

Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study

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Table of Contents

<i>Executive Summary</i>	3
Background	3
Contribution	3
1. CONTEXTUALIZING CLIMATE CHANGE: WHERE DO ICTS STAND?	5
<i>1.1. The Evolution of the ICT and Climate Change Debate</i>	5
(a) Sustainable Development & the Environment: A Global Approach	6
(b) Mitigation: Developed Countries' Focus	8
(c) Adaptation and Climate Change Strategies: Developing Countries' Priorities	9
Literature Summary	10
<i>1.2. From Theory to Practice: Identifying the Challenges</i>	12
(a) Sustainable Development & the Environment	12
(b) Mitigation	13
(c) Adaptation and Strategies	13
2. ICTS, CLIMATE CHANGE AND DEVELOPMENT: AN OVERVIEW	15
<i>2.1. The Main Components of the Climate Change and ICT Debate</i>	15
(a) Mitigation	15
(b) Monitoring	16
(c) Adaptation	17
(d) Strategy	20
<i>2.2. ICTs, Climate Change and Development: Overview Model</i>	21
3. EMERGING EXPERIENCES FROM DEVELOPING COUNTRIES	24
(a) Mitigation and Monitoring	24
(b) Adaptation and Strategy	25
Review	26
4. ISSUES FOR FUTURE RESEARCH	27
(a) Mitigation	27
(b) Monitoring	28
(c) Adaptation	28
(d) Strategy	28
(e) Disaster Management and Response	29
(f) Technologies: Impacts and Issues	29
<i>Conclusions</i>	30
<i>Bibliography</i>	32
<i>ANNEX 1. Emergence of Literature on ICTs and Climate Change *</i>	37
<i>ANNEX 2. Table of ICTs, Climate Change and Development Resources</i>	39
<i>ANNEX 3. Glossary</i>	51

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 CO₂ 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 CO₂ 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 CO₂ 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 I*).

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 exist 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 CO₂ 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 CO₂ 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 CO₂ (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 CO₂ 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 "CO₂-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 CO₂ 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**.

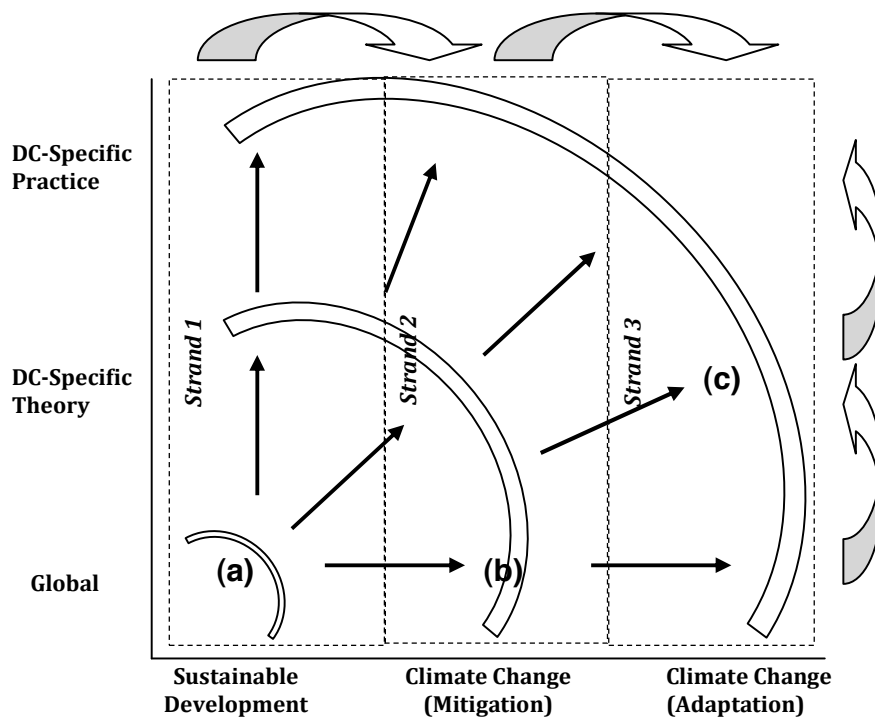


Figure 1: Additions to Literature on ICTs, Climate Change and Development Over Time

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 CO₂ 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 effects¹ and the growing rates of e-waste.

(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.

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).

- **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 undertaken 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 CO₂), 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 CO₂ 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, it 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 CO₂ 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 through 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 on 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 includes 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.

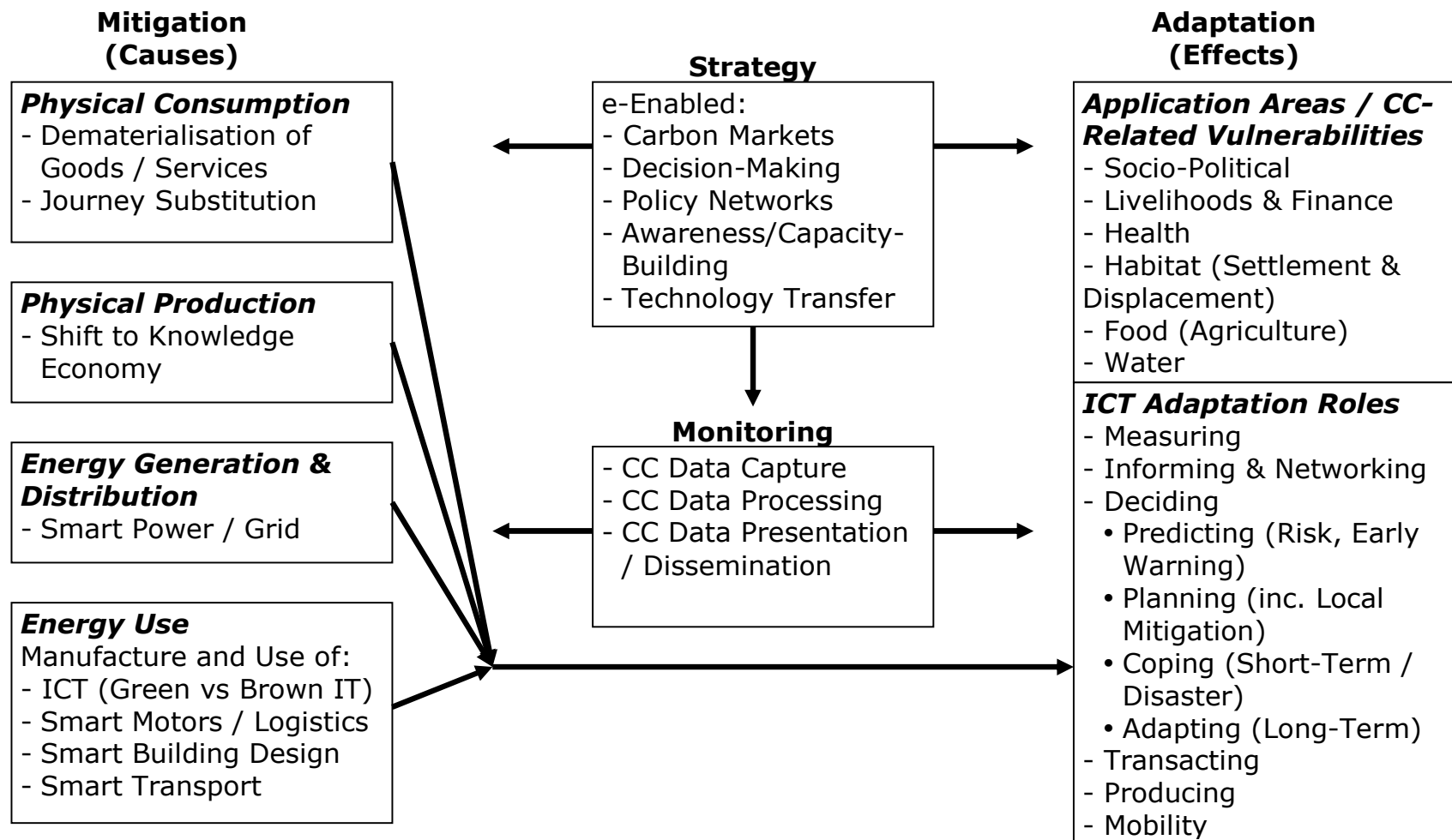


Figure 2: Overview Model on ICTs, Climate Change and Development

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.

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.

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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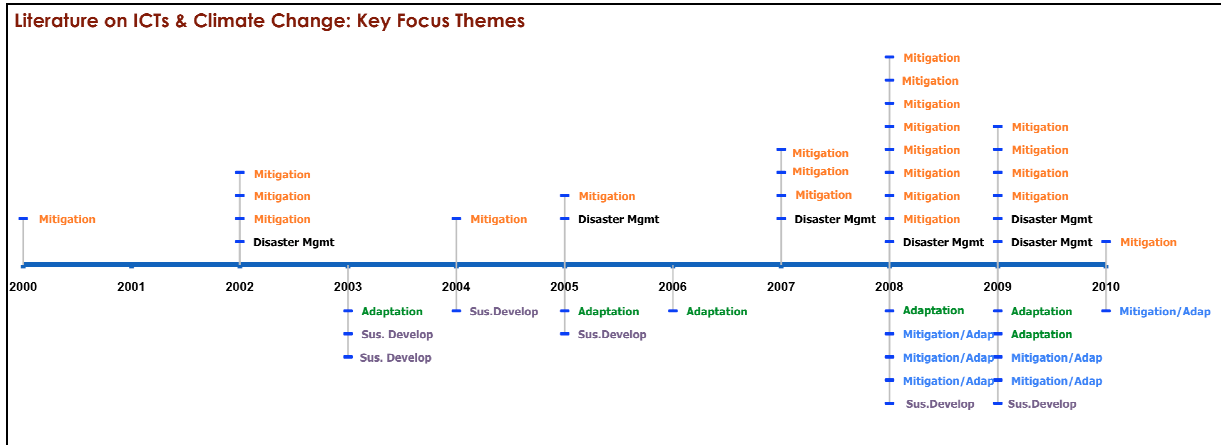
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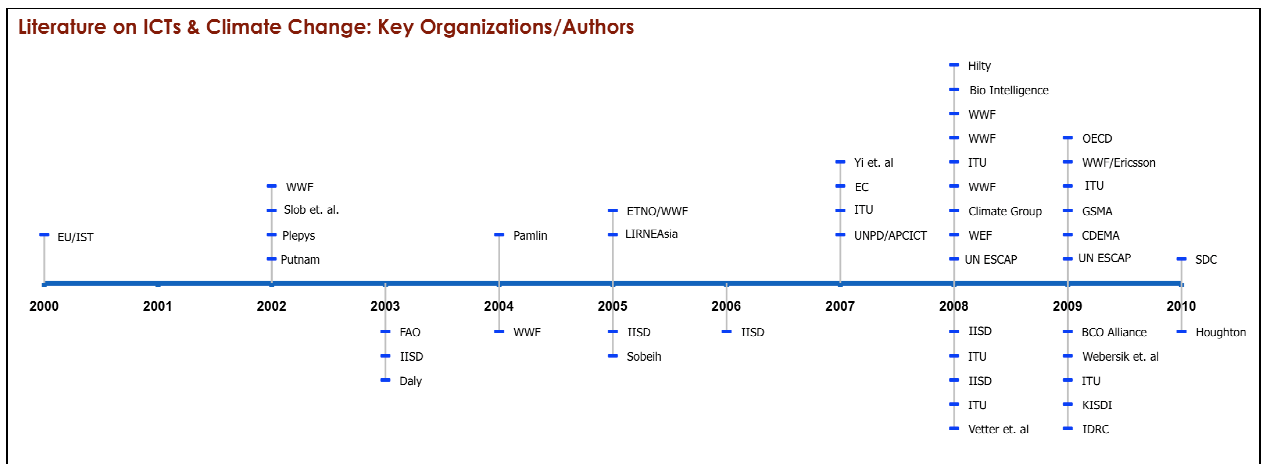
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ANNEX 1. Emergence of Literature on ICTs and Climate Change *

a) Key Focus Theme



b) Author/Organization



*Based on the categorization 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 Developing Countries: 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	Information Technology 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, L. et. al.
2007	Climate Change and ICT, European Commission
2006	Saving the Climate @ Speed of Light, ETNO & WWF
2006	Mobile Telephony as Enabler of Environmental 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, and will be updated as new publications become available. Resources have been organized <u>chronologically</u> , according to their publication year, and <u>alphabetically</u> , according to their title.				
YEAR	TITLE	AUTHOR / INSTITUTION	MAIN OBJECTIVE	AVAILABLE AT:
2010	<i>ICTs and the Environment in Developing Countries: Opportunities and Developments</i>	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. <i>*Note:</i> 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	<i>Smarter Moves: How Information Communications Technology can promote Sustainable Mobility</i>	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	<i>Achieving Environmental Sustainability and Growth in Africa: the Role of Science, Technology and Innovation.</i>	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	<i>JOURNAL ARTICLE</i>

			role of science and innovation, including ICTs, in addressing sustainability challenges.	
2009	<i>A five-step Plan for Low Carbon Urban Development</i>	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	<i>E-Environment Toolkit and Readiness Index (EERI)</i>	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	<i>Enhancing the effectiveness of ICT applications for disaster management</i>	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	<i>ICTs, the Environment and Climate Change, High-level OECD</i>	Organisation for Economic Co-operation and Development	The document presents the main outcomes of the OECD High level	http://www.oecd.org/dataoecd/49/59/44149232.pdf

	Conference: 27-28 May 2009	(OECD)	meeting held 27-28 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. The theme of "Green ICTs" was discussed in the context of the economic crisis and the role of innovation for green growth.	
2009	<i>ICTs and Climate Change, ITU Background Report: Symposium on ICTs and Climate Change. Quito, Ecuador, 8-10 July 2009</i>	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 climate change.	http://www.itu.int/dms_pub/itu-oth/06/0F/T060F00600C0004PDFE.pdf
2009	<i>ICT World Today</i>	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	<i>Issues and Challenges of Climate Change for Women Farmers in the Caribbean: The potential of ICTs</i>	Nidhi Tandon. Commissioned by the International Development Research Centre (IDRC)	The objective of this concept paper is to identify and analyze the potential that ICT can offer to women farmers of the Caribbean region, in order to better to prepare for, adapt to and manage climate change.	http://www.networkedintelligence.com/Issues_Challenges_of_Climate_Change_for_Women_Farmers_in_the_Caribbean.pdf
2009	<i>Mobile's Green Manifesto</i>	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	http://www.gsmworld.com/documents/mobiles_green_manifesto_11_09.pdf

			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.	
2009	<i>Planting the Knowledge Seed: Adapting to Climate Change using ICTs</i>	Patrick Kalas & Alan Finlay, Commissioned by Building Communication Opportunities (BCO) Alliance	The report explores the role of ICTs (i.e. radios, mobile phones, personal computers, the internet and interactive media) 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	<i>Policy Brief on ICT Applications in Knowledge Economy</i>	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	<i>From Fossil to Future with Innovative ICT Solutions</i>	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	<i>ICTs for e-Environment: Guidelines for Developing Countries with a Focus on Climate Change</i>	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	http://www.itu.int/ITU-D/cyb/app/docs/itu-icts-for-e-environment.pdf

			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.	
2008	<i>ICTs, Adaptation to Climate Change, and Sustainable Development at the Edges</i>	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	<i>ICTs, Innovation and the Challenge of Climate Change.</i>	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) 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.	http://www.iisd.org/publications/pub.aspx?no=973
2008	<i>ICTs and Climate Change: ITU Background Report.</i>	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-oth/06/0F/T060F0000070001PDFE.pdf

2008	<i>ICT-enabled disaster risk reduction in Asia & the Pacific</i>	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	<i>Information Technology and Sustainability: Essays on the Relationship between Information Technology and Sustainable Development</i>	Hilty, Lorenz M.	This book presents a compilation of essays on various topics related to the role of IT and environmental sustainability.	<i>BOOK</i>
2008	<i>Impacts of Information and Communication Technologies on Energy Efficiency.</i>	Bio-Intelligence (European Commission DG INFSO)	This study examines the impacts of ICT on the energy 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	<i>ITU and Climate Change</i>	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 identifies areas of ICT potential in monitoring, mitigation and adaptation efforts.	http://www.itu.int/themes/climate/docs/report/index.html
2008	<i>Outline for the first global IT strategy for CO2 reductions</i>	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	<i>SMART 2020: Enabling the low-carbon economy in the information age.</i>	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	<i>The Contribution of ICT to Climate Change Mitigation</i>	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	<i>The ICT Sector and the Global Connectivity System: A Sustainable Development Overview</i>	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	<i>The Potential global CO2 Reductions from ICT use</i>	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	<i>Climate Change and ICT: An environment of change.</i>	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/policy_report/INF%207%200100%20IST-R%20policy%20report-forweb.pdf
2007	<i>A review of research on the environmental impact of e-business and ICT</i>	Lan, Y. & Hywel R, T. In: <i>Environment International</i> , 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.	<i>JOURNAL ARTICLE</i>
2007	<i>ICTs and Climate Change</i>	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	<i>Mobile Telephony as an Enabler of Environmental Action in the Philippines</i>	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	<i>Geographic Information Systems (GIS) in Egypt</i>	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.	<i>BOOK CHAPTER</i> <i>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</i>
2005	<i>Saving the Climate @ the Speed of Light: First roadmap for reduced CO2 emissions in the EU and beyond.</i>	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	<i>Tsunami lessons, LIRNEAsia</i>	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	<i>Using ICTs for Poverty Reduction and Environmental Protection in Kenya: The "M-vironment" Approach.</i>	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	<i>IT and Sustainable Development</i>	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	http://assets.panda.org/downloads/itsustainabledev.pdf

			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.	
2003	<i>Communication and Natural Resource Management</i>	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 community-based action and the potential of ICT tools in the management of natural resources.	http://omec.uab.cat/Documentos/11.pdf
2003	<i>ICTs and Ensuring Environmental Sustainability</i>	Daly, John. In: <i>The Digital Pulse: Current and Future applications of ICTs for Developmental Health Priorities.</i> 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	<i>The Information Society and Sustainable Development</i>	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	<i>By Choice or by Chance: How the Internet is used to prepare for, manage, and share information about emergencies.</i>	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/issue711/putnam/
2002	<i>Sustainability @ the Speed of Light</i>	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	<i>The contribution of ICTs to the transition towards a climate-neutral society.</i>	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.	<i>BOOK CHAPTER</i> 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	<i>The Grey Side of ICT</i>	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.	<i>JOURNAL ARTICLE</i> <i>Environmental Impact Assessment Review</i> , 22(5)

2000	<i>The Knowledge Economy and Climate Change: An Overview of New Opportunities</i>	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	<i>Deep information: The role of Information Policy in Environmental Sustainability</i>	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.	<i>BOOK</i>

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* behavior. *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 resource 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 specific 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, loss of livelihoods and services, social and economic disruption, or environmental damage. Examples of technological hazards include industrial pollution, nuclear radiation, toxic wastes, dam failures, transport accidents, factory explosions, fires, and chemical spills. Technological hazards also may arise directly as a result of the impacts of a natural hazard event. Source: UNISDR, *Terminology: Basic terms of disaster risk reduction.*

Uncertainty: An expression of the degree to which a value (e.g., the future state of the *climate system*) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain *projections* of human behaviour. Source: *Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

United Nations Framework Convention on Climate Change (UNFCCC): The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It contains commitments for all Parties. Under the Convention, Parties included in Annex I (all OECD countries and countries with economies in transition) aim to return *greenhouse gas* emissions not controlled by the *Montreal Protocol* to 1990 levels by the year 2000. The convention entered in force in March 1994. Source: *Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Urban heat island (UHI): The relative warmth of a city compared with surrounding rural areas, associated with changes in runoff, the *concrete jungle* effects on heat retention, changes in surface *albedo*, changes in pollution and *aerosols*, and so on. Source: *Intergovernmental Panel on Climate Change (IPCC), 2007 Report, Glossary.*

Urban sprawl: Is a phenomenon that plagues cities in both developing and industrial countries. It is an uncontrolled or unplanned extension of urban areas into the countryside that tends to result in an inefficient and wasteful use of land and its associated natural resources. Source: *Stockholm Resilience Centre,*

Vulnerability: Refers to the propensity of social and ecological system to suffer harm from exposure to external stresses and shocks. Research on vulnerability can, for example, assess how large the risk is that people and ecosystems will be affected by climate changes and how sensitive they will be to such changes. Vulnerability is often denoted the antonym of resilience. *Source: Stockholm Resilience Centre, Stockholm University*

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