also illuminates the genderisation of such activities.

Women and girls are partners as well as pariahs in forest conservation. In their participatory research in Indonesia, Haynes *et al*. (2010) demonstrate that children 'choose which trees to cut when [they] go to collect the firewood either after school or during holidays. But [they] can also plant trees' (p23). Despite their mixed and important roles, existing forest governance arrangements in many poor countries exclude women from the decision-making processes. They are under-represented in forest committees (Castren and Pillai, 2011).

In a nutshell, improving forest governance by ICTs needs to take gender seriously. In forest monitoring and protection, men may bear higher personal risks and physical threats than women in confronting illegal loggers by ICTs. The uneven distributions of risks may legitimise men's domination of decision-making. However, forests help sustain women's livelihoods. Without equal participation of women in forest conservation, ICTs alone will not be effective in slowing down the rates of deforestation.

3.1.3 e-Agriculture

Agriculture, according to FAO (2002), is an important source of greenhouse gas emissions, 'representing 14% of the global total' and developing countries are 'the sources of 74% of these emissions' (p10). Methane and ammonia, generated from dairy production and animal manure, are 20 times more powerful than CO_2 in their warming action. FAO warns that, by 2030, emissions of methane and ammonia from the livestock sector in developing countries could be 60% higher than at present (*ibid*).

The concept of 'e-agriculture' suggests that farmers in developing countries should have better access to agricultural information via various ICT applications (Fernando and Okuda, 2009). EU (2010) also argues that increasing farming productivity does not necessarily worsen greenhouse gas emissions because ICTs 'could improve the monitoring of several phases of production and improve their management' (section 19).

For example, ICTs help reduce energy usage by optimising the harvest time via growth forecasting. The electronics company, Hitachi, claims in its own website that satellite image analysis provides 'a visual indication of the best time to harvest wheat, rice and other crops' (www.hitachi.com). Creating a database of land, crops and fertilizers also 'ensure[s] an optimum level of agricultural chemical application'. Hussain (2010) suggests that the Space Research and Remote Sensing Organisation has been monitoring agricultural crops and making forecasts to attain food security (p48). On the ground, wireless-enabled water management devices monitor soil water content and optimise crop growing conditions. They assess and control irrigation on a just-in-time basis by incorporating weather information and water evaporation, plant transpiration and sub-soil leakage data (IISD, 2011:29)

In addition, ICTs provide farmers with information about pest and disease control, planting dates, seed varieties and irrigation applications and early warning systems. This approach, according to Wollenberg and Negra (2011), increases the energy efficiency of farming, maintains existing biomass and soil carbon, and reduces emissions. Offering real-time climate information through mobile phone messages and internet also helps farmers make faster responses in finding solutions to crop-related problems (Fernando and Okuda, 2009).

Nevertheless, the potential of e-agriculture is mediated by gender relations. AfDB (2011) points out that effective mitigation depends on land ownership. Owing to traditional custom and legal barriers, women are restricted from land ownership. Without legal rights to land, women do not make the decisions about whether, and which, agriculture-related ICTs would be adopted. Without land to serve as security, women have great difficulty securing formal credit or loans. Without proper access to loans and extension services, women are less able to afford ICTs. As a result, Hafkin and Odame (2002) indicate that many successful agriculture-related ICT projects are 'often taken over by men' (p6).

3.2 Adaptation

Climate change brings about erratic climatic conditions and seasonal unpredictability. Changing rainfall patterns result in prolonged droughts and floods and trigger shifting patterns of agriculture. The reduction of agricultural productivity could lead to food shortages and malnutrition, worsening poverty and vulnerability (IISD, 2011).

Changing farming and water management practices, induced by climate change, has significant gender impact. Research by IDS (2008) shows that 80% of women in Sub-Saharan Africa are involved in food production. Women and girls are also expected to secure water, energy and food resources for their families. Water stress, caused by prolonged droughts, means that they have to walk a longer distance to find water in rural areas or spend more time queuing for intermittent water supplies in urban areas. These changes have long-term implications for their health in light of the rising workload and physical exhaustion (Bathge, 2010). Rural women and girls often take up the role as domestic carer. This gender norm constrains them from migrating to cities and towns (Oxfam, 2011).

3.2.1 ICTs and Adaptive Capacity

The concept of 'e-adaptation' suggests that ICTs could enhance adaptive capacity of the vulnerable by strengthening their 'coping strategies to withstand, recover from, and adapt to climate change' (Ospina and Heeks, 2010: 1). E-resilience strategies are also claimed to offer an opportunity to identify innovative tools, to foster social learning and to promote multi-stakeholder collaboration.

There are three main functions of ICTs in adaptation. Firstly, aerial photographs, satellite imagery and grid technology predict, identify and measure the extent of the problems of climate change (ITU, 2009). Weather projections and vulnerability assessments predict climate change impact, such as rainfall patterns. Locally-specific information feeds into decision support tools, and these inform policy makers and local stakeholders to enable them to come up with different adaptation strategies. Secondly, ICTs reduce the costs of information exchange and raise awareness and facilitate dialogue. For example, Harvey and Mitchell (2011) show how ICTs have been used to share information about adaptation strategies across Africa. Thirdly, ICTs promote community-based adaptation exchange and citizen involvement. For instance, UNDP (2011) shows that participatory sensing by mobile phones and scenario planning workshops promote community-based solutions.

ICTs also provide adaptation tools for specific sectors. In agriculture and food security, ICT-based agrarian information systems use scenario mapping and local crop modelling to assist farmers to make long-term planning, crop diversification, food storage and distribution decisions (Hogan *et al*., 2011). According to Munang and Nkem (2011), agro-meteorological information can be linked to seasonal growing features of various crops, and that enables farmers to identify alternative seed varieties and livestock breeds that address environmental variations. ICTs also promote self-organisation and build networks for pastoralists to find suitable land for grazing (Hussain, 2010). Community radio and village knowledge centres can provide farmers with information about pest and disease control and provide contacts to local climate change organisations (Braun and Islam, 2012). In water, GIS and remote sensing provide information, such as the source, quantity and quality of water resources, for better water management. On the occurrence of floods and droughts, mobile phones facilitate participatory monitoring systems by passing on real-time data (IDS, 2008). For instance, a small network of telecentres was developed in the Huaral Village, Peru to help farmers improve their irrigation techniques; helping them adapt to changing water availability levels (CEPES, 2010).

3.2.2 Gendering e-Adaptation

Different perceptions and interpretations of climate change between men and women highlight the need to take diverse adaptation strategies to match their needs. In relation to technologies for agricultural adaptation, for example, Oxfam (2011b) shows that women do not use pits or stone walls to protect their farms because they believe they 'do not have the necessary physical strength and support' to do so (p4). Turning to gendered use of ICTs, while most women use emails to build social networks, Bathge (2010) finds that men tend to use ICTs for business or education. In addition, men and women have different priorities in receiving information, so their use of mobile telephony, community video or other social media applications to disseminate information could have a differing impact. Acknowledging that women 'have particular knowledge and skills that can contribute to climate solutions' (UNDP, 2011:1), some NGOs particularly target women in their e-adaptation interventions. Oxfam (2011a), for example, provides support for women's village water committees to identify alternative water sources. GenARDIS initiated women's drama groups and used community radio to deliver the message of pest control (Radloff, 2010).

There is a sense of optimism in the e-adaptation literature that ICTs could open up an opportunity for previously-marginalised groups, especially poor women, to re-negotiate their roles in their communities. IDS (2008), for example, suggests that the process of selecting heat-tolerant plants and drought-resistant animal breeds would help women farmers assert their authority in their farms (p11). Nelson *et al*. (2002) also indicate that building women's resilience would improve farm productivity. Increasing women's incomes would result in economic and other forms of empowerment. Nevertheless, Resurreccion (2011) argues that many e-adaptation interventions focus too much on technical solutions to reduce the impact of climate change, and too little on 'a complex set of responses to existing climatic and non-climatic factors that contribute to people's vulnerability' (p2). Men and women may re-negotiate their roles in the process of adaptation, but Ospina and Heeks (2010) warn that the process gives 'voice to the interests of certain groups that may not be the most vulnerable' (p30).

In particular, women feel more constrained from building adaptive capacities because they are deprived of 'land rights, ownership rights for the means of production, technology, finances, information and training in climate adaptation' (Bathge, 2010:5). Without control over productive resources and with lower access to loans, credit and agricultural extension services, Olson *et al*. (2010) argue that women do not have the power to decide what changes are needed in their farms. All these constraints, IDS (2008) suggests, reduce their incentives 'to engage in environmentally sustainable farming practices and make long-term investments in land rehabilitation and soil quality' (p4).

Nelson *et al*. (2002) also warn that many adaptation practices build on women's unpaid labour. It assumes that 'rural women are predisposed to taking an environmental care-tending role' (MacGregor, 2010: 8). Their e-adaptation involvement could increase their workload, without properly addressing their strategic needs. In order to juggle increasing demands, women may shift more domestic responsibilities to their daughters, and that could reproduce inter-generational inequalities (Oxfam, 2011b).

3.3 Disaster Management

ICTs are considered to play a crucial role in disaster management including disaster prevention, early warning and emergency communication, and post-disaster coordination (ITU, 2009). Satellite-based systems capture detailed meteorological data and offer more accurate weather forecasts. On the ground level, wireless sensor networks can monitor localised weather changes and can create a database of disaster history to enable trend- and pattern-analysis (IISD, 2011). Local hazard mapping and vulnerability assessments help identify houses and farmlands at risk and illustrate evacuation routes. Early warning systems help reduce causalities. Furthermore, mobile phones, text messaging and real-time on-line collaboration are useful for immediate response (Hussain, 2010). Rapid data gathering, during emergency response, facilitates logistics and provides decision-making support. ICTs also allow more flexible response to post-disaster reconstruction efforts.

Alongside typical climate-related disasters such as landslides and flooding, global warming also increases the risk of infectious water- and vector-borne diseases, such as malaria and dengue fever (Dankelman *et al*., 2008). ICTs provide detailed maps to show the extent and the spread of the diseases and rationalise allocation of resources for disease control (Ospina and Heeks, 2010). Community radio also helps raise public awareness and promote public health campaigns.

The effectiveness of ICTs in disaster planning, however, depends on who has, and uses this, access to information. Radio provides a simple and effective tool to transmit information in emergency, but research by Gurumurthy (2004) shows that it is often men, rather than women, who control the access to radio. In Gurumurthy's words, 'if the household has one radio, it is most likely to be used by men. Women may not have the leisure to listen to the radio, nor may be allowed to join the men sitting outside the house listening to radio' (p5).

Disaster management is also gendered. This cannot be completely generalised because 'the relationships between natural hazards and gender do vary' (Nelson *et al*., 2002:56). Men and boys may be in greater danger, considering attempts to save others such as family members to be heroic, and placing themselves at additional risk (UN, 2011). However, there seems to be greater weight of evidence pointing to increased vulnerability for girls and women.

In their participatory gender study in Indonesia, Haynes *et al*. (2010) find out that both male and female adults have negative perceptions of girls' responses to disasters. While they praise the boys for being able to evacuate the elderly and move livestock from the affected areas, they think 'girls can't escape from disaster' because they only know screaming (p24). As a result, boys are allocated more disaster-relevant resources and roles, and girls are left more vulnerable.

Using the major floods in Bangladesh in 1991 as an example, Rohr (2005, quoted in IDS, 2008) highlights gender biases in the early warning systems. Rohr explains that warning information was rarely communicated to women:

> '...... warning information was transmitted by men to men in public spaces, but rarely communicated to the rest of the family and, as many women are not allowed to leave the house without a male relative, they perished waiting for their relatives to return home and take them to a safe place' (p7).

Early warning systems also need to address the cultural constraints that delay the timely escape of the vulnerable. Swimming and tree climbing, for example, are useful to escape flash floods, but women are not equipped with the same skills as their male counterparts (IDS, 2008). Women's clothes in some countries could reduce their mobility. Many were drowned because of this in the 1991 Bangladesh floods.

Bathge (2010) suggests that women's lack of land rights affects post-disaster re-construction efforts. They are denied the rights to buy a new plot of land for resettlement. In case of disaster, women are expected to stay at home and take care of the sick and the elderly. This also constrains them from enacting alternative coping strategies.

4. Indirect ICT Impact on Gender Relations

ICTs try to address many problems in developing countries; tackling climate change is only one of many. Many ICT projects have the potential to raise people's incomes by improving farm productivity and creating job opportunities. For example, the World Bank (2011d) suggests that women's income in India has increased through telephony as they are getting information on the market price of the vegetables they grow. Mobile applications reduce the costs of job searching by 'connect[ing] informal sector workers with potential employers in India' (IISD, 2011:34). In addition, more ICT projects also encourage poor people to become service providers and entrepreneurs. Raising incomes makes ICTs more affordable to poor people and increases their access to information. Women earning more money, Speranza (2010) argues, would re-shape their relationships with men because they have more power to decide how money is spent (p3).

Mobile phones provide women with greater flexibility in managing their business and domestic obligations. They allow women to re-negotiate their productive, reproductive and community roles. ICTs also make an impact on inter-generational relationships. Using ICTs to identify water sources, for instance, helps free up girls' time in water searching and collection. This may encourage girls to spend more time in schools. As a result, improving their literacy may have positive impact on their use of, and control over, ICTs; pointing to the potential for a 'virtuous circle' of ICT-enabled empowerment (World Bank, 2006).

Lowering information costs by use of ICTs could encourage a higher rate of rural-urban migration and worsen regional imbalance. However, ICTs could also reduce the costs of sending remittances to families in villages (Ospina and Heeks, 2010). The absence of men in villages, because of migration, could speed up the process of feminisation in agriculture. Oxfam (2011a) found that women become employers, hiring male farming services that involve physical strength and use of mechanisation. In the longer run, women controlling more and more everyday farming decisions could raise their bargaining power in negotiating the inheritance and land rights (Radloff, 2010). This could both be, and have, a significant impact on their use of ICTs.

To summarise, ICTs have indirect impact on women's lives in areas such as income generation, human capital building and land ownership. These, in turn, will affect the outcomes of the efforts of mitigation, adaptation and disaster management. The increasing rate of women's literacy, for instance, may raise their awareness of using ICTs in natural disaster prevention. Rising incomes and more land rights may make women less reluctant to adopt ICT-related mitigation and adaptation practices. But of course this only occurs if women are able to take the first steps onto the 'ICT ladder'.

5. Potential Recommendations: Interrogating Four Digital Empowerment Proposals

The previous sections have examined how gender mediates the effectiveness of ICTs in mitigation, adaptation and disaster management. They have also highlighted the obstacles that constrain some groups of men and women from exercising agency in using ICTs to tackle climate change. In this section, we will focus on four proposals in the literature which claim to shift ICT-climate change interventions from gender inadequacy to gender empowerment. These proposals are: gender mainstreaming, governance strengthening (including women-only interventions), gender-sensitive financial mechanisms, and linking agency and structure.

5.1 Gender Mainstreaming and Sex-Disaggregated Data Collection

Gender mainstreaming aims to integrate gender analysis into project design and public policy-making. UNDP (2008:3) defines gender mainstreaming as:

> 'The process of assessing the implications for women and men of any planned action, including legislation, policies or programmes, in all areas and all levels. It is a strategy for making women's as well as men's concerns and experiences an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes in all political, economic and societal spheres, so that women and men benefit equally and inequalities are not perpetuated'.

The intention of gender mainstreaming is to avoid the absence of a clear ICT strategy and policy which could affect gendered outcomes (World Bank, 2011d) and to ensure that gender concerns are incorporated from the beginning and not as a corrective afterwards (Hafkin and Taggart, 2001).

The main obstacle to achieving gender mainstreaming in developing countries, Etta (2005) claims, lies in a lack of a clear set of sex-aggregated data over the use of ICTs and the impact of climate change interventions. UN (2011) also suggests that a systematic gender analysis requires a good set of sex-aggregated data in order to establish gender-sensitive benchmarks and indicators to measure changes and improvement.

A gender-sensitive approach, IDS (2008) argues, requires more than a set of disaggregated data since it risks reinforcing fixed binary roles assigned to women and men. Instead, good quality data should reflect the 'contested, changed and reinforced' processes of gender and social inequalities (Resurreccion, 2011:7). Qualitative information, such as local power structures, control over key economic assets and social norms, is crucial to 'evaluate women's situation as compared to that of men in relation to specific environmental concerns' (Lambrou and Piana, 2006:12). In addition, Gurumurthy (2004) stresses that engendering ICTs is not simply about greater use of ICTs by women or men, but it is about 'transforming the ICT system' to meet their strategic needs (p2).

5.2 Governance Strengthening and Women-Only Interventions

Gender disparities in ICT and climate change policies, Marcelle (2000) suggests, are a result of a lack of participation of the powerless in the decision-making process. Governance strengthening is, therefore, intended to identify and overcome barriers to gender participation in decision-making. To enhance gender involvement, two key questions are raised in the literature: firstly, who participates, and secondly, how the institutions are designed.

The first question touches on whether women are targeted exclusively in the interventions or whether men should equally be considered. The women-only advocates suggest that women are generally poorer than men (70% of the world's poor are women (MacGregor, 2010)), and consequently, they are more vulnerable to climate change. More women live in rural areas than men, and they rely more on natural resources for survival. Yet, their land rights are often denied (Oxfam, 2011b). In addition, the literacy rate of women is lower than that of men. In Sub-Saharan Africa, for example, only 53.3% of women are literate whilst men have achieved 71.2% (UNDP, 2011). We have also seen above the greater vulnerabilities or exclusions of women at the interface of ICTs and climate change.

To enhance female participation, gender experts and female scientists are targeted and invited to join in the preparation of climate change policies in order to 'improve dialogue between IT and gender policy makers' (Hafkin and Taggart, 2001:5). A quota system, such as fixing the number of senior female officials and a percentage of women's activities per district, is proposed to foster women's leadership in key institutions and gender-responsive funding for action (Jolly *et al*., 2004). Another women-only group example includes women's community gardens in Malawi to ensure food security in times of flooding, and women-only self-help groups to produce organic staple crops to cope with climate change (MacGregor, 2010).

The women-only interventions have, however, been criticised for homogenising women's experiences. UN (2002) suggests that single mothers, widows, disabled women, aged women and women in urban and rural areas have different identities, and their strategies to adapt to climate change can be very different. Furthermore, not all women in developing countries lack ICT access. South Africa and Chile are two examples that have achieved 50% internet connection nationally. Cleaver (2003) warns that a single-minded focus on women as excluded also risks considering the power relationships between men and women a 'zero-sum game'. She argues that, while not all men are powerful, not all women are powerless. Middle class women, for example, usually have higher access to ICTs than most poor men in rural areas (World Bank, 2011b).

Men are 'gendered beings' too (MacGregor, 2010). Poor men and boys are also vulnerable to climate change. Older men, for instance, are less tied into social networks than women, and that would put them at a disadvantage when they seek help from their communities (IDS, 2008). Understanding masculinity also helps understand how men and boys facilitate, as well as hinder, women and girls in building resilience and using ICTs. For example, in the 'hole of the wall' computer experiment in India, Hafkin and Odame (2002) find that: 'the aggressiveness of boys pushing away girls prevented the girls from using the computers' (p13).

Despite an at-first-sight incompatibility, women-only interventions and the proposal to include men are not mutually exclusive, but they may often require separate approaches. In many cases, women feel more comfortable to express their concerns in meetings, without the presence of their husbands or other men. Thus, when UNDP (2010a) conducted vulnerability assessments in Morocco, men and women were consulted separately, but the interests of men and women were equally taken into account.

The second question concerning institution building is about how institutions are built. Developing a close partnership with local NGOs is one recommended approach to governance. NGOs may offer ICT training and access in their outreach strategies and climate change-related capacity building programmes (UNDP, 2011). However, UN (2002) finds that many women's organisations and gender-focused groups perceive ICT policies 'an issue reserved for specialists' (p10). This reflects the concern by Dankelman (2002) that ICT components remain techno-centric and are imposed in a top-down manner. A genuine bottom-up approach working with local stakeholders to develop ICT capacity rarely materialises. Although the World Bank (2011c) suggests that improving governance provides an opportunity to combine modern communication systems with indigenous knowledge, Gillard *et al*. (2007) find that indigenous knowledge is often ignored or unnoticed. The 'bureaucratisation of gender guidelines' and the prescribed initiatives, they argue, do not pay adequate attention to cultural specificity of gender relationships (p6).

5.3 Gender-Sensitive Funding Mechanisms

The financing of ICT and climate change projects has significant implications for affordability, accessibility and gender. The World Bank (2011a) suggests that privatisation and liberalisation help lower user prices of ICTs. Reforming the telecommunication sectors in developing countries and licensing of new operators to introduce competition, the Bank argues, would ensure ICT access to the poor and the underserved. To finance broadband infrastructure, innovative public-private partnerships are seen as 'catalytic vehicles to attract additional private sector investment' (*ibid*, p2).

But such ideas may be gender-blind, and hence perpetuate gender divisions. UN (2002) shows scepticism of privatisation. It suggests that: 'ICT policy is frequently driven by the politics of the ICT sector, often impelled by commercial interests' (p11). Even ideas like micro-finance may be problematic. Oxfam (2011a) argues that expanding financing options by micro-finance would risk imposing greater financial burden and stress on vulnerable women and men. Oxfam instead stresses the need to set up 'gender-sensitive funding guidelines' and 'equal gender representation in all decision-making bodies' (*ibid*, p3).

Likewise, UNDP (2011) suggests improving women's access to micro-finance and other sources of credit. It also encourages the development of 'gender-sensitive climate change investment plans' which will facilitate access to financing for those most in need, particularly women and community groups (p13). In Ghana, for instance, a specific fund was set up to support initiatives that target women and promote gender equality in adaptation strategies.

5.4 Linking Agency and Structure

ICT and climate change solutions lie on the continuum of agency and structure. The agency approach focuses on 'the individual capability to be and to act' (Bebbington, 1999:5) and considers access to information an act of empowerment. Sending SMS messages to alert individual members about forest deforestation, as described in section 3.1.2, for example, stresses personal responsibility and action. The structural approach, in contrast, highlights social enablement and constraints. The denial of women's rights to land, for example, underlines the constraints that women face in mitigating and adapting to changing climate.

This agency-structure dualism, however, may not be that useful in understanding the 'gender-ICT-climate change' nexus. It is not clear how individual and collective interests are aligned, across sectors and levels, in the agency approach. Neither is it clear in the structural approach that individuals negotiate and contest gender relations in relation to the technology environment (Gurumurthy, 2004). This paper suggests the social embeddedness approach, exploring the interplay between agency and structure, is more useful in understanding the mechanisms of how gender shapes, and is shaped by, ICT and climate change interventions. Ospina and Heeks (2010) adopt a similar approach, highlighting the combination of personal preferences, social pressure and other decision-making mechanisms that influence adaptive capability and the outcomes of *achievable* and *actual* functionings (p9-10, original emphasis). Women, for example, feel constrained from using public cybercafés and rural information centres, not only because cultural norms restrict their mobility, but also because of the perception of safety and of the unsuitability of opening hours (Bathge, 2010). By understanding agency-structure interactions rather than duality, for example, we may see that design of ICT projects and climate change projects must seek to work with – but extend – existing structures, while enhancing women's agency (UN, 2002).

5.5 Summary

In a nutshell, to improve the likelihood of positive gender outcomes when using ICTs to address climate change, policy-makers and practitioners should contextualise the process of gender mainstreaming in their interventions and consider how women, and men, respond differently in various cultural contexts. Enhancing gendered governance of ICTs and climate change, for example by ensuring equal participation of both men and women in natural resource conservation, is of paramount importance. It may be desirable to implement women-only interventions on some occasions, but the interests of powerless men should also be considered. Securing adequate funding to support ICT interventions is crucial to gender empowerment. Yet, putting an additional financial burden on already-poor populations should be avoided. Lastly, recognising the interplay of agency and structure helps better understand all processes, from climate change adaptation to digital exclusion. Building new, and reforming old, institutional arrangements can promote digital inclusion.

6. Conclusions

This paper has offered a systematic review of how gender shapes, and is shaped by, the interaction of ICTs and climate change. Based on our devised conceptual framework in section 2.3, it has demonstrated the underlying processes by which gender inequalities are challenged, and reproduced, in the process of using ICTs to reduce CO_2 emissions, to adapt to the changing climate and to manage disasters.

To conceptualise the exclusion of women in ICT-climate change interventions, we can draw on Ospina and Heeks' climate change adaptation model (2010). In our analysis, women are systematically disadvantaged in terms of assets, institutions and structures. Firstly, compared to men, women have less access to ICT-based information. Deprived of land rights, they cannot make decisions about whether, and which, agriculture-related ICTs would be implemented. In addition, women struggle to make their voice heard in mitigation policies because of their restricted access to finance.

Secondly, women are more institutionally-constrained than men. Cultural norms of behaviour shape what decisions women, and men, can take and what responsibilities they are required to take on. The exclusion of women in forest governance, for example, is related to the perceived danger to women of using ICTs to monitor illegal logging activities. Men bearing risk to protect their forests are given a legitimate voice to make decisions on behalf of women. In disaster management, rigid gender norms and cultural practices delay the evacuation of women and girls in cases of emergency. (That said, on some occasions, the heroic culture among men and boys puts them at risk.)

Thirdly, in term of social structures, women are excluded from decision-making in policy design and resource allocation. The effectiveness of ICTs in disaster prevention is undermined by the masculine culture of information dissemination. Women are also less represented in formal decision-making bodies, such as CDM and REDD.

To summarise, restricted access to assets, gender-biased institutional arrangements, and unfavourable social structures have reduced women's capability to draw on ICTs in tackling climate change. In addressing these limitations, we have made four digital empowerment proposals that may make 'ICT-climate change' interventions more gender-sensitive:

(1) ***Contextualise gender mainstreaming***: gender mainstreaming helps integrate gender analysis into ICT policies. It acknowledges that men and women perceive and receive information differently, and that this requires diverse approaches to adaptation. However, the attempt to re-position women and girls as 'eco-carers' is problematic because this fails to capture their protective, as well as their destructive, role in relation to natural resources. Without addressing the unequal power relations between women and girls, e-adaptive practices can also help reproduce the inter-generational equalities.

(2) ***Strengthen governance***: crafting new and reforming old, institutional arrangements is essential to improve gender inclusion. Women-only interventions are sometimes necessary to empower previously-excluded women to engage in ICT-related decisions. However, poor and powerless men should also have their say in climate change policies.

(3) ***Develop gender-sensitive funding mechanisms***: securing adequate funding to support ICT interventions is crucial to gender empowerment. Yet, targeting women by micro-credit projects risk putting an additional financial burden on them, and that needs serious re-consideration.

(4) ***Recognise agency-structure dynamics***: women are active agents, but they are socially constrained from engaging in ICT-related decisions. Women's preferences, institutional arrangements and politics need to be taken into account in order to tackle digital exclusion.

We believe that these four proposals are useful for development agencies, governments and NGOs to improve the gendered outcomes from use of ICTs in response to climate change.

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Glossary of Acronyms

AfDB	African Development Bank
CDM	Clean Development Mechanism
EU	European Union
FAO	Food and Agriculture Organisation
GeSI	Global eSustainability Initiative
GIS	Geographical information systems
GTZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit
ICT	Information and communication technology
IDPM	Institute for Development Policy and Management
IDS	Institute of Development Studies
IISD	International Institute for Sustainable Development
ITU	International Telecommunication Union
REDD	Reducing Emissions from Deforestation and Forest Degradation
UN	United Nations
UNDP	United Nations Development Programme
WB	World Bank

Chapter 10: The ICTs, Climate Change Adaptation and Water Project Value Chain:
A Conceptual Tool for Practitioners

ANGELICA VALERIA OSPINA, RICHARD HEEKS and EDITH ADERA

The research presented in Chapter 10 is the result of work commissioned by the International Development Research Centre (http://www.idrc.ca) and the Association for Progressive Communications (http://www.apc.org), which had the key objective of informing the research support agenda of IDRC in the field of ICTs, climate change and water. It has also been published as a chapter in the book "Application of ICTs for Climate Change Adaptation in the Water Sector".

Executive Summary

Water resources are one of the cornerstones of socio-economic development, and as such, they are central to understanding climate change impacts on vulnerable populations. Emerging research at the intersection of climate change, information and communication technologies (ICTs) and development indicates the existence of increasing linkages between use of ICT tools and developing country efforts to mitigate, adapt, monitor and strategise in the face of climate change. Critical resources such as water are at the forefront of developing countries' adaptation agendas.

This paper maps conceptually the linkages between climate change adaptation, water and ICTs, drawing on various approaches from the development, ICTs, and climate change fields[631]. It presents a conceptual tool that can be used by ICT and climate change practitioners and researchers seeking to analyse and plan field interventions in contexts facing water stress due to short- and long-term climate change.

The '*ICTs, Climate Change Adaptation and Water Project Value Chain'* maps a process-focused approach for integration of ICT tools into the design, operation and evaluation of projects in the field of climate change adaptation and water resources.

It will be argued that, while ICTs have the potential to enable adaptive capacities and actions for water resources under climatic stress, their role needs to be integrated into ongoing and future initiatives from a holistic perspective; one that considers the complete 'project value chain'. Ultimately, projects in the field should ensure not only the availability, affordability and accessibility of ICT tools (all aspects of "digital capital"), but also their actual uptake and use if adaptation goals and ultimately, development outcomes, are to be achieved.

The analysis will suggest that integrating this 'hybrid' process-focused approach into the design, operation and evaluation of water-adaptation projects, could help build the adaptive capacity of vulnerable communities to climate-induced shocks and chronic trends.

This document was prepared building on the findings of three regional reports commissioned by the International Development Research Centre (IDRC) and the Association for Progressive Communications (APC) on ICTs, Climate Change and Water; from discussions held by experts and practitioners at an international workshop on the subject (Johannesburg, July 7th-10th 2011[632]); and on research conducted by the authors in the field of ICTs, climate change, water and development.

[631] The paper draws upon principles from the sustainable livelihoods approach (SLA), the ICT4D Value Chain, and the concepts of digital poverty and adaptive capacity.
[632] Further information about the workshop is available at: http://ccw.apc.org/

Introduction

The intersection of climate change, ICTs[633] and development is an emerging area of research where crucial developing country priorities converge. Within contexts affected by poverty and marginalisation, the impacts of climate change and climate variability on critical resources such as water are evidencing the need for innovative approaches to better withstand, recover from, and adjust to uncertainty. Building adaptive capacity for the management of water resources is among the most urgent areas for action in the climate change agenda of developing countries.

At the same time, one of the biggest challenges in the emerging climate change, ICTs and development field involves the provision of practical conceptual tools that can be applied to specific resources (e.g. water), and that can help practitioners with the design, implementation and evaluation of ICT initiatives aimed at strengthening adaptive capacities within vulnerable contexts.

In response to that need, this paper develops a conceptual model linking ICTs' role with water resource adaptation to climate change. By mapping the key factors that need to be considered in order to integrate ICTs into project design, operation and evaluation, the conceptual model is expected to provide guidance to practitioners and researchers, and to contribute to the transition from ICT availability ito concrete e-enabled adaptation actions in the water sector.

The model is developed in three progressive stages. The first stage contextualises the analysis by identifying the main linkages that exist between climate change, vulnerability, and water resources. This includes the vulnerability dimensions that are exacerbated by acute climatic shocks and slow-changing trends on water. The second stage of the analysis introduces the concept of adaptive capacity, identifying priority areas for adaptive actions in the water sector, and providing examples of ICTs' potential with regards to each of those areas. Having acknowledged the empirical role of ICTs in this field, the last stage of the analysis builds a conceptual model linking their role with the achievement of enhanced adaptation of water resources. It focuses on the key factors that need to be considered in order to effectively integrate ICTs into the design, operation and evaluation of projects in the field.

1. Climate Change Impacts on Water Resources

Water will be the resource most severely affected by climate change (Chavarro Pinzon et al., 2008). Scientific evidence suggests that climate change manifests itself in both slow-changing trends (long term) and in acute shocks (short term events) that have profound effects on water resource sustainability. Changes in precipitation and runoff patterns, as well as in the intensity and frequency of hydro-meteorological events linked to climate change, including floods and droughts (IDB, 2010), exacerbate the development stressors that prevail within vulnerable contexts.

The magnitude of climate change-related effects upon vital water resources has been documented in a variety of areas, including sea-level rise and melting glaciers, lower quantity and quality of water sources, and greater complexity of water management and governance, among others (IPCC, 2007). Expected climatic impacts such as temperature increases in high mountain areas can

[633] ICTs are defined as technologies that process or communicate digital data (Heeks & Leon, 2009b).

accelerate the evaporation of water and contribute to the loss of glaciers and moorlands, adding new pressures to the water supply, and causing flooding and landslides due to an increase in river flow. Higher temperatures are also expected to increase demand for irrigation water, and to decrease natural sources such as lakes (ibid).

While the extent of climate change impacts varies among and within geographical regions, studies conducted in Asia, Africa and Latin America (Cliche and Saravia, 2011; Shaw, 2011; Ochola and Ogada, 2011) suggest a number of critical areas where water resources are most severely affected by the impacts of changing climatic trends and acute events. The identification of these areas or 'vulnerability dimensions' can help to map the impacts of climate change on water resources, particularly within developing countries.

1.1. Vulnerability Dimensions of Water Resources

Vulnerability involves both the likelihood of exposure to external shocks, as well as the ability of a given system (household, community, region or nation) to cope with the impacts of that shock (Elbers and Gunning, 2003; Ospina and Heeks, 2010). Thus, a systems perspective suggests that the analysis of vulnerabilities – such as those related to the impacts of climate change – should consider both the external shocks and variations that impinge upon the system, as well as the ability of that system to cope with their impacts (ibid). In the case of developing contexts, climate change impacts have been documented mainly in relation to a set of critical dimensions, namely livelihoods and finance, food security, health, human settlement and displacement, socio-political issues and water (IISD, 2003; Parry et al., 2007; Magrath, 2008; Oxfam, 2009).

Given the fact that this last resource is of transversal importance to all sectors, the impacts of climate change on water exacerbate prevailing development challenges across the other vulnerability dimensions, as illustrated in the (non-exhaustive) examples provided below.

- **Water, Livelihoods and Finance**

More frequent and intense precipitation cycles (e.g. unexpected periods of extreme drought or strong rainfall) can affect vulnerable livelihoods in multiple ways. Unexpected changes in precipitation patterns can affect the productivity of the land, fostering erosion and nutrient loss and lowering production levels, negatively affecting the main livelihood of millions of agricultural producers.

Both excess and lack of water can make some plant species more susceptible to plagues and diseases, which can also have serious consequences on the quality and the volume of crops produced. In the longer term, changes in sea levels can affect local livelihoods that depend on tourism and fishing, while threatening the availability of fresh water sources for consumption and productive activities. Ultimately, these effects weaken the income level and the quality of life of those with resource-dependent livelihoods.

The availability of water resources is also closely linked to agricultural production costs. Heightened precipitation cycles can translate into mudslides or flooding, which affect the transportation and distribution of produce, raw materials and equipment, ultimately raising production costs and reducing availability of local finance. Water scarcity and fluctuations in river flows can also impact hydropower generation (IDB, 2010), which is an important source of energy in developing countries.

- **Water and Socio-Political Conditions**

Climate change is linked to potential tensions and conflicts around access to water by different user groups such as different farming groups, or farmers and industrialists (Pageler, 2009). At the same time, extreme hydro-meteorological events can weaken political structures and institutions, as their capacity can be overwhelmed by the effects of climatic shocks (WHO, 2009). It can also destabilise weak water governance structures that lack robustness, redundancy and flexibility to deal with intensified water stress (Bapna et al., 2009; Ludi, 2009). Additionally, in situations of water stress, the increased amount of time required to collect water, as well as the higher risk of water-related health hazards, can heighten the vulnerability of specific groups such as women and girls (Ludi, 2009; UNESCO, 2011b).

- **Water and Health**

Climate change can impair the quality and the quantity of water resources available for human consumption and sanitation, jeopardising the health of vulnerable populations such as elders and children (IDB, 2010). Heavy rainfall can lead to the rapid spread of pollutants (such as pesticides) and water-borne disease, and can affect traditional crops, thus altering local diets and nutrition, especially among low-income populations (UN-WATER, 2010; Calow et al., 2011). Floods can also overwhelm the capacity of sewers, and water and wastewater treatment plants, with negative effects on human health (UNESCO, 2011a).

- **Water, Human Habitat and Migration**

Hydro-meteorological events can affect the stability of human habitats, particularly by damaging the already weak housing infrastructure that characterises low-income and informal settlements. The intensification of hydrological cycles can affect the coping capacity of water infrastructure, overwhelming storm water drainage systems and wastewater treatment facilities, and affecting the regulation and the distribution of water, particularly to densely-populated urban centres (WHO, 2009). Extreme episodes of water excess (flooding) or deficit (drought), as well as changes in the use of productive land have also been linked to human migrations and displacement (usually rural-to-urban), contributing to poverty and marginalisation (Brown, 2008; UNESCO, 2011b).

- **Water and Food Security**

The impact of extreme climatic events and more intense variability on water resources poses multiple threats to food security. The loss of crops and productive assets that results from unexpected periods of water surplus or deficit constrains the ability of vulnerable populations to access sufficient and adequate food. More intense and frequent precipitation periods also contribute to food insecurity through fluctuations in crop yields and local food supplies, as well as a decline in nutritional intake (FAO, 2008; Ludi, 2009).

- **Water, Biodiversity and Ecosystems**

Water plays a pivotal role in the stability of ecosystems and in the maintenance of biodiversity. Sea level rise can affect natural coastal habitats by decreasing beach areas and eroding mangrove formations, which play an important role as natural barriers against the force of hurricanes and storms. Reefs, coral formations and animal species can also be affected by changes in salinisation and currents, or by runoff from land areas, impacting biodiversity and coastal ecosystems. Likewise, changes in precipitation patterns in high mountain areas and moorlands can weaken native species to the detriment of biodiversity, wildlife and water supply (UN-WATER, 2010; UNESCO, 2011a).

While the specific impacts of climate change on water resources are highly localised and dependent upon the spatial, temporal, socio-economic and institutional conditions of each context, adaptation constitutes a shared and pressing priority among developing countries. Defined by the IPCC (2001) as – a system's adjustment in response to observed or expected climatic stimuli and events, in order to alleviate its impacts or take advantage of the opportunities that may arise from change – climate change adaptation is a complex process that is best approached from a systemic perspective. We therefore turn next to a systemic understanding of adaptation, and of how it relates to particular aspects of water resource management.

2. Climate Change Adaptation, Water Resources and ICTs

The ability of individuals, groups or organisations to adapt to change and uncertainty, as well as their ability to translate adaptation decisions into concrete actions, represent two important dimensions of adaptive capacity (Ospina and Heeks, 2010). Adaptation decisions occur continuously, and while they are not solely necessitated by climate change manifestations, the increased frequency and intensity of these manifestations are challenging the ability of vulnerable populations to withstand, recover from and adjust to change.

Studies of climate change impacts on water resources in different regions of the world (Cliche, 2011; Shaw, 2011) have identified a number of adaptive measures that are being implemented in response to and in anticipation of climate change. From improvements in the storage, distribution, management and use of water, through the development of flood controls and drought monitoring, to water policy reforms, developing countries are starting to prioritise the adoption of measures to better withstand, recover from and adjust to climate-induced changes.

Sources in the field (Nicol and Kaur, 2009) suggest that adaptation priorities for water can be categorised in five key areas, which are closely linked to the vulnerability dimensions identified in section 1.1:

(a) **Adaptation to Changes in Water Supply**, relates to changes in precipitation patterns, loss in snowcaps, ice-melt and moorlands, changes in evapotranspiration and soil moisture, changes in flooding and drought patterns, as well as in the intensity with which they will impact vulnerable systems (ibid). Adaptive actions in this area include new investments on water reservoirs, irrigation systems, capacity expansions, levees and wastewater treatment facilities, among others.

(b) **Adaptation to Changes in Water Demand**, reacts to increased consumption from agricultural, domestic and industrial sources; that increase being prompted by population and economic growth, urban migration, warming, and changes in land use – some of which are exacerbated by climate change (ibid). Adaptive actions in this area include awareness-raising, monitoring, regulation, and support for technological change among water users; largely aimed at reducing their consumption levels (UN-Water, 2010).

(c) **Adaptation to Changes in Water Availability**, addresses water deficit at the national and sub-national level, and changes in the quality and quantity of water resources available to users (linked to climatic and non-climatic factors of physical, social or economic scarcity, as well as to prevailing weaknesses in water models and assessment mechanisms) (ibid). Adaptive actions in this area include the re-engineering of dams, irrigation and distribution systems, the adoption of desalination technologies and improved wastewater reuse, the construction of canals, and the implementation of community-based water pumps, among others.

(d) **Adaptation to Changes in Water Management**, may be taken in anticipation of or in response to the involvement of new stakeholders in the sector, to increasing competing uses of the resource (including urban development and industrialisation), and the increased uncertainty over patterns of supply and demand. Changes in water management may lead to new decision-making processes over water resources (including the coordination, planning and implementation of initiatives), and/or tensions and conflicts that may arise from unequal access to and restricted knowledge about the resource. Adaptive actions in this area include the implementation of multi-stakeholder approaches (i.e. public, private, civil society) for water conservation, including awareness raising and capacity building at the national and/or local levels, among others.

(e) **Adaptation to Changes in Water Governance**, involves the implementation of new climate policies, water policy frameworks, or national and sectoral regulations that impact the four areas mentioned before. Adaptive actions in this area can also be needed due to exacerbated tensions across transboundary river-basins and sectors; requiring new governance mechanisms. Adaptive actions in this area include the adoption of new water pricing systems, funding mechanisms for the protection of ecosystems, or new legislation for river basin management, among others.

These five areas for adaptation reflect the complexity of hydrological changes that are linked to climate change. They also reflect the importance of building adaptive capacities that are not limited to climate-induced impacts, but that acknowledge the multiple vulnerability dimensions that play a role in the achievement of development outcomes. Ultimately, they suggest that adaptation efforts should address 'change' in a broad sense; as a function of multiple, climatic and non-climatic factors which are best understood from a systemic perspective.

While extreme events such as flooding capture significant public attention and help raise political support for the adaptation agenda, the areas of change identified above suggest that climate change challenges in the water sector will be closely linked to long-term patterns in hydrological systems, and that non-climatic factors such as demography and economic growth also have to be considered.

Within this context, the access and use of information and knowledge constitutes a pivotal component of improved water sector responses to climate change (Nicol and Kaur, 2009). Widely-diffused ICTs in the global South, particularly mobile phones (UNCTAD, 2009; UNCTAD, 2010; ITU, 2011) have been linked to improved access to development opportunities, employment and income generation, and broader access to health, education and government services (ibid).

Growth of ICT service availability and uptake is also contributing to the emergence of new approaches to the challenges posed by climate change, particularly in the adaptation field. Tools such as the Internet, mobile phones, Web 2.0 and social media, participatory video and community radio, are being integrated into both spontaneous and planned adaptation strategies, providing users from the national to the local levels with a new set of tools to address adaptation challenges. With that in mind, we move to look at what ICTs can offer water-related adaptation.

2.1. ICTs and Water Resources Adaptation

While the impact of climate change and climate variability on water resources is well documented (IPCC, 2001, IPCC, 2007, UN-Water 2010), less is know about the design and impact of innovative adaptation approaches that integrate the use of ICTs. Recent evidence (e.g. case studies supported by IDRC and APC) has started to provide a more systematic understanding of ICTs' role within adaptation processes in the water sector. Examples of this potential in regards to the priority areas identified before include:

- **Water Supply and Demand**: ICT-enabled meteorological information systems can support the monitoring of precipitation patterns, while the use of GIS/remote sensing applications can help to measure glacial and snow cap loss as well as flood patterns. ICTs such as the Internet and community radio have been used to raise awareness about the impact of climate change on water resources, helping to influence perceptions and behaviour towards more efficient water use, conservation practices, water recycling and optimisation of consumption.

- **Water Availability**: remote and local ICT-based sensing technologies can enable the monitoring of surface and groundwater supply levels, and the degradation of water quality due to increased temperatures and pollutants, providing updated data that can inform decision-making processes (including those related to water pricing and irrigation) (Ospina and Heeks, 2010; UNESCO, 2011a). The use of new digital modelling techniques can help to manage and document scarce water resources (e.g. melting glaciers, salinisation and pollution of fresh water sources) (ibid), as well as modelling and monitoring water distribution systems, thus contributing to water security. ICTs can support hydro-climatic information systems, enabling the identification and assessment of water resource availability. ICT applications can also map existing vulnerabilities and address information gaps (including data gathering and analysis) in regards to the use of water resources, and to develop improved systems to monitor and manage more efficiently water quality and quantity.

- **Water Management**: applications such as GIS and remote monitoring can strengthen in various ways water resource management techniques in the field. ICTs can help to address the informational gaps that affect lower-income sectors of the population, contributing to the adoption of water-efficient technologies, improved management practices to prevent erosion or water logging, or modify the timing of cropping activities (Ludi, 2009). Internet-based applications can provide tools to improve forecasting and warning, as well as drought monitoring, all of which are central to water management decision-making (IHP, 2011). ICTs' potential in this area includes enabling cross-sectoral and interdisciplinary dialogue and knowledge exchange on water issues, the effective communication of research findings (between sectors and scales), as well as the promotion of inter- and intra-regional learning processes on water security issues.

Tools such as mobile phones and community video can foster knowledge sharing and dissemination among audiences with low-literacy levels, contributing to more equitable access to water resources.

- **Water Governance**: ICTs such as mobile phones can be used in participatory governance and monitoring systems, enabling users to provide near-real time data during the occurrence of floods or droughts, as well as providing updated data to inform decision-making systems on water resources. By enabling access to relevant water information (including issues of water quality and availability) at the local level, ICTs can support empowerment of community water users and hence more participative forms of water governance. Likewise, the use of Internet and mobile-based tools, as well as more traditional technologies such as community radio, could support processes of water policy design by integrating voices and opinions from groups that have been traditionally excluded from decision-making processes (e.g. women, youth, ethnic minorities). Tools such as Web 2.0 and social media can support partnership building, networking and stakeholder collaboration in the water sector; again contributing to more open and democratic models of water governance.

As summarised in Figure 1, the analysis conducted thus far suggests a chain of linkages that exist, with short- and long-term climate change impacting the six water-related vulnerability dimensions of households, communities, regions, etc. These impacts demand adaptive actions which are shaped by the vulnerabilities, but which in turn reshape those vulnerabilities, ultimately leading to outcomes in terms of broader development goals.

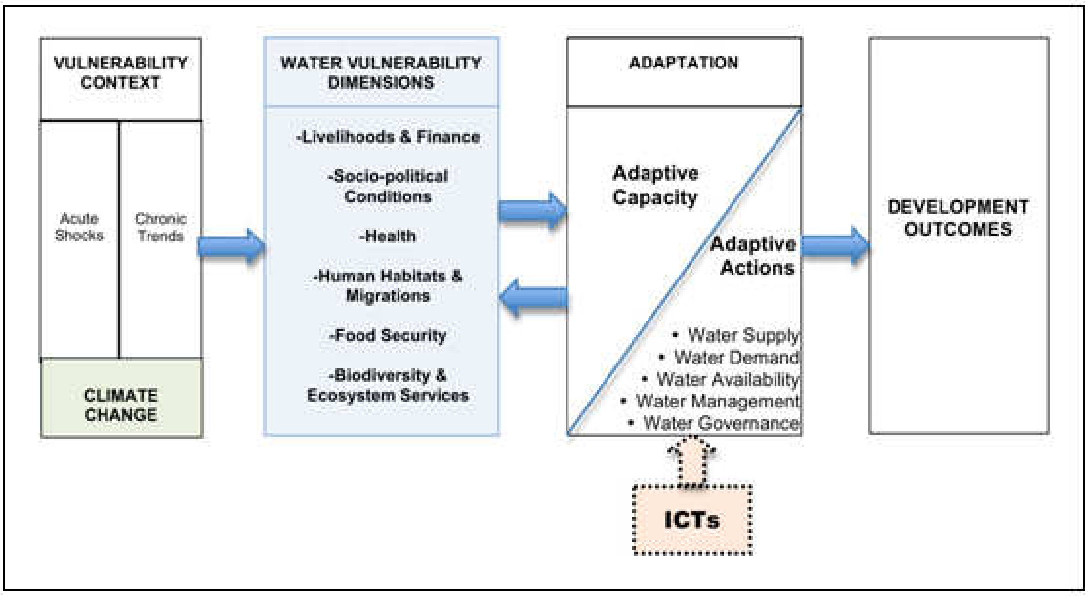

Figure 1. Vulnerability to Climate Change and Water Resources Adaptation (adapted from Ospina & Heeks, 2010)

As reflected in Figure 1, both adaptive capacity and adaptive actions are closely linked, yet distinctive components of adaptation. This distinction is linked to the notion that what a system (household, community, etc) is free to do – its 'capabilities' – should not be automatically equated with what it actually achieves – its 'functionings' (Sen, 1999; Heeks and Molla, 2009). Thus, adaptive capacity refers to the system's ability to cope with, adjust to, and take advantage of the opportunities associated with a changing climate (Jones et al., 2010, p.5), while adaptive actions are the actual actions taken (Ospina and Heeks, 2010). Adaptive capacity relates to the availability of core livelihood factors such as assets, institutions and structures, knowledge and information, innovation and flexible forward-looking governance, among others (Jones et al., 2010). Adaptive actions are based on the ability of the system to implement and use, in practice, those precursors and inputs towards realised adaptations in one or more of the five fields of water resource adaptation.

Figure 1 (via the dotted box) shows – as described above – the potential for ICTs to contribute to water-related adaptations. But this current model does not offer a conceptual foundation for those seeking to understand how ICTs make this contribution. Nor does it offer specific guidance for project practitioners. Further development of this model is therefore needed. On the one hand, this can help to identify the key factors, enablers and constraints that lie behind ICTs' impact on adaptive capacity. On the other, it can help to identify the stages that need to be considered in ICT-enabled interventions that seek to achieve such an adaptive impact; for example in relation to water resources. The proposed conceptualisation can also help practitioners to distinguish between ICT interventions that merely build adaptive capacity, and those that go a step beyond to achieve actual adaptive actions.

The following section will explore these linkages, drawing from conceptual foundations within the climate change, ICTs and development fields.

3. An Integrated Conceptual Approach: ICTs, Climate Change and Water

The analysis conducted in the two previous sections suggests that any approach aimed at building adaptive capacity within developing contexts needs to consider a range of non-climatic factors and pre-existing vulnerabilities that are best understood from a systemic perspective. But which systemic perspective would be most suitable? Ludi (2009) argues that understanding water use within livelihood strategies "is key in the assessment of water stress and drought impacts, and, as such, will be key in the assessment of climate change impacts" (p.5). We have already seen echoes of the livelihoods approach in Figure 1. Here the suggestion is to take this one step further, and understand the availability, access and use of water as being part of a livelihood system, and thus needing to relate to core livelihood concepts such as the assets, institutions and structures that enable livelihood strategies and the achievement of development outcomes.

3.1. Adaptive Capacity within Livelihood Systems

The livelihood determinants (i.e assets, institutions and structures), livelihood strategies and outcomes identified by the Sustainable Livelihoods Approach (SLA) (DFID, 1999) are thus seen to provide a useful systemic basis to explore the challenges and opportunities that developing countries face within the climate change adaptation field. As pointed out, the SLA encompasses a number of elements already identified in the analysis that supports Figure 1 (i.e. the vulnerability context of shocks and trends, the vulnerability dimensions that are present within the system, the livelihood strategies of adaptation – including the adaptive capacity and the adaptation actions aimed at withstanding, recovering and adjusting to change – as well as the livelihood / development outcomes) (Ospina and Heeks, 2010).

Drawing from the principles of the SLA, the capacity of livelihood systems to adapt to climate change is connected to the set of assets or resources (i.e. human, natural, financial, social and physical capital), structures and processes that are available within a given system. A varied asset base is key for the sustainability and security of livelihoods, and thus to the ability of vulnerable populations to adapt to the impacts of acute and chronic climatic manifestations, forming the basis of both adaptive capacity and realised adaptation strategies (Chambers and Conway, 1991; IISD, 2003; Ospina and Heeks, 2010).

At the same time, institutions and structures play a key role in determining access to resources, mediating the effects of hazards, and enabling the decision-making frameworks required for adaptation processes to take place (Burton and Kates, 1993; Ospina and Heeks, 2010). By blocking or enabling access to assets, what the SLA refers to as 'processes' (laws, policies, culture, and other institutions), and structures (formal, such as those belonging to the private or civil society sectors, or informal, such as family groupings) are pivotal in the implementation of livelihood strategies, and consequently, in the ability of systems to cope with and adapt to change.

But while the SLA provides the basis for a system-based approach to the linkages between vulnerability, adaptation capacity and development outcomes, it does not identify any specific role for ICTs. In particular, it does not recognise the role of 'digital capital' as part of the asset base of livelihood systems. Defined by May et al. (2011) as the availability of ICT supply infrastructure, the resources necessary to afford ICT services, and the skills necessary to effectively access and use ICT tools, 'digital capital' can play an important complementary and supportive role to other livelihood determinants. It comprises the specific set of assets that are required in order to deliver working ICT systems; such systems comprising digital capital if they are available, affordable and accessible to vulnerable populations.

The lack of explicit acknowledgement by the SLA of the role of digital capital, or that of information and knowledge mediated through ICTs within livelihood strategies, suggests that exploring the role of these tools within water resources adaptation requires a new, specific and more holistic conceptualisation. Towards that aim, the following subsection will build upon and develop further the linkages identified in Figure 1, in order to present a conceptual model that can help identify and operationalise the role of ICTs within climate change adaptation projects; in this case with specific reference to water resources.

3.2 Integrating ICTs into Water Resources Adaptation

The analysis conducted thus far has established conceptual linkages between climate change impacts on water resources, livelihood components and processes, and the potential of ICTs to support adaptation capacity and development outcomes within vulnerable contexts. However, the aim of this paper is to develop a conceptual model that contributes to the implementation of ICT-enabled adaptation projects in the water sector, and thus, that helps practitioners to identify the key elements that need to be considered in such projects.

With this in mind, and drawing from the principles of the ICT4D Value Chain[634], the SLA, and the concept of digital capital, the role of ICTs will be mapped,

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[634] The ICT for Development Value Chain (Heeks, 2010) offers a model to analyse, sequentially, the role of ICT4D resources and processes. It constitutes a useful tool to explore the historical progression of ICT-related projects, as well as to design, implement, assess and/or evaluate ICT interventions. The value chain is focused on four key domains, namely readiness, availability, uptake and impact, which are here modified to correspond to project lifecycle stages.

sequentially, throughout the main stages that characterise development projects: design, operation and evaluation.

(a) Project Design

This stage involves the identification of the systemic prerequisites for any ICT4D initiative. It includes two main components.

- The first is identification of the **contextual structures and institutions** that are present in the context of implementation. They constitute the foundational precursors that need to be in place, mainly at the macro and meso level, for the implementation of ICT4D projects (e.g. ICT policy and regulations, human and technological infrastructure, legal structures and institutions; plus the institutional driver of demand for intervention in the particular project area). They need to be considered in light of the specific context and dimensions of vulnerability, e.g. water vulnerabilities to climate change.

- The second is the identification of the **project inputs**; a specific **set of livelihood assets** that feed into ICT4D initiatives. As suggested by the SLA, these assets can be 'hard' such as financial, physical or natural resources and technology, as well as 'soft' such as social networks, human skills, values and motivations. They can be summarised by the SLA 'pentagon' of asset types: financial, physical, natural, social (sometimes expanded to socio-political), and human.

(b) Project Operation

This stage is largely based on the implementation of the project design, and consists of two key components.

- The first is the conversion of the contextual structures, institutions, and livelihood assets identified during the stage of project design into actual **ICT deliverables** (i.e. ICTs applied in the project, for example, a telecentre, a mobile application, a Web-based software program, etc). Activities within this component are aimed at the formation of **digital capital,** which encompasses three key dimensions: availability (e.g. the specific ICT deliverable is in place), affordability (e.g. sufficient income to afford ICT services), and accessibility (e.g. skills required to use ICT services).

- The second is the process of **ICT uptake**. This involves the conversion of the digital capital (ICT that is available, affordable and accessible) to *actual use* in development practice (e.g. as part of adaptation actions that specifically address water supply, demand, etc). Thus, ICT uptake involves issues of actual adoption and use, as well as strategies for the sustainability and potential scaling-up of successful ICT-based approaches if they are to achieve a meaningful level of impact.

(c) Project Evaluation

This stage constitutes the last of the project value chain, and involves the assessment of ICT's impact. This can be divided out into three sub-elements: *outputs* (e.g. micro-level behavioural changes associated with technology use), *outcomes* (e.g. wider costs and benefits associated with ICTs, encompassing the particular adaptive actions that have been taken), and *development impacts* (e.g. the contribution of ICTs to broader development goals) (Heeks, 2010).

The value of the 'project value chain' model is seen as two-fold. It has a conceptual depth that enables it to be used for comprehensive analysis of initiatives at the intersection of climate change adaptation, water resources and ICTs. But it also has a practical value for project managers, enabling them to understand concrete decision factors and actions at each stage of their projects.

Figure 2 reflects the way in which the ICT4D project value chain can be linked to the conceptual elements that have been identified thus far.

The upper portion of the model represents the linkages discussed in Figure 1, namely those that exist between climate change manifestations (acute shocks and chronic trends), their impact on the set of vulnerability dimensions that characterise water resources, the adaptive capacity and actions required to respond, and the achievement of development outcomes. The lower portion of the model reflects the main livelihood components (i.e. the conversion of livelihood assets to digital capital within a specific structural and institutional context) and well as the stages (i.e. design, operation and evaluation) of the particular project.

ICTs are linked to climate change adaptation in the water sector through the stage of project operation (i.e. implementation), when available digital capital converts into actual ICT usage, contributing to enhanced adaptive capacities and actions. These links are realised through the uptake of ICT tools (the two upward-facing arrows), which reflect the conversion of digital capital into ICTs that are actually adopted, used, sustained and/or scaled up towards the achievement of water adaptation goals (i.e. supply, demand, availability, management and governance). The impact of ICTs on the achievement of adaptation and development outcomes is subsequently assessed as part of the project evaluation stage.

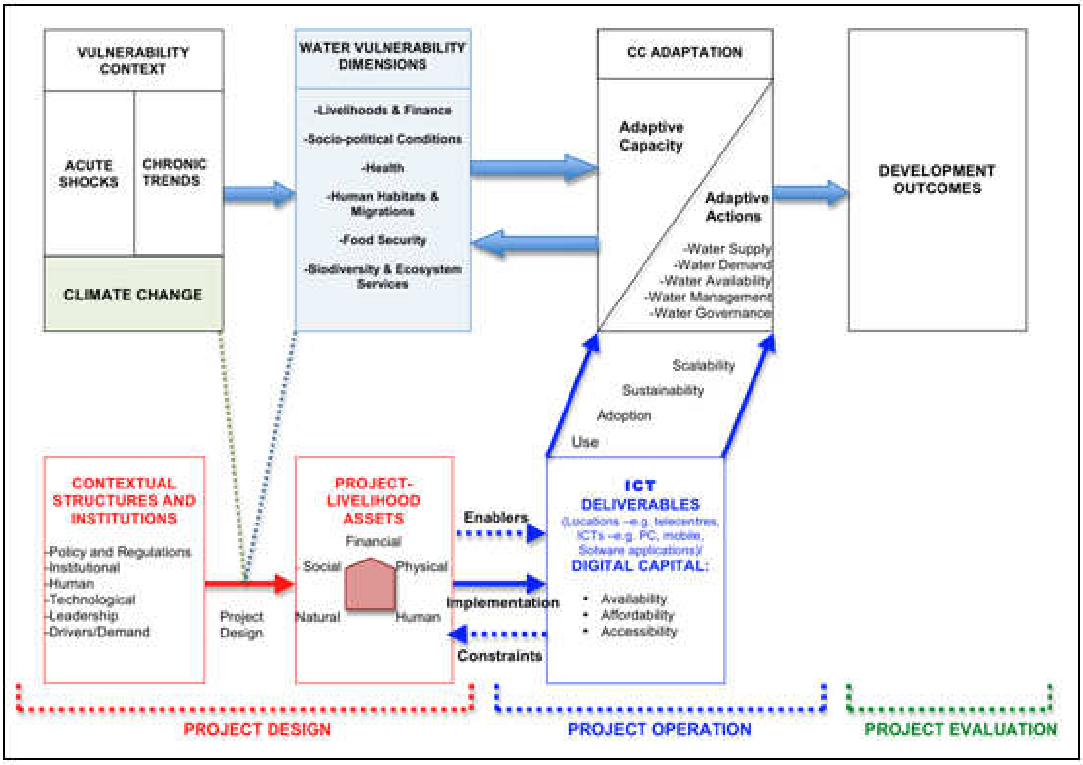

Figure 2. ICTs, Climate Change Adaptation and Water Project Value Chain

The model suggests a series of key process-based factors to be considered by practitioners and researchers working at the intersection of ICTs, climate change adaptation and water resources. First, in the stage of project design the model reflects the need to understand the relation between broader structures and institutions (contextual/national level precursors) and the specific inputs (livelihood assets of financial, physical, human, natural or social capital) that are required for the operation of a particular project in the field. The model also suggests that the project design needs to integrate local climate change impacts (i.e. acute shocks and chronic trends) and water sector priorities (i.e. vulnerability dimensions), in order to ensure that the subsequent stage of project operation responds to and is rooted in local realities (this is reflected by the two dotted lines linking the upper and the lower portions of the model). These considerations are key in order to ensure solid linkages between the use of ICTs and the water adaptation needs that the projects in the field are ultimately trying to tackle.

The model also reflects the need to acknowledge the presence of enablers and constraints that may either foster or hinder the implementation of project activities (reflected by the dotted lines facing right and left, in the lower portion of Figure 2). The *enablers* refer to the technical (e.g. end-user technologies, applications and networks), economic (e.g. markets, enterprises and regulatory frameworks) and social components (e.g. social actors, interactions and networks, content) (ibid) that shape the functioning of ICT systems, and that ultimately determine the way in which ICT tools are implemented and used at the macro, meso and micro levels (May et al., 2011). The *constraints* are the substrates of 'digital poverty' (which is defined by Barrantes (2005) as "the lack of goods and services based on ICTs" (p.30)). Digital poverty limits the availability, the affordability and the accessibility of ICT tools at the individual, the community and the national levels, constraining their potential use in achievement of adaptation and development outcomes.

At the same time, the model distinguishes between the availability of ICT infrastructure, resources and skills (i.e. of digital capital and its dependent assets), and their actual adoption and use (i.e. uptake), which can enable the transformation of adaptive capacities into adaptive functionings[635] or actions. Strengthened adaptation capacity can, in turn, contribute to the effective implementation and use of ICT applications in response to the set of vulnerability dimensions identified in section 1.1, which is reflected by the double-pointed arrows in the upper portion of Figure 2.

The stage of project design reflected in the conceptual model is closely linked to the foundations of the Sustainable Livelihoods Approach (SLA). While the 'Conceptual Structures and Institutions' refer to the macro-level generic foundations that need to be in place for the implementation of ICT initiatives, the 'Project-Livelihood Assets' reflect the specific resources, mainly at the meso and micro levels, that need to be present to feed into a particular project in the field. Thus, the stage of project design includes the role of the SLA's livelihood determinants.

The effective implementation and use of ICTs for adaptation is based on the recognition that the presence of digital capital within vulnerable livelihoods cannot be automatically equated with the contribution of these tools to adaptation. Instead, the analysis of ICTs' role and potential in regards to the adaptation of water resources should be conducted systemically, taking into account the

[635] Adaptive functionings can be defined as the ability of a system to transform adaptive capacity into action by implementing adaptive decisions (Nelson et al., 2007; Ospina and Heeks, 2010).

presence of other livelihood determinants (e.g. enabling institutions, structures and assets in the climate change and ICT fields), as well as the influence of both enablers and constraints in the process of ICT implementation.

Within vulnerable developing contexts characterised by poverty and marginalisation, the way in which ICT tools are actually adopted, used, sustained or scaled, will also determine the extent of their contribution to adaptation processes, or in turn, their potential role towards maladaptive practices and enhanced vulnerabilities.

Implications for Practitioners and Researchers

The 'ICTs, Climate Change Adaptation and Water Project Value Chain' model has multiple implications for the way in which practitioners and researchers approach the integration of ICTs into climate change adaptation processes in the water sector. The following are some key aspects to be considered through the stages of project design, operation and evaluation of water adaptation initiatives:

- **The Stage of Project Design** would involve: 1) the identification of the vulnerability context (specific climate change shocks and trends) that impinge upon existing development challenges; 2) the identification of the specific vulnerabilities, linked to water resources, that exist within a given context; 3) the establishment of the presence or absence of structures, institutions and livelihood assets that could enable or constrain the project's implementation (including implementation of the ICT-specific components), as well as the strategy that converts contextual precursors into specific project inputs (e.g. climate change leadership into political support, institutions into enabling frameworks, etc).

- **The Stage of Project Operation** would include 1) the conversion of available assets into ICT applications (i.e. deliverables) that can be used to tackle water adaptation issues in a given context; 2) the specific potentiality of those applications in terms of their availability, affordability, and accessibility for the target user group; 3) the actual adoption and use of ICT tools with regards to water resources at the individual, community or national level; and 4) the identification of sustainability and scaling up options for the applications implemented. This stage would also involve the identification of critical enablers and constraints that ultimately determine the role that ICTs can play towards the enactment of adaptation capacities into actions.

- **The Stage of Project Evaluation** would involve analysis of the ICT-enabled adaptation actions in regards to areas of climate-induced change. The *outputs* would correspond to micro-level behavioural changes associated with the use of ICTs within adaptive actions, while the *outcomes* would relate to the costs and benefits associated with ICTs' use within specific (water-related) adaptive actions. The assessment of impacts also involves the identification of *development outcomes* (broader adaptation and water management goals) that the initiative contributed to.

The sequential stages reflected in the model can help to integrate ICTs more systematically and rigorously into water and climate change adaptation initiatives. The model suggests that ICT tools have the potential to strengthen the capacity of developing countries to withstand, recover from and adapt to the water-related challenges posed by climate change (e.g. changes in water supply and demand, availability, management and governance), given the presence of key precursors and inputs, the uptake of digital capital, and the impact of ICT-enabled interventions.

4. Conclusions

The increasing linkages that exist between ICTs, climate change and development are posing new challenges and opportunities to practitioners working in these fields. This is particularly true of those that work within vulnerable developing environments where the growing rate of ICT adoption is redefining the ways in which development objectives are pursued and met. The urgency of adapting to the effects of climate change and climate variability demands innovative approaches, such as those enabled by ICTs. And evidence is growing of the role ICTs can play in enhancing the capacity of vulnerable systems to withstand, recover from and adapt to the effects of acute climatic events and chronic trends.

Water resources are at the core of climate change adaptation strategies. Experiences in the field suggest the potential of ICT tools to help countries and communities adapt to changes in water supply, demand, availability, management and governance, exacerbated by the effects of climate change. But there is a growing need for conceptual tools that can help practitioners to better understand, plan, implement and evaluate projects at the intersection of ICTs, water and climate change adaptation.

The 'ICTs, Climate Change Adaptation and Water Project Value Chain' model constitutes a first step in that direction. Building on the principles of the SLA and the ICT4D Value Chain, the model provides a tool for practitioners to effectively integrate ICTs into water adaptation projects through a series of sequential stages. These could ultimately contribute to better design, implementation and evaluation of ICTs' contribution to adaptive capacity and adaptive actions.

The conceptual model presented suggests that the availability and even use of ICTs within a given context cannot be automatically equated with a contribution of these tools to climate change adaptation. Instead, a more holistic and systematic approach has to be taken in order to integrate their role, maximise their potential and evaluate their impacts within water adaptation processes.

The model suggests the importance of identifying the particular set of water-related vulnerabilities that affect a given context (at the community, regional and national level). It is also important to narrow down on the key areas impacted by climate induced change where ICTs could help to improve the system's ability to accommodate water shocks and stress, cope with the uncertain impacts of future climatic conditions, and take advantage of potential opportunities. Within vulnerable developing contexts characterised by asset scarcity and by the presence of inequality, marginalisation, weak institutions and centralised governance structures – among other development challenges – the timely identification of enablers and constraints to the implementation of ICT applications in the water adaptation field could also be crucial.

Further research in this field could explore in greater detail the practical and conceptual implications of utilising this model to strengthen adaptation projects in the field, particularly through its use and assessment within initiatives implemented in the adaptation of water resources of developing contexts.

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Part 2: Strategic Actions on ICTs, Climate Change and Development

Chapter 11: Making Policy on ICTs and Climate Change in Developing Countries

ANGELICA VALERIA OSPINA & RICHARD HEEKS

Executive Summary

As climate change gains momentum within the global agenda, there is an increasing need for the development of policies that enable coherent, innovative and flexible climate change responses. This need is particularly acute in developing countries, where the magnitude of climate change impacts calls for novel policy approaches and regulatory environments that foster effective mitigation, adaptation and monitoring strategies.

The rapid diffusion of information and communication technologies (ICTs) within low-income contexts, the most vulnerable to climatic manifestations, is adding a new dimension to the climate change policy debate. Emerging experiences suggest that ICT tools are playing an increasing role in the capacity of developing countries to withstand, recover from, and adjust to climate change impacts. But they also suggest that policies which acknowledge and build on the linkages between ICTs, climate change and development are pivotal in enabling innovative responses to mitigate, monitor, and adapt to climatic impacts and uncertainty.

Recognising these linkages, as well as the embryonic nature of national policy approaches that explicitly integrate ICTs and climate change, the objective of this paper is two-fold. It identifies the key climate change issues that ICT policy-makers should address within developing country environments, and also the key ICT issues that climate change policy-makers should integrate in order to ensure coherence, innovation and flexibility in the implementation of climate change actions.

The paper is aimed at an audience of ICT/telecommunications and climate change/environment policy-makers and strategists. It explores the ICTs, climate change and development (ICCD) policy context, identifying key policy domains and principles. Based on that, the analysis suggests that three main components should be in place for the formulation and implementation of effective ICCD policies, namely (a) content, (b) structures and (c) processes. After exploring each of those components, the paper presents key opportunities and challenges faced in the integration of ICCD policies, suggesting key entry points for developing country policy-makers and strategists in this field.

Introduction

The unprecedented impacts and level of uncertainty posed by climate change are redefining the way in which policies and strategies are designed and implemented at the international, national and local levels. Emerging evidence suggests that the impact of acute weather events (e.g. floods, droughts and cyclones) and long-term changes in the environment (e.g. sea level rise, melting glaciers and changes in seasonality) are magnifying existing development challenges in areas such as livelihoods and finance, food security, health, water supply, habitat, migrations, and governance (IPCC, 2007; Ospina & Heeks, 2010). They are also placing additional constraints on the capacity of developing countries to overcome poverty and marginalisation.

Within vulnerable contexts affected by more frequent and intense climatic manifestations, traditional policy approaches are no longer sufficient to effectively anticipate and respond to unforeseen climatic impacts, while at the same time striving to achieve development objectives. Innovative, flexible and coherent policies are required to tackle both the challenges and the opportunities posed by climate change.

Considering the urgency of undertaking actions to mitigate, adapt to, and monitor the impacts of climate change, developing country governments must exercise new roles as leaders, enablers, conveners and facilitators of climate change information, action and collaboration among a highly diverse group of stakeholders. Governance within a changing climate implies the design of policies that recognise and build upon the multi-disciplinary nature of the climate change field, that consider climatic impacts and actors from multiple sectors, scales (local, national and international) and timeframes (short, medium and long term), and that help developing countries to anticipate and prepare, but also to adapt and change amidst new climatic stressors and livelihood options.

Thus, developing country governments are starting to explore new tools and approaches to face the magnitude and uncertainty posed by climate change within challenging socio-economic and political contexts. Among them, the use of widely diffused information and communication technologies (ICTs) such as mobile phones, community radio and Internet-based applications, is emerging as a new area of research and practice that can foster innovative climate change responses utilising readily available and low-cost tools.

ICTs are a key source of greenhouse gases but they simultaneously offer a significant potential to mitigate emissions[636], reduce energy consumption and improve the performance of a number of sectors of the economy (Labelle, 2008; ITU, 2010). Further to their role in mitigation and energy efficiency, ICTs are being increasingly adopted as part of local adaptation strategies, including disaster management (e.g. early warning, prevention and relief) and monitoring (Ospina and Heeks, 2010; Yap, 2011). But while increasing evidence is being built on such ICT applications[637], less is known about the policy approaches that are required to address the adoption and use of ICT tools within climate change strategies and vice versa (i.e. to address climate change priorities within ICT strategies).

Policy instruments of governance and management (e.g. legal norms such as laws, decrees and enforcement actions, licensing, planning and funding regulations) help create an enabling environment where ICTs can effectively contribute to the achievement of climate change goals, and more generally, of development objectives. Policies are key in the provision of frameworks for resource mobilisation, and can provide the necessary incentives for private sector investment in infrastructure and low-cost connectivity required to bridge the digital divide. Policies can also facilitate access to the financial and human capital resources required to align and integrate ICTs, climate change and development strategies (e.g. through budget allocation, identification of roles and responsibilities or capacity building goals).

Thus, new policies are required to integrate the productive, informational and transformative potential of ICTs into emerging and ongoing climate change strategies, and at the same time, to ensure articulation between ICT policies and

[636] According to the Broadband Commission for Digital Development (2012) ICT solutions have the potential to reduce 15% of global emissions by the year 2020.
[637] See: www.niccd.org.

climate change priorities in order to strengthen the achievement of development goals.

This paper responds to the growing need to develop innovative policy mechanisms that ensure coherence and articulation between climate change responses, ICT tools and development strategies (i.e. by integrating ICTs into climate change policies and strategies, and integrating climate change into ICT policies and strategies). It provides guidance to developing country policy-makers and strategists working at the intersection of ICTs, climate change and development, contributing to the process of design, adoption and implementation of new policies aimed at realising ICTs' potential to mitigate, adapt to and monitor climate change impacts within vulnerable contexts.

1. The ICT, Climate Change and Development (ICCD) Policy Context

The ICCD policy context is characterised by the close linkages and interactions that exist between the ICTs, the climate change and the development fields. Within this context, ICCD policy making refers to the design, development and implementation of policies, laws, decisions and regulations that acknowledge and integrate the use of ICTs in international, national, sectoral or local responses to address the impacts of climate change, while acknowledging existing and future development needs. More concretely, ICCD policies foster the use of ICTs in climate change mitigation, adaptation, monitoring and strategising, articulating climate change needs and development priorities from different sectors, such as agriculture, food security, water management, health or human habitats, among others.

*The aim of **ICCD Policies** is to provide courses of action that integrate ICTs into climate change responses within specific development contexts. ICCD policies consist of laws, regulations, decisions and actions carried out by government and other agencies. These foster use of ICT tools to help mitigate, adapt to, and monitor the impacts of climate change, and design strategies to develop climate change resilience and the achievement of development*

The interactions that take place between these three domains, and that ultimately characterise the ICCD policy context, are reflected in Figure 1.

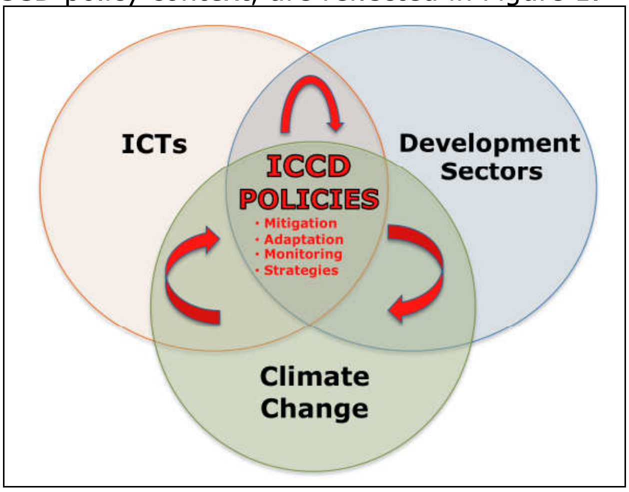

Figure 1. Overlapping Fields of Action of ICCD Policies

The uncertainty of climatic manifestations and the magnitude with which they are felt within vulnerable contexts, evidences the need for innovative policies that acknowledge and take advantage of the porous boundaries that exist between climate change impacts, existing development needs, and emerging tools such as ICTs. The acknowledgement of these porous boundaries constitutes the first step towards ICCD policy making.

This section explores the main characteristics of the ICTs, climate change and development (ICCD) policy context in developing countries. It focuses on identifying the key stakeholders and areas of action at three policy levels or domains: international, national and sub-national, and concludes suggesting the key principles for policy-making at the intersection of ICT, climate change and development fields.

1.1 ICCD Policy Domains

The design and implementation of ICCD can be categorised according to three levels of action, which correspond to the international, the national and the sub-national policy domains. In practice, climate change, ICTs and development issues interact closely at each of these levels, as represented in Figure 2. Thus, they can be used as reference domains in order to explore further the current state and future perspectives of policies in the ICCD field.

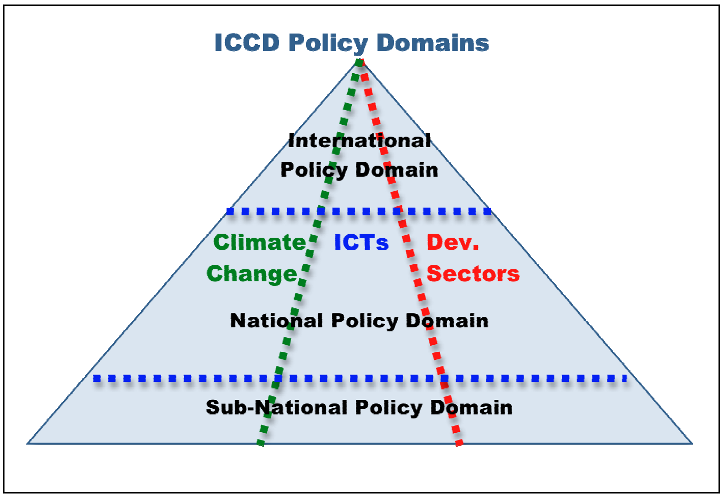

Figure 2. ICCD Policy Domains

Each of these domains is characterised by the role of distinctive actors and areas of action, which can be summarised as follows:

1.1(a) ICCD International Policy Domain

The United Nations Framework Convention on Climate Change (UNFCCC) is the global mechanism for the coordination of intergovernmental efforts in the climate change field. The Convention's goal is to achieve "the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (U.N, 1992, p.4). With 195 country signatories and Conferences of Parties (COP) held on a yearly basis, the UNFCCC provides the main framework within which long-term emission reduction targets are negotiated and agreed between governments. The issue of public policies for the information society is very young (UNESCO, 2009), even more so in regards to topics of environmental sustainability and climate change.

Within the ICT international domain, information society forums such as the World Summit of the Information Society (WSIS) have integrated general issues related to 'sustainable development' since 2003. The 'e-environment' was introduced more prominently during the 2011 WSIS forum[638], with a one-day event focused on issues of ICTs and the environment, predominantly from the emissions reduction and e-waste perspectives[639]. Within the climate change international domain, ICTs gained momentum at the 2011 United Nations Climate Change Conference (COP17), held in Durban, South Africa.

At COP17, a newly formed Coalition on ICTs and Climate Change[640] mobilised efforts to give visibility to the use of these tools for mitigation and adaptation, highlighting the importance of coordinating actions, at both the policy and the practice level among diverse stakeholders working in the field[641]. Key international stakeholders, such as the International Telecommunication Union (ITU), have played an active role in the development of the Coalition, suggesting increasing collaboration and articulation of efforts in this field.

ITU is the UN specialised agency in ICTs, with the mandate to exercise leadership in the application of ICTs to address the causes and effects of climate change (ITUb, 2010). With 192 government members and more than 700 private sector entities[642], the ITU is one of the most influential stakeholders in the ICTs and climate change international policy domain. In addition to awareness raising and training on key ICT and climate change related issues, ITU's efforts include (a) the formation of a Dynamic Coalition on Internet and Climate Change (DCICC) in 2007, a body aimed at moderating the environmental impact of the Internet and at harnessing its potential to reduce greenhouse gas emissions; (b) several study groups involved in the development of recommendations, handbooks and reports on ICT and climate change issues including ICTs' contribution to energy consumption and standardised measures of ICT industry emissions; (c) a 'Joint Coordination Activity on ICTs and Climate Change' (JCA-ICT&CC) established in 2009 to coordinate ITU 's work in this field with that of other key sectors and institutions[643], and (d) a series of ICT and climate change symposiums hosted by the Ministry of Communications / Telecommunications of member countries[644], among others.

During these international symposiums, policy-level discussions tackle issues related to the role of ICTs in mitigation and adaptation to climate change, disaster planning, and e-waste; and on cost-effective ICT technologies, methodologies for environmental impact assessment of ICTs, as well as the key challenges and opportunities faced in the transition to a green and resource-efficient economy (Government of Ghana, 2011). The Ghana symposium held in July 2011

[638] For further information about this event, visit http://groups.itu.int/wsis-forum2011/Agenda/Highlights/EEnvironmentDay.aspx
[639] The World Summit on the Information Society (WSIS) is a United Nations (UN) summit aimed at creating a multi-stakeholder platform to address the issues raised by ICTs through a structured and inclusive approach at the national, regional and international levels. The goal of WSIS is to achieve a common vision, desire and commitment to build a people-centric, inclusive and development-oriented Information Society. http://groups.itu.int/Default.aspx?tabid=1227
[640] Organisations in the coalition include the International Telecommunication Union (ITU), the Global e-Sustainability Initiative (GeSI), the UNFCCC Secretariat, the UN Global Compact, TechAmerica, as well as high-level representatives from the governments of Ghana, South Africa and Egypt.
[641] ICT-related actions implemented at COP17 included two side meetings focused on ICTs, mitigation and adaptation, an 'ICT Day', a Digital Media Lounge showcasing experts and practitioners via tele-presence, and the launch of a 'PoliWiki', aimed at raising awareness on the potential of ICT tools within international climate change negotiations.
[642] http://www.itu.int/ITU-T/climatechange/
[643] http://www.itu.int/en/ITU-T/jca/ictcc/Pages/default.aspx
[644] ICTs, the environment and climate change symposiums have been organised in Kyoto, London, Quito, Seoul, Cairo and Ghana.

concluded with a Call to Action to address the linkages between ICTs and climate change at the COP17 meeting held in Durban, and the 2012 United Nations Conference on Sustainable Development (UNCSD 2012 or Rio+20), focusing on two main issues: the adoption of an agreed methodology for measuring the carbon footprint of ICT equipment and industry, and its inclusion in National Adaptation and Mitigation Plans.

Considering the current state of policy development in the ICCD field, issues such as these are emerging as important policy objectives at both the international and the national policy domains. They also evidence the close linkages and interactions that characterise these two levels of policy design and implementation, as explained below.

1.1(b) ICCD National Policy Domain

The national policy domain constitutes the most pivotal level for policy action in the emerging field of ICTs, climate change and development (ICCD). Evidence from the field (IPCC 2001; IPCC 2007) suggests that the impacts of both acute climatic shocks (e.g. extreme events, flooding or landslides) and chronic trends (e.g. changing temperatures, sea-level rise) are exacerbating a wide-range of development challenges, including livelihood and finance, food security, water, health, socio-political conditions, and habitat and migrations. For example, extreme floods simultaneously jeopardise the livelihood of vulnerable communities that depend on agriculture and their access to food and clean water for consumption, damage infrastructure, and motivate migrations to urban areas, contributing to poverty and possibly to social unrest. Thus, policy-makers at the national level are encountering increasingly overlapping areas of action in the management and response to climate change mitigation, adaptation and strategising, which require articulated responses and multi-sectoral coordination.

Climate change has gained momentum in the agenda of a wide range of policy stakeholders at national level, reflecting the increasing number of areas and sectors vulnerable to or affected by climatic manifestations. The key national policy actors in the ICCD field are reflected in Table 1.

National Level	ICCD Policy Actors
Ministries	Highest-level national authorities in the climate change, ICT and development fields. They provide policy guidance and national directions, and are responsible for the process of policy development and implementation at the national level. Examples of Ministries involved in ICT, climate change and development policies include: • Ministry of the Environment and Natural Resources (leads the climate change agenda at the national level). • Ministries of key development sectors affected by climatic impacts (e.g. the Ministry of Agriculture and Rural Development, Commerce, Industry and Tourism, Transportation, Housing and Territorial Development, among others). • Ministry of ICTs, Science and Technology and/or Communications (responsible for the design of national ICT policies and strategies).
National-level Coordination Commissions, Councils, Units or	Responsible for coordinating the actions of the national/federal administration on national policies concerning ICTs, climate change and development issues. Often formed by representatives from several Ministries and

Secretariats	experts, and focused on the operationalisation and oversight of Ministerial mandates. Examples include: • Coordination Unit for the Development of the Information and Knowledge Society • Inter-sectoral Commission on Climate Change • Advisory Council on Climate Change • Energy Efficiency and Climate Change Unit • Clean Development Mechanism Authority • REDD+ Secretariat
National-level Agencies	Specialised agencies that are designated as lead bodies in all matters concerning the environment, including the implementation and monitoring of government policies, mainstreaming the environment into development processes and emergency response. This category also includes regulatory agencies that exercise functions aimed at promoting infrastructure investment, penetration and accessibility in the telecommunications field. • Environmental Protection Agency • National Regulatory Agency for Telecommunications • National IT and Telecom Agency
National Research Institutions	Research institutions that are linked to national Ministries and that can serve as thematic advisors in the process of policy design and implementation. Examples include: • National Institute of Meteorology • National Institute of Climate Change Research • National Institute of Ecology and Biodiversity • National Institute of Agricultural Research
House of Representatives and Senate	Generally involved in the process of policy design and ratification into laws through specialised Commissions. Examples include: • Commission on Climate Change • Commission on the Environment and Natural Resources • Science and Technology Commission • Digital Access Commission
Private Sector	Private sector companies from the natural resource, telecommunications or related industry sectors. • Telecommunications Service Providers • Internet Service Providers • E-waste Management Companies
Civil Society Organisations	Civil society organisations that have experience on ICTs, climate change and development issues at the national and/or local level. • ICT4D Non-Governmental Organisations (NGOs) • Climate Change and Natural Resources NGOs • Civil Society Networks on ICT, Climate Change and/or Environmental issues.

Table 1. National Level ICCD Policy Actors

Considering the complexity of stakeholders, interests and agendas at the intersection of the ICT, climate change and development fields, national ICCD policy making can follow different routes, often related to the lead stakeholders involved and the areas of climate change impact that are tackled. Thus, ICCD policies can be developed (a) in response to the specific needs and priorities or role of key development sectors affected by climate change, and/or (b) according to the four main areas of climate change action where ICTs can make a contribution (i.e. mitigation, adaptation, monitoring and climate change strategy).

These two approaches to the process of national ICCD policy making are illustrated in Tables 2 and 3.

Development Sector	Example of Climate Change Priorities	Example of ICCD Policy Focus
Agriculture and Food Security	• The increased frequency and intensity of severe events such as floods and droughts threaten the livelihoods of populations that depend on natural resources (e.g. crop and livestock production, fisheries and forestry), and jeopardise the access, intake and production of food from the local to the national levels. The development of more tolerant/resistant crops, the diversification of crops and the strengthening of the supply chain, constitute imperatives for this sector.	→ ICCD policies can strengthen local agriculture and livestock production systems through improved access to climate-related and agri-related information and knowledge through ICTs. • ICCD policies can support the implementation of an ICT-based national system that combines the use of the Internet, mobile phones and radio in order to provide farmers with information on agro-meteorology, new varieties of crops, crop diseases, production processes, prices and consumer trends, among others, fostering productivity and market access, and enhancing the capacity of the sector to respond to the impacts of climate change.
Human Health	• The impact of extreme events (e.g. cyclones) and chronic trends (e.g. temperature rise), have a negative impact on the emergence and the spread of vector-borne (e.g. malaria and dengue) and waterborne diseases, affecting human health.	→ ICCD policies can improve the capacity of national health systems to respond to and prepare for the challenges posed by climate change to the health sector, with the support of ICT tools. • ICCD policies can foster the use of ICTs to help Ministries and national agencies to coordinate actions and implement national-level health campaigns. ICCD policies can also foster the provision of mechanisms of prevention and response, including decentralised disease surveillance, remote information and assistance, and monitoring of disease prevalence associated with climatic impacts.
Education	• The occurrence of extreme climatic events can affect provision of, and access to education. In some cases, school closures are extended for indefinite periods of time, when the resources required to recover damaged	→ ICCD policies can strengthen the ability of the education sector to face the challenges posed by climate change and uncertanty. • ICCD policies can promote flexible approches to the delivery and access to education at the primary, secondary and tertiary

	infrastructure and re-engage teaching personnel are not available.	levels, based on the use of ICT applications (e.g. online courses, radio programming).
Habitat and Infrastructure	• Climate change manifestations such as sea-level rise, extreme precipitation, extensive flooding and desertification affect the condition of human habitats and endanger vulnerable infrastructure.	→ ICCD policies can help to reduce the vulnerability of vulnerable habitats and infrastructure by strengthening planning and response in face of climate change impacts. • ICCD policies can foster the adoption and use of ICT applications that allow advanced mapping and visualisation, piloting and modelling, among national agencies involved in habitat and infrastructure. ICT applications such as GIS and remote sensing can be used to reduce the vulnerability of human settlements to climatic threats, protect vulnerable infrastructure, design more efficient transportation systems, and improve the implementation of building standards in areas of high exposure to climatic impacts.
Terrestrial and Coastal Ecosystems	• Terrestrial and coastal ecosystems are highly sensitive to climate-induced changes and events such as glacier melting and storm surges, which affect local species and biodiversity.	→ ICCD policies can strengthen the capacity of local ecosystems to withstand and recover from the effects of climate change. • ICCD policies can foster use of ICT applications to identify and monitor natural reserves and protected areas, assess ecosystem vulnerability, monitor the impacts of climate change on local biodiversity, and implement new planning and zoning practices for the protection of coastal ecosystems.

Table 2. Approaches to ICCD Policy Making: ICCD Policies Focused on Development Sector Priorities (adapted from Ospina and Heeks, 2010; 2011)

Climate Change Action Area	Example of Climate Change Priorities	Example of ICCD Policy
Mitigation	• Reduce greenhouse gas (GHG) emissions.	→ ICCD policies can promote the use of ICTs to tackle the main causes of GHG emissions: • Policies aimed at reducing physical consumption, through dematerialisation of goods/services and journey substitution. • Policies aimed at reducing physical production, by fostering the shift to the

		knowledge economy. • Policies aimed at improving energy generation and distribution, utilising ICT for smart power/grid. • Policies aimed at improving energy use, by fostering the production of green IT, smart motors/logistics, smart building design and transport.
Adaptation	• Develop the capacity to withstand, recover from and adjust to the impacts of climate change and uncertainty.	→ ICCD policies can strengthen national adaptive capacities by promoting the use of ICTs to enable improved access to climate change information and knowledge, improve networking and awareness raising, strengthen decision making processes (e.g. predicting, planning and coping), as well as transacting, producing and mobilising resources. • ICCD policies can also foster the use of ICTs towards climate change adaptation in specific vulnerability areas (e.g. livelihoods and finance, water, health, food security).
Monitoring	• Design and implement appropriate mechanisms to track, measure and document the impacts of climate change at multiple levels.	→ ICCD policies can contribute to innovative climate change monitoring mechanisms by enabling improved data collection and management. • ICCD policies can foster the use of ICTs in more participatory and transparent methods of climate change data collection, processing and dissemination, thus improving the effectiveness of monitoring mechanisms.
Strategy	• Develop innovative strategies to identify and address climate change needs and priorities, in accordance with national priorities and international commitments.	→ ICCD policies can support and strengthen the implementation of National Mitigation and Adaptation Programs of Action, fostering the use of traditional (e.g. radio, TV) and emergent (e.g. mobile phones, social media) ICT tools towards the accomplishment of their goals. • ICCD policies can enable the use of ICTs as part of national strategies to improve the efficiency of carbon markets, decision-making processes, climate change policy networks, awareness and capacity building, and technology transfer, among others.

Table 2. Approaches to ICCD Policy Making: ICCD Policies Focused on Key Areas of Climate Change Action (adapted from Ospina and Heeks, 2010; 2011)

While the two approaches suggested for the design of ICCD policies place their emphasis on different climatic impacts and areas of action, the two are not exclusive but rather complementary. Thus, policy-makers can choose to engage in the process of ICCD policy design based on either specific sectoral priorities (e.g. ICTs and climate change impacts on agriculture, ICTs and climate change impacts on infrastructure), and/or on climate change areas of action (e.g. ICTs and climate change adaptation, ICTs and climate change mitigation).

In addition to the design and enforcement of policies, laws, decrees and regulations at the national level, ICCD policies can also be implemented at the sub-national level, as explained below.

1.1(c) ICCD Sub-National Policy Domain

The ICCD sub-national domain involves specific development programmes and projects that are being implemented by regional and local governments or territorial authorities (e.g. departments, municipalities, territories of indigenous peoples), and that involve the use of ICTs in climate change mitigation, adaptation, monitoring and strategising. Examples of sub-national policy initiatives include:

- A state-level initiative to reduce government carbon emissions via use of ICTs in one Indian state (Mahalik, 2012).
- Regional government programmes to incorporate ICT-based climate change monitoring and modelling data into climate change and development strategies (Anderton, 2012).
- City-wide use of electronic sensor stations to enable monitoring and reporting of climate data in Cairo (Hassanin, 2012).

As experiences linking the role of ICTs with climate change mitigation, adaptation and monitoring strategies continue to emerge, particularly in developing contexts, ICCD policy making will continue to gain momentum within the international, national and sub-national domains. This includes the increasing exploration of ICTs' potential towards emissions reduction and adaptation actions at the national and sub-national levels, as well as broader international policy dialogue toward the explicit mention of ICTs as part of UNFCCC agreements, and as such, as part of the umbrella topics that are included as part of global climate change funding mechanisms.

Based on the increasing importance of policy processes in this emerging field, the following section identifies a series of key ICCD principles that should be taken into account in the design and implementation of policies at the intersection of ICTs, climate change and development.

1.2. ICCD Policy Principles

As the analysis conducted thus far suggests, the increasing linkages between ICTs, climate change and development require new policy approaches that foster more holistic, coherent and innovative ICT-enabled responses to the challenges posed by climate change.

Policy and decision makers involved or interested in promoting the process of ICCD policy design and implementation, should consider the following guiding principles:

- ***ICCD Policy as a Process, not a Blueprint***

The availability and use of ICT tools, the magnitude of climate change impacts and the range of prevailing development needs, are unique to each country and context of implementation. Thus, ICCD policies cannot be completely blueprinted or prescribed, as there is no single 'best' approach to tackle the challenges that lie at the intersection of these three fields. Instead, ICCD policy design should be approached as an iterative *process* that involves multi-stakeholder dialogue, learning, capacity building and facilitation (Heeks, 2001).

- ***ICCD Policy as a Reflection of Local Priorities***

Via a process-based approach that allows feedback and contributions by experts and practitioners from the climate change, the ICT and the development fields, ICCD policies should be 'localised' in order to respond to both national and local priorities. This translates into ICCD policies that reflect and respond to local patterns of ICT usage and appropriation, to the climate change issues that are prioritised by local actors, and to the development challenges and opportunities that characterise the context of implementation, and that acknowledge the role of existing institutions, past and ongoing programmes and strategies in order to avoid the duplication of efforts and build upon lessons learned. Localised ICCD policies may be designed by providing them with their own separate identity (i.e. separate from existing policies in the ICT, climate change or development fields), or alternatively, by integrating them into existing climate change or development approaches.

- ***ICCD Policy as an Opportunity for Innovation***

The momentum gained by climate change issues at the international and national levels, as well as the growing visibility of ICTs' potential, should be used to leverage the development of innovative policy approaches in this field. ICCD policies should be seen, especially by developing countries, as an opportunity for innovation and pioneering in an area where there is ample room to learn. Project and policy experience already acquired by both developed and developing countries in the e-governance field can provide useful lessons to draw upon.

- ***ICCD Policy as an Integrated Approach***

The integration of ICTs into ICCD policies must be driven by broader climate change objectives. The climate change vulnerabilities experienced in different development sectors, and the consequent need to mitigate, adapt, monitor and strategise in face of climatic impacts and uncertainty, must remain at the core of ICCD policy-making processes. Within them, ICTs are a means towards the achievement of climate change-related goals and development outcomes. They are not an end in themselves. Recognising the need to articulate the use of ICT tools with different stakeholders, institutions, processes, information and knowledge (i.e. traditional and emergent), all within broader climate change goals, the notion of '*i-climate change*' –integrated climate change (instead of the technology-biased 'e-climate change') – could better reflect the aims of policy making in this field (Heeks, 2003).

- ***ICCD Policy Based on a "Climate-Smart Development" Vision***

There are many important lessons that can be drawn from the progress achieved by Ghana's government in the field of ICTs and climate change. As the government moves forward with the design of its National Climate Change Policy Framework, the notion of '*climate smart economic development*' (i.e. development to build climate resilience with a low carbon footprint) (Asiamah, 2012) is being used as the basis to mainstream climate change into national development planning. The comprehensiveness of this approach suggests that ICCD policy design can be facilitated if there is a unifying, holistic vision of "Climate-Smart Development", shared between stakeholders at the national, sectoral and local levels.

2. ICT, Climate Change and Development Policy Components

Building on the policy domains and principles identified, this section explores the three main components required in the design of coherent ICCD policies, namely *policy content*, *policy structures* and *policy process*, represented in Figure 3.

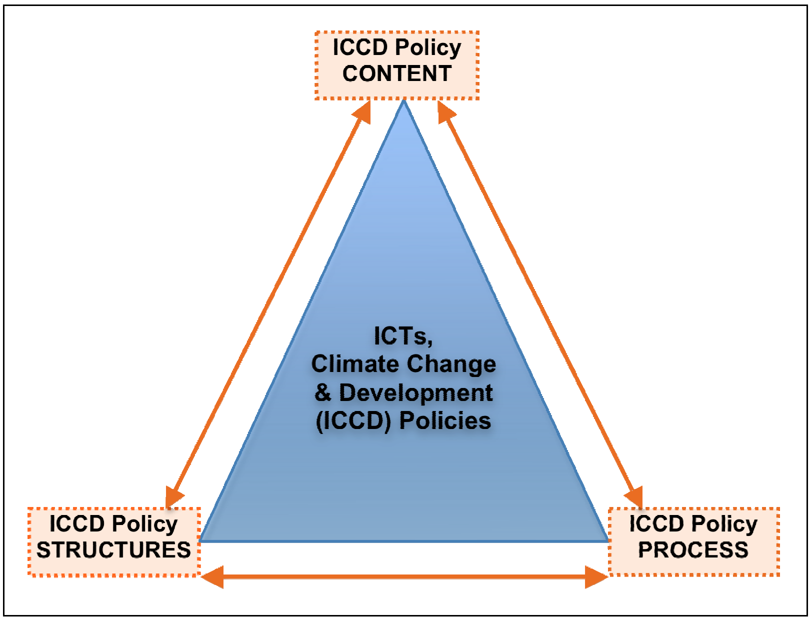

Figure 3: Key Components of ICCD Policies

Each of these policy components will be examined in the following sub-sections.

2.1. ICCD Policy Content

Located at the intersection of three fields, ICCD policy content integrates issues regarding (a) ICTs (e.g. infrastructure, connectivity, ICT use and appropriation), (b) climate change (e.g. climate change impacts and viable mitigation, adaptation and monitoring responses), and (c) development (e.g. prevailing development vulnerabilities and priority areas in the context of policy implementation). The underlying issue in the process of ICCD content development is the provision of *relevant* and *useful* policies that reflect the climate change priorities at the national and local levels; that build upon the availability, use and potential of ICT tools, and that address the prevailing development challenges that characterise the context of policy implementation.

The development of ICCD policy content can be explored from the perspective of each of these fields, as illustrated below. While the development of policy content is required at the international, national and sub-national domains, the examples provided below focus on the national level, given the importance of policy action in this domain (examples of ICCD content at the international and sub-national domains are provided in Boxes 1, 2, 3 and 4).

2.1(a) ICT Policy

The following examples illustrate the integration of **climate change** into **ICT policies.** The content proposed focuses on three key areas for policy action, namely the recognition of the linkages between ICTs and climate change, ICTs and climate change mitigation, and ICTs and climate change adaptation. We also acknowledge the role of generic ICT policy.

1. Policy Content Aimed at Recognising ICT & Climate Change Linkages

This area of action refers to the development of policy content aimed at acknowledging and raising awareness on the linkages that exist between ICTs and climate change. Building awareness is a key step in integrating ICTs and climate change within decision-making processes, and in mobilising action at the international, national and sub-regional domains. At a general level, policies can aim at fostering the use of ICTs to raise two kinds of public awareness: (a) initial/generic awareness of climate change issues (e.g. national radio and TV programmes used to disseminate key climate change concepts and terminology), as well as (b) specific awareness of local issues (e.g. digital videos used to raise awareness on community risks/vulnerabilities to climate change such as crop diseases, production levels, or water availability) (Ospina and Heeks, 2012).

More specifically, the development of policy content should focus on the following key components (Table 4):

Components	Aim	ICT and CC Linkages Policy Content
AWARENESS RAISING	*Raise public awareness on the linkages between ICTs and climate change*	ICT policies can generate a better public understanding on the potential of ICT tools with regards to climate change mitigation, adaptation, monitoring and climate change strategies. Towards this end, national ICT policies should include content on: • Programmes to raise awareness and build a knowledge base about the relevance of climate change mitigation and adaptation in developing countries, and about the relevance of ICTs (a) in the delivery of mitigation and adaptation goals, (b) in the achievement of development objectives within a changing climate, and (c) in the fulfilment of international and national commitments in this field.
CAPACITY BUILDING	*Use ICTs to generate capacities among the stakeholders involved in ICCD policy design and implementation*	• Promote and sponsor training programmes to build capacity within government, organisations and communities for understanding and undertaking action on e-mitigation, e-adaptation, and e-monitoring of climate change. This includes "the capacity to conduct ICT-related assessments such as energy audits and e-environment

		readiness studies, which provide baseline carbon emissions and related data" (Roeth et. al, 2012).
e-ENABLED ACCESS TO CLIMATE CHANGE INFORMATION	*Use both traditional and emergent ICT tools to ensure universal access to climate change information*	• Use a wide range of digital and non-digital ICT tools (e.g. radio, Internet, TV, video, mobile phones) to ensure ample access to climate change information that is reliable, context-specific, targeted to local audiences, delivered in non-technical language and in user-friendly formats. • Encourage access to ICT-enabled climate change information in public community points of access (e.g. libraries, post offices, museums, archives and schools) to foster broader availability and production of local content on the subject.
SYSTEMATISING AND COMPILING KNOWLEDGE	*Provide e-enabled national information systems to systematise, preserve and share information and knowledge on the linkages between ICTs and climate change*	• Facilitate and generate ICT-based systems to compile, order, store and disseminate information and knowledge generated from experiences and lessons learned from the use of ICTs in climate change mitigation, adaptation and monitoring initiatives. • Foster the use of ICT tools to conserve and share traditional knowledge on adaptation practices, including intangible heritage such as life stories on adaptive practices.

Table 4. Integrating Climate Change Awareness and ICT Policies

2. Policy Content Aimed at Integrating ICTs & Mitigation

This area of action refers to the development of policy content aimed at moving rapidly to low-carbon solutions, and at reducing operating costs alongside carbon emissions by investing in e-mitigation. Policy content should acknowledge the challenges faced within developing country contexts (e.g. lack of resources, awareness, appropriate technologies and market/policy regimes). Thus, ICT and mitigation policies can play a key role in "building new capacity and partnerships, and to create a business environment that incentivises innovation and the adoption of e-mitigation applications" (ibid, p.1).

ICT and climate change mitigation policy content should focus on three main components: green ICT, smart ICT and community ICT, as reflected in Table 5.

Components ICTs & Mitigation Policy	Aim	ICT and CC Mitigation Policy Content
GREEN ICT	*Reduce the carbon emissions from ICT production and consumption*	ICT policies can contribute to climate change mitigation by fostering the development of a **green ICT strategy** that seeks to minimise emissions from ICT production and consumption. Towards this end, national ICT policies should include content on: • Adoption of ICT components that are as energy efficient as possible, including the incorporation of green criteria into ICT procurement. • Innovation by ICT firms of new components that use even less energy. • Transfer of data centres to cooler locations and/or close to greener energy sources such as hydropower, and more effective management of data centre energy design and use. • Lifecycle analysis and planning of ICT production including the minimisation of e-waste and maximisation of component recycling. • Use of smart technologies within ICT production and logistics. • Virtualisation: moving both server and desktop services to the cloud. • Use of renewable energy sources to power ICT-related infrastructure, with a significant potential contribution relating to green, off-grid mobile base stations in developing countries.
SMART ICT	*Use ICTs in other sectors - energy, buildings, transportation, logistics, manufacture and forestry - to shrink their carbon footprint*	ICT policies can contribute to climate change mitigation by fostering the application of **"smart" ICT applications** in other sectors to save both money and emissions, particularly in urban areas. Towards this end, national ICT policies should include content on: • **Smart Energy:** Foster ICTs' potential to help decarbonise energy supply and use, and to realise carbon reduction opportunities through the use of applications for energy generation (e.g. smart grids to monitor power consumption and use), energy transmission and distribution (e.g. ICTs for remote measurement and monitoring of energy use), efficient end-use technologies (e.g. smart meters), and decentralised energy production (ICTs for both energy control and connection). • **Smart Buildings:** Promote the use of ICT-based technologies to enhance the efficient use of energy in buildings, through applications such as building information modelling (BIM), wireless sensor networks to control energy consumption, and building management systems (BMS).

		• **Smart Transportation:** Support the implementation of ICT-driven applications across transportation systems, including software to improve the design of transport networks (e.g. eco-driving, route optimisation, inventory reduction), and improve systems integration (e.g. smart charging and vehicle-to-grid systems). • **Smart Commerce:** Foster the use of ICT applications in the development of "smart logistics" to monitor, optimise and manage operations, as well as in "smart manufacturing" solutions to increase manufacturing process efficiency. • **Smart Forestry:** Foster the use of ICT to improve land-use change and reduce deforestation through applications for data capture via remote sensing, geographic information systems, wireless sensor networks and "participatory sensing" by local citizens or activists, for example using mobile devices.
COMMUNITY ICT	*Apply ICTs at the community level to reduce energy consumption and substitute for journeys*	ICT policies can contribute to climate change mitigation by fostering the use of ICTs within developing country communities in which, as yet, green and smart ICT applications play little role. Towards this end, national ICT policies should include content on: • Actively implementing ICTs in **community awareness raising campaigns,** using broadcast and narrowcast media to make individuals and groups aware of climate change issues and mitigation strategies. • **Local contributions to deforestation:** Support the use of ICT applications such as participatory sensing, as well as community radio to encourage replanting and more efficient use of wood burning for heating and cooking. • Foster the adoption of **"climate-smart' agricultural practices,** to contribute to the reduction of methane and related emissions. • Actively engage the use of ICTs towards **journey substitution** and other **energy savings to be adopted at the community level,** through use of dematerialised services such as e-government, e-commerce and e-health initiatives. (e.g. use of videoconferencing - including Skype - to substitute for journeys that require meetings with government or other officials, use of renewable energy sources such as solar chargers and panels to power ICT devices within the community).

Table 5. Integrating Climate Change Mitigation and ICT Policies. Adapted from Roeth et al. (2012)

Box 1. ICTs and Climate Change Mitigation
Policy Content - International Domain

Policy content at the ICCD international level should aim at incorporating ICTs more clearly into low-carbon technology transfer and global financing initiatives. Example:

> *"Develop a long-term international strategy, including financing options and incentive programs for the development and localisation of low-carbon technology and applications that provide solutions to major GHG-emitting sectors".*

Box 2. ICTs and Climate Change Mitigation
Policy Content - Sub-regional Domain

Policy content at the ICCD sub-regional level should aim at incorporating ICTs explicitly into low-carbon technology transfer and financing plans of territories/regions. Example:

> *"Develop a sub-regional strategy in support of green, smart and community ICT applications that can support the socio-economic development of the sub-region, including the adoption of specific measures in support of carbon-saving initiatives, to spur innovation and sub-regional level adoption of e-mitigation practices".*

3. Policy Content Aimed at Integrating ICTs & Adaptation

This area of action refers to the development of policy content aimed at supporting the design and implementation of e-adaptation applications at the national level. ICT and climate change adaptation policy content can be developed in support of national adaptation plans (across the different stages of implementation) (Ospina and Heeks, 2011), as well as in support of specific sectoral strategies (focusing on key areas affected by climate change such as poverty, water, agriculture, and food security, health, disasters, etc). These two approaches to e-adaptation policy content development are reflected in Table 6.

ICTs & National Adaptation Plans	Aim	ICT and CC Adaptation Policy Content
INFORMED DECISION MAKING	*Use ICTs to inform decision-making within climate change adaptation processes*	ICT policies can contribute to National Climate Change Adaptation Plans by identifying the specific needs and priorities at the local and national level, as well as the vulnerabilities, resources and capacities available in support of informed decision making processes. Towards this end, national ICT policy content should include content on: • The use of applications such as (GIS) and meteorological information systems to understand both the current extent of climate change, but also to model future impact on not just weather but also agricultural productivity, health and disease, disaster incidence, etc. • The application of traditional and

		emerging ICT tools to draw on a wide range of information and knowledge perspectives, and present them in appropriate languages and user-friendly formats • The use of ICTs to localise adaptive actions and to strengthen the capacity of local actors to analyse climate models and predictions.
STAKEHOLDER ENGAGEMENT	*Use ICTs in the consolidation of partnerships between public, private and civil society sectors, towards the formulation and implementation of National Adaptation Plans*	ICT policies can contribute to National Climate Change Adaptation Plans by facilitating the inclusion of multiple voices in the design of adaptation strategies at various levels. Towards this end, national ICT policies should include content on: • The use of ICTs to broadcast and raise awareness on the issues to be decided as part of adaptation plans, including the use of social media and online polling amongst those likely to be affected; and the use of group decision-support systems to model and analyse different scenarios, and enable decisions to be made. • The use of ICTs to foster new forms of engagement and participation in climate change adaptation and crisis response.
ADAPTATION DELIVERY	*Use ICTs in the delivery of adaptation priorities, in regards to key sectors/issues*	ICT policies can contribute to National Climate Change Adaptation Plans by supporting the delivery of adaptation priorities in regards to specific development vulnerabilities, sectors or issues. Towards this end, national ICT policies should include content on: • The use of ICTs in support of adaptation measures in sectors such as agriculture and food security, human habitat and health, water resources, terrestrial ecosystems, marine and coastal ecosystems, and disaster management, among others. • Examples of ICTs and sector/issue-based policy approaches to adaptation delivery include: ❖ **Food Security:** Promote the use of ICTs to access information about resistant seed varieties and planting methods, or to access agro-meteorological information to protect crops. ❖ **Water Supply:** Promote the use of ICTs to build local capacity for the conservation of water sources and more efficient water management during the production cycle. ❖ **Income Generation:** Promote the use of ICTs to explore/access alternative

		sources of income generation, including the productive use of ICTs (e.g. to access agricultural markets, prices, or to commercialise products). ❖ **Health:** Foster ICT adoption to disseminate information on prevention and treatment of new diseases triggered by climatic impacts, or in early warning systems on disease forecast and control. ❖ **Infrastructure:** Promote the use of ICTs to share lessons on safe building practices in areas of high risk for rural communities.
FEEDBACK AND LEARNING	*Use ICTs in the generation of feedback, the creation of new knowledge and the dissemination of existing and emerging adaptation experiences*	ICT policies can help to strengthen adaptation plans by facilitating the generation of feedback on the impact of adaptive actions through geographical and sectoral information systems, while facilitating continuous adjustment of adaptation actions. Towards this end, national ICT policies should include content on: • The use of ICT tools such as Web 2.0 and online media to document traditional adaptation practices, and to convene different sources of expertise in joint efforts towards the creation of climate adaptation tools. • The use of ICTs for environmental observation, monitoring and networking, in order to involve users in the analysis, translation and use of climate change information. • The use of e-governance systems to provide transparency and accountability of the resources invested in adaptation.
INSTITUTIONAL CAPACITY BUILDING	*Use ICTs to strengthen the institutions involved in adaptation strategies*	ICT policies can help to the strengthen adaptation plans by building the capacity of institutions to enable the flow of assets, skills and values necessary for undertaking adaptive actions Towards this end, national ICT policies should include content on: • The use of ICTs as part of capacity-building processes aimed at providing a digital institutional infrastructure that can readily develop, share and utilise a wide range of digital climate change data. • The use of ICTs as part of multi-level networking and coordination of intra/inter-institutional actions in the adaptation field. • The use of ICT applications to strengthen efficiency and transparency in the assignation of adaptation resources. • The use of ICTs for e-learning, capacity building and skills-update programmes on

		climate change issues, particularly among institutional actors/employees located in remote areas.

Table 6. Integrating Climate Change Adaptation and ICT Policies. (Adapted from Ospina and Heeks, 2011; 2012)

Box 3. ICTs and Climate Change Adaptation Policy Content - International Domain

Policy content at the ICCD international level should aim at incorporating ICTs explicitly into global adaptation strategies. Example:

> *"Develop innovative approaches to climate change adaptation through the integration of traditional and emerging ICTs, including the development of 'e-adaptation' applications that foster new mechanisms for information and knowledge sharing, capacity building, networking and collaboration towards adaptation goals".*

Box 4. ICTs and Climate Change Adaptation Policy Content - Sub-regional Domain

Policy content at the ICCD sub-regional level should foster the use of ICTs in the design and implementation of sub-regional projects and initiatives. Example:

> *"Integrate the use of ICT tools as an integral component of sub-regional strategies, projects and initiatives. The use of ICTs should be based on the specific needs and priorities of the sub-region, and should build upon and complement the ICT, the human and the economic resources available within the context of implementation".*

4. Generic ICT Policy

Alongside the specific policy areas identified above, it should also be recognised that "generic" ICT policy has a relevance to climate change and to climate change action. The growing diffusion of ICTs adds to the sector's carbon footprint (something, as noted above, that needs addressing via green ICT policies). More generally, the "informatics infrastructure" of a nation will be the foundation for any low-carbon or carbon-smart future. Hence, governments must recognise that generic policies – e.g. facilitating broadband or next-generation network infrastructure; enabling e-services; building informatics design and use capacity; addressing the digital divide – are all "climate-relevant", and all need to be considered in light of their climate impact.

2.1(b) Climate Change Policy

Where Section 2.1(a) dealt with the integration of climate change issues into ICT policy, this section deals with its mirror image: the integration of ICT issues into climate change policy. Given that mirror-imaging, we will not repeat what has already been laid out. The content discussed above is equally required in climate change policies, which should make explicit reference to the role of digital technologies and their abilities to:

- Build the foundations of data, awareness and knowledge through awareness raising, capacity-building, enabling access to climate change information, and knowledge-building (see Table 3).

- Address climate change mitigation through green ICT, smart ICT and community ICT initiatives (see Table 4).

- Address climate change adaptation by enabling better decision-making, stakeholder engagement, adaptation delivery, feedback/learning, and institutional capacity building (see Table 5).

Additional ICT roles that should be explicitly recognised within climate change policies are related to the areas of climate change *monitoring* and *disaster management*, as explained below.

- **Climate Change Monitoring**

Monitoring systems based on ICTs play a key role in tackling the emerging challenges posed by climate change. Policy makers should develop climate change policies that reflect the following areas of ICT potential:

(a) Strengthen decision making processes: Climate change policies should promote the use of ICTs to improve the reliability and comparability of climate change data, to evaluate the outcome of actions, and guide law enforcement actions in regards to key natural resources, such as forest conservation (e.g. satellite based monitoring systems can provide deforestation estimates based on actual observations of land-use change, informing decisions about strategies to reduce greenhouse emissions) (Rajão, 2012).

(b) Improve the understanding of climate change impacts on the most vulnerable: Policies should support the adoption of ICTs such as satellite imagery, mapping and modelling technologies to gather and monitor real-time, location-specific climate change impacts, particularly among remote and vulnerable populations. ICT-based monitoring systems should also be used to better integrate knowledge of future climatic impacts into mitigation, adaptation and development planning (Anderton, 2012).

(c) Foster projects based on demand-driven information needs: ICTs should be supported as part of demand-driven initiatives aimed at providing localised climate- related information for monitoring, modelling and related uses. Demand-driven e-monitoring initiatives should pay attention to the access, uptake and utilisation of data by communities and decision makers, as well as to the enactment of those decisions (ibid).

(d) Provide resources to ensure e-monitoring quality and sustainability: Policies should ensure access to the financial and technical resources required for the design, implementation and maintenance of e-enabled monitoring systems, including building local capacities in the management of hardware, software or data techniques, as well as in the analysis and interpretation of climatic data (Hassanin, 2012).

- **Disaster Management**

Information and communication play a critical role within disaster management strategies. From enabling rapid access to reliable data, to the capacity to analyse and integrate information from varied sources in local responses, and the ability to mobilise and coordinate efforts among a myriad of stakeholders, ICTs are key tools for disaster preparedness, response, recovery and reconstruction (Yap, 2011).

Climate change policy makers should focus on the integration of four key ICT roles in policies related to disaster management:

(a) Ensure a 'last mile' communication approach: Integrate ICTs into disaster management strategies in order to ensure timely and effective communication of disaster alerts to the 'last mile' (e.g. using a wide range of technology tools – such as television, radio, satellite radio, mobile phones, short message service (SMS) and remote sensing, among others – to reach vulnerable "people who, for reasons of age, gender, culture or poverty, are not reached by disaster preparedness") (ibid. p.13).

(b) Enable rapid two-way communication within contexts affected by disasters: The use of ICT tools (e.g. mobile phones, wireless ad-hoc mesh networks with GPS, e-mail and radio) (ibid.) should be fostered among front-line disaster responders, affected communities, diaspora communities and other key stakeholders, in order to facilitate the access and distribution of critical information, effectively mobilise aid resources and deploy rescue operations (ibid).

(c) Foster the use of integrated/standardised geospatial data to ensure the coordination of disaster management efforts. This to be done by promoting the development of a common set of geospatial data resources based on ICTs (e.g. geographic information systems, GIS, satellite remote sensing and global positioning systems, GPS) to facilitate the coordination of disaster preparedness and response among institutions and agencies (ibid).

(d) Contribute to transparency and accountability: ICTs should be fostered as enabling tools of transparency and accountability in the allocation of disaster management resources. Emphasis should be placed on policies that foster the use of Web 2.0 tools as part of citizen-led monitoring mechanisms that oversee and share real-time information about the allocation and use of resources in the field.

2.1(c) Development Sector Policy

Development sector policies – on agriculture, health, water, education, transport, housing, etc – face what we might see as a "triple requirement": to incorporate the potential of ICTs; to incorporate the challenge of climate change; and to specifically incorporate the potential of ICTs vis-à-vis climate change. It is beyond the scope of this policy paper to address the first two issues and, in any case, sectoral policies have been steadily adapting to both the diffusion of ICTs, and the growing awareness and impact of climate change.

To incorporate the ICT/climate change intersection is where the main current policy challenge lies. Sectoral policy makers can best start with the overview model shown in Figure 4. They need to identify which of the component parts are priorities, and then incorporate those into policy as specific statements, programmes and/or objectives.

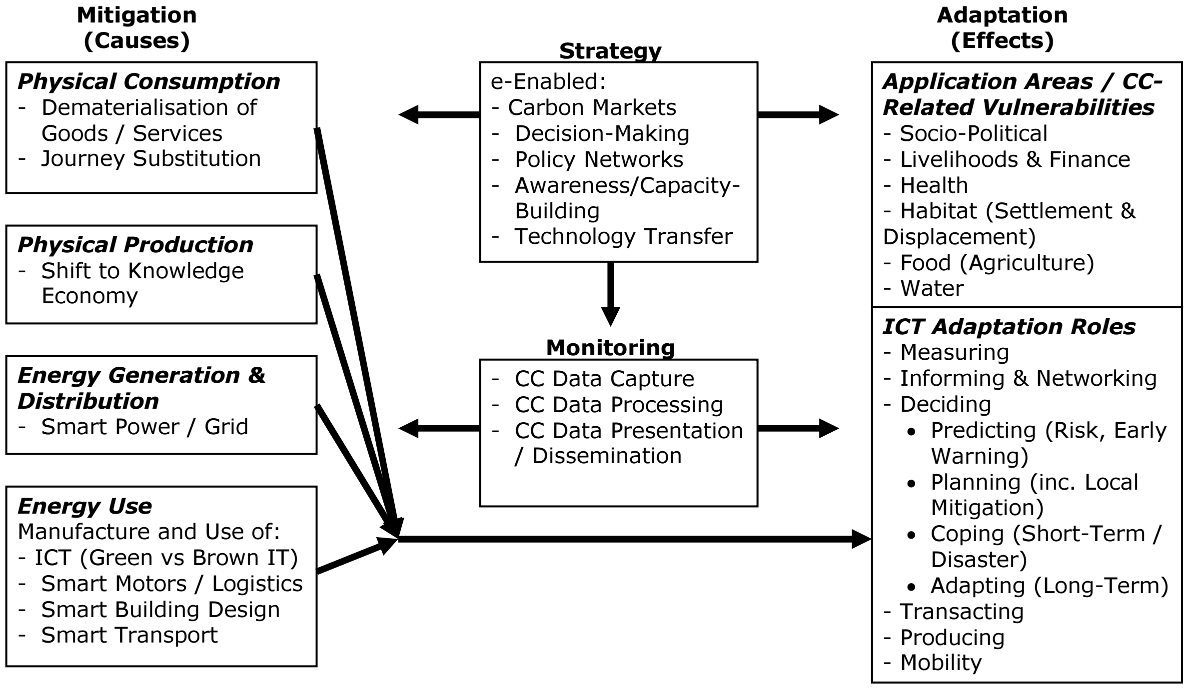

Figure 4. Overview Model on ICTs, Climate Change and Development (ICCD)

Overview guidance on most of these components can be taken from the content already provided in this paper; for example Tables 3-5 in looking at overall awareness, mitigation and adaptation measures. These can readily be converted to sector-specificity (and, indeed, there are some sector-specific pointers already within the Tables).

However, each sector will require also require its own detailed analysis to identify the particular role of the ICT-climate change nexus and, hence, appropriate policy components. It is beyond the scope of the current paper to illustrate such an analysis, but one is provided for ICTs and climate change adaptation in the water sector by Ospina et al (2012).

2.2. ICCD Policy Structure

Policy structure refers to the availability of effective institutional arrangements, including stakeholder capacities, roles and responsibilities, required for the design and implementation of ICCD policies. Generally, the basic structure required for ICCD policy making involves four main groups of stakeholders representing the State, the scientific community, the business sector and the civil society, as reflected in Figure 5.

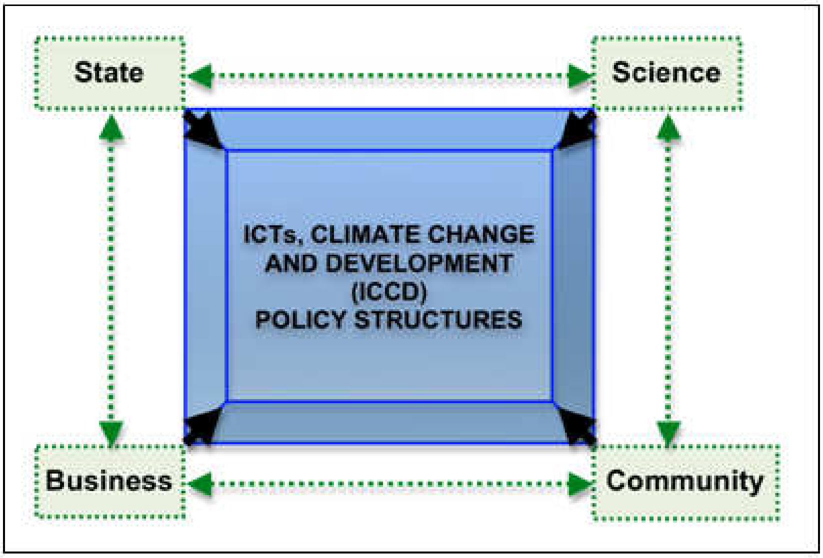

Figure 5. Key Stakeholders in ICCD Policy Structures

The coordination of actions between these stakeholders faces challenges related to the existence of a myriad of 'divides' between the four groups, which include the differential access to information and knowledge, and the different skills and languages used by each group, among others. Examples include the lack of a common 'language' between the different groups (e.g. the terminology and concepts used by the scientific and the government groups), the lack of (participatory / consultative) mechanisms to integrate traditional/community-based knowledge within policy-making processes, as well as the information gaps that exist between and within groups (e.g. between the Ministry of Environment and other Ministries, or between the private sector and civil society groups), among others.

Thus, representativeness and relational factors play a key role within policy structures, and involve the effective participation and interaction between the different groups towards policy making, as well as the forums through which they are brought together (Heeks, 2010).

An effective ICCD policy structure ensures that the views of these different stakeholders are represented and that their interests are balanced in the process of policy design and implementation. Thus, structures are needed that provide cross-sectoral and inter-institutional coordination mechanisms between ICT, climate change and development policy stakeholders at both the strategic and operational levels of the policy process. An effective structure involves clearly defined roles and responsibilities for each institution/stakeholder involved in policy design and implementation, as well as the availability of an agreed organisational arrangement for multi-stakeholder collaboration.

ICCD structures can take multiple forms. Institutional arrangements can be based on different domains of policy influence (i.e. international, national or sub-regional), or built upon pre-existing systems of institutional collaboration (e.g. national climate change committees, national environmental systems). Ultimately, they should reflect the variety of ICT, climate change and development stakeholders that are present in each context.

Building on different examples of institutional arrangements available for the coordination of ICT and climate change activities in developing countries (Asiamah, 2012), Figure 6 provides an example of an ICCD policy structure that could be considered by policy-makers in this emerging field.

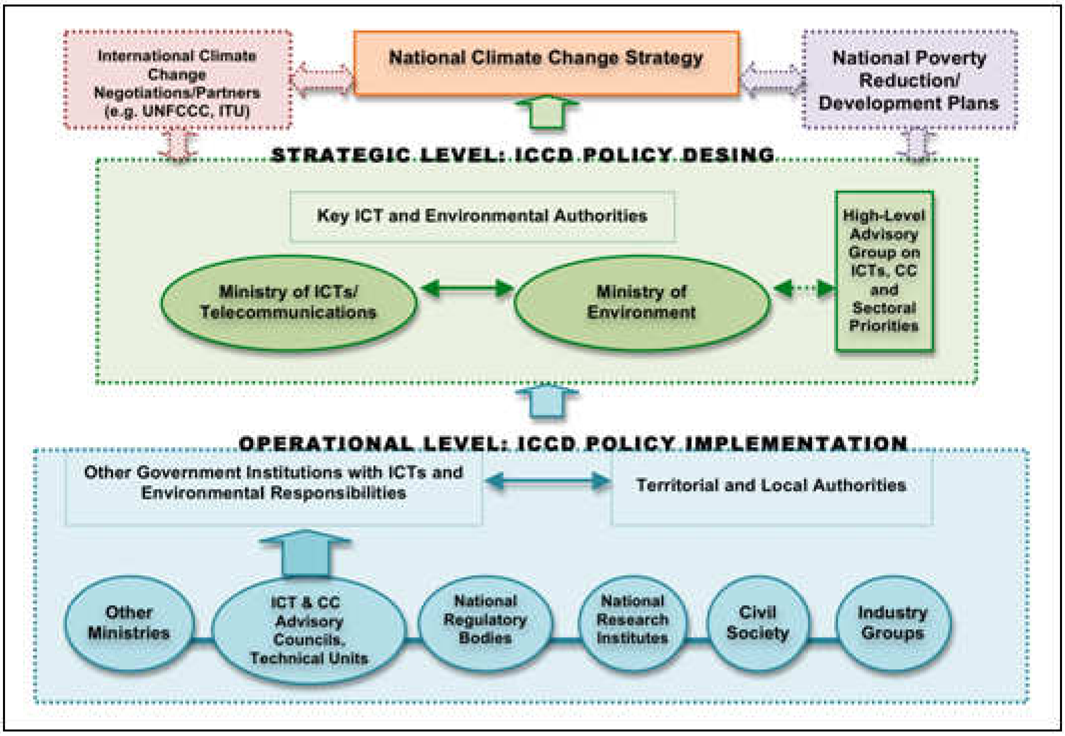

Figure 6. Example of a National ICCD Policy Structure

The ICCD policy structure reflected in Figure 6 has several important characteristics for the consideration of decision-makers:

- The structure distinguishes between two main levels of the ICCD policy process, namely the strategy level of policy design, and the operational level of policy implementation. In doing so, the structure facilitates the identification of roles, responsibilities and areas of competency of the different stakeholders involved.

  - At the *strategic level*, the two national authorities of the ICT and climate change fields (e.g. Ministry of ICT/Telecommunications and Ministry of the Environment) are supported by a high-level advisory group that includes development sector representatives.

  - At the *operational level*, stakeholders from other government institutions with ICT and environmental responsibilities and implementation mandates, interact with a variety of actors from the state, the private sector, the scientific and civil society communities. These institutions also interact with territorial and local authorities that not only have the mandate to exercise policy actions at those levels, but can also contribute to the understanding of local priorities.

- The Figure also reflects that, while the goal of the ICCD policy structure is to articulate ICT and climate change policies within broader climate change national strategies, articulation also needs to be achieved with national development and poverty reduction programmes, ensuring coherence with agreements reached at the international domain (e.g. UNFCCC) and with the support of international partners and institutions (e.g. ITU).

The design of ICCD policy structures should build upon experiences from the ICT for development (ICT4D) and the climate change fields, drawing best practices and strategies to overcome the challenges involved in the design and implementation of inter-institutional/cross-sectoral collaboration mechanisms. Such challenges may concern the absence of effective representative bodies for key stakeholder groups (e.g. civil society groups, micro-enterprises), or the shortage of institutional capacities and technical competencies in the ICT and/or climate change fields.

Regardless of their specific design, ICCD policy structures must be flexible to reflect and adapt to the changing nature of the ICCD field (i.e. integrating emerging actors and issues, as well as emerging technologies, trends and patterns), in order to reflect ICT4CC coherence (the role of ICT in climate change policy, and also the role of climate change in ICT policy).

2.3. ICCD Policy Process

ICCD policy *process* refers to the coherent implementation of the overall policy cycle, from the process of content development and structure design, to the actual integration of ICT, climate change and development issues in policy implementation This translates into processes that ensure both horizontal and vertical policy coherence between the ICT and climate change fields (Figure 7).

Horizontal coherence of ICCD policy processes refers to the alignment of the different components that are necessary for ICTs' impact as part of climate change mitigation, adaptation and monitoring responses. It involves ensuring the "e-readiness" of the context of policy implementation (i.e. the elements necessary for making ICT tools available, such as awareness, infrastructure, human capacities, economic resources, motivations and political support, among others) as well as providing conditions for ICT availability, uptake and development impact (Heeks, 2010) (e.g. climate change awareness through the delivery of appropriate content via mobile, Internet-based applications, etc).

Vertical coherence of ICCD policy processes refers to the steps taken to ensure policy articulation between the sub-regional, the national and the international policy domains, considering the ICT and the climate change and the development fields. It requires ICCD policies to acknowledge or build upon existing policies in the fields of ICT and climate change, including climate change and information society legislation, national laws, planning strategies and declarations, international documents and agreements (UNESCO, 2009).

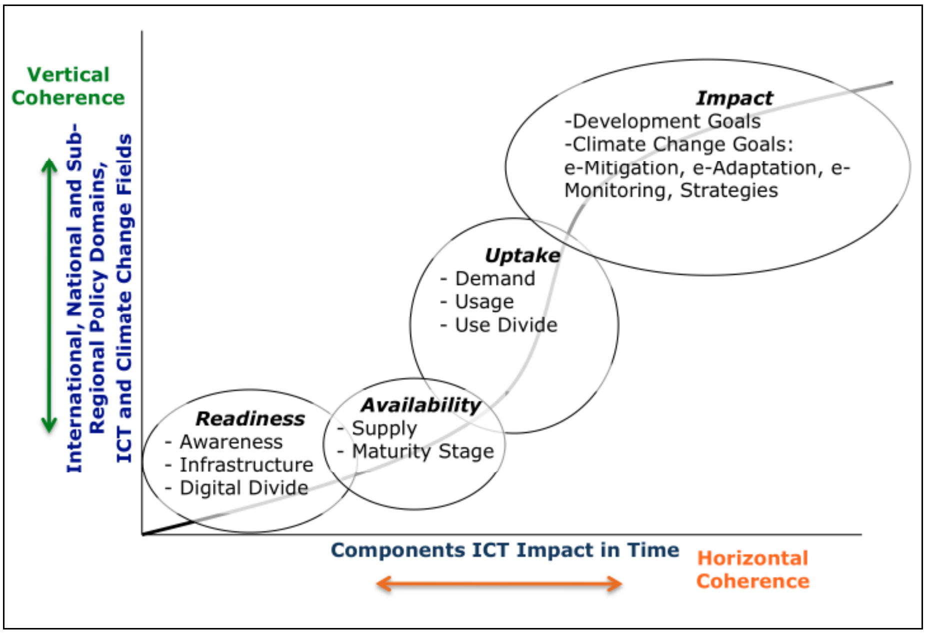

Figure 7. ICCD Horizontal and Vertical Policy Coherence. Adapted from Heeks (2009)

In addition to consideration of vertical and horizontal policy coherence issues, the operationalisation of ICCD policy process involves six main stages, namely awareness raising and strategy, problem definition, identification of ICT-enabled solutions, identification and selection of policies, implementation of those policies, and then their evaluation. The main tasks involved in each of these stages are reflected in Figure 8.

<table>
<tr><th rowspan="2">AREAS OF ICCD POLICY FOCUS</th><th colspan="6">ICCD POLICY CYCLE STAGES</th></tr>
<tr><th>Awareness Raising Strategy</th><th>Problem Definition</th><th>Identification of e-Mitigation, e-Adaptation & e-Monitoring Options</th><th>Identification and Selection of Policies</th><th>Implementation of Policies</th><th>Evaluation of Policies</th></tr>
<tr><td>ICT and CC Linkages</td><td rowspan="5">Raise awareness among policy-makers/key policy stakeholders on the climate change needs and priorities in regards to specific issues of focus, sectors or contexts.</td><td rowspan="5">Define the problem of focus through vulnerability and technology needs assessments in consultation with multi-sector/cross -level stakeholders</td><td rowspan="5">Identify ICT tools/ applications to tackle the mitigation, adaptation or monitoring issues identified. Identify the stakeholders that need to be involved in design and implementation</td><td rowspan="5">Design or identify adequate policies (e.g. laws, regulations, decisions) to respond to the problem (i.e. climate change impacts), integrating the use of ICTs</td><td rowspan="5">To be conducted in the appropriate domain (i.e. international, national or sub-regional), in collaboration between different stakeholders (e.g. national and local governments)</td><td rowspan="5">Identify an external body to conduct an assessment of ICCD policies and provide strategic recomm-endations for improvement</td></tr>
<tr><td>e-Mitigation</td></tr>
<tr><td>e-Adaptation</td></tr>
<tr><td>e-Monitoring</td></tr>
<tr><td>Sector-Specific Climate Change Priorities</td></tr>
</table>

Figure 8. ICCD Policy Cycle Stages. Adapted from Hagemann et. al, 2011.

It is important to note that the boundaries between these different stages are porous, and their implementation often overlaps (i.e. some of the tasks involved in different stages may occur in parallel, for example, awareness raising and problem definition, or the identification of ICT-enabled options). This reflects the need for ICCD policy processes to be flexible, and to be able to respond and adapt to the changing priorities, uncertain climatic impacts, emerging technologies and actors that play a role in the ICCD field.

3. ICCD Policies: The Way Forward

Having identified the main components of ICCD policies, this final section elaborates the potential benefits and challenges that may be encountered in the integration of ICT and climate change policies within developing contexts. The section concludes with a series of key entry points that policy-makers in the ICT and climate change fields can consider in order to foster the adoption of an integrated ICCD approach forward.

3.1. Potential Benefits and Risks

A recent report by the Broadband Commission for Digital Development (2012) identifies key challenges faced by ICT policy processes at the national level. These include the lack of policies and cross-Ministry co-ordination for the adoption of greener ICT solutions and the reduction of emissions within large industries (p. 14), as well as the 'silo' approach of current regulatory environments, where key ICT sector decisions are taken in isolation. The report also suggests that the fast pace of technological advances in the ICT field poses a challenge for policy-makers, which reinforces the importance of adopting flexible, forward looking policy approaches to the role of ICTs in the achievement of climate change goals.

Within this context, the adoption of an integrated policy approach to ICTs, climate change and development (ICCD) poses a series of potential benefits and risks, as reflected in Table 7.

Potential Benefits of ICCD Policies	Potential Risks for ICCD Policies
Strengthen Informed Decision-Making ICCD policies could foster the use of new and emerging ICT tools (e.g. GIS, remote sensing, Internet-based climate models) to inform decision-making processes within contexts characterised by increased climatic risk and uncertainty.	**Add Complexity to Decision-Making** Without measures aimed at building local capacities, fostering the appropriation of ICT tools, and producing locally-appropriate content, ICCD policies could add new complexity to local decision-making processes.
Avoid Duplication of Efforts ICCD policies could help coordinate efforts and build upon existing experiences and expertise of stakeholders from the climate change, the ICT and the development fields, towards integrated responses.	**Require New Institutional Roles/Structures** Ensuring a coordinated policy approach that integrates ICTs, climate change and development sectors may require the redesign of certain institutional structures and/or roles, identifying clear responsibilities among climate change and ICT stakeholders, as well as mechanisms for information-exchange and inter-agency consultation.

Foster New Livelihood Opportunities within Vulnerable Contexts	Disconnect Livelihood Needs and Information Supply
Within resource-dependent/agricultural livelihoods, the integration of ICTs into climate change strategies could lead to the identification of alternative livelihood opportunities (e.g. by accessing information on credit programmes, new seed varieties and substitute/more resilient crops, by having access to extended networks and skills, by accessing new markets, etc).	Fostering livelihood opportunities amidst a changing climate requires the provision of information that is updated, reliable, locally appropriate, and relevant for a broad set of audiences that have different needs and priorities. In order to ensure that ICT tools help create and strengthen livelihoods, ICCD policies need to narrow the gap between local needs (information demand) and information supply.
Help to Integrate Short-term Responses and Long-term Climate Change Strategies By acknowledging the role of existing and emerging ICT tools within climate change responses, an integrated ICCD policy approach can contribute to tackle both short-term responses (e.g. mobile based early-warning systems) and long-term strategies (e.g. Internet-based climate change models and projections).	**Failing to Anticipate/Integrate Emerging Technologies and Climatic Uncertainty** The fast pace of technological innovation poses the challenge of designing policy frameworks and regulatory approaches that tackle both existing *and* emerging technologies. Given the fast pace that characterises technological development, the future is particularly hard to predict or anticipate from a policy perspective. Similarly, the uncertainty of climate change impacts requires policies that provide an enabling environment to respond to both present *and* future climatic impacts, which are uncertain.
Bridge the Divide Between Local, Sectoral and National Policies Due to its innovative nature, the first step in the design of an integrated ICCD policy approach involves the review of roles and responsibilities, past and ongoing projects, regulations and areas of expertise of actors involved in ICTs and climate change fields at the local, the sectoral and the national level. Thus, the design and implementation of ICCD policies could help to identify and formalise the collaboration among a varied set of actors who otherwise would not work together, as well as to bridge policy approaches.	**Competing Policy Agendas/Perspectives** Stakeholders working in the ICT, climate change and development fields respond to different institutional mandates and priorities. Coming from diverse backgrounds, stakeholders use distinct scientific, academic and/or technical languages and lack a shared understanding of concepts and issues. Integrating ICTs, climate change and development priorities requires a long-term process of collaboration and trust-building, the identification of a common language and a common understanding of key issues, as well as the articulation of often diverging objectives, timing and priorities.
Enhance Local Adaptive Capacity Policies, regulations and strategies play a key role in the provision of an enabling environment for the implementation of innovative climate change actions. The integration of ICT tools can help to strengthen the creation, management and dissemination of climate change information and knowledge, enhancing the capacity of local actors to adapt to the challenges and the opportunities	**Deepen Existing/Create New Inequalities** While the use of ICT tools can facilitate access and dissemination of knowledge and information, it can also deepen existing or create new inequalities and forms of exclusion based on differential access to resources (e.g. access to climate change information through Internet-based applications could exacerbate gender-based power differentials). ICCD needs to be based on the identification and

posed by climate change.	understanding of existing power differentials and inequalities in the context where they will be implemented.
Strengthen Institutional Capacities Fostering the use of ICT tools for achievement of climate change goals can help to strengthen and develop new capacities and competencies in institutions working in the field, including improved information management, networking, production and dissemination of content, mechanisms for awareness raising and education.	**Weaken Capacities + Perpetuate Ineffective Institutions** The absence of national and local institutional capacities to deal with ICT and climate change from an integrated perspective, could limit the implementation of ICCD policies in the field. At the same time, ICCD policies that are not based on initial assessments of needs, institutions and stakeholders, pose the risk of fostering or perpetuating ineffective institutional roles by assigning new responsibilities that weaken/exceed available human, technical and/or environmental capacities.

Table 7. Potential Benefits and Risks of ICCD Policies

Despite the complexities that characterise the junction of the three fields, the potential benefits identified above suggest that there is ample room for ICCD policy innovation and development impact. Within the emerging ICCD field, policy processes remain largely unexplored. The following section will provide a series of key entry points for policy- and decision-makers, with a focus on developing country contexts.

3.2. Key Entry Points for Developing Country Policy-Makers

(a) ICCD Policy Content

- **ICCD Awareness:** Despite the ubiquitous use of ICTs in both developed and developing countries, the linkages that exist between these tools and climate change mitigation, adaptation and monitoring are still unknown by a large number of stakeholders. The recognition of the low-level of awareness that exists on the topic constitutes an important entry point to the process of ICCD policy content, in order to include clear terminology and concepts that can be understood and appropriated by a variety of stakeholders.

- **ICCD Data, Information and Knowledge:** The development of ICCD policy content should be built upon a solid body of data, information and knowledge, including both traditional and emerging ICT and climate change sources. Identifying and assessing existing gaps and needs in terms of ICT and climate change data, information and knowledge, constitutes a crucial entry point for the design of appropriate ICCD policy content.

- **ICCD Based on ICTs' Productive AND Transformative Roles:** ICCD policy content should reflect the multiple development roles and climate-change-related capabilities that ICT tools enable. This involves making reference to the informational, productive and transformational potential of ICT tools, including their role in support of local livelihoods, content creation and income generation; all of which constitute important preconditions for the adoption of climate change mitigation and adaptation practices.

(b) ICCD Policy Structures

- **ICCD Leadership:** A key entry point for the development of ICCD structures is the availability of a well-known, trusted and credible leader who takes forward the process of inter-stakeholder and cross-sectoral coordination of policies. Ideally the ICCD process would involve leaders from both the ICT and the climate change sectors who could, in turn, be in a position to facilitate the articulation of efforts between the Ministerial and municipal levels.

- **ICCD Participation:** The active engagement from ICT, climate change and development sector stakeholders from the government, the private sector, the scientific and the civil society communities, is key in the operationalisation of representative ICCD structures. Consultative mechanisms should be put in place from the onset of the policy cycle, in order to improve the understanding of ICT and climate change needs at the local, national and global levels, maximise the access to economic and knowledge resources, and foster the scalability and sustainability of initiatives.

- **ICCD Institutional Capacities:** ICT, climate change and development institutions play a pivotal role in the implementation of ICCD policies. Thus, assessing the current role, available capacities and capacity-building needs of the institutions involved in ICT and climate change policy design and enforcement, constitutes an important entry point for decision makers.

(c) ICCD Policy Process

- **ICCD Prioritisation:** The design of a systematic mechanism to set priorities across ICT and climate change programmes and subsectors, constitutes a key entry point for policy-makers at the international, national and sub-national domains. This type of mechanism can add transparency and accountability to the policy cycle, helping to balance competing interests from the different stakeholders involved.

- **ICCD and Prevailing Gaps:** ICCD policy processes should start by identifying and assessing prevailing gaps in terms of connectivity (especially in sub-urban towns and rural areas), access and use of ICTs, as well as in the access and use of climate change information and knowledge.

- **ICCD Incentives for Early Action and Innovation:** ICCD policy processes should include mechanisms to incentivise the development of innovative ICT applications on e-mitigation and e-adaptation. Policies should also foster investment, scale-up, commercialisation, domestic market development, and reduction of the costs for implementing use of low-carbon technology, while promoting enforcement mechanisms for intellectual property rights (Roeth et. al., 2012).

The ICT sector is characterised by the constant emergence of new technologies, the growing patterns of ICT adoption, and the wide range of applications given to these tools by a wide range of stakeholders. In face of this changing context, and given the uncertainty posed by climate change impact, the success of ICCD policy will depend on its ability to remain flexible and to adapt – in terms of content, structure and process – to an ever-changing environment. It will also depend on its ability to ensure the provision of policies that tackle both long and short/medium-term challenges and opportunities at the intersection of the ICT, climate change and development fields.

4. Conclusions

As the frequency and intensity of climate change impacts become more manifest, and the diffusion and adoption of ICTs advances, particularly within developing country environments, the design of ICCD policies is becoming an area of increasing importance. Policy action at the intersection of the ICT, climate change and development fields is crucial to provide and mobilise the resources - both human and financial - necessary for the adoption of innovative climate change responses.

This paper presented an overall picture of the main principles, components and entry points to ICCD policies, in order to position the topic in the agenda of policy- and other strategic decision-makers, and to encourage the emergence of new actions in this field. The analysis conducted suggests that, through the design of ICCD content, structures and processes, developing country policy-makers have a historic opportunity to pioneer in an emergent field, through the provision of legal frameworks, regulations, strategies and actions that utilise ICT tools to prepare and anticipate climate change impacts, ensure the coherence of ICT, climate change and development approaches, and foster the articulation of efforts between different sectors and levels.

ICCD policies face the challenge of fostering innovation by supporting new research and funding programmes to develop, test and scale-up applications in the low-carbon/energy efficiency, e-adaptation and monitoring fields. It is crucial for ICCD policies to provide incentives and foster multidisciplinary research and technical cooperation between stakeholders from the scientific community, the private sector, civil society and the state, which will help to promote the development of relevant sectoral applications and bottom-up solutions.

As the penetration and adoption of ICTs continue to grow amidst contexts impacted by climate change, the need for ICCD policies will become more evident. But while the design of ICCD policies is gaining momentum, ICCD policy making should not be approached as a short-term political fix, but as a long-term process of continuous learning, adaptation and interaction with a changing set of actors and priorities, traditional and emerging technologies, and uncertain climatic threats and opportunities. By exploring the process, content and structures required for the development of ICCD policies, developing country policy-makers can be 'ahead of the curve' in this field, while pioneering policy approaches that support and strengthen national goals and international commitments.

Future policy action in this field should build upon the experience of countries such as Ghana, a country that has pioneered in the development of ICCD policy processes. Further research is necessary to draw lessons learned and develop policy guidelines from this and other emerging experiences, in order to ensure a solid path for policy development and implementation at the intersection of the ICT, climate change and development fields.

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Chapter 12: Strategies for ICTs and Climate Change Mitigation in Developing Countries

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Urgent action is required to reduce greenhouse gas emissions. Developing countries overall are significant emitters, and they must maximise use of ICTs in three ways:

- Green ICT: reducing the emissions from production and use of ICTs themselves.
- Smart ICT: using ICTs in other sectors – energy, buildings, transportation, logistics, manufacture and forestry – to shrink their carbon footprint.
- Community ICT: applying ICTs at community level to reduce energy consumption and substitute for journeys.

Developing countries have an opportunity to leapfrog to low-carbon solutions, and to reduce operating costs alongside carbon emissions by investing in e-mitigation. However, they face important challenges: lack of awareness, capital, skills, appropriate technology, and appropriate market/policy regimes.

Action is therefore needed by:

- International organisations: to incorporate ICTs more clearly into low-carbon technology transfer and financing.
- Governments: to build capacity and partnerships, and to create a business environment that incentivises both innovation and adoption of e-mitigation applications.
- Businesses: to develop new e-mitigation solutions appropriate to developing countries, and to drive adoption of such solutions within their entire supply chain.

Carbon dioxide emissions are growing at a rate that is consistent with the worst-case scenario for global warming[645]. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change[646] along with the Stern Review[647] predict that unless this trend is reversed, it will have dire consequences, including catastrophic changes to key earth systems.[648]

Although historically associated with the world's developed countries, greenhouse gas (GHG) emissions are fast becoming a developing country issue. Developing countries already account for 50% of global GHG emissions and by 2030 this figure is expected to rise to 65%.[649] At present, the least developed countries are

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[645] IEA (2011) *World Energy Outlook 2011*. International Energy Agency, Paris http://www.iea.org/weo/

[646] IPCC (2007) *Climate Change 2007: Synthesis Report*. IPCC, Geneva http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

[647] Stern, N. (2006) *Stern Review on the Economics of Climate Change*. HM Treasury, London http://www.hm-treasury.gov.uk/sternreview_index.htm

[648] POST (2005) *Rapid Climate Change*. Parliamentary Office of Science and Technology, London http://www.parliament.uk/documents/post/postpn245.pdf

[649] Tan, X. & Seligsohn, D. (2010) *Scaling-up Low Carbon Technology Deployment, Lessons from China*, World Resources Institute, Washington, DC

minor contributors – responsible for just 0.5% of cumulative emissions between 1995 and 2008.[650] The major sources are the "emerging economies", particularly Brazil, China, India and South Africa – the largest emitters on their continents.[651]

On average (see Figure 1), developing countries have a different emissions profile to developed countries: lower emissions from energy but higher emissions from manufacturing, construction, deforestation, and agriculture. And within developing countries, profiles differ: China's emissions come mainly from energy and manufacturing, Brazil's and Indonesia's from deforestation and agriculture.[652] Developing countries also have particular needs – alleviating poverty, bridging the digital divide, building institutions – that are less of a priority in the world's richer nations.

GHG Emissions by Sector in 2005
CO_2, CH_4, N_2O, PFCs, HFCs, SF_6
(includes land use change)

non-Annex I

Sector	MtCO2e	%
Energy	12,719.5	54.5
Electricity & Heat	5,581.4	23.9
Manufacturing & Construction	3,019.4	12.9
Transportation	1,703.9	7.3
Other Fuel Combustion	1,522.8	6.5
Fugitive Emissions [1]	892.0	3.8
Industrial Processes	1,137.6	4.9
Agriculture	3,748.5	16.1
Land-Use Change & Forestry	5,000.7	21.4
Waste	746.7	3.2
Total	**23,353.0**	

Figure 1: GHG Emissions by Sector in Developing/Emerging Countries[653]

Excepting the ambitious (and, some argue, highly risky and unlikely) route of geo-engineering, then climate change mitigation via the reduction of carbon emissions is essential if the predicted catastrophe is to be avoided. Given their contributions, developing countries must play a key role in mitigation, and ICTs – information and communication technologies – will have a central part to play. ICTs can be used in numerous ways to mitigate climate change by providing solutions that help measure, monitor, manage, and enable more efficient use of resources and energy. ICTs provide immense opportunities to improve the operation of infrastructure and systems and can contribute to dematerialisation, transport substitution, and smarter ways to live, work and spend our leisure time.

What follows in this Brief is an outline of the ways in which ICTs can make a contribution. This breaks down into three main areas (see Figure 2):

- Green ICT: the reduction of carbon emissions from ICT production and consumption.
- Smart ICT: the application of ICT in other sectors to save both money and emissions.

[650] UN-OHRLLS (2010) *Factsheet on Least Developed Countries*, UN-OHRLLS http://www.unohrlls.org/UserFiles/File/Elle Wang Uploads/UN_LDC_Factsheet_061610.pdf
[651] UNFCCC (2005) *Sixth Compilation and Synthesis of Initial National Communications from Parties Not Included in Annex I to the Convention*, UNFCCC http://unfccc.int/resource/docs/2005/sbi/eng/18a02.pdf
[652] WRI (2010) *Climate Analysis Indicators Tool Version 7.0*, World Resources Institute, Washington, DC
[653] WRI, ibid.

- Community ICT: the use of ICTs within developing country communities in which, as yet, green and smart ICT applications play little role.

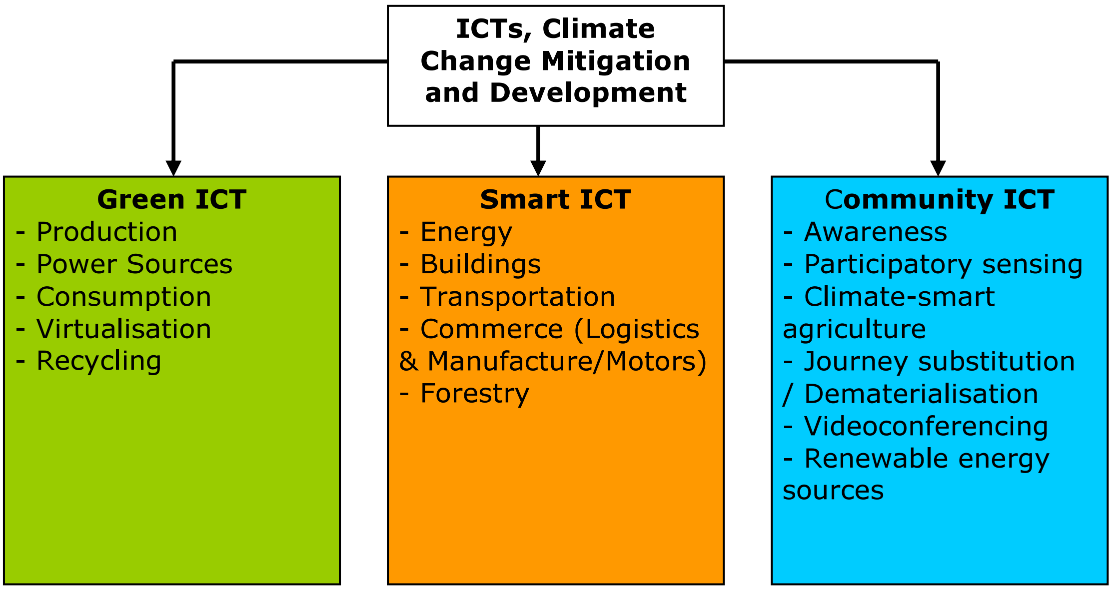

Figure 2: Mapping ICTs' Contribution to Climate Change Mitigation

1a. Green ICT

According to Gartner, the ICT industry "accounts for 2% of global CO_2 emissions".[654] This is expected to increase by 6% each year until 2020.[655] 40% of these emissions come from the operation of PCs and monitors, and 23% from data centres.[656] Emissions from data centres are rising particularly rapidly and the proliferation of mobile devices in developing countries is also making an increasing contribution.

To address this problem, nations, organisations and individuals need to adopt a green ICT strategy that seeks to minimise emissions from ICT production and consumption. Measures include[657]:

- Adoption of ICT components that are as energy-efficient as possible, including the incorporation of green criteria into ICT procurement.
- Innovation by ICT firms of new components that use even less energy.
- Transfer of data centres to cooler locations and/or close to greener energy sources such as hydropower, and more effective management of data centre energy design and use.
- Lifecycle analysis and planning of ICT production including the minimisation of e-waste and maximisation of component recycling.[658]
- Use of smart technologies within ICT production and logistics.
- Virtualisation: moving both server and desktop services to the cloud.

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[654] Gartner (2007) Gartner estimates ICT industry accounts for 2 percent of global CO_2 emissions, 26 Apr

[655] The Climate Group/GeSI (2008) *SMART 2020: Enabling the Low Carbon Economy in the Information Age*, The Climate Group, London http://www.smart2020.org/publications/

[656] IHS (2007) Gartner: data centres account for 23% of global ICT CO_2 emissions, 5 Nov

[657] Pratt, M.K. (2008) A green IT checklist, *Computerworld*, 8 Sept

[658] Magalini, F. & Kuehr, R. (2011) *Electronic Industry and E-Waste Recycling: An Underestimated Contribution to Climate Change Mitigation Strategies*, United Nations University, Tokyo

- Use of renewable energy sources to power ICT-related infrastructure, with a significant potential contribution relating to green, off-grid mobile base stations in developing countries.[659]

1b. Smart ICT

Although carbon emissions from ICT itself are growing, use of "smart" ICT applications in other sectors could far more than outstrip this growth:

> *ICTs could reduce global carbon emissions by 7.8 $GtCO_2e$ by 2020 (from an assumed total of 51.9 $GtCO_2e$ if we remain on a BAU trajectory), an amount five times larger than its own carbon footprint. Savings from avoided electricity and fuel consumption would reach €600 billion.* (The Climate Group/GESI 2008)[660]

ICT applications in various sectors are outlined below (see also Figure 3) but a cross-cutting point is that the majority of these will arise in urban areas. Cities generate up to 60 per cent of GHG emissions. Urban energy consumption per capita is estimated to be three times higher than that of rural areas, and this will be exacerbated as the world urbanises, with expectations that the urban population of developing countries will reach 50 percent by 2020.[661]

Areas of savings	Identified Opportunities	Carbon Savings	Cost Savings
Smart Grid	• Reduction in Transmission losses • Integration of renewable energy • Reduction in consumption	2 Gt CO_2e	$125 billion
Smart Building	• Intelligent Commissioning • Building management systems • Voltage optimization	1.52 Gt CO_2e	$442 billion
Smart Logistics	• Optimization of logistics network • Optimization of route planning • In-flight fuel efficiency	1.68 Gt CO_2e	$341 billion
Smart Motor Systems	• ICT smart motor system • ICT-driven automation of industrial processes	1 Gt CO_2e	$107 billion
Dematerialization	• Online-media, e-commerce, e-paper, • telecommuting	1 Gt CO_2e	N/A

* Figures extracted from the Smart 2020 report – The Climate Group - GeSI

Figure 3: Smart ICT Solutions and Impact[662]

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[659] Gross, I. (2012) *Mitigating ICT-Related Carbon Emissions: Using Renewable Energy to Power Base Stations in Africa's Mobile Telecommunications Sector*, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/NICCD_Mitigation_Case_Study_MobileBasestations.pdf

[660] BAU means "business as usual" and refers to emission levels that would occur if emissions grew at the same rate as has accompanied economic growth in the past and no actions to reduce emissions were taken. $GtCO_2e$ is giga-tonnes of carbon dioxide equivalent.

[661] UN Habitat (2010) *For a Better Urban Future*. UN Habitat, Nairobi

[662] Accenture (2009) *Mobile Telecommunications and Carbon. Future Low Carbon Product and Service Growth Opportunities*, paper presented at Infocomm Industry Forum 2009, Singapore, 1 Dec

Smart Energy

It is estimated that the world's primary energy needs will grow by about 45 percent from 2006 to 2030, and that this growth will largely occur in developing countries (about 87 percent) where carbon-intensive fossil fuels remain the dominant source of primary energy. Developing countries need to meet their growing energy needs in order to maintain robust socio-economic development,[663] but therefore also need urgently to find ways to decarbonise energy supply and use.[664]

ICTs have the potential to bring about this systematic change and realise carbon reduction opportunities through a number of applications:

- ***Energy generation***: This includes using smart grids that will allow the monitoring of power consumption and use over the electricity grid. The goal is to allow more efficient power distribution and power use by the grid itself, including the possibility of making greater use of renewable and non-GHG emitting sources of energy.
- ***Energy transmission and distribution***: These include remote measurement and monitoring of energy use, remote grid element management and energy accounting, which together would help utilities monitor energy use across the grid better and allow them to trace the source of energy losses.[665] Energy transmission and distribution monitoring is the most significant single carbon reduction opportunity and can significantly reduce the share of electricity losses; a key problem for developing countries.
- ***Efficient end-use technologies***: These technologies are expected to play a fundamental role in the transition to low-carbon societies[666] and include smart meters which can influence consumer energy-use patterns.
- ***Decentralised energy production***: This could allow renewable energy such as solar and micro-hydro sources to be integrated into the grid, reducing carbon-intensive generation. Decentralised energy sources use ICTs for both control and connection, and could also allow the grid to respond to local power surges and shortages, making it easier to manage.[667]

Smart Buildings

According to the International Energy Agency, direct emissions from buildings account for around 10 per cent of global CO_2 emissions, while indirect emissions from the use of electricity by systems and appliances within buildings increase this share to almost 30 per cent.[668] Yet demand for new buildings is high – in Asia, for example, 20,000 new housing units are needed every day, which creates large demand for construction materials (the sector uses 40% of all raw materials).[669]

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[663] IEA, ibid.
[664] See for example Ockwell, D., Ely, A., Mallett, A., Johnson, O., & Watson, J. (2009) *Low Carbon Development: The Role of Local Innovative Capabilities*, STEPS Working Paper 31, SPRU, University of Sussex, Brighton, UK
[665] The Climate Group/GeSI, ibid.
[666] Ockwell et al., ibid.
[667] The Climate Group/GeSI, ibid.
[668] IEA (2010) *Energy Technology Perspectives 2010,* IEA, Paris http://www.iea.org/techno/etp/etp10/English.pdf
[669] IBM (n.d.) *Smarter Buildings*. IBM http://www.ibm.com/smarterplanet/uk/en/green_buildings/ideas/index.html

Several ICT-based technologies have an important role to play in enhancing the efficient use of energy in buildings, with the green building technology market in India alone forecast to touch US$100bn in 2012.[670] Applications include:

- Building information modelling (BIM) to facilitate building design and to optimise energy and material use in a sustainable fashion throughout the life cycle of a new building or retrofit. BIM also streamlines the building process and facilitates sustainable building certifications such as Leadership in Energy and Environmental Design.
- Wireless sensor networks to connect and potentially control everything that consumes or affects the consumption of energy in the building and its envelope and to monitor environmental variables including the surrounding microclimate to allow the building to adapt its energy balance accordingly and instantaneously.
- Building management systems (BMS) to automatically manage and reduce energy consumption and control heating, ventilation and air conditioning systems, lighting systems, and the sensors and smart motors / variable rate motors that control and operate them.
- Integrated BMS systems extending over a larger area via the Internet and integrated with the smart grid via wide area situational awareness technology.

Smart Transportation

ICT-driven applications across transportation have the potential to achieve a reduction in total global emissions of 1.68 $GtCO_2e$.[671] Many industries already rely on software systems to optimise transportation systems to reap big energy savings.

Transport challenges faced by developing countries include increasing urbanisation (especially in the mega cities) and worsening congestion leading to adverse economic, health and safety impacts. An increasing number of cities are rethinking their transportation systems to better meet these challenges. This represents a huge potential for ICT-driven solutions including software to improve the design of transport networks with specific levers such as intermodal shift, eco-driving, route optimisation, inventory reduction, or moving to the most efficient type of transport.

New ICT-based technologies and services are also being developed in relation to areas such as systems integration (smart charging and vehicle-to-grid systems), vehicle navigation and driving assistance, fees and bill payment systems, vehicle fleets, and mobility services. Finally, ICTs are also core to the greater use of electric vehicles.

Smart Commerce

Although the globalisation of trade and manufacturing has brought significant economic benefits to a number of developing countries, it has also increased their carbon emissions. For example, during the mid-2000s, 50 per cent of the growth in China's emissions was attributable to the production and international trade of goods exported for consumption in other countries.[672]

Addressing this requires progress on two fronts.

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[670] Business Standard (2011) Green building space at 648 mn sft, 25 Apr http://www.business-standard.com/india/news/green-building-space-at-648-mn-sft/433361/
[671] The Climate Group/GeSI, ibid.
[672] Le Quéré, C., Raupach, M.R., Canadell, J. G., Marland, G. (2009) Trends in the sources and sinks of carbon dioxide, *Nature Geoscience*, 2, 831-836

First, in development of "smart logistics". Part of this relates to transportation: it is estimated that optimising logistics using ICT could result in a 16 percent reduction in transport emissions and a 27 percent reduction in storage emissions globally.[673]

ICTs can improve the efficiency of logistics operations in a number of ways by helping to monitor, optimise and manage operations. This in turn helps reduce the storage needed for inventory, fuel consumption, kilometres driven and frequency of vehicles travelling empty or partially loaded. Smart logistics solutions include software enabling improved design of transport networks, running of centralised distribution networks and of management systems facilitating flexible home delivery services.[674] Various machine-to-machine technologies can help improve operational efficiency including onboard telematics, loading monitoring devices, and tracking systems.[675]

Second, "smart manufacturing" solutions can be used to

- increase manufacturing process efficiency by automating communications between production sub-processes,
- support predictive maintenance by remotely monitoring machinery to improve maintenance planning and overall service management, and
- optimise order fulfilment by integrating order capture in production planning, output and dispatch, and increasing the intensity of batch production to reduce continuous production.[676]

Smart motors will also be an important part of the solution (since motors constitute up to 70% of industrial electricity consumption), including:

- Variable speed drives: VSDs control the frequency of electrical power supplied to the motor, thereby adjusting the rotation speed to the required output and are the most effective means of saving energy – up to 25-30 percent.
- Intelligent motor controllers: IMCs monitor the load condition of the motor and adjust the voltage input accordingly. They offer minor efficiency gains (3-5 percent), but have the benefit of extending the motor lifespan, which reduces the number of new motors required and therefore the associated manufacturing emissions.[677]

Smart Forestry

One third of total emissions of developing countries is caused by land-use change and forestry – primarily deforestation – with the largest contributors being Indonesia and Brazil (others include Malaysia, Myanmar and the Democratic Republic of Congo).[678] Reducing or preventing deforestation is "the mitigation option with the largest and most immediate carbon stock impact in the short term".[679] It is estimated that reducing deforestation by 50 percent over the next century would help prevent 500 billion tonnes of carbon from being released into the atmosphere per year.

The primary ICT application is data capture via remote sensing, typically via satellite, displayed on a geographic information system. These may be used in

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[673] The Climate Group/GeSI, ibid.
[674] Ibid.
[675] Accenture, ibid.
[676] Vodafone and Accenture (2009) *Carbon Connections: Quantifying Mobile's Role in Tackling Climate Change*, Vodafone, UK
[677] The Climate Group/GeSI, ibid.
[678] Baumert, A., Herzog, T., and Pershing, J. (2005) *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, World Resources Institute, Washington, DC
[679] IPCC, ibid.

combination with earth-based data sources e.g. wireless sensor networks to detect plant status, and "participatory sensing"[680] by local citizens or activists, for example using mobile devices.

These systems can be used by government regulators – for example to monitor and then intervene on illegal deforestation.[681] The systems can also be used by local NGOs, for example:
"– Satellite data to identify areas of forest loss where urgent reforestation or tree planting should be carried out.
– GIS and remote sensing to … delineate the extent of specific potential community-based tree planting project sites.
– Field measurements to estimate baseline biomass and carbon stocks for community tree planting project sites.
– Mapping and field based-monitoring using GIS to ensure high survival of the planted trees.
– Web-based mapping application for and analysis and reporting of project progress to management and project partners".[682]

1c. Community ICT

Most of the applications listed above lie outside the scope of use of community members within developing countries. Given their limited contribution to climate change – at least if we focus on poor rural communities – the impetus for action may seem limited.

However, there are many examples of ways in which community members can be users of ICT applications that may make some contribution to climate change mitigation:

- Awareness raising, using broadcast and narrowcast media to make individuals and groups aware of climate change issues and mitigation strategies.
- Local contributions to deforestation: the type of participatory sensing noted above, but also use of ICTs such as community radio to encourage replanting and more efficient use of wood burning for heating and cooking.[683] In many cases, these initiatives must be put in place alongside alternative sources of income and fuel for the community.
- Obtaining information and guidance on "climate-smart agriculture", which may include attempts to reduce methane and related emissions.[684]
- Journey substitution and other energy savings through use of dematerialised services such as e-government, e-commerce and e-health initiatives.
- Use of videoconferencing (including Skype) to substitute for journeys that require meetings with government or other officials.[685]

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[680] Shilton, K. et al et al. 2009. *Participatory Sensing.* Woodrow Wilson International Center for Scholars, Washington, DC http://www.wilsoncenter.org/sites/default/files/participatory_sensing.pdf
[681] Rajao, R. (2012) *ICT-Based Monitoring of Climate Change-Related Deforestation*, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/NICCD_Monitoring_Case_Study_AmazonDeforestation.pdf
[682] Ndunda, P. (2010) *The Green Belt Movement International*, paper presented at Map Middle East 2010, 23 Mar
[683] Jones, R. & Siemering, B. (2012) *Combining Local Radio and Mobile Phones to Promote Climate Stewardship*, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/NICCD_Mitigation_Case_Study_Cookstoves.pdf
[684] Saravanan, R. (2011) *e-Arik: Using ICTs to Facilitate "Climate-Smart Agriculture" among Tribal Farmers of North-East India*, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/NICCD_AgricAdapt_Case_Study_eArik.pdf
[685] Mahalik, D.K. (2012) *Reducing Carbon Emissions through Videoconferencing: An Indian Case Study*, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/NICCD_Mitigation_Case_Study_VideoConferencing.pdf

- Use of renewable energy sources such as solar chargers and panels to power ICT devices within the community.

2. Opportunities and Challenges in Developing Countries

As noted above, each individual developing country has a unique carbon emissions profile, and this will shape their particular "e-mitigation" priorities. However, there are some generalisations we can put forward.

Developing countries face an important opportunity as regards ICTs and mitigation: for technological "leapfrogging", whereby they can overleap emissions-intensive intermediate technology in favour of cleaner technologies.[686] Thus they would implement low-carbon strategies from the outset and avoid the legacy infrastructures and technology lock-ins that constrain available options in richer economies.[687]

Most of the mitigation applications outlined above also have a dual benefit for developing countries. Not only do they reduce carbon emissions – they also save money, typically energy costs – a significant attraction given the limitations on availability of capital.

However, such limitations are a reminder that the roll-out of green, smart and community ICT solutions faces a number of specific challenges in developing countries, which include:

- Lack of awareness of technological developments and their potential for more carbon- and energy-efficient solutions.[688] A challenge for many organisations and individuals is to take informed decisions on ICT adoption (or non-adoption), as they are not familiar with ICT options and the carbon-/cost-saving opportunities they offer.[689]
- Limited access to capital as the result, for example, of a conservative banking sector and scarce as well as highly sector-specific venture capital and private equity sources.[690]
- High or uncertain costs of new technologies and no proven commercial viability for large-scale investments, in particular for smart grids and smart cities.[691]
- Limited or uncertain suitability of technologies for local conditions: there is a challenge of ensuring technology compatibility across countries or even within single organisations (e.g. with smart grids and smart logistics). To ensure compatibility and accelerate technology adoption there is a need for technology and telecommunication providers and affected industries to collaborate and develop common operating standards.[692]

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686 Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., and Meyer, L.A. (eds) (2007) *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK

687 WWF (2008) *The Potential Global CO_2 Reductions from ICT Use*. WWF, Stockholm

688 ITU (2010) *Measuring the Information Society 2010*, International Telecommunication Union, Geneva

689 EC (2010) *ICT and e-Business for an Innovative and Sustainable Economy*, European Commission, Luxembourg

690 Carbon Trust (2008) *Low Carbon Technology Innovation and Diffusion Centres, Accelerating Low Carbon Growth in a Developing World*, London

691 Vodafone and Accenture, ibid.

692 Ibid.

- Limited resources, capacity or technical and managerial skills to identify suitable technologies, adapt them for specific local application, and conduct installation and maintenance services.[693]
- Unpropitious regulatory and political circumstances such as market distortions and subsidies in favour of fossil fuels[694] on the one hand and lack of policies and incentives to encourage investment in green, smart and community ICT solutions on the other.[695]

3. Strategic Action Steps

Action steps for **international organisations**[696]:

1. ***Extend existing technology transfer and finance schemes*** under the United Nations Framework Convention on Climate Change to include broader deployment of ICT in developing and emerging economies. Cap-and-trade and offset mechanisms that result in the transfer of ICT technology to developing countries need to be further promoted and new mechanisms may need to be added to drive inclusive low-carbon growth by utilising the opportunities ICT could bring if technology were widely available and effective implementation viable.

2. ***Identify e-mitigation applications from existing ICTs***: mitigation is strongly associated with ICT innovation – and much-beloved of ICT firms and ICT engineers as a result. However, a critical success factor in a number of e-mitigation projects has been the use of existing ICTs, which are already in use within developing countries. International organisations can usefully map out the e-mitigation application opportunities from such technologies.

Actions steps for **governments in developing countries** include:

1. Make a ***deliberate, holistic plan and long-term commitment*** to the localisation of low-carbon technology or a number of key technologies that provide solutions to major GHG-emitting sectors.

2. ***Raise awareness and build a knowledge base*** about the relevance of climate change mitigation to developing countries, and about the relevance of ICTs in delivering mitigation goals. At the same time, developing training initiatives to ***build capacity*** within government and other organisations for understanding and dealing with e-mitigation. Such capacity-building should include the capacity to conduct ICT-related assessments such as energy audits and e-environment readiness studies, which provide baseline carbon emissions and related data.

3. Design national-level and in particular sector-wide ***regulation, laws, policies, and subsidies***. This will incentivise investment, scale-up commercialisation, create domestic markets, and drive down the costs for implementing the widespread use of low-carbon technology. For example, regulation could require the integration of low-carbon energy-efficiency

[693] ITU, ibid. and Carbon Trust, ibid.
[694] Carbon Trust, ibid.
[695] ITU, ibid.
[696] Recommendations were derived from various studies, including UN (2010) *Energy for a Sustainable Future*, UN, New York; WRI (2010b) *Scaling-up Low-carbon Technology Deployment*, World Resources Institute, Washington, DC; and Vodafone and Accenture, ibid.

modules into high-value capital investments. There is also a need to promote enforcement mechanisms for intellectual property rights.

4. ***Establish research and development funding programmes*** to support the launch and scale-up of low-carbon technology innovation. This should include reinforcing multidisciplinary research and technical development and bring together academia, ICT providers and targeted sectors to promote interoperability and standardisation of services. It will encourage the deployment of large-scale pilot projects and allow the technical feasibility and anticipated capital expenditure requirements of technologies to be assessed.

5. ***Support and drive business innovation*** by making funding available as well as providing "soft" support e.g. by creating additional linkages between businesses, research institutions and civil society; and by building up the existing ICT infrastructure. The strategic use of challenges and awards may be another effective approach to incentivising and nurturing innovation and creative solutions. With the majority of economic activity in developing economies generated in small and medium-sized enterprises (SMEs), such supportive mechanisms will be essential to enable business innovation otherwise hampered by lack of investment capital.

6. ***Expand local lending capabilities and access*** through local commercial banks and micro-finance institutions to scale up investments. The existing systems could be adapted to the emerging challenges, e.g. by adding special incentives for off-grid areas or the deployment of particular smart solutions, and making access to funding mechanisms more conducive to the needs of SMEs in these countries.

7. ***Incorporate a sector-based approach*** which focuses on key carbon-emitting sectors of the economy, and identifies what green, smart and community ICT applications have to offer for that sector, and what specific measures are required to spur innovation and adoption.

8. ***Develop multi-stakeholder partnerships*** that integrate across sectors – public, private and civil society – and that integrate across levels – local, national, global – in order to maximise the access to resources, the sharing of knowledge, and the potential for scalability and sustainability of initiatives.

Actions steps for **private firms** based in or trading with developing countries include:

1. Make all efforts necessary to ***reduce the carbon footprint of the ICT sector*** and its products and help understand lifecycle impacts of ICTs in a developing country context.

2. ***Establish best practice projects*** to benchmark and showcase the potential of smart ICT solutions to climate change mitigation in developing countries.

3. ***Invest in R&D*** for improved technology and applications suitable for poorer country contexts and their specific challenges.

4. ***Establish ambitious GHG emission reduction targets and extend these through the value chain***: take responsibility to support small and medium-sized suppliers in developing countries to meet those targets. This can happen, amongst others, by investments to support the implementation of low-carbon technologies and ICT-enabled efficiency-enhancing processes – a

strategy that also has the potential to significantly contribute to technology transfer.

5. Take a leading role in ***developing and disseminating low-cost low-carbon products and services*** in developing and emerging countries, e.g. by engaging in joint ventures with small and medium-sized enterprises in those countries and thereby contributing to the dissemination of technical know-how and building local innovation capacity to avoid the perpetuation of import dependency.

6. ***Engage in policy advocacy*** at international and national levels to promote the regulatory and policy reforms needed for better investment opportunities and the removal of market barriers, and to encourage greater incorporation of ICTs within international climate change technology transfer schemes.

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Chapter 13: ICTs and Climate Change Adaptation – Enabling Innovative Strategies

ANGELICA VALERIA OSPINA & RICHARD HEEKS

As the impacts of climate change intensify, developing countries must implement innovative strategies to adapt to changing climatic conditions and uncertainty. Information and communication technologies (ICTs) can play a key role in strengthening adaptive capacity. This Brief identifies ICTs' contribution to national adaptation strategies (e.g. NAPAs) and to specific sectoral adaptations in developing countries.

It argues that ICTs provide generic support to the process of information-gathering, decision-making, implementation and evaluation for national-level adaptation. Specific ICT applications enable delivery of particular adaptational actions for the vulnerabilities that climate change affects including poverty, water, agriculture and food security, human health, terrestrial and marine ecosystems, and disaster management among others.

The Brief concludes by identifying guiding principles for use of ICTs in adaptation processes, suggesting that their role goes well beyond the use of climate-specific applications. The informational, productive and transformational potential of ICT tools must be harnessed and designed with a holistic, integrated view of adaptation; one that looks at the complete 'info-system' of mobile phones, Internet applications, telecentres and mass media to foster adaptation at the national, sectoral and community levels.

Adaptation within Vulnerable Contexts

Faced with the unprecedented challenges posed by climate change, developing countries are starting to address the need to adjust and adapt to new, and often uncertain climatic conditions.

Climate change adaptation is a process by which "strategies to moderate, cope with and take advantage of the consequences of climate events are developed and implemented"[697]. Within complex developing environments, these processes cannot be understood or addressed in isolation from other development stressors. Climate change and other shocks such as economic crises and conflict are mediated through a set of vulnerabilities – financial, social, political, etc – that communities face; vulnerabilities that in turn create constraints to adaptive capacity[698].

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[697] UNDP (2004) *Adaptation Policy Frameworks (APF) for Climate Change: Developing Strategies, Policies and Measures*, Cambridge University Press http://www.undp.org/climatechange/adapt/apf.html#about
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Knowledge and information play a key role in overcoming such constraints, and are pivotal for building and strengthening the capacity of multiple stakeholders involved in adaptation strategies at the micro, meso and macro levels. Information and communication technologies (ICTs) - the Internet-based applications, mobile phones, telecentres, community radio, etc that are increasingly available in developing regions – provide an exceptional opportunity to improve the creation, management, exchange and application of relevant climate change information and knowledge. They should also be recognised for their productive and transformative capabilities.

1. ICTs & Climate Change Adaptation Strategies

Climate change adaptation can be planned or emergent. While the latter refers to spontaneous actions taken by actors affected by climatic stimuli or events, planned or policy-driven adaptation processes involve the formulation of strategies that consist of a general plan of action, including policies and measures, for addressing climate change impacts within a given context[699]. The reach of adaptation can be national, sectoral or local, and its formulation is context-specific (e.g. dependent on climatic risks and vulnerabilities, adaptive capacities, policy context and stakeholders' support).

Thus, the role of ICTs in climate change adaptation can be explored at three main levels: national, sectoral and local/community level, as reflected in Figure 1.

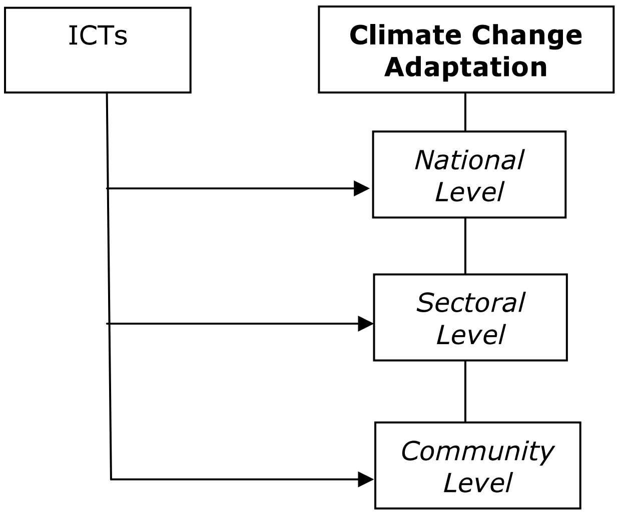

Figure 1. Relation Between ICTs and Climate Change Adaptation

This Brief focuses on the linkages between ICTs and adaptation at two levels: (a) national adaptation plans, based on the different stages involved in their formulation, and (b) sectoral strategies, based on the key areas affected by climate change (poverty, water, agriculture and food security, health, disasters, etc)[700].

(a) ICTs & National Adaptation Plans (NAPAs)

The formulation of national adaptation plans or strategies – often known as, or formulated from, National Adaptation Programmes of Action (NAPAs) – involves different activities aimed at producing an effective policy framework to reduce the

[699] UNDP, op.cit.
[700] The linkages between ICTs and community-based adaptation will be explored in a separate NICCD Strategy Brief.

country's vulnerability to current and future climatic threats. Based on the model developed by UNDP[701], those activities can be categorised into three main stages:

1. Gathering of information and synthesising available knowledge about the current and future state of climate change and adaptation requirements.
2. Design of the adaptation strategy, including making decisions about what adaptation measures to undertake.
3. Implementation of the adaptation strategy, including evaluation of the impact of that strategy.

From this perspective, ICTs can contribute to the formulation of NAPAs/national plans in five main domains, as reflected in Figure 2.

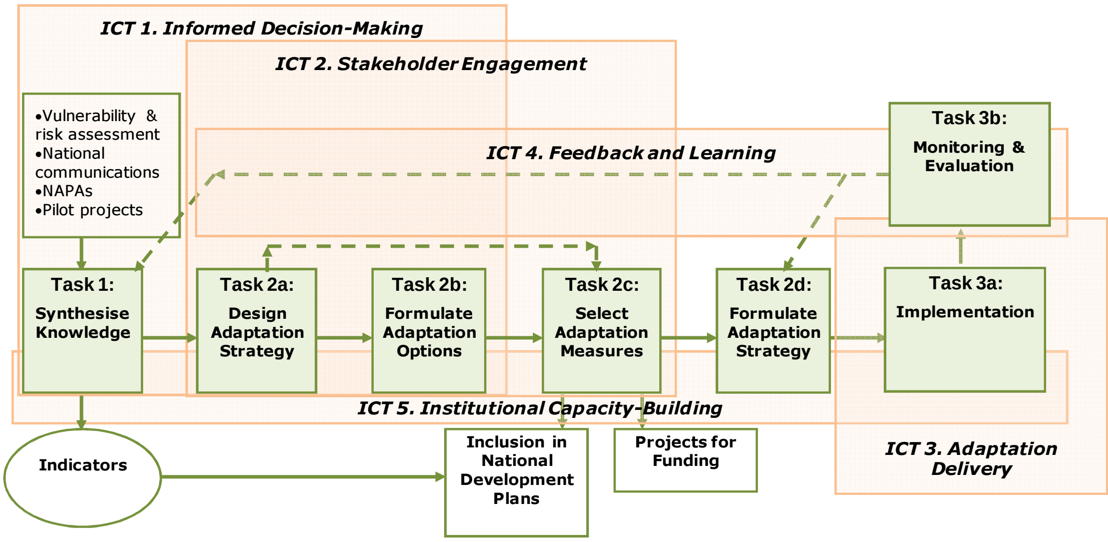

Figure 2. ICTs and Formulation of an Adaptation Strategy (adapted from UNDP 2004)

1. *Informed Decision Making*

Within complex developing contexts, the creation of adaptation plans is an information-intensive activity. Knowledge and information inputs from diverse sources can help to inform decision-making processes by identifying the specific needs and priorities at the local and national level, as well as the vulnerabilities, resources and capacities available in support of adaptation processes. ICT applications such as geographic information systems (GIS) and meteorological information systems can help to understand both the current extent of climate change, but also to model future impact on not just weather but also agricultural productivity, health and disease, disaster incidence, etc. Simpler ICT tools like email and web-enabled databases can draw in a wide range of information and knowledge perspectives (presented in appropriate languages and user-friendly formats). ICTs can also support planning and decision-making processes by helping to localise adaptive actions and to strengthen the capacity of local actors to analyse climate models and predictions.

2. *Stakeholder Engagement*

The formulation of adaptation plans requires a partnership between public, private and civil sectors. ICTs can facilitate the inclusion of multiple voices in the design of adaptation strategies at various levels, from simple broadcast

[701] Ibid.

and awareness-raising of issues to be decided; to fuller engagement through the use of social media and online polling of those likely to be affected; to the use of group decision-support systems to model and analyse different scenarios, and enable decisions to be made. GIS applications, earth browsers, and Web-based clearinghouse sites are offering possibilities for citizen monitoring and accountability, strengthening the public's support and engagement in the implementation of adaptation strategies. Likewise, Web 2.0 tools (e.g. social networking sites, Wikis and blogs), smart phones (mobile phones with Internet capabilities, allowing text and audio-visual data sharing) and online discussion fora (such as the Adaptation Learning Mechanism, ALM)[702], are fostering new forms of engagement and participation in climate change adaptation and crisis response. Thus ICTs are helping foster dialogue and exchange for participative planning through applications for remote collaboration, online networks and forums that help to converge and mobilise stakeholders' interests towards common adaptational goals.

3. Adaptation Delivery

Rarely does climate change directly affects countries or communities. Instead, as shown in Figure 3, it is one of a number of shocks that are mediated by – and exacerbate – existing vulnerabilities. Adaptational priorities vary depending on particular national vulnerabilities, and ICTs' role in delivery of those priorities generally relates to specific vulnerability sectors or issues. These are discussed in greater detail in the next section and in Figure 4.

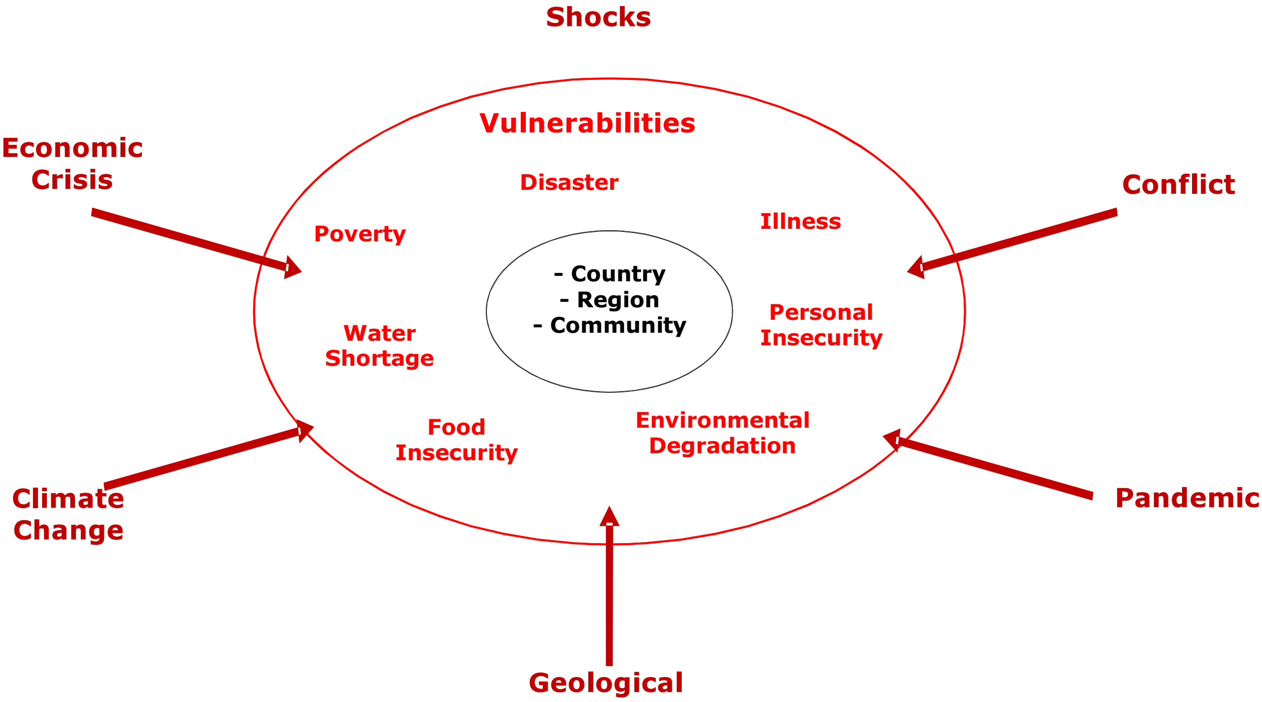

Figure 3. Relation Between Climate Change, Other Shocks and Vulnerabilities

4. Feedback & Learning

The development of an adaptation strategy/plan is not an end in itself, but the start of a process of continuous learning. The generation of feedback, the creation of new knowledge and the dissemination of existing and emerging

[702] http://www.adaptationlearning.net

experiences are key components of successful adaptation strategies. At present, adaptation strategies have too often been implemented according to a linear rather than a cyclical model. ICTs can help bridge the missing link by providing feedback on the impact of adaptive actions through geographical and sectoral information systems.

ICT tools such as Web 2.0 and online media can play a key role documenting traditional practices, and convening emerging sources of expertise in joint efforts towards the creation of climate adaptation tools. The use of ICTs for environmental observation, monitoring and networking enables users to assimilate, translate, use and share information in novel ways, enhancing the learning cycle[703]. e-Governance systems can provide transparency and accountability of the resources being invested in adaptation. And through online communities of practice, ICTs can provide the means for learning and continuous improvement in strategic planning and implementation. Thus, emerging digital knowledge and learning can help to strengthen adaptation plans by providing iterative flexibility, facilitating continuous adjustment of adaptational actions.

5. Institutional Capacity-Building

Effective formulation and implementation of plans requires institutions that can enable the flow of assets, skills and values necessary for undertaking adaptive actions, including the provision of access and connectivity in marginalised areas. The four areas for ICT application described thus far strengthen the institutions involved in adaptation strategies, and can foster a broader capacity-building process aimed at providing a digital institutional infrastructure that can readily develop, share and utilise a whole range of digital data.

Examples that illustrate how ICTs contribute to institutional strengthening include the facilitation of multi-level networking and coordination of intra/inter-institutional actions, as well as efficiency and transparency in the assignation of adaptation resources. The use of climate models and GIS applications for visualisation, mapping and modelling of climatic risks and vulnerabilities can contribute to informed decisions in planning and policy design, as well as to build synergies between adaptation and other development and environmental strategies implemented in the country. Information systems have a key role to play in the effectiveness of policy measures such as tax administration or incentive structures designed to encourage environmental practice, or mitigate climatic impacts among vulnerable populations[704]. At the same time, the use of ICTs for e-learning can support capacity building and skills-update programmes on climate change issues, particularly among institutional actors/employees located in remote areas.

The availability, access to and dissemination of relevant climatic information and knowledge constitute the basis upon which subsequent stages of strategising (i.e. planning, design, implementation, monitoring and evaluation) can be tailored to the specific adaptive needs and priorities of developing contexts. At the same time, a flux of relevant information and knowledge among all stakeholders throughout the adaptation process is pivotal to ensure continuous learning, feedback and flexibility of plans in face of future climatic uncertainty.

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[703] Ospina, A. V. & Heeks, R. (2010) *Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study*. Centre for Development Informatics, University of Manchester http://www.niccd.org/ScopingStudy.pdf

[704] Ibid.

(b) Sectoral Adaptation

The role of ICTs in delivery of adaptation actions can also be analysed from a sectoral perspective, by linking their potential to the specific needs and priorities of key sectors affected by climate change, as overviewed in Figure 3 and as specifically detailed in Figure 4.

VULNERABLE SECTORS	Examples of Adaptation Measures	Sample Areas of ICT Potential
POVERTY	• Increasing income	• ICTs can be used to get money; most obviously through e-enabled or m-enabled remittance systems. • ICTs can be used to better manage money; for example through m-finance and m-banking applications, and also (overlapping with the category above) through ICT-enabled microfinance. • ICTs can be used to make money through the formation of ICT-enabled microenterprise, including ICT-based retailing (e.g. sales of mobiles, accessories and calls), creation of digital content (e.g. music, photographs), digital services (e.g. cyberkiosks, telecentres), and digital production (e.g. data entry, digitisation).
WATER RESOURCES	• Better management and use of water supply • Development of flood controls and drought monitoring • Water policy reform	• ICT applications such as GIS and remote monitoring can support the improvement of water resource management techniques, and the monitoring of water resources. Software and ICT-based models can contribute to water security by helping to manage and document scarce water resources (e.g. melting glaciers, salinisation and pollution of fresh water sources), and water distribution. • ICTs such as mobile phones can be used in participatory monitoring systems, enabling users to provide near-real time data during the occurrence of floods or droughts. • ICT tools can also help to monitor water supply levels and the degradation of water quality due to increased temperatures and pollutants, providing updated data that can inform policy processes - including those related to pricing and irrigation.
AGRICULTURE & FOOD SECURITY	• Development of tolerant/resistant crops • Diversifications of crops • Supply chain strengthening • Policy measures	• ICTs can be used to access information and knowledge to strengthen local agriculture and livestock production systems. Applications such as mobile phones and community radios can be used to disseminate information in appropriate, simple formats on new seeds and crops variety, livestock breeds, irrigation applications, reminders about planting dates, pest and disease control, livestock vaccinations, alternative fertilizers, among others. • The use of ICTs such as mobile phones can also help to improve market access (through information on prices and consumer trends) and support capacity building opportunities for local farmers via better links to suppliers. • GIS and related applications provide essential data for monitoring short- and long-terms agricultural trends that inform policy formulation and implementation.

VULNERABLE SECTORS	Examples of Adaptation Measures	Sample Areas of ICT Potential
HUMAN HEALTH & HABITAT	• New or improved disease/vector surveillance and monitoring. • Changes in urban settlements and housing design	• ICTs such as community radio can help to raise public awareness on methods to prevent or mitigate the spread of some vector-borne (i.e. malaria and dengue) and water-borne diseases. Web and mobile applications can draw data from, and provide guidance to, healthcare professionals. • ICT applications can be used in urban planning (i.e. GIS), and in monitoring and provision of relevant environmental information to support decision-making processes contributing to the adaptation of human habitats and infrastructure. • ICTs are central to monitoring the displacement and settlement of populations due to sea-level rise, drought, desertification, etc.
TERRESTRIAL ECOSYSTEMS	• Creation of parks/reserves and protected areas • Better assessment of the vulnerability of ecosystems • Monitoring of species/biodiversity	• GIS and remote sensing applications can provide valuable information to manage and monitor parks/reserves and protected areas, contributing to the conservation of ecosystems. • ICT applications are used in climate models and predictions to inform decision-making processes and raise awareness on the impacts of climate change in local and national biodiversity. ICTs can provide illustrations, satellite images and photographs related to human and climate change impacts on the environment.
COASTAL ZONES & MARINE ECOSYSTEMS	• Better coastal planning and zoning • Development of legislation for coastal protection • Research and monitoring of coastal ecosystems	• ICTs can be used for mapping, visualisation and generation of real-time data to monitor short and long-term trends affecting coastal ecosystems. GIS and remote sensing applications can support coastal planning and zoning, by providing updated and locally relevant information for decision makers. • Mobile technologies (e.g. smart phones and PDAs) are used to facilitate the collection, retrieval and analysis of data, as well as its dissemination of information in near-real time in order to mobilise diverse stakeholders towards local conservation actions.
DISASTER MANAGEMENT	• Early warning • Disaster response • Reconstruction	• ICTs such as mobile phones and local radio are central to broadcast of disaster early warnings. • ICTs enable rapid data gathering during emergency response, prioritised decision-making, and facilitate logistics. • Decision-support and geoinformatic systems underpin the planning of post-disaster reconstruction; ICTs can also help to mobilise and monitor reconstruction efforts.

Figure 4. ICTs' Contribution to Sectoral Adaptation Measures & areas of ICT potential (adapted from UNFCCC 2007)

2. Moving Forward: Principles and Practice

ICTs can play a foundational role in enabling innovative climate change adaptation strategies at both the national and the sectoral level. The following good practice principles and action steps highlight how this potential can be realised:

(a) Guiding Principles for ICTs and Climate Change Adaptation

- ***Integrate Don't Isolate***

  Climate change is one of many shocks that will ripple through to developing countries via multiple vulnerabilities. Thus nations, regions and communities need to adapt to all of the challenges of the 21st century, not just to climate change. ICTs should not be understood narrowly in terms of climate change adaptation, but broadly in terms of adaptation overall. Instead of building unique, stand-alone ICT applications for climate change adaptation, it is necessary to adopt an integrated approach. Priorities are to integrate climate change issues into current and future ICT initiatives; and simultaneously to integrate both climate change and ICTs into current and future development initiatives.

- ***Empower Emergent, Grassroots Adaptation***

  Pre-planned NAPAs and other high-level strategies have an important role to play. But local, flexible, emergent adaptation will also be required because of the unpredictability and disruptiveness of climate change. ICTs must not just support NAPAs, but must also help to create and extend local resilience and adaptive capacity so that the latter type of adaptation can also flourish.

- ***Bottom-up … and Top-Down***

  Local and national actions should not be seen in isolation from one another. Building adaptation capacity and fostering participation at the grassroots level with the help of ICT tools needs to be combined and complemented with top-down political buy-in. That high-level political support includes action on general ICT policy, extending connectivity to all areas but also ensuring the full range of 'information chain' resources that enable data to be converted into developmental action[705]. In addition, adaptation strategies need to be informed not only by emerging scientific knowledge that is relevant to the local context, but also by traditional knowledge, acknowledging the empirical and indigenous resources that exist locally. ICTs can be used to help bring these two knowledges together; integrating them for more effective adaptation.

- ***Embrace the Current Informatics Ecosystem***

  Thinking about ICTs' role within adaptation strategies is not about specific applications, but about informatics – the ecosystem of data, information, knowledge, technology, and social processes that can support adaptation. To focus on informatics, adaptational strategies must encompass the

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705 Heeks, R. & Kanashiro, L.L. (2009) *Remoteness, Exclusion and Telecentres in Mountain Regions: Analysing ICT-Based "Information Chains" in Pazos, Peru*, IDPM Development Informatics Working Paper no.38, University of Manchester, UK
http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/

informational and social context within which the technology operates. An ecosystem approach will also recognise the 'stovepiping' that separates technologies of reach (mobiles, radio) from technologies of power (Internet, computers). It will seek applications that combine reach and power by working with an integrated 'info-system' of mobiles, telecentres, mass media, etc[706].

- ***Recognise ICTs' Productive and Transformative Roles***

  Current adaptation efforts have a narrow and outdated worldview that sees ICTs as data-handling tools. This perspective does not reflect the rapidly evolving user roles and capabilities that digital technologies allow for. Well beyond their informational capacity, ICTs have demonstrated productive and transformation potential through their support to social and market transactions, the productive creation of content and livelihoods, and the "Development 2.0" model that is transforming existing structures and processes[707]. In particular, both applications and implementations are lagging in ICT-enabled income generation, despite money being the single most important component of adaptive capacity. There has to be a new mindset. And further collaboration is needed between the private sector and social enterprise to innovate; to roll out new hardware, software, and systems that can shift outdated ICT paradigms in regards to climate change; and to fulfil ICTs' adaptational potential.

(b) Action Steps

These principles can be enacted through concrete, action-oriented measures:

- ***Identify the role of ICTs*** in both emergent and planned adaptation in the country, including the main information needs and gaps.

- ***Identify priority areas and windows of opportunity*** where the role of ICTs could be strengthened or integrated in support of adaptation.

- ***Form partnerships and coordinate actions*** with climate change adaptation stakeholders at different scales (micro, meso and macro), and from different sectors.

- ***Engage key high-level players*** working at the Ministerial level in climate change adaptation, disaster management, development planning and ICTs.

- ***Raise awareness*** and provide discussion forums (both face-to-face and online) on the potential of ICTs in adaptation, at both national and grassroots levels.

- ***Design, implement and document*** ICT pilot demonstration projects as part of ongoing adaptation initiatives or strategies, in order to engage multi-sectoral stakeholders and draw lessons for larger scale implementation.

[706] Prasad and Heeks (2011), op.cit.
[707] Heeks, R. (2010) *Development 2.0: Transformative ICT-Enabled Development Models and Impacts*, Development Informatics Short Paper no.11, Centre for Development Informatics, University of Manchester
http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/#sp

The potential of ICTs within processes of climate change adaptation is multi-dimensional and transversal, and it can also be transformative. Efforts to integrate these tools within innovative adaptation strategies should look beyond the provision of information, and include their role in the development of local capacities, the empowerment of local actors, and the strengthening of institutions through enhanced collaboration, networking, self-organisation and informed decision-making, ultimately building the resilience of vulnerable contexts.

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Chapter 14: ICT-Enabled Responses to Climate Change in Rural Agricultural Communities

ANGELICA VALERIA OSPINA & RICHARD HEEKS

Rural agricultural communities play a pivotal role in the economic, social, and cultural fabric of developing countries. At the same time, they are placed at the forefront of multiple development stressors that include increasing climate change impacts. Within contexts often characterised by poverty, remoteness and marginalisation, information and communication technologies (ICTs) can enable new responses to the challenges posed by more frequent and intense climatic events.

This Strategy Brief identifies the role of ICTs within the climate change responses of rural agricultural communities in developing countries. It argues that ICTs can become strategic enablers of action to create awareness about, mitigate, monitor and adapt to climate change within these communities. Despite their differences, rural agricultural contexts share similar attributes and challenges (geographical, economic and social) that are exacerbated by climate change impacts, and that require the adoption of innovative strategies based on emerging and traditional knowledge and information tools.

The analysis identifies different types of ICT interventions, key enablers and constraints to the use of these tools within rural agricultural settings impacted by climate change. It suggests the importance of adopting an 'Information-plus' approach that targets the improvement of local livelihoods through a variety of content and tools, while tackling climatic impacts as part of a broader set of development vulnerabilities.

1. Climate Change in Rural Agricultural Communities

Rural agricultural communities (RAC) are placed at the forefront of climate change impacts, and are the most prone to suffer from its effects. The unpredictability of weather patterns and the increased frequency and intensity of severe events such as floods and cyclones, are posing unprecedented challenges on vulnerable sectors such as agriculture (crop and livestock production, fisheries and forestry), affecting the livelihood of nearly half of the economically active population in developing countries[708].

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[708] Nelson, G. C., Rosegrant, M., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M. & Lee, D. (2009) *Climate Change: Impact on Agriculture and Cost of Adaptation*. International Food Policy Research Institute (IFPRI), Washington, DC. http://www.ifpri.org/sites/default/files/publications/pr21.pdf
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What makes rural agricultural communities a priority in the design of innovative climate change responses?

The agricultural sector remains at the core of developing countries' economies, playing a critical role in food security (at the local, national and international levels) and in the sustainability of millions of livelihoods of small producers and rural inhabitants. Rural agricultural communities are closely linked to the conservation of natural habitats and vulnerable ecosystems, and to the cultural identity of developing nations.

In spite of their developmental significance, these communities are also characterised by systemic poverty and marginalisation, which aggravate – and are aggravated by – the effects of climatic variations, seasonal changes and constant uncertainty caused by climate change.

Increasing climatic manifestations on critical water resources, fragile ecosystems and crop yields are fostering the proliferation of new pests and diseases, and the decline in production and income levels in rural regions of Africa, Asia and Latin America[709]. According to FAO (2011)[710], "while farmers in some regions may benefit temporarily from the effects of CO_2 fertilization, longer growing seasons and higher yields, the general consequences of climate change are expected to be adverse, particularly for the poor and marginalized", who, in turn, constitute the main inhabitants of rural agricultural communities.

Located in areas of high environmental risk and climatic exposure, the subsistence of these communities is largely resource-based, and thus, dependent on the sustainability of vulnerable agricultural livelihoods. More intense and uncertain weather patterns and extreme events such as floods and droughts contribute to deforestation, desertification, land degradation, depletion of water sources, infrastructural and social damage, among others[711], eroding not only local incomes but ultimately the ability of rural agricultural communities to respond to the challenges posed by a changing climate.

In spite of the differences that exist between these communities (both among and within countries) they share similar attributes and challenges related to the prevalence of poverty, remoteness and marginalisation[712]. These include low levels of education and access to health, weak infrastructure and difficult transportation, as well as exclusion from political decision-making processes, among others. The lack of livelihoods assets (e.g. economic, human, informational) heightens their vulnerability to climatic impacts, and also undermines their capacity to respond to the challenges and to benefit from potential opportunities derived from climate change.

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[709] According to the IPCC, approximately 20–30 percent of plant and animal species will be at increased risk of extinction if the global average temperature increases more than 1.5–2.5°C. IPCC. (2007) *Fourth Assessment Report (AR4)*: Intergovernmental Panel on Climate Change (IPCC). http://www.ipcc.ch

[710] FAO. (2011) *FAO-Adapt: Framework Programme on Climate Change Adaptation*. Food and Agriculture Organization of the United Nations, Rome http://www.fao.org/docrep/014/i2316e/i2316e00.pdf

[711] Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, P.J.v.d. & Hanson, C.E. (eds.) (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge University Press, Cambridge, UK.

[712] The marginalisation of rural agricultural communities takes place in several fronts. Geographic marginalisation is linked to their remoteness and establishment in often hazardous locations, economic marginalisation is linked to low-income levels and high dependence on agriculture, social marginalisation to the lack of social protection and deficient access to health services, and political marginalisation to exclusion from political processes and low representation in government structures, among others. Gaillard, J.C. (2010) 'Vulnerability, Capacity and Resilience: Perspectives for Climate and Development Policy', *Journal of International Development,* 22:218-232.

In addition to the multiple exogenous and endogenous stressors within which they operate, rural agricultural communities face the need for action in four key climate change related areas: awareness, mitigation, monitoring and adaptation.

Climate Change Awareness in RAC
• Climate change awareness plays a critical role within decision-making processes and is the basis to mobilise action within and for rural agricultural communities. The lack of appropriate climate change information (i.e. information that is reliable, context-specific, targeted to local audiences, delivered in non-technical language and in user-friendly format) has been identified as one of the most serious constraints to the capacity of rural agricultural communities to undertake effective responses in face of the challenges – and the opportunities – posed by climate change[713].
In Practice…
Within rural agricultural communities of Uganda, where climate change has affected productivity and food security, drama, songs and radio broadcasts are being used to raise awareness about the causes and effects of climate change, particularly among women (who constitute 80% of the agricultural workforce)[714]. Heightened awareness motivates community discussions on potential responses and willingness to engage in action.
Climate Change Mitigation in RAC
• Within rural agricultural communities, mitigation challenges have been linked for the most part to strategies for the maintenance and enhancement of natural carbon stocks, the sustainable management of forest resources, and the adoption of sustainable practices in agricultural production[715]. Agricultural and livestock-based livelihoods can play an important role in the regulation of carbon emissions and flows, as well as in the protection of forests to enhance biodiversity, in water regulation and soil conservation, among other ecosystem services, which in turn impact the livelihoods and quality of life of local populations.
In Practice…
Rural agricultural communities are starting to adopt 'climate-smart' agricultural practices (e.g. integrated soil nutrient management, crop diversity and alternative energy sources) and organic agriculture (e.g. agricultural management practices can enhance soil carbon sequestration)[716]. In Kenya, smallholder dairy producers are testing alternatives for reducing the climate change 'footprint' of the dairy industry with the goal of raising 'carbon-neutral' cattle. In Tanzania, methods are being developed to measure carbon accumulation resulting from climate-smart practices, while in Ecuador farmers are substituting intensive monoculture cultivation of maize, sugar cane and rice, a major contributor to deforestation[717].

[713] Rezaul Haq, A. H., Bakuluzzaman, M., Dash, M., Uzzaman, R. & Nandi, R. (2011) *An ICT-Based Community Plant Clinic for Climate-Resilient Agricultural Practices in Bangladesh*. ICTs and Agricultural Adaptation to Climate Change Case Study, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/casestudies.htm
[714] http://www.adaptationlearning.net/project/climatic-change-awareness-creation-and-adaptation-improved-livelihoods-among-rural-communiti
[715] Bertzky, M., Ravilious, C., Araujo Navas, A. L., Kapos, V., Carrion, D., Chiu, M. & Dickson, B. (2010) *Carbon, Diversity and Ecosystem Services: Exploring Co-Benefits. Ecuador*. UNEP-WCMC, Cambridge, UK http://www.unep-wcmc.org/carbon-biodiversity-ecosystem-services-ecuador_571.html
[716] Muller, A. (2009) *Benefits of Organic Agriculture as a Climate Change and Mitigation Strategy for Developing countries*. Environment for Development, Discussion Paper Series http://www.ifr.ac.uk/waste/reports/benefitsoforganicagriculture.pdf
[717] http://www.fao.org/climatechange/micca/70795/en/

Climate Change Monitoring in RAC
• The ability to monitor and track the impacts of climate change in the local environment constitutes a key enabler of action, and when based on participatory methodologies, it can act as a source of empowerment for rural communities facing unprecedented change and uncertainty. Monitoring gathers up-to-date data on climatic trends relevant at the local level, contributing to the decision-making process of policy makers and community-based stakeholders.
In Practice…
Local communities can participate by monitoring the climate – temperature, rainfall, water flows and levels. Monitoring is also enabling rural agricultural communities to track species and the amount of vegetation to assess the impacts of climate change within the local ecosystem. By reporting changes in growing patterns and the emergence of diseases in their crops, farmers can help create awareness and adopt measures to protect their livelihood. Participatory monitoring methods are helping to generate natural resource management interventions in Philippine forests, while helping to strengthen adaptive capacities amongst Tanzania's rural communities[718].
Climate Change Adaptation in RAC
• Adaptation – the implementation of strategies to moderate, cope with and take advantage of the consequences of climatic events – constitutes a priority within rural agricultural settings[719]. Within these communities, climate change adaptation involves measures to withstand and recover in face of short-term climatic stimuli and events like storms and landslides, but also measures to adapt to the long-term impacts of change and uncertainty upon vulnerable livelihoods. Experiences from the field indicate that within agricultural contexts, adaptation is closely linked to the impacts of climate change on food productivity and food security, and thus to the maintenance of local livelihoods as a fundamental base for the adoption of anticipatory or reactive adaptation measures. Traditional knowledge plays a key role in the adaptive capacity of rural agricultural communities, as local and indigenous practices have enabled them to cope with change over centuries.
In Practice…
Faced with increased temperatures and the recurrence of extreme weather events, communities located in the Colombian Andes are developing 'Adaptation Life Plans': social-participatory initiatives that document local vulnerabilities and lessons learned, and reach social agreements on adaptive practices[720]. Farming systems have adopted more sustainable practices, including water management to improve conservation and restore ecosystem services in high mountain regions. In Zambia, crop diversification and conservation farming to improve the quality of the soil and minimise erosion has been central to efforts to adapt to changes in rainfall patterns, while in Mozambique rural communities have relied on strong social networks to adjust to severe drought and storms[721].

While the implementation of climate change awareness, mitigation, monitoring and adaptation is taking place, to varying degrees, within developing contexts,

[718] http://www.asp.ucar.edu/ecsa/wcrp_docs/Shaffer.pdf

[719] UNDP (2004) *Adaptation Policy Frameworks (APF) for Climate Change: Developing Strategies, Policies and Measures*, Cambridge University Press, Cambridge, UK http://www.undp.org/climatechange/adapt/apf.html#about

[720] IUCN. (2010) *Building Resilience to Climate Change: Ecosystem-based Adaptation and Lessons from the Field*. International Union doe Conservation of Nature (IUCN), http://data.iucn.org/dbtw-wpd/edocs/2010-050.pdf

[721] Mitchell, T. & Tanner, T. (2006) *Adapting to Climate Change: Challenges and Opportunities for the Development Community*. Institute of Development Studies (IDS) and Tearfund http://www.preventionweb.net/files/567_10352.pdf

their implementation within rural agricultural communities still faces crucial challenges.

Awareness is constrained by issues such as geographical remoteness, difficult transportation and social marginalisation, low literacy levels, and lack of relevant and appropriate information that reaches local audiences. Mitigation actions face challenges related to the lack of adequate skills and technologies to record and analyse carbon emissions data, while monitoring efforts are often restricted by the lack of appropriate tools to gather, report and reflect on the use of natural and financial resources within rural agricultural settings. Adaptation efforts are often constrained by the lack of appropriate information and knowledge-sharing mechanisms, by scarce economic resources, and the lack of public policies and decision-making mechanisms to implement local adaptive actions, among others.

In view of the challenges and the potential opportunities that emerge amidst changing conditions, the use of ICTs can enable new approaches to address climate change within rural agricultural communities.

2. ICT-Enabled Responses in Rural Agricultural Communities

Diffusion of ICTs in the global South has been characterised by a very dynamic uptake of these tools in rural areas, where their adoption has been led by the rapid growth of mobile telephony[722].

The increasing importance of ICTs – not just mobile phones but also telecentres, community radio, etc – in rural livelihoods can be related to multiple factors, among them, the limited availability/uptake of fixed telephony, the rapid expansion of mobile networks, relatively low barriers to adoption and use (e.g. low cost, payment plans, easy use), growth of wireless Internet connectivity, donor and government universal service actions, etc.

The potential of ICTs in regards to climate change and rural agricultural communities can be linked to the four key areas of action identified before, within which there are different types of possible interventions, as reflected in Table 1.

[722] ITU. (2010) *ITU Sees 5 Billion Mobile Subscriptions Globally in 2010: Strong Mobile Cellular Growth Predicted Across All Regions and All Major Markets*. Press Release, International Telecommunication Union (ITU), Geneva. http://www.itu.int/newsroom/press_releases/2010/06.html

Area	Role of ICTs	Intervention Focus
CLIMATE CHANGE AWARENESS	Emerging experiences in rural agricultural communities suggest that the use of ICTs such as mobile phones, radio, TV and video can facilitate the dissemination of climate change messages among vulnerable populations. Within geographically dispersed, remote populations or communities with low-literacy rates and a strong oral culture, the use of voice-based and visual applications (e.g. participatory community videos, podcasts, audio-blogs, radio) has contributed to reach and engage wider audiences in climate change-related topics[723].	• **Initial/Generic Awareness of Climate Change:** ICTs used to disseminate generic information about key climate change concepts and terminology, and sensitise wide rural audiences about its relevance (e.g. national radio and TV programmes, Internet). • **Specific Awareness of Local Issues:** ICTs used to raise awareness on community risks/vulnerabilities to climate change, and climatic impacts on specific local issues (e.g. crop diseases, production levels, water availability, land distribution, migration), and localised seasonal forecasts. Message is targeted to more specific audiences/needs (e.g. Internet-based applications used to map and visualise local vulnerabilities, community-produced radio and video programmes, and circulation of specific alerts or information via mobile phone contact networks).
CLIMATE CHANGE MITIGATION	Within rural agricultural settings, use of ICTs can facilitate analysis of the spatial relationships that exist between carbon emissions and local socio-economic conditions, contributing to decision-making processes and to the implementation of incentive-based mitigation mechanisms such as REDD (Reducing Emissions from Deforestation and forest Degradation). Applications such as geographic information systems (GIS) and remote sensing technologies can enable innovative approaches to the analysis of forest carbon stocks, as well as to the participatory management of forest resources within rural and marginalised settings (e.g. forestry information systems, geo-referenced databases of land tenure, and local awareness regarding reforestation/afforestation trends).	• **Natural Resource-Oriented:** -**Forest Management:** ICTs used to record, measure and analyse local information on carbon stocks and emission levels, and inform decision makers (e.g. GIS used to systematise the rates and trends of deforestation, local forest cutting and burning). **-Agriculture Management:** ICTs used to foster the use of sustainable agricultural practices among farmers (e.g. telecentres used to access information on soil conservation and organic farming) that contribute to mitigate climatic impacts on local production and to protect ecosystems. **-Land Evaluation and Use:** ICT-based tools and software to support land evaluation and land use planning involving local communities, in order to identify land with the highest productivity and potential for carbon sequestration under different climate scenarios. • **Capacity-Building Oriented:** ICTs used to build local capacities and support on-site and distance learning targeted to agricultural producers on the control of carbon emissions and income-earning opportunities derived from sale of carbon stocks.

[723] Caceres Cabana, Y. (2011) *Using Radio to Improve Local Responses to Climate Variability: The Case of Alpaca Farmers in the Peruvian Andes*. ICTs and Agricultural Adaptation to Climate Chage Case Study, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/casestudies.htm

Area	Role of ICTs	Intervention Focus
CLIMATE CHANGE MONITORING	Climate monitoring is closely linked to the lifecycle of information systems, and as such, it can be strengthened through the use of ICTs for data capture, processing and dissemination by and among local stakeholders in rural contexts. ICTs are being increasingly used in remote areas to map, record and analyse changes in local resources such as water basins, animal and vegetal species and biodiversity, as well as changes in pollution levels and greenhouse gas emissions, fostering the engagement of community actors in participatory monitoring and information exchange. Members of rural agricultural communities are being trained in use of ICTs to monitor changes in local conditions, e.g. rain levels, number of frost days or the length of growing seasons, which contribute to the understanding of local climatic impacts, and the adoption of measures to adjust/adapt to new conditions. ICT-based tools such as Internet portals and online databases are used to track the allocation and disbursement of climate change-related funds[724], contributing to transparency and accountability; while GIS applications are playing an increasing role in REDD programmes[725]	• **External Data:** ICTs used to monitor climate change based on data captured externally to the community (e.g through remote sensing, satellite or aerial photography, meteorological systems, Global Positioning Systems, and modelling). • **Local Data:** ICTs used to monitor change through the local collection and analysis of data (e.g. data collected by community stakeholders using smart-phones or mobile devices to report on forest cover, crop levels and quality, pest forecast and control, biodiversity or water levels; Internet-based platforms to report on the use of mitigation or adaptation funds at the local level and the status of climate change projects implemented locally). ICTs can also support local hydro-agro-meteorological early warning systems to decrease risks. • **Hybrid Local-External Systems** ICTs used to monitor change using both external and local data.

[724] http://www.undp-adaptation.org/portfolio/

[725] Mukama, K., Mustalahti, I. & Zahabu, E. (2012) 'Participatory Forest Carbon Assessment and REDD+: Learning from Tanzania', *International Journal of Forestry Research,* 2012:1-14.

Area	Role of ICTs	Intervention Focus
CLIMATE CHANGE ADAPTATION	The availability, access and use of livelihood assets are closely related to adaptive capacity of vulnerable communities. Emerging adaptation experiences from rural agricultural areas in Bangladesh, India and Perú[726] suggest that the role of ICTs in the field is closely linked to the strengthening of agricultural and livestock production systems (i.e. through information about pest and disease control, planting dates, seed varieties and irrigation applications, and early warning systems)[727], as well as to the improvement of rural livelihoods through enhanced access to markets (e.g. through information on prices, consumer trends and dissemination opportunities)[728]. ICTs are also playing an increasing role in the delivery of emergent climatic knowledge, in the facilitation of cross-scale networking (e.g. interactions by community members with scientists, diagnosticians, researchers or government officials located in urban areas) and in the implementation of capacity building programmes for local farmers[729].	• **Vulnerability-Oriented:** ICTs used to address adaptation needs in key vulnerability areas for rural agricultural communities, for example: ▪ **Food Security:** ICTs used to access information about resistant seed varieties and planting methods, or to access agro-meteorological information to protect crops. ▪ **Water Supply:** ICTs used to build local capacity for the conservation of water sources and more efficient water management during the production cycle. ▪ **Income Generation:** ICTs used to explore/access alternative sources of income generation, including the productive use of ICTs (e.g. to access agricultural markets, prices, or to commercialise products) ▪ **Health:** ICTs used to disseminate information on prevention and treatment of new diseases triggered by climatic impacts, or in early warning systems on disease forecast and control. ▪ **Infrastructure:** ICTs used to share lessons on safe building practices in areas of high risk for rural communities. ▪ **Political Participation:** ICTs used to facilitate the participation of rural communities in democratic processes. ▪ **Security:** ICTs used among social networks to share security risks and early warning related to climatic events. • **Climatic Threat-Oriented:** ICTs can also be used in the design and implementation of adaptation actions focused on specific climatic threats that affect rural agricultural communities (e.g. disseminating information about flood prevention, supporting capacity building on managing extended droughts, knowledge sharing on the local impacts of glacier melting, or implementing early warning and response systems for storms and landslides).

Table 1. ICTs and Climate Change Interventions in Rural Agricultural Communities

These examples suggest that ICT interventions within rural agricultural communities can be used to foster both ***one-way*** and ***interactive*** information flows. While one-way flows can be effective in dissemination of relevant information and best practices, interactive flows can foster mutual learning and sharing among multi-sector stakeholders on issues of climate change awareness, mitigation, monitoring and adaptation. Ultimately, the design of ICT interventions should be based on an initial assessment of local vulnerabilities, capacities, needs and priorities, and can combine mechanisms for one-way and interactive information flows.

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726 '*Climate Change, ICTs and Innovation'* Project Case Studies, http://www.niccd.org/casestudies.htm

727 Ospina, A. V. & Heeks, R. (2010) *Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study*. Centre for Development Informatics, Institute for Development Policy and Management, University of Manchester, UK http://www.niccd.org/ScopingStudy.pdf

728 Stienen, J., Bruinsma, W. & Neuman, F. (2007) *How ICT can Make a Difference in Agricultural Livelihoods*, International Institute for Communication and Development, The Hague http://www.iicd.org/files/ICT%20and%20agricultural%20livelihoods.pdf

729 Braun, P. & Faisal Islam, M. (2011) *ICT-Enabled Knowledge Brokering for Farmers in Coastal Areas of Bangladesh*. ICTs and Agricultural Adaptation to Climate Change Case Study, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/casestudies.htm

Further enablers and constraints to be considered in the design of ICT initiatives in the climate change field are explained below.

2.1. Key Enablers and Constraints

Emerging experiences from rural agricultural communities suggest positive linkages between use of ICTs and climate change responses in mitigation, adaptation, monitoring and awareness. But while use of traditional and emergent ICTs is starting to contribute to the actions that rural agricultural communities undertake in face of climatic challenges, experiences from the field[730] also indicate the existence of factors that can either *enable* or *constrain* the role of ICT tools within these contexts.

The analysis of available case studies suggests six key factors that can ultimately determine the effectiveness of ICTs' role within rural agricultural communities. In other words, these are critical success/failure factors which should therefore be a main focus during design and implementation of ICT and climate change initiatives:

- **Access**

  In spite of the growing penetration and adoption of ICTs in developing countries, barriers of access (that range from power supply to infrastructure provision) still persist in many rural agricultural communities, limiting their ability to implement ICT-enabled actions in relation to climate change[731]. These access constraints require 'hybrid' technological approaches that integrate both digital and non-digital ICTs: building on the important role that traditional/widespread tools such as radio and TV play within rural contexts, and complementing it with the value added of emerging, mobile and Internet-based applications. The potential of a hybrid approach can be illustrated by the 'mobile-telecentre' architecture that combines the reach of mobiles with the power of the telecentre[732]. Hybrid approaches can also bring mobility to traditional telecentre services through smart mobile 'info-carts' (carts equipped with different ICTs), in order to expand the reach of services to a broader set of users. This mobile-plus-fixed-telecentre approach integrates telephone calls, SMS, email, Internet browsing and digital literacy classes, and is led by the local telecentre operator as a way to help develop local capacities that in turn contribute to adaptation[733].

- **Knowledge Infomediaries**

  Rural agricultural communities often lack the economic and human capacity required to access, interpret and analyse climate change data, and to implement response measures. The engagement of local knowledge infomediaries (e.g. agricultural extension officers and other trained professionals drawn from local residents, particularly youth) contributes to ensure a 'last mile' approach in the delivery of information and knowledge within rural agricultural communities. Their 'insider' knowledge of the local context, and relationships based on trust play a pivotal role in the effective

[730] '*Climate Change, ICTs and Innovation'* Project Case Studies http://www.niccd.org/casestudies.htm
[731] Ospina & Heeks *op.cit.*
[732] Pant, L.P. & Heeks, R. (2011) *ICT-Enabled Development of Capacity for Climate Change Adaptation*. Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/PantHeeksClimateChangeAdaptationICTs.pdf
[733] Pant & Heeks *op.cit.*

delivery and local appropriation of messages related to climate change awareness, mitigation, adaptation and monitoring. Local knowledge brokers help to complement ICT-based information through face-to-face meetings and field visits, train local stakeholders in the use of ICT tools (helping to reduce digital scepticism and age-related barriers to adoption), help to identify sources of credit and funding to implement action, and personalise the delivery of agricultural supply chain information (e.g. inputs, processes and outputs).

- **Content Appropriateness**

  The availability of appropriate climate change content constitutes one of the most critical challenges for the effective use of climate change information at the local level[734]. Appropriateness refers not only to the provision of scale-relevant climatic data (e.g. local forecasts, models and projections), but also to the way in which the information provided responds to the livelihood priorities of rural agricultural stakeholders, and to the format in which it is delivered. Experiences from the field suggest that successful approaches go beyond the provision of climatic information and agricultural practices, integrating resources that relate to the complete agricultural supply chain (e.g. inputs such as machinery, seeds and fertilisers; processes like planting weeding and harvesting; and outputs such as post-harvest procedures and access to markets)[735]. ICTs can be part of the production and delivery of holistic resource packages, thus fostering the transformation of information into agricultural action. Applications such as participatory videos and radio programmes can deliver content in appropriate formats, using indigenous languages and integrating traditional knowledge and culturally-recognised symbols to facilitate local appropriation.

- **Multi-Stakeholder Engagement**

  The complex set of vulnerabilities within which developing country communities operate require multi-stakeholder strategies that build upon the complementary roles, resources and strengths of these actors. Experiences from the field suggest the value of engaging a wide variety of actors in ICT-enabled solutions to mitigate, adapt, monitor and create awareness of climate change within rural agricultural communities. But while the use of ICTs can facilitate dialogue and exchange among community members, local governments, NGOs and funding bodies, among others (e.g. through online communities, e-mail exchange or more frequent mobile communications), these relations can also add new layers of complexity to local interactions and to the management of local resources, becoming time-consuming and politically sensitive. Clarity about the roles and responsibilities of each actor, as well as the role of community leaders can help mediate and manage multi-stakeholder interactions.

- **New and Traditional Knowledge**

  In addition to ICT-enabled access to new climatic knowledge and information, the traditional knowledge of indigenous peoples and local communities plays a critical role in their capacity to respond and adjust to climate change. Adaptation practices in the agricultural sector can be strengthened with the integration of local knowledge on resilient crop

[734] Braun, P. & Faisal Islam, M. *op.cit.*

[735] Saravanan, R. (2011) *e-Arik: Using ICTs to Facilitate Climate-Smart Agriculture among Tribal Farmers in North-East India*. ICTs and Agricultural Adaptation to Climate Change Case Study, Centre for Development Informatics, University of Manchester, UK http://www.niccd.org/casestudies.htm

species and varieties, plant breeding, wild crops to supplement diets, traditional farming practices and natural resource conservation, as well as local climate forecasting techniques[736]. ICTs can play an important role ensuring the two-way flow of climate knowledge and resources, helping document and disseminate new and traditional practices, while fostering dialogue and exchange between the scientific community and local stakeholders. ICTs can also facilitate market access to traditional crops and local varieties, and support adoption of resilient seed varieties and good practices for sustainable production.

- **Focus on the Information Chain**

  In addition to facilitating *availability* and *access* to relevant information, ICTs should foster the *usability* of climate change information within vulnerable agricultural contexts. ICTs can help disseminate information on loans and credits targeted to local producers, as well as strengthening local productive practices (e.g. through online training and access to information on new agricultural technologies) and market access, thus helping to access additional resources for the implementation of climate change actions.

As summarised in **Figure 1**, the potential of ICTs within rural agricultural communities affected by climate change goes well beyond the provision of climatic information, and is subject to the effect of key enablers and constraints. Integrated within broader development and climate change strategies, ICTs' contribution to local climate change actions is largely based on the strengthening of agricultural livelihoods (e.g. through increased and diversified income sources and capacities), and on a holistic, action-based approach that enhances the ability of these communities to respond to the challenges and opportunities posed by climate change.

[736] Swiderska, K., Song, Y., Li, J., Reid, H. & Mutta, D. (2011) *Adapting Agriculture with Traditional Knowledge*. Briefing, International Institute for Environment and Development, The Hague http://pubs.iied.org/17111IIED

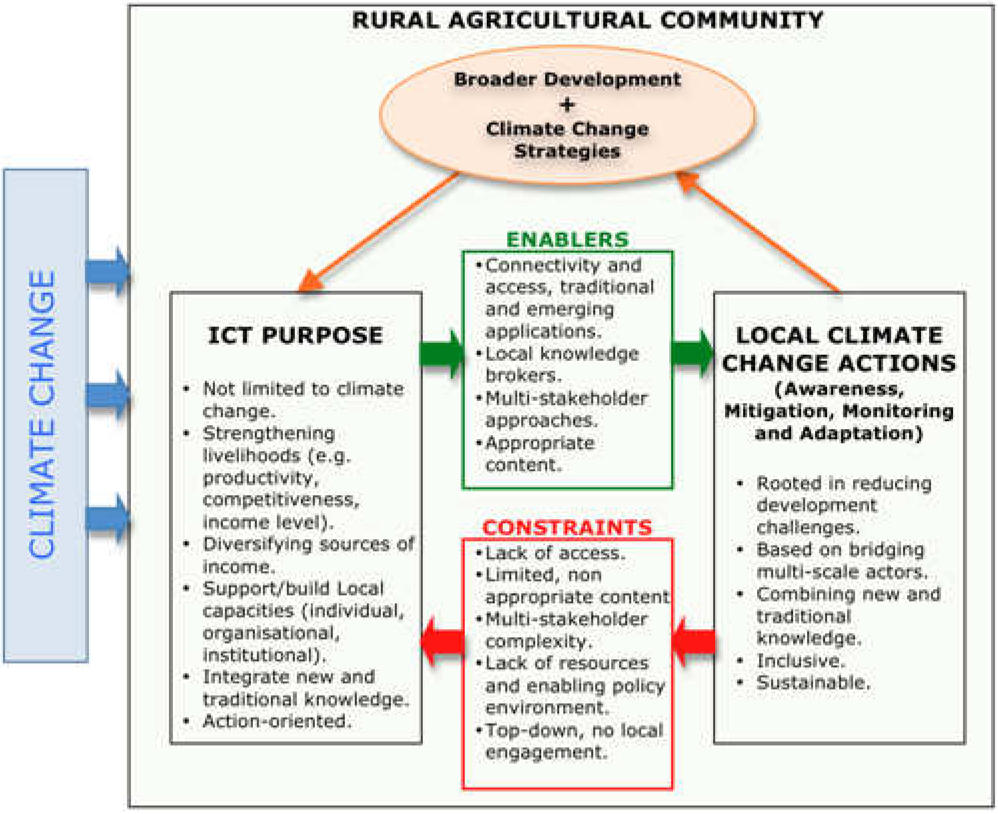

Figure 1. ICTs' Role in Rural Agricultural Community Climate Change Actions

3. Moving Forward: The 'Information Plus' Approach

How can this analysis contribute to climate change initiatives implemented within rural agricultural communities? By identifying the key success factors that have emerged from experiences in the field, these can then be integrated into ICT-enabled approaches to climate change awareness, mitigation, monitoring and adaptation at local level.

Some of these factors are presented in Table 2, and reflect an '***Information Plus***' approach to various areas of climate change action within agricultural communities.
This approach is based on the recognition that use of ICTs within contexts affected by climate change needs to go beyond the provision of information in order to involve new and more inclusive ways of accessing, appropriating and using knowledge resources and then turn these into adaptation actions.

For that potential to be realised in climate change awareness, mitigation, monitoring and adaptation, ICT strategies must incorporate three key factors:

(a) the role of local knowledge infomediaries to facilitate the delivery and appropriation of climate change messages;

(b) the dissemination of information 'packages' that are not limited to climate change but that address a wider set of development stressors and vulnerabilities that are relevant at the local level; and

(c) the implementation of various (digital and non-digital) applications 'bundled' together in order to address the challenges (e.g. connectivity, remoteness, literacy, etc) and potential opportunities (e.g. income and skills diversification, collaborative networks) related to climate change within vulnerable contexts.

The first row of the 'Information Plus' matrix provides examples of stakeholders that can play the role of knowledge infomediaries at the local level, supporting the use of ICTs for climate change awareness, mitigation, monitoring and adaptation. The second row provides examples of content that can be relevant for different actors within rural agricultural communities, and that can be combined with climate change-oriented content. It is key for this content to be presented in appropriate formats, targeting the specific needs and capacities of local audiences (e.g. considering literacy levels, age groups, local practices and cultural traditions). The last row of the matrix provides examples of ICT applications that can be useful, especially when combined, in the achievement of climate change and broader development goals within rural agricultural communities.

Area of ICT Contribution: ***Key Factors to Consider in ICT Strategies:***	**Climate Change Awareness**	**Climate Change Mitigation**	**Climate Change Monitoring**	**Climate Change Adaptation**
Local Knowledge Infomediaries **(Engaging Trusted Agents for Information Delivery/Appropriation)**	Agricultural Extension Officers Local Associations and NGOs Telecentre Operators Local Youth	Local NGOs Farmer Cooperatives	Community Leaders Local Youth Local NGOs	Agricultural Extension Officers Local Youth and Elders Trained Professionals Women Associations Telecentre Operators
Info-Package **(Ensuring Content Relevance + Addressing Broader Range of Development Stressors)**	Climate Change Concepts Local Vulnerabilities, Risks and Impacts Importance of Ecosystem Services Protection of Natural Resources Available Sources of Climate Change Funding Role and Responsibilities of Local Actors/Institutions	CO_2 Emissions Forest Protection Income-Generating Opportunities Access to Carbon Markets	Meteorological Information Climatic Trends Deforestation Trends/ Reforestation Practices Biodiversity Water Sources Local Natural Resources (e.g. river levels)	Meteorological Information Agricultural Supply Chain Emerging and Traditional Knowledge (e.g. seeds) Strengthening Production & Increasing Productivity Diversifying Income Sources Credits, Access to Adaptation Funds

Area of ICT Contribution: ***Key Factors to Consider in ICT Strategies:***	**Climate Change Awareness**	**Climate Change Mitigation**	**Climate Change Monitoring**	**Climate Change Adaptation**
(Cont. Info-Package)	Relevant Policies/Legislation			Water Access and Management Other Local Priorities
ICT-Bundle **(Combine Digital and Non-Digital Applications and Ensure their Appropriateness within Rural Areas)**	- Radio - Television - Mobile Phones/SMS - Internet - Online Networks - Social Media - Web 2.0 Tools - Videos **PLUS:** - Face-to-Face Meetings/Training	- Internet - Mobiles/Smart Phones - GIS/Remote Sensing	- Mobile Phones/SMS - Internet - GIS/Remote Sensing - Online Communities - Software Apps - Databases - Spatial Analysis Tools - Data Sharing Platforms - Open Source Software Tools	- Radio - Television - Mobile Phones/SMS - Internet - Databases - Online Portals - Online Networks - Social Media - Web 2.0 Tools - Videos **PLUS:** - Face-to-Face Meetings/Training

Table 2. 'Information Plus' Matrix

4. Action Steps

The effective integration of ICTs into climate change responses within rural agricultural communities can be achieved through concrete action steps:

- **Focus on Income Generation** as a key enabler of action in the climate change field, and a pillar upon which rural agricultural livelihoods can build resilience in face of increasing change and uncertainty.

- **Localise Interventions** by fostering bottom-up approaches that start by identifying the needs and priorities of rural agricultural communities, and engage local actors in the design, monitoring and evaluation of initiatives.

- **Foster the Role of Local Knowledge Infomediaries** as trusted sources through whom climate change information can be translated and integrated into local practices, helping to bridge power, knowledge and digital gaps[737]. They are crucial for the multi-channel reinforcement of climate change strategies, and the integration of ICTs into broader development strategies (e.g. food security and productivity) within rural agricultural communities.

- **Build Capacity for Emergent Action** among local communities, in order to provide them with new tools to cope with change and uncertainty using new and traditional ICTs, while strengthening local decision-making capacity.

[737] Saravanan, R. *op.cit.*

- **Drive the Whole Information Chain** by planning all the connections from information provision to decision-making to actions to results, including the economic and human resources necessary to implement actions at each stage of the chain.

- **Strengthen the Foundations** by building climate change and ICT awareness, providing locally-relevant information, and developing indicators and action plans based on current and future vulnerabilities.

- **Combine Different Applications,** exploiting the potential that both emergent and traditional, digital and non-digital tools can provide within the local context.

- **Build upon Traditional Knowledge,** thus helping to bridge the existing gap between scientific resources and indigenous/local practices.

- **Integrate Climate Change and ICTs** into livelihood information systems and within broad development interventions, thus contributing to their sustainability.

- **Adopt a Process Approach** that involves beneficiary participation, flexible and phased implementation, learning from doing, as well as mechanisms for local and multi-stakeholder support. Process approaches include measures to address climate impacts in both the short and the long term (acute and chronic impacts).

Rural agricultural communities are not only key in the provision of food security and in the socio-economic and cultural fabric of developing countries, but are also the subject of a wide set of development stressors and vulnerabilities that are exacerbated by the effects of climate change. Acknowledging the broader development context within which they operate constitutes the departure point of any ICT-related intervention in the climate change field.

Ultimately, the enabling role of these tools for climate change awareness, mitigation, monitoring and adaptation is closely linked to their contribution to local agricultural livelihoods (e.g. income and productivity), and to the capacity of local actors and institutions to respond to the challenges and the opportunities that may emerge from change. Issues of financial sustainability, gender and inclusion, as well as evaluation and monitoring of ICTs' role within climate change processes, are among the key areas that remain to be explored through further academic research and practical experiences.

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Chapter 15: The Future Research Agenda for ICTs, Climate Change and Development

ANGELICA VALERIA OSPINA & RICHARD HEEKS

This Strategy Brief explores the future research agenda for information and communication technologies, climate change and development (ICCD). It argues that new research on the role of digital tools is needed to identify innovative, locally-appropriate approaches to face the challenges and benefit from the opportunities posed by climate change. Emerging research in this field has started to shed light on the role of ICTs to mitigate, monitor and adapt to the effects of climate change within developing country settings. However, much remains to be done in order to provide evidence-based knowledge that can be used by decision-makers at the community, sectoral, national and international levels.

This Brief identifies key enablers and constraints for ICCD research. It then summarises a series of current knowledge gaps which can set the agenda for future research priorities in the field. The Brief concludes with concrete action steps to move the ICCD research agenda forward.

1. Relevance of ICTs, Climate Change and Development (ICCD) Research

As climate change-related impacts grow in developing countries, there is an increasing need to develop innovative approaches which help vulnerable populations to better cope with, mitigate and adapt to the effects of both short- and long-term climatic effects. Alongside the momentum gained by climate change within national and international agendas, research in the field has risen exponentially – albeit from a very small and recent base – opening new ground for emerging fields of study where traditional climate change science, development studies and the application of innovative tools converge.

The emerging field of *Information and Communication Technologies (ICTs), Climate Change and Development (ICCD)* is situated at this junction (see Figure 1). ICCD research seeks to explore the linkages that exist between ICT tools (such as mobile telephony, community radio and Internet applications) and key climate change issues that are affecting the global South in the areas of mitigation, adaptation, monitoring and strategising. It is based on the recognition that information and knowledge are crucial enablers of action and change, and that the lack of appropriate information resources and knowledge sharing often lie at the core of developing countries' vulnerabilities to a multitude of stressors, including climate change.

Available research suggests the existence of close links between ICTs' potential in the climate change field, and the vulnerabilities and resource constraints that characterise developing regions[738]. But it also suggests that the availability and

[738] http://www.niccd.org/casestudies.htm

increasing use of ICT tools offers new opportunities for the way in which climate change information is gathered, analysed, processed and disseminated and, ultimately, for the way in which knowledge is created and used as part of climate change responses within vulnerable contexts.

Exploring the future research agenda at the intersection of ICTs, climate change and development is essential to understand the opportunities and the risks involved in ICTs' role within developing contexts facing increasing climate change-related challenges.

2. ICCD Research: Enablers and Constraints

Recent developments suggest an increasing level of interest and awareness about the ICCD field from a number of stakeholders. Among these developments are the availability of new research-oriented resources[739], the creation of a multi-stakeholder Study Group on ICTs and Climate Change[740] led by the International Telecommunication Union (ITU), as well as the unprecedented visibility that the topic had during the climate change Conference of Parties (COP17) held in Durban, South Africa in 2011[741]. These efforts coincide with the launch of a global 'Coalition on ICTs and Climate Change'[742] whose objectives include raising awareness, showcasing innovative initiatives, mobilising political will, and encouraging governments to include ICTs as part of climate change policies.

While these constitute encouraging developments that build upon and could help advance research in the ICCD field, there are also critical factors that need to be considered in order to move the research agenda forward:

- ***A Hybrid Field of Research:*** The role of ICTs in the climate change field cannot be understood in isolation from wider development processes, stressors and vulnerabilities. These include not just issues of infrastructure and connectivity, but also socio-economic, cultural and scientific factors that are not limited to the lens of a single discipline, or to a single method of study. Thus, ICCD research is a 'hybrid' field that builds upon knowledge from the climate change, the development and the information systems fields. This therefore favours inter- and multi-disciplinary approaches, which can be more methodologically challenging to enact.

- ***Bridging Knowledge Gaps:*** ICTs are transversal tools, used by stakeholders from different sectors and at different scales (i.e. macro, meso and micro). One starting point of ICCD research is acknowledgement of the diversity of interests and stakeholders that play a role in mitigation, adaptation, monitoring and climate change strategies, and of the need to bridge existing knowledge and information sharing gaps across sectors and scales. Of particular importance is the gap that exists between academic/university-based research, and the needs of climate change and ICT-for-development stakeholders in the field.

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[739] See for example: http://www.niccd.org, http://www.itu.int/ITU-T/worksem/climatechange/resources.html

[740] http://www.itu.int/ITU-T/studygroups/com05/index.asp

[741] Side events focused on ICTs' role in adaptation and mitigation were led by the United Nations Climate Change Secretariat (UNFCCC), ITU, the Global e-Sustainability Initiative (GeSI) and TechAmerica. http://www.itu.int/themes/climate/events/cop17/ICTcoalition.html

[742] Organisations in the coalition include the International Telecommunication Union, the Global e-Sustainability Initiative, the UNFCCC Secretariat, the UN Global Compact, TechAmerica, as well as high-level representatives from the governments of Ghana, South Africa and Egypt http://www.itu.int/themes/climate/events/cop17/coalitionflyer.pdf

- ***The Need to Build South-Based Research Capacities:*** ICCD research is delivering ever-more empirical knowledge and experiences about the use of ICTs within climate change responses. However, it also demonstrates the need to build and strengthen research capacity - particularly of developing country organisations – in order to produce the required level of locally-relevant research outputs.

- ***Integrating Emergent and Traditional Knowledge:*** Researchers at the intersection of the ICTs, climate change and development fields need to acknowledge and integrate both new and traditional knowledge. While the former is key to cope with and prepare for the magnitude and intensity of emerging climatic challenges, the latter is fundamental in bottom-up/community-based strategies. Thus, both types of knowledge should be considered and integrated as part of holistic research approaches in the ICCD field.

- ***Building a Conceptual Foundation*****:** ICCD research to date has often been somewhat anecdotal[743]. This has limited its transferability and impact. ICCD research needs to adopt a foundation of frameworks and models – which are readily drawn from its constituent disciplines – in order to ensure rigour and value[744].

- ***Adopting a Balanced Systemic Perspective*****:** ICCD research should acknowledge that ICTs can have both positive (e.g. efficient transport and travel substitution) and negative effects on the environment (e.g. increased energy consumption and e-waste). ICCD research approaches should go beyond the effects of particular applications to include the lifecycle of ICT products[745], as well as the systemic effects that may be associated with new production or consumption processes[746]. Likewise, it should consider the way in which ICTs may contribute to both adaptation and maladaptation, at both the local and national levels.

The interaction of these factors is illustrated in Figure 1. The integration of multi-stakeholder perspectives and audiences in the development and dissemination of ICCD research, the strengthening of South-based capacities, as well as the acknowledgement of both new and traditional knowledge (e.g. Western/scientific and indigenous/empirical) and ICT tools (e.g. radio, television, as well as mobile phones and Internet-based applications) constitute key contributing factors to research at the intersection of the ICTs, climate change and development fields.

Research products resulting from the interaction of these factors include models and frameworks (conceptual tools to support the planning, implementation and monitoring of interventions in the field), analysis of key topics (as reflected in Section 3) as well as developing country case studies on the role of ICTs in climate change mitigation, adaptation, monitoring or strategising, among others.

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743 Ospina, A.V. & Heeks, R. (2010a) *Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study*. Centre for Development Informatics, Institute for Development Policy and Management (IDPM), University of Manchester, UK http://www.niccd.org/ScopingStudy.pdf

744 See, for example, Ospina A.V. & Heeks, R. (2010b) *Linking ICTs and Climate Change Adaptation: A Conceptual Framework for e-Resilience and e-Adaptation*. Centre for Development Informatics, Institute for Development Policy and Management (IDPM), University of Manchester, UK http://www.niccd.org/ConceptualPaper.pdf

745 Pamlin, D. & Szomolanyi, K. (2005) *Saving the Climate @ the Speed of Light: First Roadmap for Reduced CO_2 Emissions in the EU and Beyond,* Brussels: World Wide Fund (WWF) and European Telecommunications Network Operators' Association (ETNO). http://assets.panda.org/downloads/road_map_speed_of_light_wwf_etno.pdf

746 Ospina & Heeks (2010a), ibid.

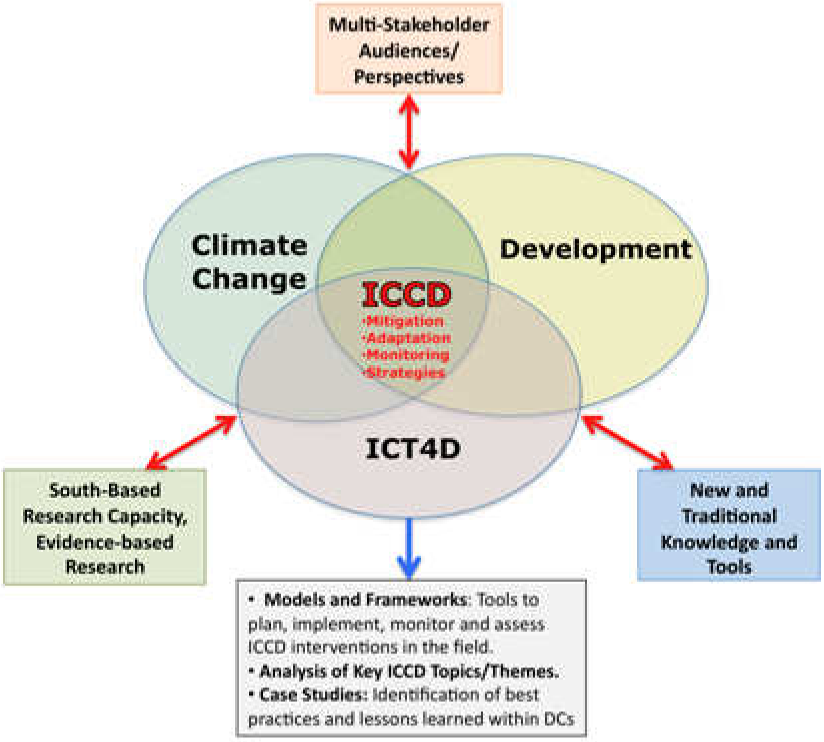

Figure 1. Mapping the ICCD Research Field

3. Moving Forward: Future ICCD Research Priorities

The following key topics constitute research gaps identified through a review of available literature in the field[747], and through multi-stakeholder discussions held at the international workshop on ICTs, Climate Change and Development in Johannesburg, South Africa, January 22nd and 24th 2012[748]. They have been categorised according to four key areas for developing country action in the climate change field (i.e. mitigation, adaptation, monitoring and climate change strategies), and constitute current knowledge gaps – and, hence, future research priorities – for the ICCD field.

[747] Ospina & Heeks (2010a), ibid.
[748] This event was attended by 35 key individuals with strategic responsibilities for either ICTs or climate change in development organisations in the NGO, public and private sector. It was organised by the University of Manchester and the Association for Progressive Communications (APC), with funding support from Canada's IDRC. http://niccd.org/workshop2012.htm

ICTs and Climate Change Mitigation
(a) Strengthening the Links between Mitigation and Development Agendas
• Most available resources in the area of ICTs and climate change mitigation continue to be focused on addressing the needs and agendas of developed countries. Further research is needed on the links between mitigation efforts and the development agenda of developing countries in key areas, including (1) the opportunities and challenges associated with fostering low-carbon societies within developing contexts, (2) the operationalisation of ICT-enabled mitigation options such as journey substitution, smart energy generation and use, and dematerialisation of goods/services within developing contexts, and (3) the role of ICTs in mitigation efforts linked to CO_2 emissions in the agricultural sector. Research in these topics could contribute to change the current perception of mitigation as a 'developed country issue', and foster actions among decision makers in the public, private and civil-society sectors.
(b) ICT-Enabled Income-Generating Opportunities in Mitigation
• Closely related to the above, the potential of ICT tools as part of income-generating activities linked to mitigation (e.g. carbon bonds and emission-reduction incentives, organic agriculture and new markets, reforestation, among others) constitutes an emerging field of research, particularly with respect to the strengthening of rural livelihoods. Research in this area could include the identification of ICT-emerging business models consistent with carbon-neutral livelihoods, including 'green IT' opportunities, and the evaluation of "smart technology" innovation and transfer models in the global South.
(c) Holistic Approaches to ICT Industry Processes and Practices
• The production, distribution and consumption processes of the global ICT industry contribute to carbon emissions. Understanding the contribution and the role of ICTs in the mitigation of carbon emissions requires the adoption of holistic, process-driven (as opposed to output-driven) research approaches. Further research is needed from developing country perspectives on issues such as ICT production models, equipment obsolescence and replacement practices, energy consumption, energy efficient materials and savings, as well as in the development of environmentally-responsible software.
(d) Climate Change Mitigation and e-Waste
• The linkage between climate change and e-waste within developing countries has yet to be fully clarified. Future research in this topic could explore the costs and benefits associated with e-waste management within vulnerable contexts, its linkages with carbon sequestration, as well as the development of indicators to measure and assess their role/contribution within mitigation strategies.
(e) Innovative/Low-Cost ICTs and Mitigation
• As part of the efforts to bring the climate change mitigation agenda closer to the priorities and the challenges faced by developing countries, research could explore the potential of innovative, low-cost ICT solutions (including open-source software, mobile and non-wireless applications) that can contribute to mitigate climate change impacts. It could also identify new pro-poor innovation models, and the role of the innovation context such as investment, business and intellectual property rights policies.
(f) ICTs and Citizen-Driven Mitigation
• The power of social media and Web 2.0 is rapidly permeating citizen-driven campaigns, mobilisation and advocacy in a number of areas, including climate change mitigation. Research could address the role of social media tools in citizen-driven approaches (e.g. online networks and digital campaigns) towards consumer practices, responsible consumption patterns and energy awareness-raising to reduce carbon emissions. Research could also address the role of ICTs in emerging trends such as "immaterialisation" and "demarketing", aimed at modification of consumer values and demands.

ICTs and Climate Change Adaptation
(a) ICTs and Adaptation Capacities / Resilience within Vulnerable Contexts
• While emerging research and field experiences suggest the existence of positive linkages between the use of ICTs and climate change adaptation, research is still required to better understand the role of ICT tools in regards to the adaptive capacity / resilience of vulnerable populations. This requires research to specify the nature of community capacity and resilience. It also includes issues such as ICTs role in the adaptation of local productive systems to the effects of acute/short term events and chronic/long term trends, their contribution to participatory natural resource management and adaptation planning, their role in advocacy and public awareness, and their support for the type of emergent actions that communities will adopt in response to climate change.
(b) ICTs, Infomediaries and Multi-Level Interactions
• ICCD research suggests that infomediaries (local agents such as agricultural extension officers who mediate between external and local stakeholders) play a crucial role in the effective delivery, appropriation and use of climate change information and knowledge. Research is still required to identify the best ways in which ICTs can enable and support their role, while strengthening knowledge sharing between stakeholders at the local, meso and macro levels (e.g. enabling information flows between national and local governments, NGOs and community members).
(c) ICTs and Institutional Capacity Strengthening for Adaptation
• Institutions play a critical role within processes of adaptation and change, as they can either enable or constrain access to key resources needed for the implementation, sustainability and potential scalability of adaptation actions in the field. Future research is required to explore the potential of ICTs to strengthen the adaptive capacity of South-based institutions, including issues of information management and knowledge sharing, as well as their capacity to support, monitor and assess adaptation initiatives.
(d) ICTs as Catalysts of Accountable Adaptation Financing
• Acknowledging the growing flows of adaptation-related funding, further research is required to explore ICTs potential to increase the transparency and accountability of these financial flows, and to enhance broader monitoring and evaluation of adaptation initiatives.
(e) ICTs and Gender-Sensitive Approaches to Adaptation
• Women constitute key agents of change within communities, and their role is crucial in the promotion of ICT tools and approaches. Considering the heightened vulnerability of female-headed households to climatic events, future research could explore the role of ICTs within gender-sensitive approaches to adaptation, including the impacts of information access, capacity building and empowerment on their adaptive capacity.
(f) ICTs and the Role of the Private Sector in Adaptation
• While private sector firms have been actively involved in the design and implementation of mitigation initiatives, their role in the adaptation field has been less prominent. Research is needed to help develop a clear innovation agenda for ICTs and adaptation, which identifies clear entry points for private sector engagement and partnerships in the field.
(g) ICTs, Climate Change Communication and Social Learning
• Research could explore the role of ICT tools in relation to climate change risk perceptions, awareness and understanding among different audiences. In terms of social learning, research could explore the technology's role in behaviour change, engagement and participation, and empowerment and action within populations impacted by climate change and variability.

ICTs and Climate Change Monitoring
(a) ICTs and Participatory Monitoring Approaches
• Gathering, analysing and disseminating climate change information through locally appropriate tools (i.e. community radio, SMS, Internet access points, community video and other interactive media) constitute key factors for capacity strengthening and empowerment within vulnerable communities. Research in this field could explore ICT-enabled participatory monitoring mechanisms, and the way in which they can contribute to implementation of bottom-up approaches in the climate change field.
(b) Empowerment and the 'Information Chain'
• If participatory monitoring is to be fully effective, it must complete an "information chain" that not only gathers data, but delivers that as information back to local communities, and – further – empowers them to then take decisions with that information, and provides the resources necessary to turn those decisions into developmental actions (thus making the connection from monitoring to mitigation and adaptation). More research is required to understand the components of the information chain for local communities, and the way in which climate change monitoring initiatives can deliver all the resources needed to ensure the chain is completed.
(c) ICTs Monitoring Local 'Hotspots'
• Use of ICTs plays a key role in the field of disaster management and response. Research in this area could explore the links that exist between ICT-enabled monitoring in key vulnerable hotspots, to be identified by local communities with the support of both digital and non-digital ICT tools. Research could include the role of ICTs in disaster prevention and planning in key vulnerability areas, and the way in which this potential could be articulated into comprehensive/national or regional climate change strategies.
(d) Citizen-Based Monitoring of CO_2 Emissions
• Research is required to look at innovative ways of monitoring emission of greenhouse gases, utilising citizen-based, collaborative approaches that build on social networking and digital mobilisation to report and measure the level of emissions in key areas of energy consumption. This research area relates to the role of ICTs in public climate change perception and digital advocacy.

ICTs and Climate Change Strategies

(a) ICTs and National Climate Change Policies and Strategies

- As the design and adoption of Nationally Appropriate Mitigation Actions (NAMAs) and National Adaptation Programmes of Action (NAPAs) rises up the climate change agenda of developing countries, further research will be required on the potential of ICT tools within national climate change policies and strategies, in particular as enablers of multi-lateral, measurable and reportable mechanisms for the implementation of NAMAs and NAPAs.

(b) ICTs and Global Climate Change Processes

- Acknowledging the increasing role of ICTs within global climate change processes such as the UN Conference of Parties (COP), future research could look at the integration of information society perspectives in international climate-related strategies, addressing the role of ICTs in assisting global strategising on climate change and in enabling policy frameworks that foster their effective use in the field.

(c) ICTs and Sectoral Development Strategies

- As the impacts of climate change emerge more clearly, they are seen to have specific implications for particular development sectors – water, health, education, rural development, housing, etc. ICTs will need to be integrated into strategies for each one of these sectors, and research is therefore needed that identifies the role of ICTs within each sectoral strategy.

(d) ICTs and Enabling Policy Frameworks

- Research is required to look at the role of public policies and regulatory frameworks for the integration of ICTs in the climate change field, including issues related to barriers of access to ICTs in developing regions; governance, accountability and service delivery; as well as other factors that impinge upon the level of ICT and climate change knowledge appropriation.

(e) ICTs and Political Inclusion

- Whatever the level of strategic climate change process – sectoral, national or global – there is a pressing need for local voices to be heard. ICTs can help enhance this and other forms of political inclusion, but further research is required to identify good practice models and technologies.

(f) ICCD Policy and Programme Integration

- As Figure 1 suggest, strategic actions on ICTs, climate change and development require at least four elements of integration – integrating ICTs with climate change; integrating climate change with development; integrating ICTs with development; and integrating all three components. Research is required to pinpoint exactly what integration means and requires in each given context, and to identify more generally some of the data, institutional and other barriers that must be overcome if integration is to be successful.

(g) Implications of Emerging Digital Technologies

- Research to date demonstrates that a technology-driven approach to strategising ICTs and climate change can easily lead to failure. Hence, the call for digital technologies to be subsumed within broader climate change and development agendas as tools: as means rather than ends. However, there are dangers that this integrated approach is not future-proofed. There is a therefore a research agenda to identify emerging ICTs and to identify the climate-relevant opportunities and issues associated with those technologies. The need is to focus not on "blue-sky" applications, but those which are emerging into the mainstream in developing countries. Examples would include Web 2.0, broadband, wireless sensor networks, mobile Web and smartphones, cloud computing, and convergent new/traditional ICTs.

4. Action Steps

The following action steps are suggested to take the ICCD research agenda forward:

- ***Take an Integrated, Multi-Disciplinary Perspective*** in order to ensure that the component parts of the ICCD field – ICTs, climate change, development – are all considered within the design and implementation of research projects.

- ***Develop an Effective ICCD Research Dissemination Strategy*** that identifies the specific audience which will benefit from the ICCD research, identifies the research demand and knowledge gap which needs to be filled for that audience, and identifies appropriate content and channels by which to reach that audience with research results.

- ***Explore Public-Private-NGO and South-North Partnerships*** as a way to draw on the richest-possible set of ideas, perspectives and capacities for ICCD research.

- ***Foster Participatory ICCD Research Approaches*** including action research methodologies that help – within the research itself – to bridge the gap between research and practice, and between new and traditional knowledge, and which draw multiple stakeholders into the research process.

- ***Provide Actionable ICCD Research Outputs*** to maximise the effectiveness of research impact, including policy briefs, practitioner guides and toolkits, and capacity-building outputs such as training workshop and materials.

- ***Build Upon Experiences, Knowledge and Lessons Learned*** that are already available in the ICCD field, to ensure that research builds upon and adds to the existing sum of knowledge, rather than just reinventing the wheel.

- ***Utilise Conceptual Frameworks*** since these are shown to be the most effective means by which policy-makers and practitioners can understand and then address the world around them.

- ***Raise Donor Awareness on ICCD***. A number of international organisations are funding ICCD research[749], but the field is still somewhat nascent. To ensure the continuity and sustainability of a research agenda and research capacity, particularly in the global South, new funding mechanisms need to be identified and fostered as part of the long-term programmatic approach of international donors in the climate change field.

Research in the ICCD field suggests that the viability and appropriateness of ICT-enabled responses to the climate change cannot be disconnected from the broader development context within which developing countries operate, including local livelihoods, capabilities and governance. The future research agenda in this field holds significant promise in terms of supporting pockets of local innovation and fostering multi-stakeholder partnerships that contribute to the ability of vulnerable groups to cope with and transform in the face of climate change challenges and uncertainty.

[749] IDRC, IISD, ITU, OECD

Further Information

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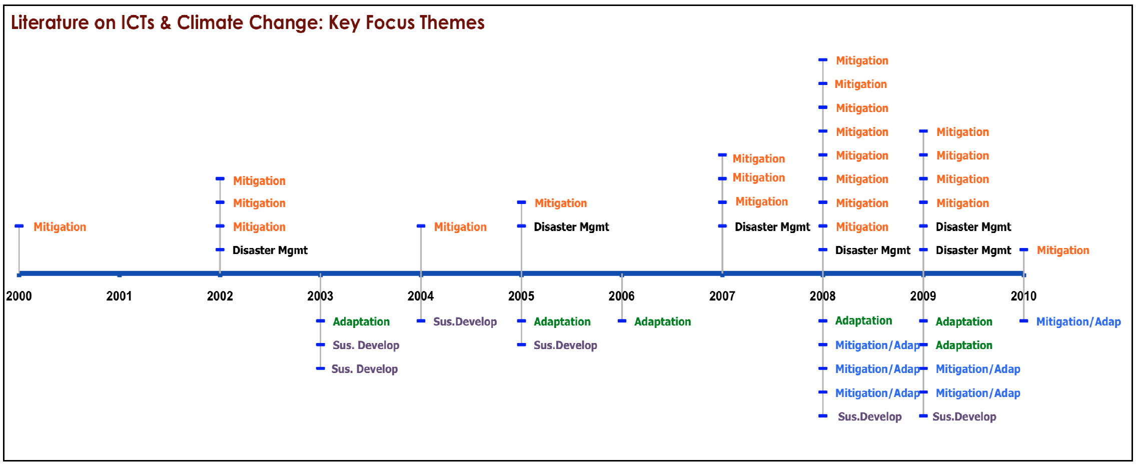
Saravanan, R. (2011) *e-Arik: Using ICTs to Facilitate Climate-Smart Agriculture among Tribal Farmers in North-East India*. ICTs and Agricultural Adaptation to Climate Change Case Study, Centre for Development Informatics, University of Manchester, UK, http://www.niccd.org/NICCD_AgricAdapt_Case_Study_eArik.pdf

Wickramasinghe, K. (2012) *Role of ICTs in Early Warning of Climate-Related Disaster: A Sri Lankan Case Study. ICTs, Climate Change and Disaster Management Case Study.* Centre for Development Informatics (CDI), University of Manchester, UK, http://www.niccd.org/NICCD_Disasters_Case_Study_EarlyWarning.pdf

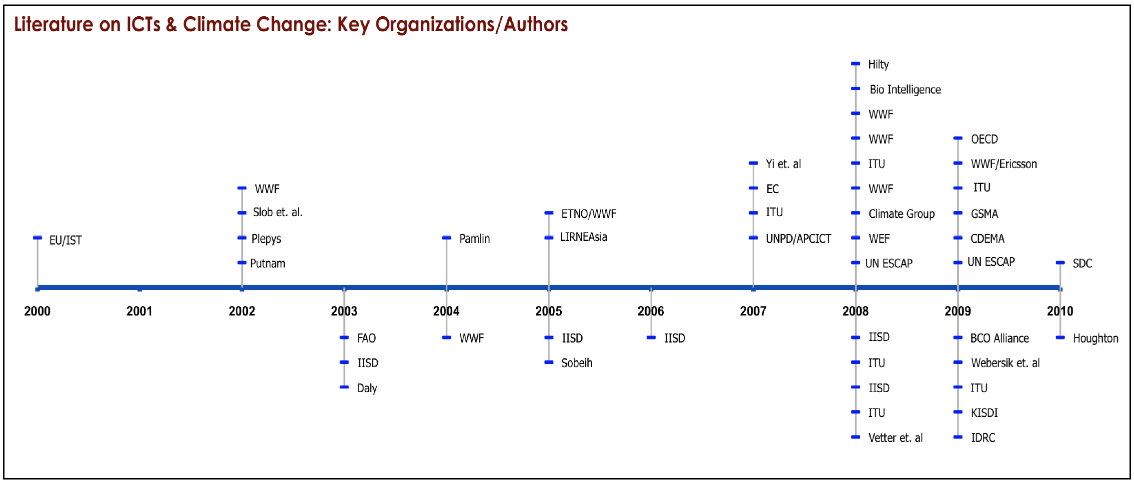
Main Annexes

ANNEX 1. Emergence of Literature on ICTs & Climate Change

a) Key Focus Theme*



b) Author/Organization



*Based on the categorisation reflected in the *ICTs, Climate Change and Development Model* (Heeks and Ospina, 2009). The focus on mitigation includes, in some cases, climate change monitoring (data capture, processing and presentation/dissemination).

KEY RESOURCES INCLUDED:

YEAR	TITLE, AUTHOR/FUNDING ORGANIZATION
2010	Smarter Moves: How ICTs can Promote Sustainable Mobility, SDC
2010	ICTs & Environment in DCs: Opportunities & Developments, Houghton J.
2009	Mobile's Green Manifesto, GSMA
2009	Planting the Knowledge Seed, BCO
2009	e-Environment Toolkit and Readiness Index- ITU
2009	ICTs, Environment and Climate Change, OECD
2009	Achieving Environmental Sustainability, Webersik et. al
2009	ICTs and Climate Change, ITU
2009	ICT World Today, KISDI
2009	Enhancing the Effectiveness of ICTs for Disaster Management, CDEMA
2009	Policy Brief on ICT Applications in the Knowledge Economy, UNESCAP
2009	A 5-step Plan for Low-Carbon Urban Development, WWF/Ericsson
2009	Issues & Challenges of CC for Women Farmers in the Caribbean, Tandon, N.,/ IDRC
2008	Outline 1st Global IT Strategy for CO2 Reductions, WWF
2008	Impacts of ICT on Energy Efficiency, EU
2008	ICTs for e-Environment, ITU
2008	SMART 2020, The Climate Group
2008	ITU and Climate Change, ITU
2008	Contribution of ICTs to Climate Change Mitigation, WEF
2008	ICTs, Adaptation to Climate Change and Sustainable Development, IISD
2008	ICTs, Innovation and Challenge of CC, IISD
2008	ICTs & Climate Change: ITU Background Report
2008	From Fossil to Future with Innovative ICT Solutions, WWF
2008	ICT-enabled Disaster Risk Reduction in Asia & the Pacific, UNESCAP
2008	Potential Global CO2 Reductions from ICT Use, WWF
2008	The ICT Sector and the Global Connectivity System, Vetter, T. et. al, IISD.
2008	IT and Sustainability: Essays on the Rel. between IT and SD, Hilty, L.M
2007	ICTs and Climate Change, ITU
2007	A Review of Research on the Environmental Impact of e-Business and ICT, Yi et. al.
2007	Climate Change and ICT, European Commission
2006	Saving the Climate @ Speed of Light, ETNO & WWF
2006	Mobile Telephony as Enabler of Env'tal Action in the Philippines, Dongtotsag et al.
2005	The M-vironment Approach, Mungai W., IISD
2005	GIS in Egypt, Sobeih, M.
2005	Tsunami Lessons, LIRNEAsia
2004	Outline for Sustainable e-Strategy, Pamlin D
2004	IT and Sustainable Development, WWF
2003	The IS and Sustainable Development, IISD
2003	ICT and Ensuring Environmental Sustainability, Daly, J.
2003	Communication and Natural Resource Management, FAO
2002	Sustainability @ the Speed of Light, WWF
2002	Contribution of ICTs to the Transition Towards a Climate-Neutral Society. Slob et. al.
2002	By Choice or by Change: How the Internet is Used to Prepare for (…), Putnam, L.
2002	The Grey Side of ICT, Plepys, A.
2000	The Knowledge Economy and CC: An Overview of New Opportunities, EC/IST

ANNEX 2. Table of ICTs, Climate Change and Development Resources

ICTs, CLIMATE CHANGE AND DEVELOPMENT RESOURCES **Please note:* **This table seeks to identify key references that integrate ICTs, Climate Change and Development. Resources have been organized chronologically, according to their publication year, and alphabetically, according to their title.**				
YEAR	**TITLE**	**AUTHOR / INSTITUTION**	**MAIN OBJECTIVE**	**AVAILABLE AT:**
2010	***ICTs and the Environment in Developing Countries: Opportunities and Developments***	John Houghton	This document explores how the Internet, ICTs and related research communities can help tackle environmental challenges in developing countries through more environmentally sustainable models of economic development. It includes the identification of key tools, emerging issues and areas of concern for developing and emerging economies. **Note:* This document is a Chapter of an OECD publication that draws on discussion papers prepared for the workshop Policy Coherence in the Application of ICTs for Development (OECD, infoDev/WB, Sep. 2009).	http://browse.oecdbookshop.org/oecd/pdfs/browseit/0309091E.PDF
2010	***Smarter Moves: How Information Communications Technology can promote Sustainable Mobility***	Sustainable Development Commission (SDC)	With the aim of providing policy recommendations to reduce UK's carbon dioxide emissions, the report explores the role of ICTs in mobility, including the scope of these tools in travel reduction, driver and vehicle behavior change, and the efficiency of transport networks, among others.	http://www.sd-commission.org.uk/publications.php?id=1050
2009	***Achieving Environmental Sustainability and Growth in Africa: the Role of Science, Technology and Innovation.***	Christian Webersik & Clarice Wilson, Sustainable Development, 17, p. 400-413.	Based on the recognition of the environmental challenges and climate change vulnerability in developing regions like Africa, the article argues for the need to rethink not only policies and practices but specially the role of science and innovation, including ICTs, in addressing sustainability challenges.	*JOURNAL ARTICLE*

2009	***A five-step Plan for Low Carbon Urban Development***	World Wild Fund/Ericsson	The document aims at promoting action and increase the understanding of how the existing ICT infrastructure can deliver immediate and transformative solutions to policy makers. It presents a five step plan to accelerate the uptake of low carbon services based on current technologies.	http://docbox.etsi.org/Workshop/2009/200911_GREENAGENDA/02Final%20policy%20paper%205-step-plan.pdf
2009	***E-Environment Toolkit and Readiness Index (EERI)***	International Telecommunication Union (ITU)	The document is aimed at helping countries, jurisdictions, communities and organizations, particularly those in the developing world, assess the contribution of ICTs in the reduction of energy consumption and greenhouse gas (GHG) emissions, as part of a national climate change strategy and action plan. The toolkit considers the readiness of countries and jurisdictions to use ICTs for mitigating and adjusting to the impacts of climate change. Indicators of the readiness of countries are captured using the e-Environment Readiness Index (EERI).	http://www.itu.int/ITU-D/cyb/app/docs/eEnv_Toolkit_draft_for_comments_Dec_09_vf.pdf
2009	***Enhancing the effectiveness of ICT applications for disaster management***	The Caribbean Disaster Emergency Management Agency (CDEMA)/ IDRC	The document presents the results of an applied research project implemented by CDEMA with funding support of the International Development Research Centre (IDRC), focused on enhancing the effectiveness of Disaster Management practices in the Caribbean region through the identification and testing of innovative ICTs applications. Research includes e-messaging, amateur (Ham) radio and GIS applications, as well as policy recommendations.	http://www.cdera.org/projects/idrc/index.php
2009	***ICTs, the Environment and Climate Change, High-level OECD Conference: 27-28 May 2009***	Organisation for Economic Co-operation and Development (OECD)	The document presents the main outcomes of the OECD High level meeting held in May 2009, hosted by the Danish Ministry of Science, Technology and Innovation. The event focused on the role of ICTs in the improvement of environmental performance and climate change mitigation in all sectors of the economy. "Green ICTs" was discussed in the context of the economic crisis and the role of innovation.	http://www.oecd.org/dataoecd/49/59/44149232.pdf

2009	***ICTs and Climate Change, ITU Background Report: Symposium on ICTs and Climate Change. Quito, Ecuador, 8-10 July 2009***	International Telecommunication Union (ITU)	The report presents an overview of the main issues faced by Latin American countries in regards with climate change, including deforestation and financing. It provides examples of ICT potential in the fields of monitoring, mitigation, adaptation, and emergency communication. The Annex to the report provides an inventory of work underway in ITU on CC.	http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F00600C0004PDFE.pdf
2009	***ICT World Today***	Korea Information Society Development Institute (KISDI)	This second issue of ICT World Today examines the role ICTs play in promoting environmental sustainability, including ways in which ICTs are being used to address climate change mitigation and adaptation. This publication is supported by the UN Asia and Pacific Training Centre for ICT4D (APCICT).	http://www.unapcict.org/ecohub/resources/ict-world-today-volume-2
2009	***Issues and Challenges of Cli mate Change for Women Farmers in the Caribbean: The potential of ICTs***	Nidhi Tandon. Commissioned by the International Development Research Centre (IDRC)	The objective of this concept paper is to identify and analyze the potential that ICTcan offer to women farmers of the Cari bbean region, in order to better to prepare for, adapt to and manage climate ch ange.	http://www.networkedintelligence.com/Issues_&_Challenges_of_Climate_Change_for_Women_Farmers_in_the_Caribbean.pdf
2009	***Mobile's Green Manifesto***	GSMA /The Climate Group	The document presents the mobile industry plans to lower its greenhouse gas emissions per connection, seeking to demonstrate the key role that mobile communications can play in lowering emissions in other sectors and industries. It provides policy recommendations for governments and the United Nations Climate Change Conference, in order to realize the potential of these tools to enable reductions in global greenhouse emissions.	http://www.gsmworld.com/documents/mobiles_green_manifesto_11_09.pdf
2009	***Planting the Knowledge Seed: Adapting to Climate Change using ICTs***	Patrick Kalas & Alan Finlay, Commissioned by Building Communication Opportunities (BCO) Alliance	The report explores the role of ICTs in the reduction of climate change risks faced by vulnerable populations. It is targeted to an audience of development practitioners and policy makers, and includes concrete project examples of innovative ICT applications that are emerging in the developing field.	http://www.bcoalliance.org/Climate-Change

2009	***Policy Brief on ICT Applications in Knowledge Economy***	UN Economic and Social Commission for Asia and the Pacific, UN ESCAP	The paper briefly examines the functional roles that a telecentre can add to its services to support Disaster Risk Management (DRM) at the community level. It also examines the challenges that could affect their usefulness and effectiveness in DRM.	http://www.unescap.org/IDD/pubs/Policy_Brief_No.5_camera-ready.pdf
2008	***From Fossil to Future with Innovative ICT Solutions***	World Wild Fund (WWF)	The report explores the opportunities for ICTs to increase efficiency and reduce CO2 emissions by using existing equipment and implementing existing solutions. It also proposes eight steps towards a low-carbon society using ICTs innovatively in order to achieve transformative change, and identifies some of the challenges that need to be addressed in this process.	http://assets.panda.org/downloads/fossil2future_wwf_ict.pdf
2008	***ICTs for e-Environment: Guidelines for Developing Countries with a Focus on Climate Change***	Richard Labelle, with input from and Tony Vetter. Commission by the International Telecommunication Union (ITU)	The report presents an overview of ICT trends and impacts on the environment and climate change, as well as their role in mitigation and adaptation efforts. The document approaches the topic from a developmental perspective, and provides an account of current activities and initiatives in the field. It also draws a set of recommendations aimed at strengthening the capacity of developing countries to make beneficial use of ICTs to mitigate and adapt to environmental change.	http://www.itu.int/ITU-D/cyb/app/docs/itu-icts-for-e-environment.pdf
2008	***ICTs, Adaptation to Climate Change, and Sustainable Development at the Edges***	Don MacLean. Institute for Sustainable Development (IISD)	The paper addresses the topic of adaptation in vulnerable regions and the role of ICTs, considering both threats and opportunities that arise from climate change effects. It presents examples of climate change adaptation in the Arctic to demonstrate that it is a complex, multi-dimensional challenge, while identifying linkages between ICTs and key adaptation issues.	http://www.iisd.org/pdf/2008/com_ict_climate.pdf
2008	***ICTs, Innovation and the Challenge of Climate Change.***	Don MacLean & Bill St. Arnaud, Institute for Sustainable Development (IISD)	The document explores the relationship between ICTs, innovation, and the challenge of climate change; with the aim of providing recommendations to help the OECD Working Party on the Information Economy (WPIE)	http://www.iisd.org/publications/pub.aspx?pno=973

			develop a work program on the subject of "ICTs and the Environment". It addresses the challenge of reconciling ICT-enabled innovation and economic growth with reductions in greenhouse gas emissions and adaptation to the consequences of climate change.	
2008	***ICTs and Climate Change: ITU Background Report.***	ITU/MIC Japan Symposium on ICTs and Climate Change. Kyoto, 15-16 April 2008.	This report looks at the potential role of ICTs from their contribution to global warming, to monitoring it, mitigating its effects in the ICT and other sectors, as well as in adaptation. It also looks at the work that the ITU has conducted on the subject, including the UN climate-neutral campaign.	http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F0000070001PDFE.pdf
2008	***ICT-enabled disaster risk reduction in Asia & the Pacific***	UN Economic and Social Commission for Asia and the Pacific, UN ESCAP	The document describes trends related to the development and application of ICT in support of disaster risk reduction. It explores the role of these tools with respect to effective early warning systems, emergency communications and disaster management systems; the implementation of the Hyogo Framework for Action 2005-2015, and strategy support for risk reduction.	http://www.unescap.org/idd/events/cict-2008/CICT_2-E.pdf
2008	***Information Technology and Sustainability: Essays on the Relationship between Information Technology and Sustainable Development***	Hilty, Lorenz M.	This book presents a compilation of essays on various topics related to the role of IT and environmental sustainability.	*BOOK*
2008	***Impacts of Information and Communication Technologies on Energy Efficiency.***	Bio-Intelligence (European Commission DG INFSO)	This study examines the impacts of ICTon the e nergy efficiency in Europe, including renewables and energy production, and GHG emissions. It analyses the environmental footprint of the ICT sector, as well as the effects of using ICT applications in support of higher energy efficiency and energy savings in other areas, including dematerialisation	ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/sustainable-growth/ict4ee-summary_en.pdf
2008	***ITU and Climate Change***	International Telecommunication Union (ITU)	The document presents a general overview of the key issues related to the ICT sector and climate change. It makes reference to ITU's actions in this field, and areas of ICT potential.	http://www.itu.int/themes/climate/docs/report/index.html

2008	***Outline for the first global IT strategy for CO2 reductions***	World Wild Fund (WWF)	The report presents ten strategic ICT-based solutions that can help accelerate the reduction of CO2 emissions. They include smart city planning and buildings, smart appliances, dematerialization, smart grids, and intelligent transport, among others.	http://www.pamlin.net/written/documents/Global%20strategy%20for%20the%201st%20%20BILLION%20tonnes%20with%20ICT-%20by%20WWF.pdf
2008	***SMART 2020: Enabling the low-carbon economy in the information age.***	The Climate Group. Global e-Sustainability Initiative (GeSI)	The report outlines a set of actions needed for ICTs to contribute to climate change mitigation and energy efficiency, including standardize and monitor energy consumption and emissions information, allow accountability in the field, rethink consumption patterns and foster business models that drive low carbon alternatives, among others.	http://www.smart2020.org/publications/
2008	***The Contribution of ICT to Climate Change Mitigation***	World Economic Forum (WEF	The paper presents three main areas in which ICTs can contribute to climate change mitigation, namely infrastructure innovation; behavioral change and green enablement; and energy efficiency of ICT products and solutions. It also explores the need for a unified and clear message on the role of ICT in mitigation, to better inform regulatory and investment decisions.	http://www.unapcict.org/ecohub/resources/the-contribution-of-ict-to-climate-change-mitigation
2008	***The ICT Sector and the Global Connectivity System: A Sustainable Development Overview***	Vetter, T. & Creech, H. International Institute for Sustainable Development (IISD)	The report explores the role of the ICT sector in sustainable development, including the environmental challenge of ICT innovation. The analysis includes the role and growth of personal computers, network traffic, data centres and mobile phones, as well as their impact on E-waste.	http://www.iisd.org/pdf/2008/ict_global_con_sd.pdf
2008	***The Potential global CO2 Reductions from ICT use***	World Wild fund (WWF)	The document provides a comprehensive global assessment of strategic opportunities for ICT solutions that can help accelerate the reduction of CO2 emissions. It proposes ten solutions areas that could deliver one billion tonnes of strategic CO2, from smart city planning, appliances and grids, to dematerialization and intelligent transport, among others.	http://www.wwf.se/source.php/1183710/identifying_the_1st_billion_tonnes_ict.pdf

2007	***Climate Change and ICT: An environment of change.***	European Commission (EC)	The report examines how ICTs can assist monitoring and preparing for climate change, while taking steps towards more sustainable growth. The document is focused on the priorities and strategies in the field in Europe, and provides examples of projects and initiatives that have been implemented in this region.	http://cordis.europa.eu/ictresults/pdf/policyreport/INF%207%200100%20IST-R%20policy%20report-forweb.pdf
2007	***A review of research on the environmental impact of e-business and ICT***	Lan, Y. & Hywel R, T. In: *Environment International,* 33 841-849.	This paper provides a review of the current state of the art of how e-business/ICT affects the environment. It includes findings from journal papers and thesis, which have been peer-reviewed, as well as other resources such as projects and project reports, conference and symposia, and websites.	*JOURNAL ARTICLE*
2007	***ICTs and Climate Change***	ITU-T Technology Watch Report #3, International Telecommunications Union (ITU)	The report looks at the potential role of ICTs at different stages of the process of climate change, including the need to developing long-term solutions, both in the ICT sector and in other sectors of the economy. It includes an overview of ITU's actions in the field, as well as strategic options for the future.	http://www.itu.int/dms_pub/itu-t/oth/23/01/T23010000030002PDFE.pdf
2006	***Mobile Telephony as an Enabler of Environmental Action in the Philippines***	Dolma Dongtotsang & Sagun, R. A. International Institute for Sustainable Development (IISD)	The paper explores how the telecommunications sector, and in particular mobile telephony, offers tools that may be used for environmental action in the Philippines. It identifies a strong need for collaboration on SMS initiatives to address air and water pollution in this country, and provides policy recommendations to use mobile telephony as an enabler of environmental sustainability in national SD policies and e- strategies.	http://www.iisd.org/pdf/2006/infosoc_issd_philippines.pdf
2005	***Geographic Information Systems (GIS) in Egypt***	Amira Sobeih	The study describes Geographic Information Systems (GIS) as a technology that could be used by Egypt and other countries to assist with natural resource management initiatives and enable increased public participation in decision-making.	*BOOK CHAPTER* *In:* Willard, T. & Andjelkovic, M. (eds.) *A Developing Connection: Bridging the Policy Gap Between the Information Society and Sustainable Development.* Winnipeg: International Institute for Sustainable Development.

2005	***Saving the Climate @ the Speed of Light: First roadmap for reduced CO2 emissions in the EU and beyond.***	Dennis Pamlin, & Katalin Szomolanyi, Commissioned by ETNO & WWF	The report explores the opportunity for ICT services to reduce CO2 emissions, with a focus on travel replacement, de-materialization and sustainable community/city planning. It also suggests a strategy for CO2 reductions in Europe, including targets and next steps.	http://assets.panda.org/downloads/road_map_speed_of_light_wwf_etno.pdf
2005	***Tsunami lessons, LIRNEAsia***	Samarajiva, R. LIRNEasia.net	This source presents key experiences and lessons learned in terms of the role of ICTs in disaster response, based on the Asian Tsunami.	http://lirneasia.net/2005/04/tsunami-lessons/
2005	***Using ICTs for Poverty Reduction and Environmental Protection in Kenya: The "M-vironment" Approach.***	Wainaina Mungai, OneWorld International, Kenya. In: A Developing Connection: bridging the policy gap between information society and sustainable development. International Institute for Sustainable Development (IISD)	The document addresses the need to integrate environmental issues in the regional and national poverty reduction and ICT discussions in developing countries such as Kenya. It presents the "M-vironment Framework," in order to explore the potential of a mobile telephony platform to enable financial sustainability for environmental protection efforts; facilitate awareness-raising and exchange of information; strengthen early warning systems; create employment and protect livelihoods, among others.	http://www.iisd.org/pdf/2005/networks_dev_connection_kenya.pdf
2004	***IT and Sustainable Development***	Pamlin, D. & Ewa, T. Ministry of Environment/Swedish EPA (Forum IT och Miljö)	The report present strategic issues related to ICT/IT and sustainable development. It explores general cultural, democratic and economic changes generated by the diffusion of IT, suggesting a series of principles that could serve as a basis for integrating discussions on IT and sustainability in organizations, both in the private and public sectors. These include shifting the focus from products to services; include the issue of environmental benefits in all major IT investments, and reducing rebound effects, among others.	http://assets.panda.org/downloads/itsustainabledev.pdf
2003	***Communication and Natural Resource Management***	Food and Agriculture Organization of the United Nations (FAO)	The book presents analyzes through a series of experiences the importance of communication in natural resource management. It presents practical cases of Africa, Asia and Latin America, illustrating the importance of	http://omec.uab.cat/Documentos/11.pdf

			community-based action and the potential of ICT tools in the management of natural resources.	
2003	***ICTs and Ensuring Environmental Sustainability***	Daly, John. In: *The Digital Pulse: Current and Future applications of ICTs for Developmental Health Priorities.* The Communication Initiative.	Seeking to identify ways in which the information revolution can be utilized to advance environmental goals, particularly the MDGs, the document examines the way in which ICTs can contribute to environmental sustainability.	https://www.comminit.com/pdf/TheDigitalPulse.pdf
2003	***The Information Society and Sustainable Development***	Willard, T. & Halder, M. International Institute for Sustainable Development (IISD)	The paper provides an introduction to various analytical frameworks available for policy research and analysis on harnessing the information society to achieve national sustainable development priorities. It includes an exploration of environmental information systems, eco-efficiency and innovation approaches, national information society and sustainable development policies, among others, in order to demonstrate the potential and of the information society in the achievement of sustainable development goals.	http://www.iisd.org/pdf/2003/networks_sd_exploring_linkages.pdf
2002	***By Choice or by Chance: How the Internet is used to prepare for, manage, and share information about emergencies.***	Laurie Putnam. In: First Monday, 7(11).	The article explores the implications of the Internet for agencies that work to mitigate, prepare for, and respond to natural and human-made disasters. The analysis includes the implications of the Internet for members of the general public who are directly or indirectly affected by disasters.	http://131.193.153.231/www/issues/issue7_11/putnam/
2002	***Sustainability @ the Speed of Light***	World Wild Fund (WWF)	The report explores the role of ICTs in tomorrow's society, through the identification of key sustainable development challenges and the potential contribution of these technologies. The analysis includes the role of the Internet in the new energy economy, e-commerce and the environment, travel substitution, technology leapfrogging and the implications of cyber-consumption, among others.	http://assets.panda.org/downloads/wwf_ic_1.pdf

2002	***The contribution of ICTs to the transition towards a climate-neutral society.***	Adriaan Slob, & Marc van Lieshout.	This book chapter presents an assessment of the potential contribution of ICTs in the transition towards a more climate-neutral society. It places technology within a social context, and identifies key trends in ICT applications, including possible effects in energy consumption.	*BOOK CHAPTER* In: Kok, M. T. J., Vermeulen, W. J. V., Faaij, A. P. C. & de Jager, D. (eds.) Global Warming and Social Innovation: The Challenge of a Climate-Neutral Society.
2002	***The Grey Side of ICT***	Andrius Plepys	The paper analyses the rebound effects of ICTs, arguing that the performance improvements in ICT lead to increased consumption of ICT products and services, which has numerous environmental implications on different levels. By presenting examples from different literature, the paper illustrates the complexity of the environmental impacts and stresses the decisive role of human behavior in determining their significance.	*JOURNAL ARTICLE* *Environmental Impact Assessment Review,* 22(5)
2000	***The Knowledge Economy and Climate Change: An Overview of New Opportunities***	European Commission/IST	The report explores the potential of various IT-based solutions to reduce emissions of carbon dioxide and other greenhouse gases. It includes the analysis of dematerialization, substitution, transport efficiency and production, among others.	http://www.forseback.se/pdf/case_climate.pdf
1997	***Deep information: The role of Information Policy in Environmental Sustainability***	John Felleman,	The book analyses the connection that exists between information and environmental sustainability. It explores a series of information and knowledge models and systems, and links them to issues of policy and regulation.	*BOOK*

ANNEX 3. Glossary

Acceptable risk: The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Adaptation: The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Adaptive co-management: Approach based on collaboration among multiple actors, for instance agencies, researchers and local resource users. Management of everything from local fisheries to global climate change is regarded as controlled experiments, with the consequent need for monitoring, evaluation and constant improvement. According to a growing number of scholars such management that is flexible and open to learning stimulates a sustainable development by enhancing resilience in coupled human and natural systems. *Source: Stockholm Resilience Centre, Stockholm University*

Anthropogenic: Resulting from or produced by human beings. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Building code: A set of ordinances or regulations and associated standards intended to control aspects of the design, construction, materials, alteration and occupancy of structures that are necessary to ensure human safety and welfare, including resistance to collapse and damage. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Capacity Development: The process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems, and the wider social and cultural enabling environment. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Capacity: The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals.

Carbon cycle: The term used to describe the flow of carbon (in various forms, e.g., as *carbon dioxide*) through the *atmosphere*, ocean, terrestrial *biosphere* and *lithosphere*. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Carbon dioxide (CO2): A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning *biomass* and of *land use* changes and other industrial processes. It is the principal *anthropogenic greenhouse gas* that affects the Earth's radiative balance. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Carbon market: A carbon market functions much like any financial market, in which carbon shares (sometimes called pollution credits), representing the right to emit carbon dioxide, methane, and other greenhouse gases, are bought and sold. The market works in conjunction with a cap on allowable emissions; within the market, polluters that are below the cap can sell the "excess" emissions rights as credits, or shares, to others who are above the limit. One goal is to create a scarcity of shares, driving up the cost of emitting chemicals into the atmosphere through conventional, fossil-fuel-powered means, and encouraging further reduction and investment in alternative fuel sources. *Source:* http://www.blueegg.com/Green-Glossary/Carbon-market.html

Climate change refers to a change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or *external forcings*, or to persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*. Note that the *Framework Convention on Climate Change* (UNFCCC), in its Article 1, defines *climate change* as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and *climate variability* attributable to natural causes. *Climate projections* often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Climate: In a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Climate prediction: A climate prediction or *climate forecast* is the result of an attempt to produce an estimate of the actual evolution of the *climate* in the future, for example, at seasonal, interannual or long-term time scales. Since the future evolution of the *climate system* may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Climate projection: A *projection* of the response of the *climate system* to *emission or concentration scenarios* of *greenhouse gases* and *aerosols*, or *radiative forcing* scenarios, often based upon simulations by *climate models*. Climate projections are distinguished from *climate predictions* in order to emphasize that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised and are therefore subject to substantial *uncertainty*. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Climate scenario: A plausible and often simplified representation of the future *climate*, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of *anthropogenic climate change*, often serving as input to impact models. *Climate projections* often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. A *climate change scenario* is the difference between a climate scenario and the current climate. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Climate shift: An abrupt shift or jump in mean values signalling a change in *regime*. Most widely used in conjunction with the 1976/1977 climate shift that seems to correspond to a change in *El Niño-Southern Oscillation* behaviour. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Climate system: The climate system is the highly complex system consisting of five major components: the *atmosphere*, the *hydrosphere*, the *cryosphere*, the land surface and the *biosphere*, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of *external forcings* such as volcanic eruptions, solar variations and *anthropogenic* forcings such as the changing composition of the atmosphere and *land use change*. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Climate variability: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the *climate* on all *spatial and temporal scales* beyond that of individual weather events. Variability may be due to natural internal processes within the *climate system* (*internal variability*), or to variations in natural or *anthropogenic external forcing.*
Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Source: UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Cloud computing: This term refers to the use of networked infrastructure software and capacity to provide resources to users in an on-demand environment. Sometimes known as utility computing, clouds provide a set of typically virtualized computers which can provide users with the ability to start and stop servers or use compute cycles only when needed, often paying only for the use of those services. *Source:* What is cloud or utility computing? *Red Hat Europe Solutions.*

Complex Adaptive Systems (CAS) include companies, the weather, our immune systems, the economy, ecosystems, single cells and brains. In these CAS simple rules of cause and effect do not apply, they are complex, unpredictable and constantly adapting to their environments. Hence, they are far from being machines that you can take apart and investigate the parts to understand the whole. *Source: Stockholm Resilience Centre, Stockholm University*

Coping capacity: The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during crises or adverse conditions. Coping capacities contribute to the reduction of disaster risks. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Deforestation Conversion of forest to non-forest. For a discussion of the term *forest* and related terms such as *afforestation*, *reforestation*, and deforestation see the IPCC Special Report on Land Use, Land-Use Change and Forestry (IPCC, 2000). *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Desertification Land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. The United Nations Convention to Combat Desertification defines land degradation as a reduction or loss in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, *forest*, and woodlands resulting from *land uses* or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical and biological or economic properties of soil; and (iii) long-term loss of natural vegetation. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Disaster risk management: The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. *This term is an extension of the more general term "risk management" to address the specific issue of disaster risks. Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Disaster risk reduction: The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events. *A comprehensive approach to reduce disaster risks is set out in the United Nations-endorsed Hyogo Framework for Action, adopted in 2005, whose expected outcome is "The substantial reduction of disaster losses, in lives and the social, economic and environmental assets of communities and countries." Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Disaster risk: The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Disaster: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Drought: In general terms, drought is a 'prolonged absence or marked deficiency of precipitation', a 'deficiency that results in water shortage for some activity or for some group', or a 'period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance' (Heim, 2002). *Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Dynamical system: A process or set of processes whose evolution in time is governed by a set of deterministic physical laws. The *climate system* is a dynamical system. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Early warning system: The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Eco-efficiency: The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and respurce intensity throughout its life cycle, to a level at least in line with the Earth's estimated carrying capacity. *Source: World Business Council for Sustainable Development, "Cross-cutting Themes: Eco-efficiency".*

Ecosystem: A system of living organisms interacting with each other and their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Ecosystem resilience: A measure of how much disturbance (like storms, fire or pollutants) an ecosystem can handle without shifting into a qualitatively different state. It is the capacity of a system to both withstand shocks and surprises and to rebuild itself if damaged. *Source: Stockholm Resilience Centre, Stockholm University*

e-Environment: Concept that refers to (a) the use and promotion of ICTs as an instrument for environmental protection and the sustainable use of natural resources, (b) the initiation of actions and implementation of projects and programmes for sustainable production and consumption and the environmentally safe disposal and recycling of discarded hardware components used in ICTs, and (c) the establishment of monitoring systems, using ICTs, to forecast and monitor the impact of natural and man-made disasters, particularly in developing countries, least developed countries and small economies. *Source: Labelle, R. et. al, 2008. ICTs for e-Environment: Guidelines for developing countries with a focus on climate change.*

e-Sustainability: Refers to the use of ICTs for sustainable development. The concept is based on the work of Pamlin and others. It also takes into consideration the role of ICTs in reducing greenhouse emissions. *Source: ITU, 2009. e-Environment Toolkit and Readiness Index (EERI)*

El Niño-Southern Oscillation (ENSO): The term *El Niño* was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Perú, disrupting the local fishery. It has since become identified with a basin-wide warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled *atmosphere*-ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as the El Niño-Southern Oscillation (ENSO). It is often measured by the surface pressure anomaly difference between Darwin and Tahiti and the *sea surface temperatures* in the central and eastern equatorial Pacific. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This event has a great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects in many other parts of the world. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Emergency management: The organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Environmental degradation: The reduction of the capacity of the environment to meet social and ecological objectives and needs. Degradation of the environment can alter the frequency and intensity of natural hazards and increase the vulnerability of communities. The types of human-induced degradation are varied and include land misuse, soil erosion and loss, desertification, wild land fires, loss of biodiversity, deforestation, mangrove destruction, land, water and air pollution, climate change, sea level rise and ozone depletion. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Environmental impact assessment: Process by which the environmental consequences of a proposed project or programme are evaluated, undertaken as an integral part of planning and decision-making processes with a view to limiting or reducing the adverse impacts of the project or programme. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Exposure: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. *Measures of exposure can include the number of people or types of assets in an area.* These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest. Source*:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Extensive risk: The widespread risk associated with the exposure of dispersed populations to repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Extreme weather event : An extreme weather event is an event that is rare at a particular place and time of year. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an *extreme climate event*, especially if it yields an average or total that is itself extreme (e.g., *drought* or heavy rainfall over a season). *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Forecast: Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Fossil fuel emissions: Emissions of *greenhouse gases* (in particular *carbon dioxide*) resulting from the combustion of fuels from fossil carbon deposits such as oil, gas and coal. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Glacier: A mass of land ice that flows downhill under gravity (through internal deformation and/or sliding at the base) and is constrained by internal stress and friction at the base and sides. A glacier is maintained by accumulation of snow at high altitudes, balanced by melting at low altitudes or discharge into the sea. Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.

Greenhouse effect: Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect.

Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.

Greenhouse gas (GHG) Greenhouse gases are those gaseous constituents of the *atmosphere*, both natural and *anthropogenic*, that absorb and emit radiation at specifi c wavelengths within the spectrum of *thermal infrared radiation* emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the *greenhouse effect. Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Grids: Grids consist of geographically distributed and heterogeneous computational, network and storage resources that may belong to different administrative domains, but can be shared among users by establishing a global resource management architecture. Source: I. Foster and C. Kesselman. 2004. *The Grid: Blueprint for a New Computing Infrastructure*. 2nd Edition, Morgan Kaufman. 748 pp. Wiley, Chichester, UK.

Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Mitigation: The lessening or limitation of the adverse impacts of hazards and related disasters. The adverse impacts of hazards often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures encompass engineering techniques and hazard-resistant construction as well as improved environmental policies and public awareness. It should be noted that in climate change policy, "mitigation" is defined differently, being the term used for the reduction of greenhouse gas emissions that are the source of climate change. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

National platform for disaster risk reduction: A generic term for national mechanisms for coordination and policy guidance on disaster risk reduction that are multi-sectoral and inter-disciplinary in nature, with public, private and civil society participation involving all concerned entities within a country. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Natural hazard: Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Natural hazard events can be characterized by their magnitude or intensity, speed of onset, duration, and area of extent. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Ocean acidification: A decrease in the *pH* of sea water due to the *uptake* of *anthropogenic carbon dioxide*. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Predictability The extent to which future states of a system may be predicted based on knowledge of current and past states of the system. Since knowledge of the *climate system*'s past and current states is generally imperfect, as are the models that utilise this knowledge to produce a *climate prediction*, and since the climate system is inherently *nonlinear* and *chaotic*, predictability of the climate system is inherently limited. Even with arbitrarily accurate models and observations, there may still be limits to the predictability of such a nonlinear system (AMS, 2000) *Source: Intergovernmental Panel on Climate Change (IPCC),* *2007 Report, Glossary.*

Preparedness: The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Prevention: The outright avoidance of adverse impacts of hazards and related disasters. Prevention (i.e. disaster prevention) expresses the concept and intention to completely avoid potential adverse impacts through action taken in advance. Examples include dams or embankments that eliminate flood risks, land-use regulations that do not permit any settlement in high risk zones, and seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake. Very often the complete avoidance of losses is not feasible and the task transforms to that of mitigation. Partly for this reason, the terms prevention and mitigation are sometimes used interchangeably in casual use. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Public awareness: The extent of common knowledge about disaster risks, the factors that lead to disasters and the*. Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Rebound effects: The rebound effect refers to the idea that some or all of the expected
reductions in energy consumption as a result of energy efficiency improvements are offset by an increasing demand for energy services, arising from reductions in the effective price of energy services resulting from those improvements. *Source:* Dagoumas, A. & Baker, T. *2009. The macroeconomic rebound effect from the implementation of energy efficiency policies at different end-use sectors at global level. Earth and Environmental Science 6.* Greening L, Greene DL, Difiglio C. *(2000). Energy Efficiency and Consumption - The Rebound Effect - A Survey. Energy Policy, 28, 389-401.*

Recovery: The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors*. Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Response: The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Disaster response is predominantly focused on immediate and short-term needs and is sometimes called "disaster relief". The division between this response stage and the subsequent recovery stage is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage. *Source:* UNISDR, *Terminology: Basic terms of disaster* *risk reduction*.

Retrofitting: Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards. Retrofitting requires consideration of the design and function of the structure, the stresses that the structure may be subject to from particular hazards or hazard scenarios, and the practicality and costs of different retrofitting options. Examples of retrofitting include adding bracing to stiffen walls, reinforcing pillars, adding steel ties between walls and roofs, installing shutters on windows, and improving the protection of important facilities and equipment. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Risk assessment: A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. *Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Risk management: The systematic approach and practice of managing uncertainty to minimize potential harm and loss. Risk management comprises risk assessment and analysis, and the implementation of strategies and specific actions to control, reduce and transfer risks*. Source:* UNISDR, *Terminology: Basic terms of disaster risk reduction*.

Sea level change: Sea level can change, both globally and locally, due to (i) changes in the shape of the ocean basins, (ii) changes in the total mass of water and (iii) changes in water density. Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.

Social resilience: The ability of human communities to withstand and recover from stresses, such as environmental change or social, economic or political upheaval. Resilience in societies and their life-supporting ecosystems is crucial in maintaining options for future human development. *Source: Stockholm Resilience Centre, Stockholm University*

Social-ecological systems: are linked systems of people and nature. The term emphasizes that humans must be seen as a part of, not apart from, nature — that the delineation between social and ecological systems is artificial and arbitrary. Scholars have also used concepts like 'coupled human-environment systems´, 'ecosocial systems´ and 'socioecological systems´ to illustrate the interplay between social and ecological systems. The term social-ecological system was coined by Fikret Berkes and Carl Folke in 1998 because they did not want to treat the social or ecological dimension as a prefix, but rather give the two same weight during their analysis. *Source: Stockholm Resilience Centre, Stockholm University*

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. *Source: Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Technological hazard: A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, etc.