Information and communication technologies (ICTs) and climate change adaptation and mitigation:

The case of Ghana

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Additional information and materials relating to this report can be found at:
www.itu.int/itu-t/climatechange.

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Towards a better environment: The Minister of Communications' perspective

Information and Communication Technologies (ICTs) are playing an increasing role in our society. From the local to the global level, ICTs have permeated all areas that pertain to socio-economic development, and are enabling the development of new skills, competitiveness and growth, particularly in developing nations.

The capacity of ICT to mitigate the harmful effects of climate change imposes a responsibility of policy makers, and indeed all stakeholders of the Information Society, to promote the technology as an effective tool to combat climate change.

In Ghana, the development of the ICT4AD policy, and provision of congenial enabling environment has contributed to massive ICT infrastructure investments and availability of broadband for national development.

The Ministry of Communications is undertaking a review of the ICT Policy to introduce an all-encompassing focus on ICTs, the Environment and climate change in response to global trends. The development of an e-Waste Policy will seek to avert the problem of inappropriate dumping of electronic waste.

The interest in integrating ICTs within climate change strategies responds to the Government's vision and commitment with innovation, and has been a collaborative endeavor among the many stakeholders and committed institutions.

As this report recognizes, tackling the informative, the productive and the transformative potential of ICT tools, it can help Ghana, as well as other developing countries, to better adapt to the challenges posed by climate change.

It is our hope that the experience that Ghana has gathered in this field can serve as fertile ground to foster further innovation and coordination of efforts among government, private and civil society stakeholders, in order to fulfill the potential that ICTs offer towards climate change adaptation, and ultimately, towards a more resilient future.

Haruna Iddrisu

Minister of Communications, Republic of Ghana

Towards a better environment: The Minister of Environment, Science and Technology's perspective

Ghana like other developing countries is vulnerable to the adverse effects resulting from the continuous alteration of climate and weather patterns. From changes in temperature and seasonality, to the occurrence of more frequent and intense weather-related events, our country is facing unprecedented challenges that can hinder our development efforts.

The magnitude of these impacts requires the adoption of novel approaches that would allow us to withstand, recover and adapt to change. Within this context, the achievement of sound environmental stewardship, natural resource management and sustainability is imperative.

The Ministry of Environment, Science and Technology is pursuing the development of a strategic and coordinated direction in the country's efforts at addressing climate change, including the creation of a National Climate Change Committee, and a national framework that ensures harmonized responses and initiatives. The use of Information and Communication Technologies (ICTs) is an important component of this process.

At the core of the Ministry's mandate is the application of innovative technologies for socio-economic development in the critical areas of agriculture, industry, health and environment. We have recognized that the effective use of ICTs can enable each of these areas to better adapt to the impacts of climate change and variability, while supporting our progress towards sustainable development.

The unprecedented climatic challenges that we are facing require that we continue to work in close collaboration with specialized agencies, Ministries and institutions, both locally and internationally, in order to promote the use of ICTs as a catalyst for change and adaptation.

By focusing on the potential of ICTs to strengthen long-term adaptation strategies, decision-making processes, raising awareness, capacity building and participation, among other areas described in this report, Ghana can be in a better position to respond, overcome and adapt to the effects of climate change and uncertainty.

Sherry Ayittey

Minister of Environment, Science and Technology, Republic of Ghana

Towards a better environment: An EPA perspective of the role of ICT

The most sensitive sectors of the Ghanaian economy such as fresh water, agriculture, forestry, energy production, health and internal security, are threatened by climate change. How climate change is addressed today will have a direct bearing on future human development prospects.

The Environmental Protection Agency (EPA) is an implementing agency, a regulatory body, and a catalyst for change towards sound environmental stewardship. In the EPA, it is recognized that climate change can have such a fundamental effect on the environment that action must be taken on two fronts. First, climate change must be minimised by drastically reducing global greenhouse gas emissions, avoiding future emissions and ensuring that carbon sinks, such as the rainforest, are preserved. The second front for action is adaptation to the effects of climate change.

It is currently estimated that the ICT sector contributes approximately 2 to 2.5 per cent of global greenhouse gas emissions, and this is likely to increase as ICTs become more widely available. Due to the potential for the ICT industry to dramatically decrease the GHG emissions in nearly every other sector, as well as providing access to information, the challenge addressed in this report is how to make ICTs available to the whole population in Ghana without having an adverse impact on climate by adding to carbon dioxide emissions.

If emissions are not capped in the ICT and other industry sectors, Ghana will become a significant emitter of carbon dioxide along with the developed countries. By focusing on the lowest power ICT solutions, as described in this report (which focuses specifically on developing countries) the evolution path for Ghana will be on a much lower emissions trajectory, saving energy cost and minimizing emissions.

Daniel Amlalo

Acting Executive Director, Environmental Protection Agency, Republic of Ghana

Towards a better environment: An ITU perspective

The International Telecommunication Union (ITU) is the specialized agency of the United Nations responsible for information and communication technologies (ICTs). Its membership, comprising 193 governments, over 700 private companies and 40 academic institutions, has called for ITU to take the lead in engaging the global community (including countries, the UN system and the ICT industry, as well as academia and NGOs) to address climate change through the use of ICTs.

Today, a world without ICTs is unthinkable. ICTs are integrated into almost every part of the world society and economy. Yet, while the increasingly widespread use of ICTs has changed people's lives dramatically and boosted economic growth, ICTs themselves, due to this success, are a growing contributor to greenhouse gas emissions. On the other hand, they probably provide the most significant opportunity to reduce greenhouse gas emissions in the major high emission industries of energy generation, waste disposal, building and transport. This is a message we must carry to the Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC).

We are committed to working in partnership with other organizations to contribute to the fight against climate change by reducing GHG emissions. We will also help communities, countries and regions to be better prepared to cope with any unavoidable effects of climate change.

This report came about as a follow-up to the Sixth Symposium on ICTs, the Environment and Climate Change, held on 7-8 July 2011 in Ghana. It has been jointly commissioned for the ITU and key stakeholders in Ghana, including the Ministry of Communications, the Ministry of Environment, Science and Technology, and the Environmental Protection Agency in cooperation with UNFCCC. The actions, if followed up, would reduce emissions and educate local communities in ways to promote adaptation to climate change.

Whilst this report focuses on Ghana, many of its principles and findings are applicable throughout Africa and beyond. The ITU would be happy to advise other nations or regional organizations on ways to promote capacity building via ICTs, tailor them to minimize their environmental impact and use them to reduce emissions in other sectors of industry. With its worldwide membership, ITU is well placed to provide internationally agreed standards and policies that governments can apply to tackle climate change.

Malcolm Johnson

Director, ITU Telecommunication Standardization Bureau

Towards a better environment: An UNFCCC perspective

The first industrial revolution shook the very foundations of society, driven by new, fossil fuel technologies. Over the past 20 years, a new revolution in information and communication has again changed the way in which people live and work. But now, yet another revolution is required. This time, we need a revolution in clean energy that will take the world away from the worst impacts of human – generated climate change.

Fortunately, this great explosion in information and communication technology (ICT) came first, giving us essential new tools and methods that will now greatly contribute towards the transformation of the global economy, helping people live and work in far more sustainable ways. This needs to happen both by helping to speed up the reduction of greenhouse gas emissions worldwide and by helping societies adapt to the inevitable effects of climate change.

The guiding principles and pathways for effective global action on climate change are already firmly established. The nations of the world formally agreed in Cancun, in 2010, to stay below a maximum two degrees Celsius rise in average global temperature, and to consider a maximum rise of 1.5 degrees Celsius should the emerging scientific facts require it. This means a clear departure from a business as usual emissions trajectory. They also agreed to support developing countries with climate finance and technology to help them build their own clean energy and climate-resilient futures. In Durban last year, governments drew up a blueprint for a new global climate change agreement, to take effect from 2020. They also acknowledged that current levels of ambition to tackle climate change need to be urgently raised before 2020.

The global policy framework is in place but not yet mature. However, no one can afford to wait for international policy perfection. Indeed, it is the continued bold and accelerated action at all levels of government, business and society which, in the end, will create the political and economic conditions for the full global plan to come to fruition. Momentum for change is building and many countries have designed their own ambitious climate change legislation and strategies, or are in the process of putting their own policies in place.

Ghana is an example of a country currently developing smart climate change policies, whilst working intensely with multilateral institutions and with the private sector to respond to climate change. And it is an example of a country that is both pioneering smart ICT applications and integrating clever ICT solutions into its climate policies. Good examples outlined in this report are the concepts of using ICTs to inform farmers about shifting meteorological conditions and of deploying ICTs for the purposes of e-Learning and e-Governance, through which citizens can acquire the know-how to become more climate-resilient.

I believe this study can be an inspiration for all those striving to tackle climate change in developing countries – policy makers, investors and researchers alike. This publication shows what is possible if all players put their minds to developing and deploying advanced technological solutions, whilst fully grasping the opportunities of national and international cooperation. I thank the ITU for its valuable contributions and support, and the government of Ghana for its leadership and initiative.

Christiana Figueres

Executive Secretary, United Nations Framework Convention on Climate Change

Introduction

Climate change has become one of the major challenges faced at the global level. The impact of more frequent and intense climatic events and long-term changes in the environment can significantly hinder the development efforts of vulnerable developing countries, causing devastating effects on fragile ecosystems, agricultural livelihoods, food and water security, human settlements and infrastructure, among many other areas that are crucial for economic growth and well-being.

But while the impacts of climate change are posing unprecedented challenges, they can also offer unprecedented opportunities for the achievement of sustainable growth and resilient development.

As this report suggests, Information and Communication Technologies (ICTs) can help developing countries to unlock those opportunities, and overcome the challenges posed by climate change through e-enabled adaptation and mitigation responses.

This report focuses on exploring an increasingly important question: '*How can developing countries effectively integrate ICT tools within climate change adaptation and mitigation strategies*?'

The contribution of this report is two-fold. It presents the potential of ICTs towards adaptation and mitigation through the concrete case of Ghana, illustrating the challenges and opportunities faced by developing countries in this field. The report complements this analysis by offering concrete lessons learned and practical suggestions aimed at developing country decision makers and practitioners, thus fostering the adoption of novel, ICT-supported approaches to climate change adaptation and mitigation.

This document is composed of two reports that present complementary views on the challenges and opportunities posed by climate change to developing countries in the fields of adaptation and mitigation.

The first report explores the integration of ICTs into national climate change adaptation strategies, based on the case of Ghana. The analysis identifies the main areas of climate change vulnerability faced by developing countries such as Ghana, as well as the adaptation strategies and actions that are being adopted in the field.

The report highlights the importance of adopting ICT-enabled responses to better withstand, recover and adjust to current and future climatic impacts, and identifies the role and potential of ICT tools as part of local, sectoral, national and international adaptation strategies.

The adaptation report concludes by identifying key areas for action towards the integration of ICTs and climate change adaptation in developing countries, including (a) fostering coherent, flexible and long-term strategies based on content, structures and process, (b) promoting awareness raising on ICTs' current and emergent areas of potential, (c) supporting inclusive and participatory processes and structures led by trusted institutions, and (d) addressing prevailing challenges of connectivity, access and use. The analysis also provides suggestions for the ICT sector of developing countries to adapt to the changing climate.

The second report is based on the role of ICTs in climate change mitigation. After acknowledging the positive and negative consequences of ICTs in the environment, the report presents a comprehensive overview of sources of green house gas (GHG) emissions in Ghana, and identifies the ways in which the ICT sector can help reduce those emissions in multiple sectors through energy efficiency and mitigation.

The report presents concrete suggestions on how developing countries such as Ghana can expand broadband infrastructure without increasing carbon emissions, exploring the potential of mobile services, mobile infrastructure sharing, wireless and fibre-base broadband networks and next generation networks (NGN), among others. The final sections of the report explore the fundamental role played by international standards and clear targets in the delivery of energy efficiency, including the use of methodologies for assessing the environmental impact of ICTs, which are currently being developed by the International Telecommunication Union (ITU) in collaboration with forty organisations, and in line with the goals of the United Nations Framework Convention on Climate Change (UNFCCC).

The mitigation report concludes by addressing the role of policy makers and regulators in reducing GHG emissions in Ghana, integrating examples from both developed and developing countries to illustrate the importance of robust regulatory design and leadership towards e-enabled mitigation.

The suggestions provided in both reports refer to strategic actions that Ghana, as well as other developing nations, can undertake to better adapt to the impacts of climate change and reduce carbon emissions with the support of ICTs. These suggestions include the pivotal role and contribution of specialised agencies and international institutions working in the ICT and climate change field.

Information and communication are among the most critical components of effective climate change responses. The high diffusion of ICTs is increasingly translating into new approaches to cope and adapt to climatic impacts, and mitigate carbon emissions.

The report suggests that ICTs are playing an increasing role in predicting, identifying and measuring the impacts of climate change in developing contexts such as Ghana, and can be key enablers of change and adaptation in vulnerable sectors such as cocoa production, forestry and infrastructure. It also suggests that ICTs can help to reduce GHG emissions in a variety of sectors, and can contribute to make broadband infrastructure broadly available in countries such as Ghana, without adding to carbon emissions.

From innovative SMS-based early warning systems aimed at delivering more effectively weather alerts, to computer training provided to women and youth to strengthen local livelihoods, or radios used to raise awareness on sustainable practices in marginalized areas, ICTs pose unprecedented opportunities for developing countries to overcome the challenges posed by climate change.

The experience of Ghana indicates that ICTs are enabling new ways to access, use and disseminate climatic knowledge and information among a broad range of stakeholders, to coordinate efforts, and to implement new mechanisms for energy efficiency.

Ghana's experience also suggests that the capacity of developing countries to mitigate and adapt to climate change impacts relies heavily on informed decision-making processes, access to locally appropriate information, and the availability of an enabling environment (including skills, resources, standards and regulatory frameworks) necessary to translate ICT's potential into more resilient, environmentally sustainable, green-growth practices. Strong political leadership and commitment, active multi-stakeholder participation, and close collaboration among specialised national agencies and international organisations, such as the ITU and UNFCCC, play a crucial role in this process.

While challenges still remain, it is evident that ICT's potential is increasingly valuable within developing countries who are at the forefront of climatic impacts and uncertainty.

As the report evidences, developing country experiences such as Ghana's can yield valuable lessons in this field, enabling new adaptive paths and ICT-enabled approaches to overcome the challenges, and benefit from the opportunities posed by the changing climate.

By exploring the linkages between ICTs, climate change adaptation and mitigation, it is expected that this report contributes to a better understanding of ICT's role in this field.

This report is part of the activities of ITU's Telecommunication Standardization Sector (ITU-T) on ICT and Climate Change, and has been commissioned by ITU and UNFCCC in support of the United Nations General

Assembly’s resolution 65/151, which designates 2012 as the “International Year for Sustainable Energy for All”.

The report was also developed in preparation for the United Nations Conference on Sustainable Development Rio+20 held in Rio de Janeiro, Brazil on June 20-22, 2012. Thus, it is hoped that the suggestions provided in this document foster the adoption of concrete actions by developing countries towards the integration of ICTs into more sustainable development paths in line with Rio+20 goals.

Climate change adaptation and Information and Communication Technologies (ICTs):

The case of Ghana

Acknowledgements

The text of this paper was prepared by Angelica Valeria Ospina (University of Manchester) and Cristina Bueti (ITU) with support from Vivienne Caisey and Stephen Young (ICT and Climate Change).

Executive summary

The objective of the report is to illustrate the integration of Information and Communication Technologies (ICTs) into national climate change adaptation policies and strategies, based on the case of Ghana. In view of the challenges posed by climate change and uncertainty, the effective use of ICTs in climate change adaptation can play a crucial role towards sustainable development goals and improved environmental management, particularly in developing countries.

As many other developing countries, Ghana is facing significant challenges linked to the increasing intensity and frequency of climate change related events. In face of these challenges, and with a rapidly expanding ICT industry and a vibrant telecommunications sector, the country has been a pioneer in the exploration of ICTs as key tools towards the achievement of adaptation goals and international climate change commitments. As the country advances in the development of a National Climate Change Policy Framework through the Ministry of Environment, Science and Technology in coordination with the Ministry of Communications, there is an increasing need to design and implement innovative, e-enabled approaches to address the opportunities and challenges posed by climatic impacts.

Thus, the combination of policy leadership and awareness about the role and potential of ICTs in the climate change adaptation field, as well as high-level collaboration between key ICT, environmental and climate change stakeholders at the international, national and sub-national levels, have contributed to make Ghana a leading country in the emerging ICT and climate change policy field. Important lessons can be drawn from analysing the context within which ICTs and climate change converge, including guidelines that can help to strengthen similar policy processes in other developing countries.

This report is structured around four key sections. The first section provides a general background of climate change as a major global challenge, highlighting the importance of adaptive responses and the key international processes that characterize this field. The second introduces Ghana as the country of focus for this study, identifying its main areas of vulnerability to climate change impacts, as well as the overall adaptation strategy and actions that have been adopted, thus far, at the national level.

Based on this background, the third section of the report explores the integration of ICTs and climate change policies in the context of developing countries, illustrating, through the case of Ghana, potential approaches that could be considered in terms of ICT and climate change content, structures and processes. Based on the key lessons drawn from the context of Ghana, the fourth section of the report suggests a series of next steps for policy and decision makers, aimed at facilitating the integration of ICTs into climate change policies and strategies at the international, national and sectoral levels. This section also identifies suggestions for the ICT sector of developing countries to adapt to the changing climate.

The report concludes by identifying key areas for action towards the integration of ICTs and climate change adaptation in developing countries. These include (a) fostering coherent, long-term strategies based on content, structures and process, (b) promoting awareness on ICTs' current and emergent areas of potential, (c) supporting inclusive and participatory processes and structures, led by trusted institutions, as well as (d) addressing prevailing challenges of connectivity, access and use.

It is expected that the results of this report will help to illustrate the key factors that need to be considered in the design and operationalization of ICT's role in climate change policies and strategies. It is also hoped that the experience and leadership of Ghana in this field serves to inspire an increasing number of countries towards the adoption of ICT-enabled adaptation strategies to better withstand, recover and adapt to the impacts of climate change.

1. Situating climate change in the global agenda

Although the Earth's climate has experienced deep changes throughout history as part of natural processes, scientific evidence accumulated over the past decades suggests that human activity is directly affecting weather patterns across the globe, increasing the overall average temperature of our planet. This section will situate climate change as an increasingly important issue in the policy, research and development practice agendas of both developed and developing countries. The analysis will introduce a working definition of climate change and climate change adaptation, identifying the international policy domain within which climate change policies and strategies are designed and fostered.

1.1 Defining climate change

The impacts of climate change, as defined in Box 1, are being felt with increasing frequency and intensity in every corner of the planet, particularly in vulnerable developing environments. Within those contexts, the consequences of both acute (e.g. short-term extreme events, such as flooding and landslides) and chronic (e.g. long-term changes, such as variations in temperature and sea-level rise), climate change manifestations have contributed to exacerbate existing vulnerabilities, posing new barriers to the achievement of development goals.

Box 1. A Definition of climate change

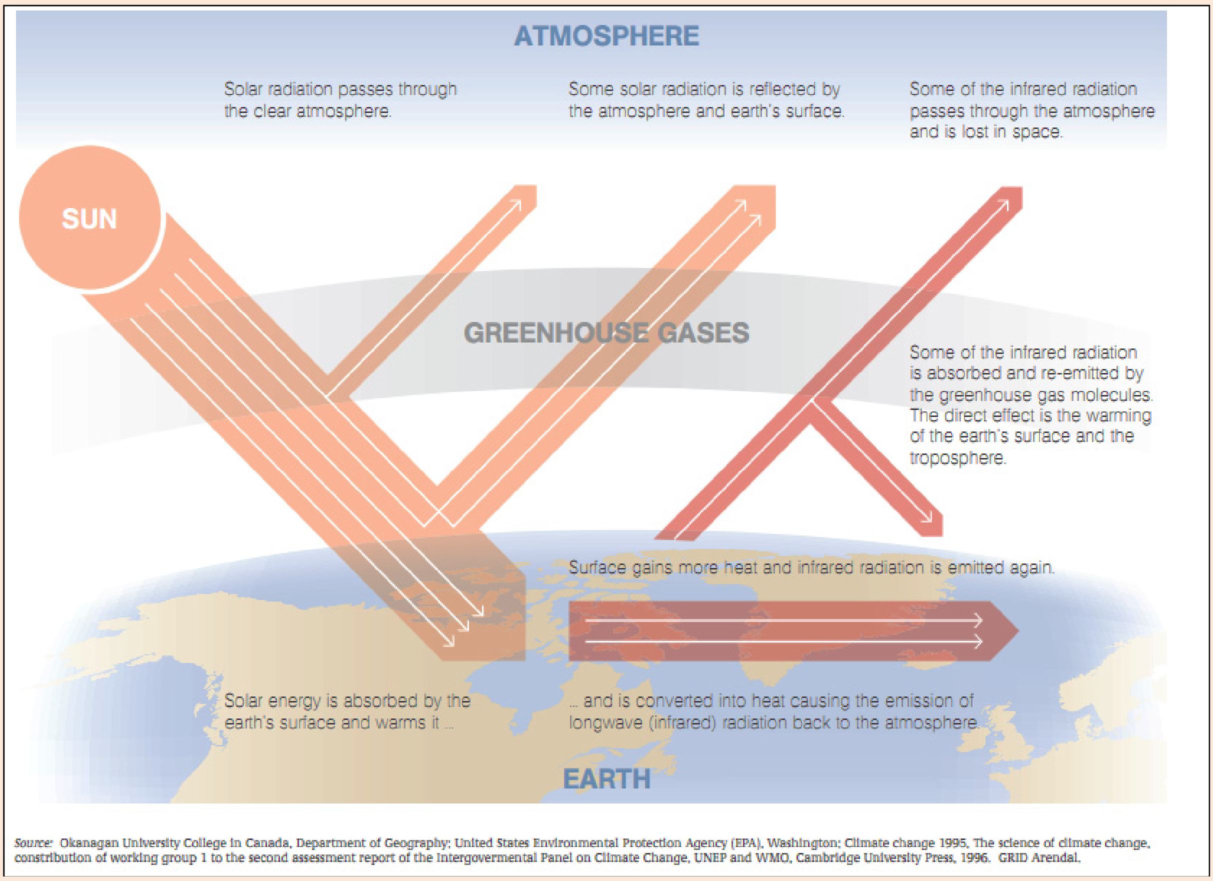
Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The Intergovernmental Panel on Climate Change (IPCC) uses a relatively broad definition of climate change that is considered to mean an identifiable and statistical change in the state of the climate that persists for an extended period of time. This change may result from internal processes within the climate system or from external processes.

These external processes (or forces) could be natural, for example volcanic eruptions, or be caused by the activities of people, for example emissions of greenhouse gases or changes in land use. Other bodies, notably the UNFCCC, make a distinction between climate change that is directly attributable to human activities and climate variability that is attributable to natural causes. For the purposes of this report, either definition may be suitable depending on the context.

Source: World Meteorological Organisation (WMO)

The main driver of climate change is the alteration of the composition of the global atmosphere, as a result of the emission of a set of gases that absorb some of the Earth's outgoing heat radiation and reradiate it back towards the surface. These heat-trapping gases are referred to as *greenhouse gases* (GHGs) (Figure 1). According to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), GHG emissions have increased by 70 per cent between 1970 and 2004[1], mainly as a result of the combustion of fossil fuels. Global climate change discussions and emerging scientific evidence indicates that, with the current patterns of economic growth, global GHG emissions will continue to increase over the next few decades.

Figure 1. Greenhouse gas effects



Source: Okanagan University College et el., 1995

In the face of a climatic future characterized by ongoing change and uncertainty, policies and strategies aimed at reducing or mitigating carbon emissions, as well as at adapting to the impacts of climate change, are gaining momentum. While both areas of action have been increasingly addressed in the international policy domain, this report focuses on the latter.

1.2. Climate change adaptation: an increasing priority

As the effects of climate change are felt with varying degrees of intensity across the globe, the need to foster actions aimed at adjusting and adapting to new climatic conditions is taking precedence in the international, national and sectoral policy agendas. Evidence from the field indicates that climatic changes such as variations in rainfall or temperature patterns are having an impact on development dimensions such as food production, local livelihoods and finance, water supply, health and disease proliferation, human habitat and migrations, among others[2], adversely affecting those countries and groups of populations that are more dependent on climate-sensitive sectors such as agriculture and natural resources. Especially vulnerable to those impacts are developing countries that possess limited resources and capacity to adapt and recover from the occurrence of climatic events. For them, climate change impacts aggravate the challenges faced in the achievement of the Millennium Development Goals (MDGs), and pose further barriers to overcoming poverty and marginalization.

Climate change adaptation (Box 2) can take the form of anticipatory or reactive, spontaneous or planned actions that are undertaken by actors in response to climatic events[3]. As climate change science predicts an increase of 2°C in the average temperature of the planet above the pre-industrial level, efforts aimed at designing and implementing strategies to moderate, cope with and take advantage of the impacts of climate change[4] are more urgent than ever before.

Box 2. A Definition of climate change adaptation

"*Adaptation to climate change can be defined as 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: Intergovernmental Panel on Climate Change (IPCC)

Adaptation measures can be planned or autonomous, and take multiple forms, ranging from strengthening local infrastructure to withstand more severe periods of precipitation and floods, improve the management of water resources to ensure sufficient supply during dry seasons, adopt more resistant seed varieties, or improve the dissemination of information as part of disaster preparedness and response programs, among others.

Ultimately, the severity of climate change impacts is closely linked to the levels of exposure and vulnerability that prevail within a given context. For the objectives of this report, adverse impacts are considered disasters when they produce widespread damage and cause severe alterations in the normal functioning of communities or societies. Thus, disaster risk management and adaptation to climate change focus on reducing exposure and vulnerability, while contributing to increase the resilience of vulnerable contexts to face the impacts of climatic events. According to the UNFCCC[5],

> *"Most methods of adaptation involve some form of technology, which in the broadest sense includes not just material and equipment but also diverse forms of knowledge. Promoting the development and diffusion of technologies, know-how, and practices for adaptation are important activities for improving and enabling adaptation to climate change"(p.36)…*adding that *"Drawing on experiences and traditional knowledge as well as modern technologies, targeted adaptive actions have been undertaken to, among other things, enhance the resilience of livelihoods and economies" (p. 41).*

Climate change adaptation is gaining momentum as an area of priority action, particularly for developing countries that are at the forefront of climate change impacts. These countries have recognized that the adoption of adaptation efforts must be intensified in order to cope with the unavoidable, yet uncertain impacts of the changing global climate. This realization has been accompanied by – and fostered through − a growing international debate at the highest policy levels, which addresses the mechanisms, measures and policies that should be in place to enable the effective adoption of adaptive actions in vulnerable contexts. Thus, positioning climate change within the international policy domain is crucial to better understand the context and levels within which national policy processes and strategies are developed.

1.3. Climate change adaptation in the international policy domain

Climate change was one of the key environmental issues discussed at the United Nations Conference on Environment and Development, held in 1992 in Rio de Janeiro, Brazil. The conference, also known as the *1992 Earth Summit*, agreed on the establishment of the *Rio Conventions*, three intrinsically linked United Nations conventions addressing the interdependent issues of biodiversity, climate change and desertification. The *United Nations Framework Convention on Climate Change (UNFCCC)* is one of them.

The UNFCCC emerged as the global response to address the challenge of climate change. The Convention aims at undertaking actions at the international, regional and national level to reduce GHG emissions (thus mitigating climate change) and to cope with temperature increase foreseen in the near future.

The ultimate objective of the Convention is to stabilize GHG concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system (*Article 2 of the Convention*[6]). With 194 States and one regional economic integration organization (the EU), the Convention enjoys near-universal membership. It entered into force on 21 March 1994, and its Secretariat is based in Bonn, Germany. As Box 3 illustrates, the UNFCCC has been linked to a number of key international climate change protocols and agreements.

Box 3. The Kyoto protocol

The Kyoto Protocol (KP) is an international agreement linked to the UNFCCC. The Protocol was adopted at the third Conference of the Parties to the Convention (COP-3), held in Kyoto, Japan, on 11 December 1997. Although the Protocol shares the objective and institutions of the Convention the major distinction between the two is that while the Convention encourages industrialized countries to stabilize greenhouse gas (GHG) emissions, the Protocol commits them to do so, establishing legally binding targets and defining three innovative market-based “flexible mechanisms” (*emissions trading, clean development mechanism and joint implementation*) to stimulate green investments and help reduce emissions in a cost-effective way.

Source: UNFCCC

In 2007, the UNFCCC produced an analysis[7] on the necessary financial resources needed to develop an effective and appropriate international response to climate change, with particular focus on the needs of developing countries. As part of this project, which was based on previous work conducted by the World Bank, Oxfam and United Nations Development Programme (UNDP), the Secretariat assessed that the investment flows that will be necessary to meet adaptation requirements could amount to USD 40-171 billion per year by 2030. According to the International Institute for Environment and Development (IIED) this estimation could be up to 3 times higher if it included other sectors not considered in the UNFCCC analysis, such as energy, manufacturing, retailing, mining or tourism, among others.

Adaptation to climate change has had a pivotal role in the UNFCCC since the establishment of the Convention[8], which requires parties to make provisions to enable adaptation, including the formulation, implementation, publishing, and updating of adaptation measures and the cooperation on adaptation. Starting from tackling the issue of funding for adaptation, discussed in 1995 at the first Conference of the Parties (COP-1), adaptation has since gained ground, marked by the *Marrakesh Accords* in 2001 (COP-7) where climate change adaptation began to be more widely seen as a prominent area for action.

The first key milestone regarding climate change adaptation within the UNFCCC was the approval in 2004 (COP-10) of the *Buenos Aires Programme of Work on Adaptation and Response Measures*[9], which set up two complimentary tracks for adaptation: the development of a structured five-year programme of work on the scientific, technical and socio-economic aspects of vulnerability and adaptation to climate change, and the improvement of information and methodologies, the implementation of concrete adaptation activities, technology transfer and capacity building. In 2006 (at COP-12), parties concluded the initial list of activities to be undertaken under the programme, which was then referred as the “*Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change*” (NWP) (Box 4).

Box 4. The Nairobi Work Programme (NWP)

The NWP was established as a five-year work programme under the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) to assist all parties, especially least developed countries (LDCs) and small island developing states (SIDS), to improve their understanding and assessment of impacts, vulnerability and adaptation to climate change and to make informed decisions on practical adaptation actions and measures to respond to climate change on a sound scientific, technical and socio-economic basis, taking into account current and future climate change and variability. The NWP provides a structured framework for knowledge sharing and collaboration among Parties and organizations.

The NWP facilitates knowledge sharing and learning and catalyzes actions by matching the identification of demand for adaptation activities with the supply of adaptation resources. On the demand side, current practice, gaps and needs are identified through workshops, meetings and official submissions of parties to the secretariat of the UNFCCC. On the supply side, NWP partners include non-governmental organizations, intergovernmental organizations, community-based organizations, the private sector, institutes and regional centers. Partners highlight actions being carried out and pledge further adaptation action in line with the goals and objectives of the NWP as well as in response to calls for action. ITU is a partner of the NWP.

Source: UNFCCC

One of the most important climate change adaptation milestones that emerged from negotiations of the Bali Action Plan under the Ad hoc Working Group on Long-Term Cooperative Action (AWG-LCA) was the establishment of the Cancun Adaptation Framework (CAF) in 2010. As part of the Cancun Agreements (COP-16), the CAF enhances action on adaptation, acknowledging the reality of climate impacts in communities and ecosystems.

Building on the achievements of this process, the Climate Change Conference of Parties held in Durban, South Africa, in November/December 2012 (COP-17) advanced towards the implementation of the CAF by agreeing on modalities, procedures and composition of a newly formed Adaptation Committee, on activities to be undertaken under the work programme on loss and damage, as well as on modalities and guidelines for the national adaptation plans[10].

Overall, the issues addressed in this section suggest that climate change adaptation requires countries and communities to improve their resilience to both short- and long-term climatic impacts through a variety of measures, resources and mechanisms. Actions aimed at providing a more accurate assessment of vulnerability dimensions, or to building more robust infrastructure, to introducing disaster relief and preparedness measures across different levels, or to improving technologies and practices in sectors such as agriculture to counter climatic uncertainty, constitute examples of adaptation actions.

While internationally agreed mechanisms such as the NWP provide UNFCCC parties with key guidelines and areas of action in regards to vulnerability, impacts and adaptation to climate change, the design and adoption of innovative strategies is crucial to strengthen adaptive capacities and overcome development challenges.

Information and knowledge play an increasingly important role within this context. The availability and accessibility to relevant data and information constitute key enablers of adaptation processes, from the assessment of climate impacts and vulnerability, to the planning and implementation of adaptation measures, and the monitoring and evaluation of adaptation actions. The increasing diffusion of Information and Communication Technologies (ICTs) such as mobile phones, radios and Internet-based applications can be effective in enabling countries to better adapt to climate change[11] (see Box 5).

ICTs provide an unprecedented opportunity to strengthen the creation, management, exchange and application of climate change information and knowledge, particularly within vulnerable developing environments that are increasingly recognising ICTs for both their productive and transformative capabilities.

Box 5. ICTs' adaptation potential

> *"ICTs in general, and radio-based remote sensors in particular, are already the main tools for environmental observation, climate monitoring and climate change prediction on a global basis. The modern disaster prediction, detection and early warning systems based on the use of ICTs are essential for saving lives and should be proliferated in developing countries. ICTs are making available vital information on the changing environment to the mass population who need information and education to help sustain basic needs such as food and water. Ideally this would be achieved through green technologies such as mobile devices and base stations powered by solar energy"*

Source: ITU-T Study Group 5 "Environment & Climate Change"

The relationship between ICTs and climate change has been explored by ITU since the publication in 2007 of the ITU-T Technology Watch report "*ICTs and Climate Change*"[12], which presents an overview of the potential role played by ICTs at different stages of the process of climate change, from contributing to global warming, to monitoring it, to mitigating its impact on the most vulnerable parts of the globe, to developing long-term solutions, both directly in the ICT sector and in other sectors like energy, transport or buildings. This report initiated a series of ITU events, publications and standardization activities[13]

ICTs' role in climate change adaptation action has also been acknowledged by international bodies such as the UNFCCC, indicating that ICT tools "*can be critical in predicting, identifying and measuring the extent of climate change; as well as in the development of effective response strategies to adapt to negative effects of climate change in sectors such as agriculture, employment, technology transfer and energy, among others*"[14].

Thus, emerging research and experiences from the field[15] suggest the potential of ICTs to strengthen processes of climate change adaptation in vulnerable contexts, highlighting the need to develop innovative policy approaches that acknowledge and build on the linkages between these tools and adaptation priorities[16].

The need for action at the policy, the research and the practice levels has been identified at several ITU International Symposiums on ICTs and climate change, organised since 2008 (Box 6).

Box 6. ICT and climate change: high level recognition

The welcome speech given by H.E. Mr. Haruna Iddrisu, Ghana's Minister of Communications, at ITU's Sixth Symposium on ICTs, the Environment and Climate Change held in Ghana, 7-8 July 2011, highlighted the potential of ICTs in the climate change field, stating that,

> "*ICT is a prerequisite for development in all its forms. Using ICT to monitor, mitigate and adapt to the negative effects of climate change remains a challenge to Africa and other developing countries as we lag behind developed countries in ICT usage and access. Mr Chairman, I will therefore urge participants at this forum to deliberate on the issue of development, deployment and the widespread use of ICT in vulnerable countries, particularly African countries so that we can benefit from using ICT in our struggle to deal with of effects of climate change to promote sustainable development*."

As identified during the Symposium held in Quito, Ecuador, in July 2009[17], "*In addition to global agreements on climate change, regional and national ICT polices could play a key role in efforts to combat climate change. Toward that end, ICT policymakers and regulators increasingly need to consider environmental impacts in developing new ICT laws, strategies and development plans*" (p. 18).

Building on the increasing acknowledgement of ICTs' potential within the climate change field, a recent report by the University of Manchester[18] highlights the need for new policies that integrate the productive, informational and transformative potential of ICTs into emerging and ongoing climate change strategies, and at the same time, that ensure articulation between ICT policies and climate change priorities towards the achievement of development goals.

In response to that need, the following sections of the report will explore the integration of ICTs and climate change adaptation policies based on the experience of Ghana, a developing country that has undertaken pioneer policy actions to advance in this emerging field.

2. Developing nations facing a changing climate: the case of Ghana

Having identified the increasing linkages that exist between climate change adaptation and ICTs, as well as the need to effectively integrate the role of these tools in climate change policies and strategies, this section focuses on presenting Ghana as the context of study.

The case of Ghana, a West African nation that has reported temperature increase of 1˚C over the past 30 years, as well as the impacts of erratic rainfall, floods and more extreme weather events[19], serves to illustrate the severity with which climatic challenges are affecting developing nations, as well as the actions taken and the resources needed to address them. Ghana's case will also help to demonstrate the potential of ICTs towards the fulfilment of adaptation goals, setting the context to draw lessons learned and suggested steps in subsequent sections of the report.

2.1 Overview of Ghana's context

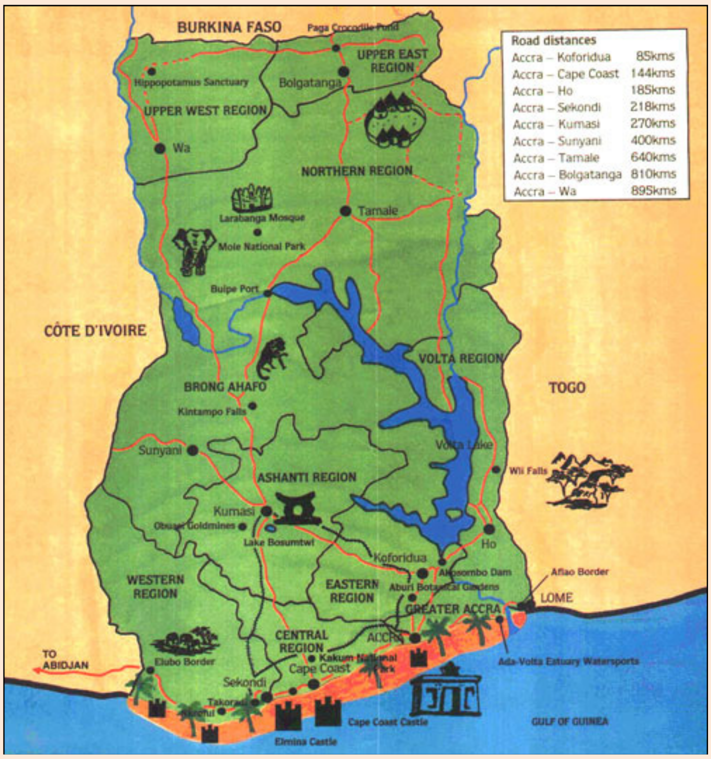
Geographic location and resources

Ghana is located in West Africa on the Guinea Coast. At latitudes of 4-12°N, the country shares borders with Togo on the East, Burkina Faso on the North, Cote d'Ivoire on the West and the Gulf of Guinea to the South (Figure 2). Ghana covers an area of 238,539 square kilometers. Extensive water bodies include Lake Volta and Bosomtwi, which occupy 3,275 square kilometers, while seasonal and perennial rivers occupy another 23,350 square kilometers.

Ghana's population is around 25.0 million[20], which is estimated to be increasing at a rate of 2.8-3.0 per cent per annum. The country is classified by the World Bank as a lower-middle-income country, with a 2010 per capita Gross National Income (GNI) per capita of USD 1,190[21].

With forested areas in 22.7 per cent of its territory[22], Ghana is endowed with abundant natural resources that have played a very important role in the agricultural, industrial, economic and social development efforts of the country. However, as a result of incessant exploitation of these natural resources to meet the legitimate socio-economic aspirations of the people, adequate care has often not been taken to guard against the depletion and mismanagement of the resources. Unsustainable development practices have caused irreparable damage resulting in deforestation, land degradation, air and water pollution, soil erosion, overgrazing, and destruction of biodiversity, among others.

Figure 2. The regions of Ghana



Source: Ghana High Commission, Ottawa[23].

Additionally, rapid population growth, increased environmental degradation, pollution of rivers, draining of wetlands and growing rainfall variability, have contributed to exacerbate pressures on water resource availability[24]. These pressures are critical considering the country's high dependence on the agricultural sector, which employs more than half of the country's work force. During the 2000-2006 periods, agriculture contributed with an average of 36 per cent to the country's GDP[25], with cocoa production being the main cash crop (responsible for approximately 25 per cent of Ghana's GDP[26]).

Successive governments and people of Ghana have come to realize that the process of democratic governance can only be guaranteed if it is based on a sound socio-economic framework that is environmentally sustainable.

Ghana's ICT sector

Developing countries are experiencing major growth in the deployment of ICTs, and Ghana is no exception. According to ITU's ICT Development Index (IDI), which combines 11 indicators on ICT access, use and skills to compare ICT development across nations, Ghana is in position number 10 out of 33 countries ranked in Africa[27].

The availability of ICT assets and skills constitute key preconditions for the fulfilment of ICTs' potential towards the achievement of development objectives and climate change adaptation goals. The availability of an appropriate ICT architecture, including skills and effective use of ICTs, can enable the implementation of applications, products and services in support of adaptive actions. Thus, a better understanding of Ghana's ICT sector is an important component in the analysis.

Ghana's mobile telecommunications sector had reached 21.2 million subscriptions at the end of 2011[28]. Coverage is extended to reach more geographical areas and user adoption continues to increase. Internet is the second ICT service with more subscribers in Ghana, used by an estimated 14 per cent of the population, followed by mobile, which is growing fast covering 23 per cent of the population with a combination of 3G and 3.5G subscriptions. Fixed-phone subscriptions, which once represented the main telecommunication network, are only available to 1.14 per cent of the population.

Table 1 presents the 2011 data for Ghana and other countries in the region.

Table 1. Take-up of ICT services in the region around Ghana ITU (2010).

	Côte d'Ivoire	Ghana	Togo	Benin	Nigeria	Burkina Faso
Population Millions	20.1	**25.0**	6.1	9.1	162.4	17.0
GDP $B	23	**32**	3.2	6.6	202	8.8
Fixed telephone %	1.33	**1.14**	3.90	1.68	0.44	0.83
Mobile cellular %	86.42	**84.78**	50.45	85.33	58.58	45.27
Mobile broadband %	0	**23.0**	0.43	0	2.83	0
Internet users %	2.20	**14.11**	3.50	3.50	28.43	3.00
Fixed broadband %	0.08	**0.25**	0.08	0.04	0.13	0.08
Households with computer %	2.00	**10.23**	3.81	2.80	9.30	2.80
Households with Internet %	1.20	**4.00**	3.0	1.80	4.60	2.40

Source: ITU World Telecommunication/ICT Indicators Database.

The rapid expansion of Ghana's ICT industry provides a fertile ground to foster and strengthen the use of ICT tools in the climate change adaptation field. This potential has been recognized by Ghana's Government. Vice-President, Mr. John Drammani Mahama, commended the Communications Ministry's decision to review the policy to cover new areas, and highlighted that the development of broadband policy is necessary to satisfy universal obligation and promote efficiency of use. In his speech, he also indicated that climate change and the environment require the development of new policies that would improve technology transfer, mitigation and adaptation.[29]

While important challenges still need to be addressed in terms of a relatively low development of advanced Internet networks and a prevailing North/South ICT divide, Ghana has advanced in the establishment of a series of ICT sector 'pillars' that could contribute to the fulfilment of ICT's potential in regard to development and climate change priorities.

Five of those key ICT sector developments are examined below, namely (a) the rapid growth in mobile penetration, (b) the increasing availability of, and falling prices for, international bandwidth, (c) the development of the Ghana Internet Exchange (GIX), (d) the launch of the new e-government telecommunications infrastructure, and (e) the deployment of the Ghanaian government's new data centre.

a) Rapid Growth in Mobile Penetration

The growth of mobile telecommunications has played a transformative role within the African continent. According to ITU, in 2011 an estimated 53 per cent of Africa's population had a mobile-cellular telephone subscription. There is a plethora of new services, applications and innovation that use this mobile technology[30].

Ghana was one of the first African countries to liberalise its telecommunications sector, which now comprises two fixed line operators and six mobile operators. Ghana Telecom and its mobile subsidiary One Touch were privatised in 2008 with Vodafone taking a 70 per cent stake. In April 2009 the company was rebranded to Vodafone Ghana. In 2009 Vodafone announced plans to invest USD700 million in the development of telecommunications infrastructure in Ghana to improve its network services[31].

Ghana's mobile telecommunications sector showed growth of 21 per cent in 2011, reaching 21.2 million mobile-cellular subscriptions. This growth is likely to continue as coverage is extended to reach more geographical areas and user adoption continues to increase. The target defined by the Ministry of Communications was to provide universal access to all communities and population groups in Ghana to telephone, Internet and Multimedia services by the year 2010[32]. This target has still to be reached and is helping to drive further growth in telecommunications services.

ITU data suggests that mobile penetration reached 84.8 per cent in 2011 compared with a fixed line penetration of 1.14 per cent. Industry sources predict that mobile penetration will rise to over 90 per cent by 2014. However, it is important to note that Dual SIM (Subscriber Identity Module) mobile phones, for which one person subscribes to more than one operator, are very popular for extending coverage while roaming, which means that the number of separate subscribers will in practice be significantly lower than the quoted percentage of the population[33].

In addition, mobile network coverage is not uniform across Ghana. Areas that lack coverage are typically those with small population centres, which cannot economically support the installation of a base station[34]. While mobile network coverage is not geographically uniform, neither is the available technology platform. Illustrating these differences, Table 2 reflects Ghana's 2G and 3G mobile network coverage in 2009 and 2010, compared with other countries of the world.

Table 2. Percentage of the population coverage by a 2G/3G network, selected countries, 2009 and 2010

	2G Population coverage (%)		3G Population coverage (%)	
	2009	2010	2009	2010
Australia	99	99	99	99
Belarus	99	100	59	67
Belgium	100	100	97	97
Brazil	97	100	55	67
Ghana	**75**	**77**	**35**	**36**
Malaysia	95	95	74	81
Qatar	100	100	95	95

Source: ITU[35]

A more detailed breakdown of the technology platform for Ghana's individual network operators is reflected in Table 3.

Table 3. Ghana network operators by technology platform (2010)

Company	Technology Platform					
	2G	2.5G	3G	3.5G	Fixed	Comment
MTN	√	√	√	√		
TiGo	√	√				
Vodafone Ghana	√	√				
AirTel	√	√	√			
Expresso	√					
Glo						3G Licence
Vodafone Ghana					√	
Zain/Airtel					√	

Source: NCA Ghana/ITU/Global Insight Telecoms Report Ghana

The data reflected in Tables 2 and 3 suggests that Ghana's mobile networks are, at present, predominantly 2nd generation GSM technology (2G), which does not provide data connectivity. This denotes a continuing requirement for voice and SMS based services and applications, and means that more advanced services and applications that rely on mobile broadband will not be capable of widespread access until 3G networks become more widely adopted.

Some of the main linkages that exist between international bandwidth, connectivity and prices are reflected in Box 7.

Box 7. Linkages between international bandwidth, better connectivity and lower prices

Prices are falling due to competition, as more service providers connect to the new submarine cables:

- Ecoband announced in late October 2010 that it had activated service on the new MainOne submarine fibre optic cable connecting Nigeria and Ghana with the Internet backbone in Europe. Ecoband offers connectivity to Internet Service Providers (ISPs) and data network operators in West Africa, from its base in Accra, Ghana. Ecoband claims that the technology deployed by the MainOne Cable Company connects Ghana to Europe with less than 100 ms RTT delay.
- The operators of the SAT3 submarine cable in Ghana have responded to the competition of MainOne with significant price reductions, according to a report in Business & Financial Times.
- The National Communication Backbone Company (NCBC) has reduced the wholesale prices by 50 per cent at which it sells international and national bandwidth capacity to ISPs, according to B&FT. NCBC, which manages SAT3 on behalf of Vodafone and the national broadband fibre-optic cable, dropped the price of an E1 (2 Mbit/s) to an ISP from USD 4,500 to USD 2,100.
- As more ISPs join the MainOne submarine cable system, market forces are likely to push down the cost of Internet connectivity in West Africa.

b) More international bandwidth for improved connectivity

Africa was largely by-passed during the "bandwidth explosion" of mid to late 1990s, when most of the deployments of new submarine cable capacity were either Transatlantic or between Europe and Asia. However, between 2009 and 2010, large parts of Africa gained access to the international fibre bandwidth for the first time via submarine cables, and more cables will begin service during 2011. As ITU notes[36],

> *"Africa has made great progress in international Internet connectivity over the 2008-2010 time period. Many African countries have doubled or tripled their international bandwidth capacity: some have witnessed a tenfold increase. If accompanied by effective policy measures that ensure competitive access to the newly available bandwidth, this increase may have a positive impact on broadband affordability – one of the major issues in the region."*

Ghana is one of the countries that are benefitting from Africa's improved access to the international submarine fibre bandwidth. Examples include the Main One cable, which came into service in July 2010; the GLO-1 in October 2010; and the WACS submarine cable in May 2011, with the ACE submarine cable scheduled to be operational during 2012. Africa's Internet and broadband sector will benefit from these developments, both in terms of availability and price of capacity[37] (Box 5).

c) Development of the Ghana internet exchange

The Ghana Internet Exchange (GIX)[38] is the facility that keeps Ghanaian Internet traffic in Ghana, allowing local ISPs and network operators to easily exchange traffic within Ghana, while improving connectivity and services for their customers.

Exchange points directly address two obstacles to ICT growth (international bandwidth costs and network latency), and thus, provide two main benefits:

- **Short-term benefits:** once ISPs are connected to the GIX, they no longer pay international bandwidth costs for local, Ghanaian traffic.
- **Long-term benefits:** once ISPs are connected to the GIX, latency or transit time of traffic is dramatically reduced, since it stays within the same network. This increased speed and reliability makes it possible to offer additional "value-added" services on the national network, including web content hosting, audio and video streaming, e-commerce, e-governance. This means that ISPs and local businesses will no longer need to go outside Ghana for advanced Internet solutions.

In Ghana, the cost of Internet bandwidth and connectivity is high compared to many other countries, and challenges related to Internet access and connectivity are still prevalent (Box 8).

Box 8. Internet access

> *"The Honourable Minister of Communications in Ghana, Mr. Haruna Iddrisu, has noted with concern the low Internet penetration figures in developing countries at a time when ICT is being used to overcome the handicaps in our development process. Giving some statistics, he said, while telephone access has reached the 75.4% mark, covering up to 17 million subscribers, the Internet access in Ghana is still low and hovering around 18% covering about 4 million people, most of whom use the mobile Internet...the Minister entreated participants to place the interests of Africa and the developing world uppermost in their considerations. "Our needs are unique, he stated. We have the challenge to provide Universal Access and develop infrastructure to reach our communities, which may not be the concern of the more endowed economies".*

Source: AfrISPA (March, 2011).

Connecting to a local or national exchange like GIX ensures that locally destined e-mails are sent at a lower cost. With the offsetting of the local traffic to the exchange point, the upgrading of international links of operators can be postponed for an additional period, saving on the International link capacity. These savings can further be extended to the operators' customers. Interconnecting to the GIX will improve uploads and higher quality of service access to local content.

d) Implementation of Ghana's e-government network

In March 2012, the National Information Technology Agency (NITA) announced that eleven Ghanaian government departments and agencies were ready to commence with e-government projects to improve service to its citizens. Plans announced include the implementation of an e-justice system, e-immigration, e-parliament, e-passport and e-Government Procurement system[39].

The nationwide e-Government infrastructure will extend the national backbone infrastructure to all districts in the country, and will provide a national data centre and a secondary data centre facility for disaster recovery capability. This network will connect all public institutions and Ministries, Departments and Agencies (MDAs) and Metropolitan, Municipal and District Assemblies (MMDAs), to a single shared communications and computing infrastructure to facilitate effective delivery of government services to citizens and businesses alike. The proposed network is configured to reach up to 1050 sites around the country covering all 170 Districts; 550 locations via wireless last mile access networks and an additional 500 locations via other means.

The target sites will be reached through several different means, including direct fibre optic connectivity, high capacity microwave links, VSAT access over the Ministry of Finance and Economic Planning (MoFEP) VSAT network and leased terrestrial circuits from local telecom and ISP providers. This will enable the network to connect the regional administrations, the regional coordinating councils, district assemblies, as well as hospitals, schools, public universities and polytechnics, police stations, the military, naval and air force barracks and any other public office or institutions in towns that are within the coverage areas of the network.

The e-Government initiative promises to deliver increased reach and access to connectivity and services across Ghana, enhancing cross-government information and communications on key issues, including those related to disaster management and climate change adaptation. Some of the key expected deliveries of the new e-Government infrastructure are reflected in Box 9.

Box 9. Ghana's proposed e-government infrastructure

The proposed network infrastructure will deliver the following:

- The network infrastructure will provide fibre optic capacity and wireless last mile connectivity over most of Accra, all the regional capitals in the country, and up to ten (10) additional municipal and district capitals that are located in close proximity to the national fibre backbone.
- The project will provide equipment for connecting up to 550 MDA facilities to the wireless last mile access network.
- The project will provide for the interconnection of all the ministries in Accra with fibre optic cable, with the core network running at 10 Gbps (Gigabits per second) and all ministries enjoying a minimum connectivity speed of a 1 Gbps with each other and to the National Data Centre.
- The network will provide a single secure gateway to internet and implement services such as access control, spam filtering, firewalls and anti-virus defences for the government network as a whole and between the individual MDAs as may be required.
- The network will also provide for the centralisation of all government voice and fax traffic within the network and directly interconnect all the existing PABX of connected MDAs and MMDAs. New IP PABX switch components will be installed at the larger MDA locations to provide voice circuit termination and forwarding facilities.
- Local area networks (LANs) in all the Ministries in Accra will be upgraded and equipped and several new LANs will be deployed in various beneficiary Assemblies and MDAs in the regions and districts. In all, a total of 6300 LAN ports will be deployed at the various beneficiary sites to support both voice and data access to the network.

Source: Government of Ghana Press Release

e) Ghana's new government data centre

The e-Government network described in the previous point will be provided with an array of e-Government applications from a new data centre. The data centre will host critical equipment, including high performance servers, fibre channel disk storage and backup storage systems, and sufficient power conditioning and availability resources to keep the data centre running with or without connection to the main electricity source.

The implementing contractor, together with support from Ghana's Information and Communications Technology Directorate (GICTeD), will be responsible for recruiting and training a team of engineers to operate, maintain and support clients on this major nationwide infrastructure for the Government of Ghana for a period of 18 months. The data centre will provide e-mail, antivirus, active directory services, document management systems and similar utility applications over time, to ensure a structured and simplified work flow between and among government offices.

Ghana's government data centre will provide scope for hosting services and applications, which in turn could provide a solid base for the development and implementation of innovative ICT applications related to climate change adaptation needs.

These five areas of ICT development suggest the emergence of an enabling ICT architecture that can serve as the basis to foster the use of ICT tools towards the achievement of Ghana's climate change adaptation goals.

To further explore the links between ICTs and adaptation in Ghana, as well as the way in which that emerging architecture can be used to strengthen adaptive capacities and resilience, the following sub-section identifies the main climate change impacts felt in the country.

2.2 Climate change impacts in Ghana

Ghana is located in one of the world's most complex climate change regions. At the intersection of three hydro-climatic zones, and subject to the impact of El Niño Southern Oscillation (ENSO), the Inter-Tropical Convergence Zone (ITCZ) and West Africa monsoon, the country is highly vulnerable to climate change, variability and uncertainty.

The increase in the frequency and intensity of rainfall, floods and landslides, along with the occurrence of extended periods of drought, intense temperatures and heat, have been linked to changing climatic patterns. Such extreme and unpredictable events have devastating consequences for Ghana's socio-economic development and food security, particularly for millions of people whose livelihoods depend on agriculture and livestock.

The intensification of extreme weather events such as excessive rainfall has led to the overflow of Ghana's major water bodies. For example, for the first time in twenty years, the level of the Akosombo Dam Reservoir, which provides electricity to Ghana and its neighbouring West African countries including Benin and Togo, rose to 274.8 ft, close to the maximum of 278 ft in 2010. Consequently, regions which have communities close to the Volta River or lying along the path of the river towards the south of the Hydro-Electric Power Generator were flooded. It is estimated that in 2010, over 377,652 people were internally displaced due to the floods, one of the most severe catastrophes that Ghana has ever had to face. The consequences were even more severe considering that some areas which were affected by the Akosombo spillage had already been hit by flood waters from the Bagre and Kompeanga dams in neighbouring Burkina Faso. According to the Volta River Authority (VRA), there are significant possibilities that the floods will reoccur if erratic rainfall patterns continue.

As in the case of other developing countries, the impacts of climate change and variability in Ghana contribute to intensify the pre-existing challenges of poverty and rural marginalization, rapid urbanization and growth of informal settlements, land depletion and fragile ecosystems, among others[40].

While the future projected changes in the climate are still uncertain, studies[41] suggest a temperature increase between 1.0 to 3.0°C by the 2060s, and 1.5 to 5.2°C by the 2090s, as well as severe changes in seasonality, among others (Box 10).

Box 10. Climate change projections in Ghana

- **Temperature**

  The mean annual temperature is projected to increase by 1.0 to 3.0°C by the 2060s, and 1.5 to 5.2°C by the 2090s. The range of projections by the 2090s under any one emissions scenario is around 1.5-2.5°C. The projected rate of warming is most rapid in the northern inland regions of Ghana than the coastal regions. All projections indicate substantial increases in the frequency of days and nights that are considered ‘hot’ in current climate, but the range of projections between different models is large.

- **Precipitation**

  Projections of mean annual rainfall averaged over the country from different models suggest a wide range of changes in precipitation for Ghana, with around half the models projecting an increase, and half projecting a decrease.

- **Other information**

  The coastal regions of Ghana may be vulnerable to sea-level rise. Sea-level rise in this region is projected to rise by the following levels by the 2090s, relative to 1980-1999 sea-level:

  - 0.13 to 0.43 m, or
  - 0.16 to 0.53 m, or
  - 18 to 0.56 m

Source: C. McSweeney, M. New and G. Lizcano (2011), UNDP Climate Change Country Profiles: Ghana
http://ncsp.undp.org/document/undp-climate-change-country-profile-11

Ultimately, the fact that Ghana is projected to “*become hotter and wetter during the wet season and drier during the dry season, with increased sea level rise and storm surges*”[42] evidences the high degree of the country’s vulnerability in both inland and coastal areas. This heightened vulnerability can be illustrated through a number of examples linked to the different geographic areas of the country, its economic sectors, vulnerable groups or resources, among others.

The following sectoral examples illustrate the complexity of the challenges posed by climate change in Ghana:

a) Agriculture and food security

Considering that approximately 70 per cent of the population depends directly or indirectly on agriculture (e.g., fisheries, crop and animal farming, etc.) as well as on the forest sector for timber and non- timber products, agriculture and food security are particularly vulnerable to climatic changes and extremes. Key economic assets such as cocoa, seed cotton, tobacco, maize, coconut and bananas, among others, are subject to shifting climatic trends and unpredictability, and thus, their affectation (in particular that of cereals that are not tolerant to drought) compromises the main source of livelihoods of the majority of Ghana’s population.

b) Water resources

Due to Ghana’s high dependency on natural resources, an increasing population growth rate and urbanization patterns, water resources are facing significant challenges with the advent of more frequent and intense climatic events. Periods of drought and flooding pose stress on the availability of water for domestic use, which in turn has been linked to the spread of diseases, negative impacts on industrial applications, hydro-electric generation, and food security.

c) Health

The deterioration of health conditions is closely linked to higher incidence of diseases that are carried in the water, food or air. According to a study commissioned by The World Bank, increased heat stress and drought-related deaths in both humans and livestock are already occurring in the extreme north of Ghana[43]. Further risks are related to the higher incidence of malaria and parasitic infections that are linked to flooding.

In spite of the existence of common sectoral challenges, it is important to note that climatic impacts are not uniform across the country, adding to the complexity of adaptation challenges. Research has identified that current climatic changes and variability have different effects on diverse ecological zones in Ghana's. Areas such as savannah, transition and coastal areas face distinctive vulnerabilities and climatic priorities, as reflected in Table 4.

Table 4. "Some prevailing climatic impacts in three ecological zones in Ghana"

Savannah	Transition	Coastal
Stormy weather and destruction	Reduced water volume	Massive erosion displacing settlements
Top soil erosion and soil infertility	Changes in rainfall patterns, affecting planting seasons	Dwindling fishing stock
Increased food insecurity and malnutrition	Water stress affecting soil fertility	Drastic reduction in the volume of water
Increasing conflicts around resources such as land	Thick forests transiting into shrubs	Severe flooding along urban cities and towns
Increased migration	Extreme heat and waterborne diseases increased	Nexus of poverty, poor infrastructure and climate impacts

Source: Yaro, J. (2010). p. 25.

These examples, among others that have been identified through recent studies in the field (including climatic effects on biodiversity and natural resources, transportation and infrastructure), indicate that climate change can significantly impair Ghana's development aspirations. Thus, efforts aimed at improving the country's capacity to withstand, recover and adjust to the effects of climate change, are being undertaken at the highest political level.

The following section presents the main policies and strategies that Ghana has implemented in the climate change adaptation field. An overview of Ghana's adaptation policies will allow situating the role and potential of ICT tools in climate change strategies, which will be the focus of subsequent sections of the report.

2.3 Climate change adaptation in Ghana

Ghana has been pro-active in the field of climate change for many years, playing a significant role in international negotiations (including hosting several international workshops and conferences in the fields of climate change adaption and mitigation).

The country ratified the UNFCCC in 1995 and the Kyoto Protocol in 2002. The articles of the UNFCCC stipulate general commitments and specific obligations that Parties must fulfil, including specific actions towards the achievement of climate change awareness raising and strategizing, mitigation and adaptation goals (Box 11).

Box 11. Examples of UNFCCC parties' commitments

- Development, updating and publishing of inventory of anthropogenic emissions by sources and removal by sinks.
- Formulation, implementation and regular updating of national programmes containing measures to mitigate or adapt to climate change.
- Promotion and cooperation in the development, application, diffusion and transfer of technologies.
- Promotion of sustainable management and enhancement of sinks and reservoirs for Greenhouse Gases.
- Mainstreaming or integrating climate change into national development.
- Promotion and cooperation in scientific technological technical, socio-economic and other research, systemic observation and development of data achieves.
- Promotion and cooperation and prompt exchange of relevant scientific, technological, technological, socio-economic and legal information.
- Promotion and cooperation in education, training and public awareness in issues relating to climate change.
- Preparation of National Communications.
- Financing, mitigation and adaptation options and other enabling activities.
- Participation in the development and periodic refinement of comparable methodologies for preparing greenhouse gas inventories and for evaluating the effective methods to limit the emissions and enhance the removal of the greenhouse gases.
- Assessment of the implementation of the Convention.

Source: UNFCCC, 1992

Pursuant to Article 4.1 (h) and Article 12 of the Convention, Ghana is to communicate to the Conference of the Parties information related to implementation of the Convention, by providing the following elements of information; namely (a) a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties; (b) a general description of steps taken or envisaged by the Party to implement the Convention; and (c) any other information that the Party considers relevant to the achievement of the objective of the Convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emission trends.

In response to this demand, an Initial National Communication (INC) to the UNFCCC was issued in 2000, followed by a Second National Communication (SNC) in 2011. These communications covered a wide range of subjects including:

- GHG emissions.
- Vulnerability and adaptation assessments for water resources, coastal zones and agriculture.
- Climate change mitigation options in the energy and forestry sectors.

These National Communications identified the clear need for Ghana to adapt to the challenges posed by climate change. Thus, there has been a raft of policy initiatives aimed at supporting this objective.

The first initiatives relating to adaptation and climate change vulnerability were started by Ghana under the *Netherlands Climate Change Study Assistance Programme*, with the support of Ghana's Environmental Protection Agency (EPA). The focus of the first phase was on sectoral vulnerability and adaptation assessment, and the programme proposed adaptation strategies to build resilience against the threats associated with climate change.

In 2003, the objective of the Netherlands Climate Assistance Programme (NCAP) was to formulate climate change policies consistent with the Ghana poverty reduction strategy, which would help the mainstreaming of these policies into regional and national development plans. The research suggested that several of Ghana's key economic areas such as coastal zones, agriculture (including fisheries, cocoa, cereals, and root crops production), and water resource sectors, as well as human health, poverty and women's livelihoods, are all affected by climate change and climate variability.

In 2009 the EPA, in conjunction with the UNEP Programme for Sub-Saharan Africa, commenced the development of Ghana's National Climate Change Adaptation Strategy (NCCAS). Published in November 2010, the stated goal of the NCCAS is *"To enhance Ghana's current and future development to climate change impacts by strengthening its adaptive capacity and building resilience of the society and ecosystems."*

The completed strategy includes a set of more detailed operational measures for adaptation. The NCCAS considers how Ghana can strategize and adapt to the impacts of climate change without compromising on immediate socio-environmental needs. The strategy is based on adopting a proactive and targeted approach, which is held to be more effective and less costly than responding reactively to climate change impacts as they occur.

The main priorities of the NCCAS are set out in 10 Adaptation Programmes, as shown in Table 5.

Table 5. NCCAS priority adaptation programme for Ghana

Item	Title of adaptation programme
1	Increasing resilience to climate change impacts: identifying and enhancing early warning systems
2	Alternative livelihoods: minimizing impacts of climate change for the poor and vulnerable
3	Enhance national capacity to adapt to climate change through improved land use management
4	Adapting to climate change through enhanced research and awareness creation
5	Development and implementation of environmental sanitation strategies to adapt to climate change
6	Managing water resources as climate change adaptation to enhance productivity and livelihoods
7	Minimizing climate change impacts on socio-economic development through agricultural diversification
8	Minimizing climate change impacts human health through improved access to healthcare
9	Demand- and supply-side measures for adapting the national energy system to impacts of climate change
10	Adaptation to climate change: sustaining livelihoods through enhanced fisheries resource management

Source: UNEP (2010)[44]

In regard to the importance of adopting a long-term policy perspective in order to implement these programmes and address adaptation goals, Ghana's NCCAS states that:

> *"Given the development challenges and threats posed by climate change and variability, Ghana needs a long-term national plan that takes these factors into account. Currently, Ghana only has a medium-term development plan covering 2010-13. The long-term plan also needs to be*

integrated into the plans of the regional coordinating councils and the district development plans to provide a coherent and integrated approach to development planning."

Thus, it is imperative that long-term planning be prioritized and undertaken, so that there is a successor to the medium-term plan mentioned above.

Ghana is currently developing a National Climate Change Committee, hosted by the Ministry of Environment, Science and Technology, which published a discussion paper titled "*Ghana Goes for Green Growth*" (GGfGG)[45] in November 2010.

In the paper, H.E. John Dramani Mahama, Vice-President of the Republic of Ghana and Chair of Ghana's Environmental and Natural Resource Advisory Council states *"We cannot allow climate change to pull us back. The only way we can go forward, developmentally, is to address its impact and to seize any opportunities it presents"*[46] .

The GGfGG paper also quotes the Honourable Sherry Ayittey, Minister of Environment, Science and Technology, as saying *"Climate change is affecting Ghana's economic output and livelihoods and is a threat to our development prospects. This is now everybody's business, and all stakeholders need to be part of the response."*

The aim of the National Climate Change Policy Framework (NCCPF), which was set out in the consultation paper, is *"to ensure a climate-resilient and climate compatible economy while achieving sustainable development and equitable low carbon economic growth for Ghana"*[47] .

Thus, the NCCPF is aimed at the fulfilment of three main objectives, namely (a) low carbon growth, (b) effective adaptation to climate change and (c) socio-economic development. The achievement of these objectives builds upon seven systemic pillars that are needed to support climate change policy. These pillars are reflected in Table 6.

Table 6: Climate change policy: supporting pillars.

Climate Change policy supporting pillars
Governance and Coordination
Capacity Building
Research and Knowledge Management
Finance
International Cooperation
Communication
Monitoring and Reporting

Source: GGfGG, 2010

There is no shortage of resources that address the need to respond to climate change in Ghana. But as the 2010 'Ghana Goes for Green Growth' report notes, *"research on climate change in Ghana is often project-driven, short-term and uncoordinated"* [48].

As a response to those challenges and in line with the Hyogo Framework for Action (HFA), the EPA and the National Disaster Management Organization (NADMO) are facilitating a series of initiatives aimed at mainstreaming climate change and disaster risk reduction in the overall development agenda. Several key Disaster Risk Reduction (DRR) initiatives have been undertaken with the aim of building the resilience of communities to disasters, as reflected in Table 7.

Table 7. Disaster risk reduction initiatives undertaken by Ghana

Initiative	DRR Actions undertaken by Ghana
Policy framework	• The government of Ghana has strengthened the Disaster Management System in the country through new legislation that will make the system more proactive. For example, the proposed new law seeks to establish a disaster management fund to manage disasters effectively and efficiently. • A National DRR Policy has been developed, validated and adopted by disaster management stakeholders. The purpose of the policy is to ensure that all public institutions and non-governmental institutions/organizations feature DRR in their individual organizational planning budgeting and operations. The policy also seeks to enjoin the local Government to take ownership of DRR and support such programmes and issues by means of budgetary allocation bylaws, and the incorporation into development initiatives. • A draft National Environmental Policy and a National Climate Change Policy Framework have been developed integrating DRR and climate change adaptation. The National Disaster Management Organization (NADMO) and the Environmental Protection Agency (EPA) are working closely towards this direction. In 2010, programmes were carried out jointly by the two organizations to build the capacity of District Assemblies (Local Government) on DRR and climate change adaptation mainstreaming. This was done in the areas of budgeting, planning and designing of structural works, as well as implementation. • Ghana has taken steps to review the National Building Regulation and the Building Code to ensure that the issues of DRR are brought to bear on all construction projects in the country. Building Guides are also being developed to simplify construction concepts for local builders.
Platforms for Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA)	• In response to the UN's recommendation for nations to establish Platforms for DRR and climate change adaptation, the Republic of Ghana launched its National Platform in May 2006. Apart from the National Platform, the country has established Sub-National Platforms in nine out of the ten administrative regions of Ghana. The Government plans to establish district platforms in all the 170 districts in the country.
Building fender responsive culture in Disaster Risk Reduction in Ghana	• Women and children are the most affected when disaster strikes, yet they are often marginalized from decision-making processes at all levels. As an effort to sensitize and increase women's understanding of DRR, NADMO in collaboration with ABANTU for Development, with support from the United Nations Development Programme (UNDP), organized regional forums on the theme "Promoting Gender Responsiveness in Disaster Risk Management/Reduction". These Forums were organized in the ten regions of Ghana. • Further to this, fifteen of the most affected districts in the disaster prone regions of the country have been selected for sensitization in gender mainstreaming in DRR.
Strengthening early warning system in Ghana	• The Ghana Meteorological Agency has acquired Automatic Weather Stations to improve the data gathering system. Also, to improve the weather surveillance, the government is procuring radar to locate areas of severe weather and precipitation. The government has also procured seismographs for effective earthquake monitoring. • Indigenous and scientific methods are being used and promoted to step up monitoring and early warning for pest and insect infestations.
Strengthening disaster preparedness for effective response at all levels	• In order to ensure an integrated national response for disasters, the National Contingency Plan captures potential disasters such as floods, earthquakes, Pandemic Influenza (H1N1) and oil spillage. The document is used together with the National Disaster Management Plan and the National Standard Operating Procedures. Furthermore, Ghana has prepared District Disaster Management Plans for some of the most vulnerable districts in the country.

While the actions undertaken by Ghana indicate a strong political commitment with the design and implementation of strategies to address the impacts of climate change, challenges still remain. Among them are the need to improve the co-ordination and articulation of efforts between the many policy initiatives and stakeholders involved in climate change adaptation, in order to avoid duplication of efforts and ensure that the deployment of further adaptation programmes builds upon lessons learned.

The analysis conducted thus far evidences the need for developing countries like Ghana to design and adopt innovative strategies that integrate the use of ICT tools as enablers of climate change adaptation at the local, national and international levels. Based on the contextual and strategic background provided, the following section of the report focuses on the integration of ICTs and climate change in developing contexts, using the case of Ghana as an example to illustrate potential approaches, good practices and next steps in this field.

3. Integrating ICTs and climate change in developing countries: the case of Ghana

Climate change adaptation processes entail the involvement and collaboration of stakeholders at the community, the sectoral, the national and the international levels. At the same time, the access, management and dissemination of knowledge and information play a crucial role in enabling networking, learning and exchange within and across those levels. Thus, ICT tools hold significant potential as enablers of change and transformation in contexts that are vulnerable to the effects of climate change and variability. Their potential ranges from supporting local livelihoods diversification, to facilitating access to learning and capacity building on adaptive actions, strengthening decision-making processes and integrating emergent and traditional adaptation knowledge, among others, to better cope with current and future climatic stress.

From the local to the national and international levels, adaptation strategies need to be built upon multi-level synergies and articulation of efforts. This approach can be illustrated through adaptation programmes that ensure articulation and coherence between Government-level actions and local interventions, which integrate stakeholders and needs from different sectors, and that foster the use of both new and traditional knowledge to strengthen local adaptive capacities. At the same time, in order to enable effective adaptation measures, Ministries and Governments, as well as institutions and non-government organizations, must consider integrating ICTs in their climate change policies and strategies.

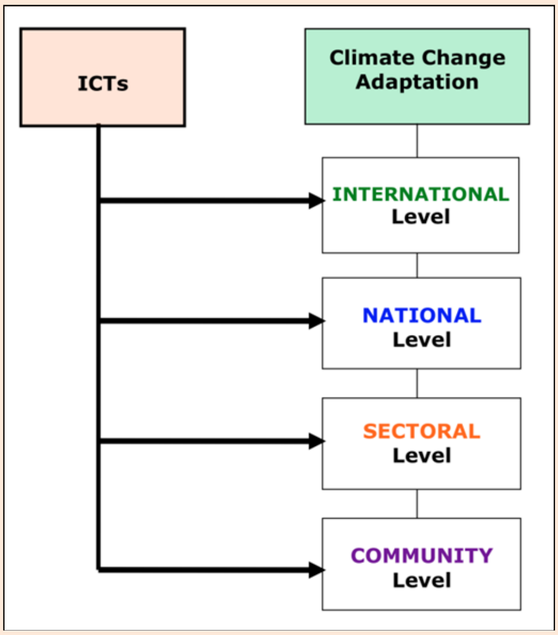
Emergent research in this field[49] suggest that wider deployment of ICT infrastructure and services will bring increased access to information, services and applications that can support adaptation to climate change. Many of these solutions do not depend on specific climate change related services and applications, but arise from innovative and unplanned use of ICT services.

According to Pant and Heeks, *"ICTs will play a crucial part in the development of climate change adaptive capacity in developing countries. They will do this in four ways: (i) by combining existing data in new ways (ii) by enabling access to new data, information and knowledge (iii) by reducing costs of access to transactions and services, and (iv) by their productive role in ICT-based enterprise"*[50] (p. 19).

As identified by sources in this field[51], the role of ICTs in climate change adaptation can be explored at four main levels: international, national, sectoral and community level, as reflected in Figure 3.

Figure 3 suggests that ICTs can assist climate change stakeholders working at the international, national, sectoral and community levels to enhance work on different aspects of technologies and know-how for adaptation, as well as on opportunities for their development, diffusion, and transfer. The use of ICTs can also assist stakeholders to integrate local and indigenous knowledge and experiences, strengthen international, national, and local-level decision-making processes on adaptation, and improve the planning, implementation and monitoring of adaptation initiatives.

Figure 3. Relation between ICTs and climate change adaptation.



Source: Bueti, C. (ITU), adapted from Ospina and Heeks (2011)

The case of Ghana provides valuable examples of the ways in which ICTs and climate change interact at these different levels, as reflected in Table 8.

Table 8. Linkages between ICTs & climate change adaptation in Ghana.

ICTs & climate change in Ghana: International level
At the **international level,** ICTs and climate change strategies gained significant momentum at the 2011 United Nations Climate Change Conference (COP17) held in Durban. At the event, a new *Coalition on ICTs and Climate Change* coordinated a series of side events aimed at raising awareness on the use of these tools as part of mitigation and adaptation strategies, highlighting the importance of coordinating actions among diverse stakeholders working in the field. Ghana's government is an active participant of the Coalition, joining efforts with the International Telecommunication Union (ITU), the Global e-Sustainability Initiative (GeSI), the UNFCCC Secretariat, the UN Global Compact, TechAmerica, and high-level representatives from the governments of South Africa and Egypt. To provide further impetus to the opportunities created by ICT in facilitating adaptation to climate change, ITU's Telecommunication Standardization Sector (ITU-T) has set up a new 'Question' (Q23) in its Study Group 5 entitled "Using ICTs to enable countries to adapt to climate change". This Question seeks to identify tools, information sources and technologies relevant to climate change adaptation, and to make this information available to local communities through the use of the internet, telecommunication networks and devices such as smart phones. Question 23 also looks at an important dimension of adaptation concerning ICTs' resilience to the effects of climate change. The efforts conducted by ITU at the international level have also looked at the potential of ICT based systems for monitoring weather and the environment worldwide. ITU conducted a survey on existing technologies and standards used by different countries in adaptation to climate change, which suggested that, while many countries have used diverse ICT technologies and tools for adaptation, best practices are not shared on a regular basis, and knowledge transfer and sharing is often lacking or fragmented. In response to those results, an ITU-T recommendation is being drafted. The first part aims at providing best practices for countries to use ICT to more effectively adapt to the effects of climate change. The second is focused on adapting the ICT sector and infrastructure to the impacts of climate change. This Recommendation will be a step towards developing an 'ICT and Climate Change Web Portal' to provide ITU Member States and Sector Members with consolidated first-hand information on existing ICT technologies that can assist them in the implementation of cost effective planning and information sharing in this field.

ICTs & climate change in Ghana: National level
At the **national level**, Ghana has demonstrated high level of political awareness about the potential of ICTs in the climate change field, which has translated into concrete actions to mobilize key stakeholders, and move forward the agenda on using ICTs to monitor climate change, mitigate and adapt to its effects. In 2011 the Ministry of Communications (MOC) of Ghana hosted the Sixth Symposium on ICTs, the Environment and Climate Change. This was the sixth symposium on climate change following successful events held between 2008 and 2010 in Kyoto, London, Quito, Seoul and Cairo[52]. The event gathered leading specialists in the field, from top policy-makers to engineers, designers, planners, government officials, regulators and standards experts, among others. The symposium in Ghana focused on the issue of ICTs, the environment and climate change in Africa and the needs of developing countries. Topics discussed included adaptation to climate change, e-waste, disaster planning, cost-effective ICT technologies, methodologies for the environmental impact assessment of ICTs, as well as challenges and opportunities in the transition to a green and resource efficient economy. The symposium concluded with a Call to Action addressing climate change as an input to the United Nations Climate Change Conference (COP17) held in Durban, and the 2012 United Nations Conference on Sustainable Development (UNCSD 2012 or Rio+20) held in Rio de Janeiro.
ICTs & climate change in Ghana: Sectoral and community levels
At the sectoral and community levels, evidence of ICT's use as part of adaptation actions is starting to emerge. Yet, further efforts are needed in order to systematise, document and analyse these experiences, particularly in regards to the role of ICTs in specific areas of vulnerability (e.g. agriculture, water management, infrastructure) that are intensified by the impacts of climate change. It is important to highlight some specific areas for ICT's potential at both the sectoral and the community levels in the context of Ghana. One of them is Ghana's cocoa sector. This sector accounts for approximately 32 per cent of Ghanaian exports, and is a key component of rural livelihoods. Much of the cocoa is grown by farmers with small farms, for whom the crop represents from 70 to 100 per cent of their annual household income. Highly sensitive to temperature and rainfall variations, cocoa is very vulnerable to the effects of climate change and variability that are affecting the country. Producers face multiple development challenges and resource constraints, and therefore, their capacity to prepare, respond and recover adequately to the effects of climatic events is limited. ICTs can play an important role in enabling more effective adaptation in the cocoa sector. ICTs such as mobile phones and radio, broadly adopted by low-income communities, can be used as part of a sector-wide strategy to disseminate appropriate technical information on efficient farming practices, drought and flood management, to build capacity on the use of resistant seed varieties, or raise awareness on local climatic conditions and future trends, among others, thus enhancing the adaptive capacity of Ghana's cocoa farmers. At the same time, cocoa farming communities can use ICT tools to strengthen networking and information sharing on new and traditional adaptive practices, as well as to access climatic and productive information in more appropriate/user friendly formats (e.g., audio and video applications).

The examples provided in Table 8 demonstrate the value of exploring the linkages between ICTs and climate change at the international, national, sectoral and community levels. As in the case of Ghana, this multi-level approach can provide a useful overview of the efforts that a country is undertaking to integrate ICTs into broader climate change strategies, while considering the actions and needs of a broad range of stakeholders (e.g., international community, national policy makers, industry sectors, local communities). Consideration of these four levels can also help to foster articulation of efforts (e.g., among international mandates, national climate change and ICT policies, sectoral strategies and civil society-/community-based initiatives) and foster a more efficient allocation of climate change adaptation resources.

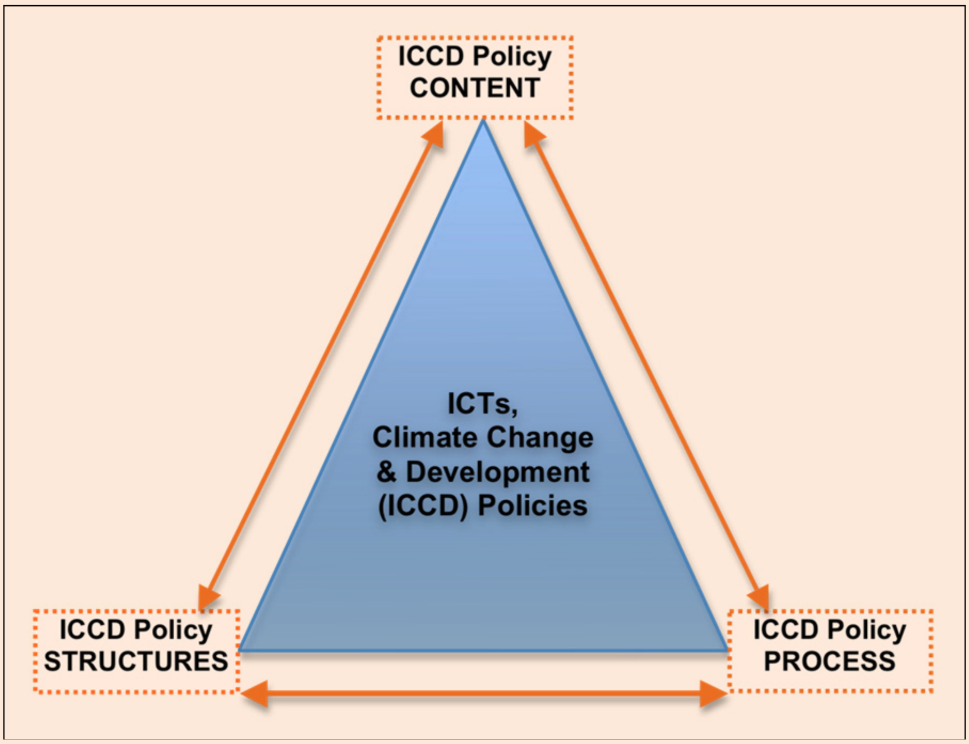
However, due to the inherent complexity of adaptation processes, policy- and decision-makers from developing countries require a more detailed set of guidelines or general framework that can facilitate the integration of ICTs and climate change adaptation strategies.

There is no single mode of adapting to the changing climate, and consequently, no single mode by which ICTs can facilitate the adaptation process. Thus, if the process of adapting to climate change is to include an explicit role for ICTs, the next question is *how should that be brought about*?

In response to this increasing need, and considering the emerging resources and outcomes of ITU's symposia and events in this field[53], it is suggested that three main components should be in place for the formulation and implementation of effective policies and strategies at the intersection of the ICTs and climate fields.

These components are: (a) content, (b) structures, and (c) processes, and are reflected in Figure 4.

Figure 4. Key components of ICT, climate change and development policies



Source: Ospina and Heeks (2012)[54]

Thus, the development of ICT and climate change *policy content*, the provision of adequate *structures*, and the implementation of *processes* constitute key areas of action for developing countries aiming at integrating the role of these tools in adaptation strategies from a systematic, holistic, long-term perspective. The following sub-sections will explore each of those components, illustrating their implications for developing countries through the case of Ghana.

3.1 Policy content

This area of action refers to the development of policy content aimed at integrating the use of ICTs in climate change adaptation strategies at the international, national, sectoral and community levels. According to Ospina and Heeks[55], in addition to the development of content that fosters the role of ICT tools in international climate change strategies, "*ICT and climate change policy content should be developed in support of national adaptation plans (across the different stages of adaptation processes), as well as in support of specific sectoral strategies (focusing on key areas affected by climate change such as water, food security, health, disasters, etc)*" p.17.

Potential approaches for the development of ICT and climate change policy content at the international, national, sectoral and community levels, are reflected in Table 9.

Table 9. ICTs and Climate Change policy content in Ghana.

<table>
<tr><th colspan="2">ICT and climate change policy content</th></tr>
<tr><td colspan="2">a) International level</td></tr>
<tr><td colspan="2">ICT and climate change content at the international level should aim at incorporating ICTs explicitly into global adaptation strategies. Content to be developed in this regard could be along the following lines:
"Develop innovative approaches to climate change adaptation through the integration of traditional and emerging ICTs, including the development of 'e-adaptation' applications that foster new mechanisms for information and knowledge sharing, capacity building, networking and collaboration towards adaptation goals" (Ospina and Heeks, 2012).</td></tr>
<tr><td colspan="2">b) National level</td></tr>
<tr><td>Key stages of adaptation processes</td><td>ICT and climate change content to strengthen adaptation processes</td></tr>
<tr><td>Informed decision making</td><td>ICTs can contribute to climate change adaptation strategies by strengthening informed decision making. ICT tools can be used to identify climate change related needs and priorities at the local, regional or national levels, and support the identification of resources and capacities available to respond to climatic opportunities and threats.
• Developing countries such as Ghana could develop policy content that fosters the use of applications such as Geographic information Systems (GIS) and meteorological information systems to understand both the current extent of climate change, but also to model future climatic impacts on agricultural productivity, health and disease, disaster incidence, etc.</td></tr>
<tr><td>Stakeholder engagement</td><td>ICTs can facilitate the inclusion of multiple voices in the design and implementation of adaptation strategies.
• Developing countries such as Ghana could develop policy content that promotes the use of ICTs (e.g., social media and online polling) to foster new forms of interaction and engagement of multiple stakeholders in the design and implementation of adaptation initiatives and crisis response.</td></tr>
<tr><td>Adaptation delivery</td><td>ICTs can support the delivery of adaptation priorities in regard to specific development vulnerabilities, sectors or issues.
• Developing countries such as Ghana could develop content aimed at fostering the use of ICTs as part of the adaptation measures adopted in vulnerable sectors such as agriculture and food security, human habitat and health, water resources, terrestrial ecosystems, marine and coastal ecosystems, and disaster management, among others.</td></tr>
<tr><td>Feedback and learning</td><td>ICTs can be used to facilitate networking, feedback and learning, across different levels, in regard to adaptation options and lessons learned.
• Developing countries such as Ghana could develop strategy content that fosters the use of ICTs for environmental observation, monitoring and networking, in order to involve users in the analysis, translation and use of climate change information.</td></tr>
<tr><td>Institutional capacity building</td><td>ICTs can be help to strengthen the capacity of institutions involved in processes of climate change adaptation, improving the availability of resources and skills needed for effective adaptation.
• Developing countries such as Ghana could develop content that promotes the use of ICTs as part of capacity-building processes, e-learning and skills-update programmes on climate change issues, as well as to foster coordination of intra-/inter-institutional actions in the adaptation field.</td></tr>
</table>

c) Sectoral and community levels
ICT and climate change content at the sectoral and community levels should foster the integration of these tools in the design and implementation of sub-regional projects and initiatives. Developing countries could develop content addressing the key vulnerabilities faced by the sectors impacted by climate change and variability, including: • **Food security:** Promote the use of ICTs to disseminate information about resistant seed varieties and planting methods, or to access agro-meteorological information to protect crops. In the case of **Ghana,** policy content should tackle the use of ICTs in support of key agricultural livelihood sources such as cocoa production and fisheries, helping to raise awareness on sustainable practices, laws and regulations, and alternative sources of income. • **Water supply:** Promote the use of ICTs to build local capacity for the conservation of water sources and more efficient water management during the production cycle. In the case of **Ghana,** policy content could tackle issues of water management during periods of extreme drought and flooding. • **Health:** Foster ICT adoption to disseminate information on prevention and treatment of new diseases triggered by climatic impacts, or in early warning systems on disease forecast and control. In the case of **Ghana,** ICTs can be used to raise awareness and prevent the spread of vector diseases, particularly malaria. ICTs can also be used to disseminate information on nutrition and health conditions linked to heat stress. • **Infrastructure:** Promote the use of ICTs to share lessons on safe building practices in areas of high risk for rural communities. In the case of **Ghana,** ICTs can be used to reduce the level of risk faced by slum dwellers, as well as in coastal and savannah zones that are exposed to frequent floods.

Source: Adapted from Ospina and Heeks (2012)

3.2 Policy structures

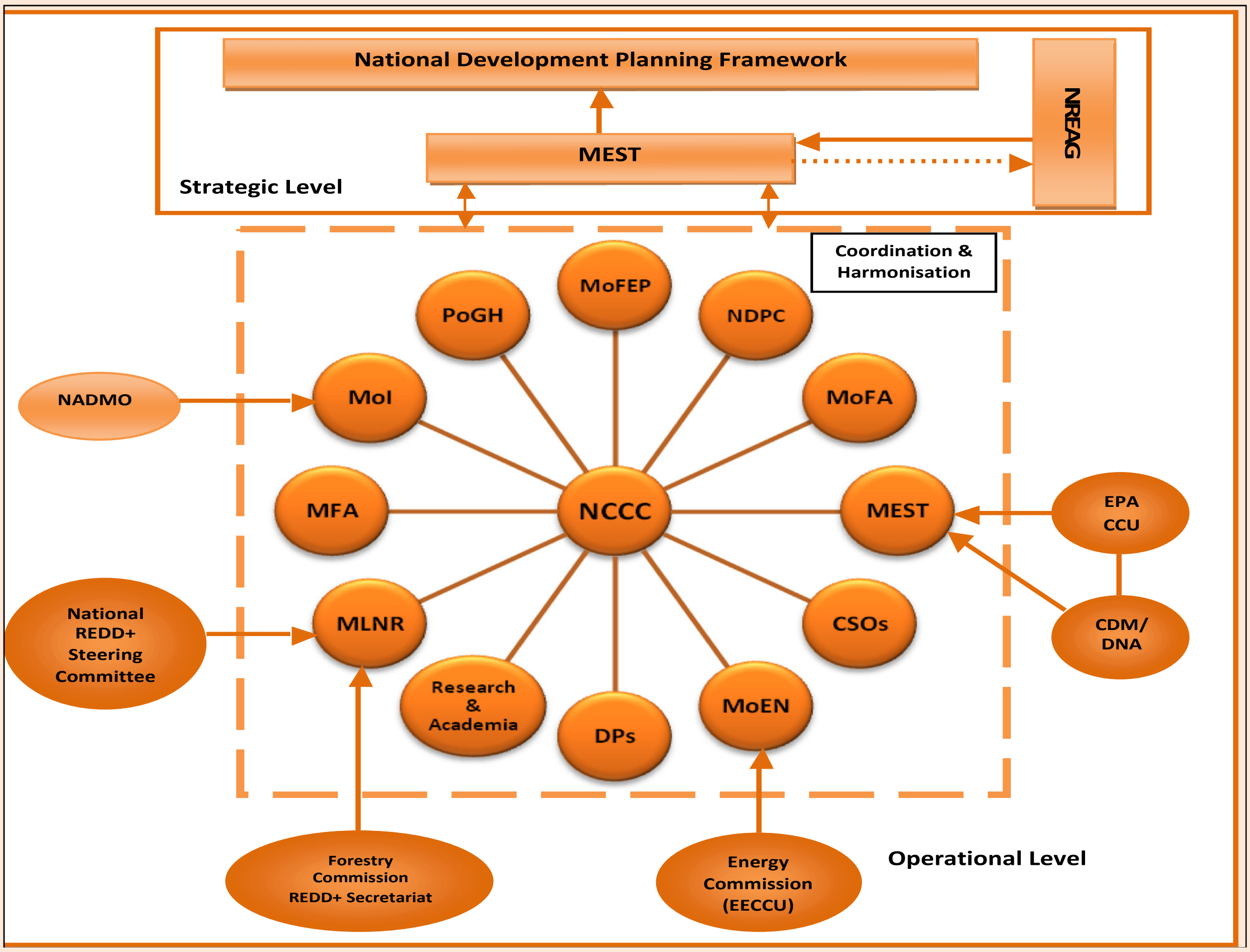
This area of action refers to the provision of effective institutional arrangements, including stakeholder capacities, roles and responsibilities, required for the integration of ICTs and climate change adaptation strategies[56]. Overall, ICT and climate change adaptation policy structures should involve stakeholders representing the State, the scientific community, the business sector and the civil society. According to Heeks[57], representativeness and relational factors play a key role in policy structures, and involve the effective participation and interaction between the different groups towards policy making, as well as the forums through which they are brought together.

Thus, effective structures for the integration of ICTs and climate change should provide cross-sectoral and inter-institutional coordination mechanisms between ICT and climate change stakeholders, at both the strategic and operational levels of the policy process[58].

Ghana is developing valuable experience in the establishment of institutional arrangements aimed at ensuring a more coherent and coordinated approach to climate change issues in the country. The Ghanaian government, through the Ministry of Environment Science and Technology and in coordination with the Ministry of Communications, is developing a National Climate Change Policy Framework (NCCPF) to provide strategic direction and co-ordinate the national framework to address issues of climate change broadly in the country. National strategies are also being targeted to enable the execution of the UNFCCC and the co-ordination and harmonization of climate change activities in the country, through the National Climate Change Committee.

Figure 5 illustrates the institutional arrangement for coordinating climate change in Ghana.

Figure 5. Ghana's climate change institutional arrangement



Key:
***NCCC** – National Climate Change Committee, **MoFeP**: Ministry of Finance and Economic Planning, **NDPC**: National Development Planning Commission, **MLNR**: Ministry of Lands and Natural Resources, **MoFA**: Ministry of Agriculture, **MEST**: Ministry of Environment, Science and Technology, **CSOs**: Civil Society Organizations; **CCU**: Climate Change Unit, **EECCU**: Energy Efficiency and Climate Change Unit, **CDM/DNA**: Clean Development Mechanism/Designated National Authority, **MoEn:** Ministry of Energy, **DPs**: Donor Partners, **MFA**: Ministry of Foreign Affairs, **PoGH**: Parliament of Ghana, **MoI**: Ministry of Interior, **NREAG**: Natural Resource and Environment Advisory Group*

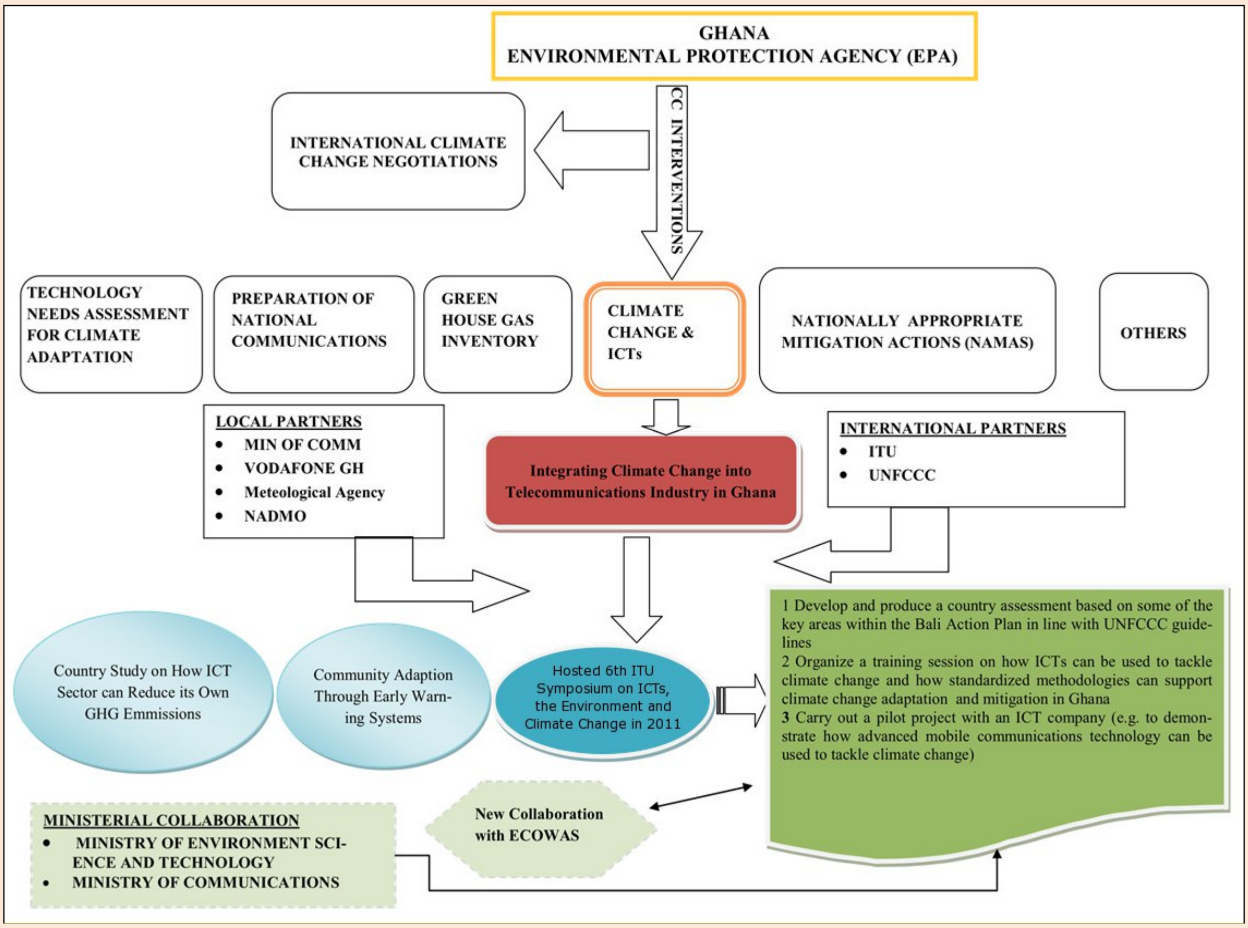
Source: Tutu Benefoh (2010).

The figure reflects the numerous stakeholders and interactions involved in the design and implementation of the Framework (reflected at the top of the figure). The strategic areas of low-carbon development, adaptation and social development are coordinated by the National Climate Change Committee (NCCC) (reflected in the centre of the figure), which has its Secretariat at the Ministry of Environment, Science and Technology (MEST) (reflected to the right of the NCCC).

Within this national level structure, issues related to ICTs and climate change are under the mandate of the Ministry of Communications and Ghana's Environmental Protection Agency (EPA), who are the national focal points for climate change in the country. The EPA works closely with frontline sector-institutions on issues related to the impact of climate change and variability on agriculture, forestry, energy, health, communications and finance, as well as on a variety of climate change programmes and initiatives[59]. The linkages between EPA's role and the NCCC Secretariat (MEST) are reflected by arrows located on the right side of Figure 5 (above).

In terms of ICT and climate change structures and multi-stakeholder interactions, examining the role and institutional interactions of Ghana's Environmental Protection Agency (EPA) and Ministry of Communications are particularly relevant. These roles and interactions are reflected in Figure 6.

Figure 6. The role of Ghana's environmental protection agency (EPA) in ICTs and climate change



Source: Asiamah, H. (2012) [60]

This structure suggests a number of key factors that need to be considered in the design of ICT and climate change structures in developing countries, including:

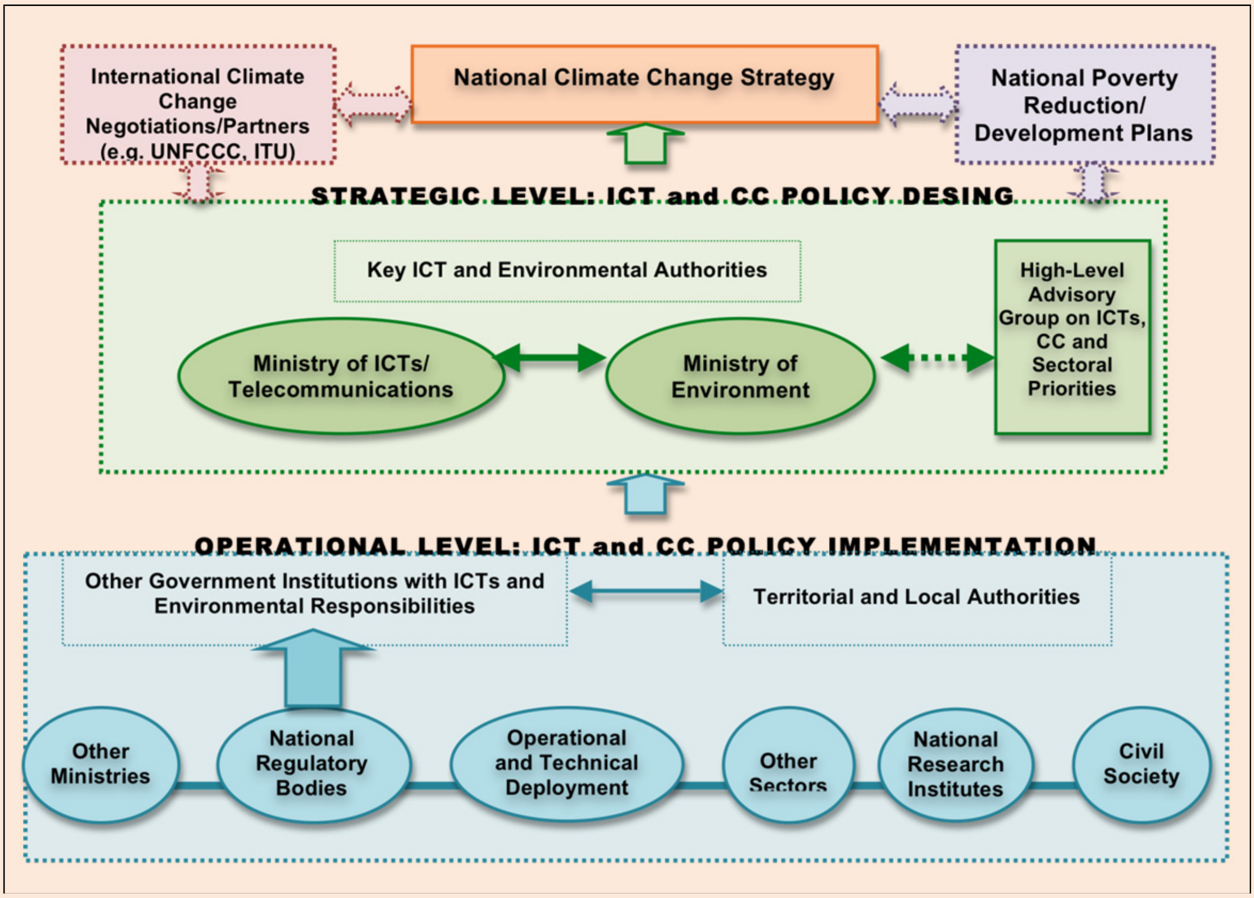
- **Multi-stakeholder collaboration:** The integration of ICTs and climate change strategies require the establishment of close linkages between a myriad of ICT and climate change stakeholders at both the national and international levels (e.g., local partners such as the Ministry of Communications, the national Meteorological Agency, the National Disaster Management Organisation, NADMO, and telecommunications sector partners, as well as International partners such as ITU and UNFCCC). This collaboration is crucial in order to build upon and leverage existing areas of expertise and technical know-how from the ICT and the climate change fields.
- **ICTs and Climate Change perspectives:** A holistic approach to ICTs and climate change needs to address both the integration of ICTs into climate change strategies, as well as the integration of climate change into telecommunications industry strategies.
- **Adaptation as a key area of action:** Ghana's approach evidences the importance of recognizing that adaptation constitutes an individual category for action (e.g., as opposed to being aggregated with mitigation goals). As a strategic area of action for developing countries, the design of ICT and adaptation strategies must be based on technology needs assessments in order to ensure that the

appropriate technologies and approaches are adopted, responding to the needs and priorities of each context.

- **Active international engagement:** The experience of Ghana also suggests the importance of an active involvement in international policy processes (e.g., international climate change negotiations, ICT and climate change conferences and events). These processes contribute to raising high-level political awareness on ICTs and climate change adaptation issues, and can act as key drivers of policy action and innovation in this field.
- **Complement policy with research and practice:** Effective ICT and climate change structures should combine policy action with research and practice (e.g. case studies, pilot projects), in order to foster the development of evidence-based data and lessons learned that can inform decision-making, as well as to identify good practices that can be used in the design of novel e-adaptation approaches and initiatives.

Building on these key factors and on Ghana's institutional arrangement experience, Figure 7 provides an example of a policy structure that can be considered by developing countries working towards the integration of ICTs and climate change policies.

Figure 7. Example of a national ICT and climate change structure



Source: Adapted from Ospina and Heeks (2012)

The institutional structure reflected in the figure distinguishes between the *strategic level* of policy design (led by the key ICT and environmental authorities in the country, supported by a high-level advisory group that integrates ICT, climate change and sectoral experts) and the *operational level* of policy implementation (where diverse stakeholders with ICT and environmental responsibilities interact towards the implementation of policy actions at the local and territorial levels).

This sample structure emphasises the importance of articulating ICT and climate change actions within broader national climate change and development strategies, as well as of ensuring coherence between national policy actions and international climate change processes, in collaboration with partners such as the UNFCCC and the ITU.

Ultimately, and regardless of the specific design of institutional arrangements adopted within a given country, ICT and climate change structures should reflect and integrate the myriad of stakeholders and issues involved in this emerging field, and should remain flexible to respond and adapt itself to emerging technologies, climatic threats and development opportunities.

3.3 Policy process

This area of action refers to the design and implementation of a coherent process to integrate ICTs and climate change adaptation, "*from the process of content development and structure design, to the actual integration of ICTs and climate change issues in policy implementation*" p. 25[61].

There are a series of key stages[62] that need to be fulfilled in the process of integrating ICTs and climate change adaptation strategies. These stages can be summarized as follows:

1. **Awareness raising and strategizing,** with a focus on the specific climatic issues, needs and priorities of the context.
2. **Problem definition**, based on vulnerability and technology assessments, conducted in collaboration with local stakeholders.
3. **Identification of ICT-enabled solutions**, with a focus on identifying ICT-enabled applications that are appropriate to the local needs and conditions.
4. **Identification and selection of policies/strategies/standards** that integrate ICTs and adaptation actions.
5. **Implementation and evaluation** of ICT and climate change policies/strategies/standards, which could be conducted by an external body.

The diversity of tasks and stakeholders involved in these processes evidence the need for flexibility, in order to adjust the process to the priorities of each context, to the impact of both expected and unexpected climatic threats, as well as to the advent of new and emerging technologies and actors working at the intersection of ICTs and climate change.

Having explored the key components and areas of action that need to be addressed by developing countries in order to integrate ICTs in climate change adaptation strategies, the following section will provide a series of suggested next steps for future actions.

4. The way forward: suggested next steps

In face of unprecedented climatic challenges and uncertainty, developing countries such as Ghana are exploring novel approaches to mitigate and adapt to the impacts of climate change. The role of ICTs is crucial for the success of such approaches, particularly in regard to adaptation. The increasing need to integrate the existent knowledge base on climate change adaptation and the potential of ICT tools in coherent policies and practices is not an easy task.

The analysis presented thus far illustrates the complexity of adaptation actions, especially in developing contexts that face multiple climatic and non-climatic stressors. At the same time, given that climate change adaptation is a multi-dimensional process, no single ICT solution can deliver all of the necessary capabilities required for adaptation in Ghana or in any other developing context[63].

This section provides a suggested framework of action to facilitate the integration of ICTs and climate change adaptation strategies by developing countries. Key entry points are drawn from the experience of Ghana, in order to illustrate how these countries could approach future actions in this field.

4.1 A framework for ICTs and adaptation policy formulation

The case of Ghana evidences the close linkages that exist between the international, the national, the sectoral and community levels in the process of integrating ICTs and climate change adaptation. Suggested actions in each of these levels include:

a) International level

Within UNFCCC, the Cancun Adaptation Framework, which resulted from negotiations on enhanced action on adaptation as part of the Bali Action Plan, established an Adaptation Committee and a Work Program which will consider approaches to loss and damage linked to climate impacts in vulnerable countries.

Ultimately, the CAF seeks to reduce vulnerability and build resilience in developing countries, taking into account the urgent and immediate needs of the most vulnerable countries. The Adaptation Committee, which will coordinate and guide adaptation action, was launched at the UNFCCC negotiations at COP-17 held in Durban, November/December 2011. Considering the operationalization of the Committee and the renewed momentum of adaptation issues, the role of ICTs as a means to rapidly communicate about extreme events and support adaptation processes should be explored and highlighted in the negotiations.

Additionally, the active engagement of developing countries such as Ghana in international efforts aimed at coordinating actions in the ICT and climate change fields (e.g., Coalition on ICTs and Climate Change) should be maintained and fostered as important ways of raising awareness, building on synergies and avoiding duplication of efforts.

b) National level

The formulation of National Adaptation Plans (NAP) or specific adaptation strategies should take into consideration several key activities aimed at ensuring a coherent approach to the use of ICT tools as part of adaptive actions.

It is suggested that ICTs can contribute to National Adaptation Plans through five main domains[64]:

(1) Informed decision-making

(2) Stakeholder engagement

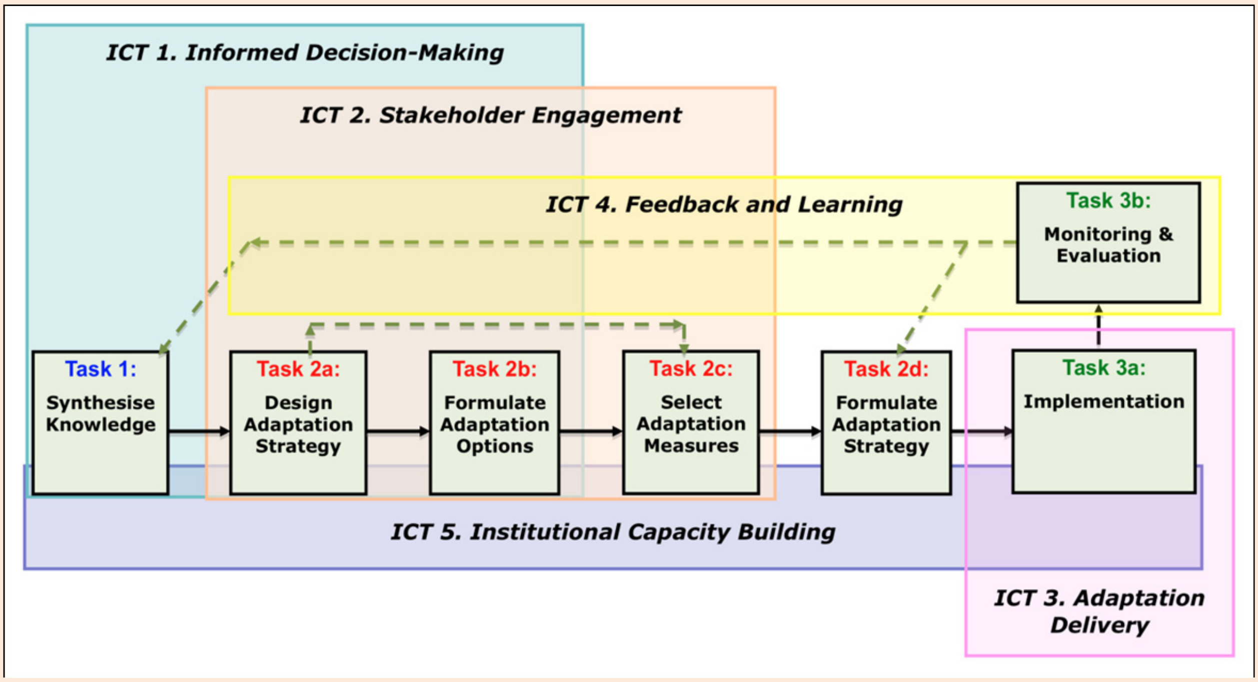
(3) Adaptation delivery

(4) Feedback and learning

(5) Institutional capacity building

Figure 8 reflects these five main areas, highlighting the potential contribution of ICTs to the overall process of formulating climate change adaptation plans.

Figure 8. ICTs and the formulation of a climate change adaptation strategy



Source: Ospina and Heeks (2011), adapted from UNDP (2004)

As reflected in the figure, the integration of ICTs in climate change adaptation strategies should be undertaken from a systemic, process-oriented, and long-term perspective. It involves the creation of content and structures that support each of the steps of the process (as explained in Section 3), and as reflected by the experience of Ghana, it involves the coordination of stakeholders from the ICT and the climate fields working at the local, the sectoral, the national and the international levels.

Ghana's experience also suggests that high-level political commitment, clear roles and responsibilities among actors, as well as the leadership of a specialized agency (e.g. Ghana's EPA) and the Ministry of Communications are key components to ensure the articulation of ICTs' role across the different stages of adaptation cycles.

Specific actions that developing countries can undertake with regards to each of these areas are reflected in Table 9.

c) Sectoral and community levels

The role of ICTs in delivery adaptation actions can be also analyzed from a sectoral perspective, by linking their potential of to the specific needs and priorities of the key sectors affected by climate change.

In developing countries such as Ghana, future actions target the needs of vulnerable sectors such as agriculture and natural resources, which constitute the main source of rural livelihoods. Examples of sectoral approaches include:

- In the case of **Ghana's cocoa sector,** the integration of ICTs should target the adaptive needs that have been identified among producers, linking a diverse set of tools (e.g., mobile phones, radio, Internet-based applications) with the need to rehabilitate and restore to sustainable production, adopt efficient farming practices, foster drought management policy through information systems that integrate changing climate conditions and patterns, and use ICTs to promote the establishment of irrigation systems in farms, including education and training.

  Towards this end, key stakeholders in Ghana should work closely with the Cocoa Research Institute of Ghana and the Ghana Cocoa Board to ensure that small farmers are able to use the relevant ICT infrastructures to access the type of services described above.

- In the case of **Ghana's forestry sector**, a report prepared by Internet Research suggests that ICTs can help to strengthen forest governance and improve information management by increasing public participation, reducing corruption and increasing incomes for the poor. Research suggests that the use of ICTs is helping to overcome traditional barriers of information generation and consumption[65].

  Towards this end, key stakeholders should foster the use of ICTs in environment advocacy campaigns and consumer awareness, to track or trace products/raw materials from point of origin to consumption to meet fair trade, legal and/or sustainable harvest criteria of consumer countries, to map the forests for better management plans and boundary monitoring, among others.

4.2. ICT sector adaptation

While the analysis conducted thus far has identified key components and suggested actions for developing countries to integrate ICTs and climate change adaptation strategies, the ICT sector also needs to adapt to the changing climate.

More intense and frequent climatic manifestations pose an obvious threat to any industry that relies on a physical infrastructure. Climate change means an increased risk of service disruption to all network infrastructures, including energy, transportation and telecommunications (and these effects are also inter-related, given, for example, the dependence of the telecommunications sector on electrical power). Climate change will likely impact the design of the networks, raising the need for more robust infrastructures, greater technical knowledge, and enhanced engineering capabilities[66].

The need for the ICT sector to adapt to climate change can be analysed from two complementary angles:

a) Direct consequences of ICTs for climate change

Many ICTs are network-based, meaning that, like other network-based sectors, they are vulnerable to the impact of climate change in general and extreme weather events in particular. This is because networks rely on physical equipment, some of which is likely to be situated in locations that are subject to climate-change induced extremes of weather. Telecommunications service providers (TSPs), as other network-based industries, may find that climate change-related weather events could result in an inability to provide services to a significant number of customers.

Telecommunication companies are significantly exposed to physical risks since extreme weather conditions could result in network damage and rising insurance costs. Network-based ICTs may have to consider protecting or relocating elements of their network that could become exposed to damage from severe weather conditions. This is particularly true in the case of remote sites, especially in developing countries, where road access to the sites is needed for access and maintenance and often for providing energy supplies.

Operators have already begun taking into consideration climate change when planning the location of new nodes for next generation networks. Wireless technologies may be seen as more resilient, and could fare better than fixed networks when climate-related events strike. As ITU has noted, "*In many cases, when* *disaster strikes the "wired" telecommunication infrastructure is significantly or completely destroyed and only radiocommunication services can be employed for disaster relief operation (especially radio amateurs and satellite systems).”*[67]

Box 12 reflects some of the actions that ITU is taking in this field, through a focus group on disaster relief systems, network resilience and recovery (FG-DR&NRR).

Box 12: ITU focus group on disaster relief systems, network resilience and recovery (FG-DR&NRR)

ITU-T Focus Group on Disaster Relief Systems, Network Resilience and Recovery (FG-DR&NRR) was established in January 2012. The objective of the Focus Group is to collect and document information and concepts that would be helpful for the work on disaster relief systems/applications, network resilience and recovery from a telecommunication perspective.

The Focus Group (FG) conducts the work on disaster relief systems/applications, network resilience and recovery aiming at

- identifying requirements for disaster relief and network resilience and familiarize the ITU-T and standardization communities with those requirements;
- identifying existing standards and existing work that are related to the requirements mentioned above;
- identifying any additional standards that may need to be developed and identifying future work items for specific ITU-T Study groups and related actions;
- encouraging collaboration among ITU-T Study Groups, in particular SG2, SG5, SG13, SG15, and SG17, ITU-R, ITU-D and relevant organizations and communities, including the PCP/TDR;

The Focus Group will collaborate with worldwide relevant communities (e.g., research institutes, forums, academia) including other SDOs and consortia.

Source: ITU (www.itu.int/en/ITU-T/focusgroups/drnrr/Pages/default.aspx)

Ghana’s ICT sector will need to ensure that it is also adapted to the challenges of climate change, and will need to contribute actively to the development of a national climate change strategy in the country.

b) Indirect consequences of climate change for ICTs

Additional consequences of climate change impacts include increases in operators’ energy demands, as higher temperatures will, under the current increasing temperatures, require more air conditioning in the exchanges. Network damage will require trucks to be used for repairs, with implications for fuel use. Operators are also likely to have to run more back-up generators in areas experiencing extreme weather conditions.

Where sea levels are expected to rise materially, network operators would likely be required to have to move or to replace a significant amount of network equipment. For example, equipment positioned in sites at risk of flooding would need repositioning, and displaced populations would likely require new networks to be built. In countries like Bangladesh, more than a fifth of the territory could be under water with a one-metre rise in sea levels, highlighting the risk to telecommunication companies in such regions. In other words, it is likely that the consequences of climate change will be very different for TSPs in different regions, and that the requirements for adaptation will, as a consequence, also be different.

The data centres, server farms and hosting environments that have become an essential part of the ICT eco-system have very demanding requirements for electricity and air conditioning[68]. Such facilities have become essential for the delivery of many telecommunication-based services and applications. Thus, adaptive (and mitigation) actions related to energy-efficient supply will need to be considered, based on the resources available within specific contexts.

Conclusions

The main objective of this report was to explore the ways in which ICTs could be integrated into national adaptation policies and strategies in developing countries such as Ghana, in order to establish a close link between the potential of these tools and the achievement of climate change adaptation goals. The results from the analysis suggest that the efforts undertaken by Ghana’s government and other stakeholder institutions in this field to explicitly include integration of ICT into policies and strategies are an effective and efficient manner to accelerate adaptation to climate change, while also increasing economic growth.

However, it is still necessary to foster realistic and viable environmental policies and strategies in order to address environmental and climate-related challenges as they emerge or reoccur. Proper management of Ghana's resources requires that efforts should be redirected into more environmentally sustainable programmes and practices that take into consideration the role of ICTs as a powerful linchpin to combat climate change.

Promoting the development and diffusion of technologies, know-how, and adaptive practices constitutes an important step for improving and enabling adaptation to climate change. Emerging research and experiences from the field suggest that there is no single ICT solution that can be applied in response to the challenges posed by climate change, but instead, developing countries should adopt flexible, combined approaches that integrate different technologies, emergent and traditional knowledge, and that ultimately prioritise the applications that are most appropriate to the needs of the local context. At the same time, technologies that address identified adaptation priorities and that build upon lessons learned from current adaptation projects are particularly valuable.

Important lessons have already emerged from the experience of Ghana with the integration of ICTs into climate change strategies. Based on the lessons and examples presented throughout this report, the following key areas for developing country action can be identified:

a) Fostering coherent, long-term strategies based on content, structures and processes

Actions aimed at integrating ICTs and climate change adaptation strategies take place in complex contexts, characterized by the impact of both climatic and non-climatic development stressors. Therefore, countries should adopt well-structured approaches based on three key areas of action: the development of ICT and climate change *content*, the design of ICT and climate change *structures*, and the implementation of ICT and climate change *processes*.

b) Promoting awareness on ICTs current and emergent areas of potential

The development of content in ICTs and climate change should acknowledge the low level of awareness that still exists on the subject, given its relative recent emergence in the policy and strategic realms. Thus, clear concepts and terminology should be used, as well as examples, particularly from developing countries’ experiences such as Ghana, in order to illustrate the potential of ICT tools towards adaptation. Likewise, considering the rapid development of the ICT sector, strategies should remain flexible in order to integrate the potential of both traditional and emergent ICT applications.

c) Supporting inclusive and participatory structures, led by trusted institutions

The design of policy structures should consider principles of representativeness and integrate mechanisms for multi-level and multi-sectoral participation in the decision-making processes. Likewise, structures should not only acknowledge and integrate the diverse set of stakeholders involved in ICTs and climate change issues, but also be fostered by credible and trusted leaders that can facilitate the articulation of efforts from the Ministerial to the municipal and local levels. This was a recognized practice in the case of Ghana, where high-level support and the work of a specialized agency with technical capacity in ICTs and climate change issues have ensured the progress of actions in this field.

d) Addressing prevailing challenges of connectivity, access and use

A key starting point for the implementation of policy processes and strategies at the intersection of ICTs and climate change should is the identification and assessment of prevailing connectivity gaps (particularly within marginalised, remote and rural areas), as well as existing barriers in the access and use of ICTs. This assessment should be complemented with the identification of challenges in terms of access and use of climate change information and knowledge by local and national stakeholders, so as to ensure that ICT-supported solutions and applications are targeted to the specific climatic, informational and development needs of the context. Mechanisms to incentivise the development of innovative ICT applications on adaptation should also be considered by developing countries.

The complexity that characterizes processes of climate change adaptation requires the adoption of multiple ICT solutions and approaches that contribute to coherent, flexible and inclusive processes of adaptation in vulnerable developing contexts. Likewise, the ICT sector should adopt measures to adapt and adjust to the impacts of climate change and variability in a number of fronts. Experiences of countries such as Ghana can yield valuable lessons in this field, enabling new adaptive paths and ICT-enabled approaches to overcome the challenges, and benefit from the opportunities posed by the changing climate.

Glossary

2G	Second-Generation Wireless Telephone Technology
3G	Third-Generation Wireless Telephone Technology
AR4	Fourth Assessment Report of the IPCC
AWG-LCA	Ad-hoc Working Group on Long-Term Cooperative Action
CAF	Cancun Adaptation Framework
CC DARE	Climate Change Adaptation and Development Initiative
COP	Conference of the Parties to the Convention
EPA	Environmental Protection Agency (Ghana)
GHG	Greenhouse Gases
GIX	Ghana Internet Exchange
GSM	Global System for Mobile Communications
ICTs	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
ISP	Internet Service Provider
ITU	International Telecommunication Union
KP	Kyoto Protocol
LDCs	Least Developed Countries
MDGs	Millennium Development Goals
NCCAS	National Climate Change Adaptation Strategy (Ghana)
NCCC	National Climate Change Committee (Ghana)
NCCPF	National Climate Change Policy Framework (Ghana)
NWP	Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change
SBSTA	Subsidiary Body for Scientific and Technological Advice
SIDS	Small Island Developing States
SIM	Subscriber Identity Module
SMS	Short Message System
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

Climate change mitigation and Information and Communication Technologies (ICTs):

The case of Ghana

Acknowledgements

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Executive summary

Greenhouse gas (GHG) emissions in the Information and Communication Technology (ICT) sector in Ghana arise from the energy used in the extraction and processing of the raw materials used for ICT production, the energy consumed when the ICTs are used, and the energy used in their disposal. Fifty per cent of the electricity in Ghana is generated using fossil fuel power-plants which have a significant impact on GHG emissions. These emissions can be reduced through improvements to the energy efficiency of ICTs in Ghana, and ways to do this are given in this report.

ICTs can also be used to reduce emissions in other sectors by enabling higher efficiencies to be achieved, and it is has been estimated that by 2020 GHG reductions in other sectors enabled by ICTs could be six times the emissions of the ICTs themselves. Proposed actions on how to achieve these savings are included in this report.

Much progress has already been made in Ghana to address the energy efficiency of ICTs and the ICT industry. A Strategic National Energy Plan spanning a twenty-year period will promote energy efficiency and renewable energy, such as wood fuels, for electricity generation which constitutes over 60 per cent of Ghana's energy utilization. During this period the use of ICTs is likely to grow, and without mitigation measures, such as those proposed in this report, ICTs will place an increasing demand on the grid. A National Climate Change committee has been set up by the Ministry of Environment, Science and Technology (MEST) to advise on climate change issues. The National Communications Authority (NCA), which is part of the Ministry of Communications (MoC), has for example mandated the sharing of masts and antennas where possible when building new mobile base station infrastructure. The Environmental Protection Agency (EPA) has shown leadership in the area of climate change, but has mainly focussed on adaptation rather than emissions' reduction.

However, much still needs to be done and the MoC, NCA, MEST, EPA and many other stakeholders have a role in assisting the ICT sector to become more energy efficient and reduce its carbon footprint. These stakeholders are identified in Section 1.3.

Section 7 of this report contains a full list of suggested actions that should lead to an improvement in energy efficiency in Ghana, both in the ICT industry and in other sectors where the use of ICT can lead to better energy efficiency, thereby reducing GHG emissions. Foremost among these suggested actions is the setting-up of a national Green ICT Council, linked to the National Climate Change Committee, to consider and explore ways of implementing the actions proposed by this report. This will ensure that all construction of new ICT infrastructure in Ghana will take into consideration energy efficiency and the use of renewable energy sources as key criteria when choosing a technology solution. This will help to ensure that GHG emissions are minimised while laying the best possible foundations for realising the NCA vision of an information-rich society and economy through the development, deployment, and operation of ICTs.

The proposed Green ICT Council should first consider strategic plans to:

- Extend the coverage of mobile networks to rural areas, adopting the best available technology for low-density applications (e.g. high antenna location, high antenna gain and solar arrays with integral wind turbines).
- Upgrade the existing mobile infrastructure and build out new infrastructure with a view to offering basic Internet access (e.g. with smartphones) from all base stations and, where possible, switch to renewable energy sources in the process.
- Adopt infrastructure sharing (e.g. utility poles) to reduce the cost of connecting the 50 per cent of Ghanaians without access to telephony (mobile or fixed) and grid electricity to broadband fibre/WiFi network and grid electricity.

In addition, it will be necessary to create a regulatory framework which encourages telecommunication service providers (TSP) to increase the energy efficiency and reduce the emissions of their infrastructure and equipment. This should include incentives for infrastructure sharing while imposing penalties for exceeding emission targets. It will also be necessary to encourage the introduction of technology to mitigate emissions in other sectors. Regulatory easements to TSPs or an appropriate carbon trading scheme could be used to achieve this.

It will also be necessary to support legislation to tackle the e-waste problem in Ghana. The Energy Commission has recently taken steps to ban used refrigerators and air-conditioners from entering the country as from 1 January 2013. This will reduce the dumping of electronic waste (e-waste) but will not stop it. The link between e-waste and climate change is highlighted in Section 2, which shows how the energy used in raw material extraction can be reduced by recycling e-waste. Ways to assess the carbon footprint of the ICT sector as a whole are provided in the Annex.

Finally, it is recommended that the Energy Commission, with advice from the EPA, considers the development of non-fossil fuel sources, such as biodiesel and micro-hydro, as substitutes for fossil fuels in base stations.

1. Introduction

1.1 The challenge

Ghana led the way in telecommunications liberalisation and deregulation in Africa when it privatised Ghana Telecom (GT) in 1996. Since then, the telecommunication sector in Ghana has experienced significant growth in the dominant mobile sector with 15 per cent growth in 2010 and 21.2 million mobile subscriptions[69] at the end of 2011. This growth is likely to continue as coverage is extended to reach more geographical areas and user adoption continues to increase. The target defined by the MoC was to provide universal access to all communities and population groups in Ghana to telephone, Internet, and multimedia services by the year 2010[70]. This target has still to be reached and is helping to drive further growth in telecommunication services.

Service providers are increasingly offering Internet access and e-mail. These services can be piggybacked on the existing GSM (Global System for Mobile Communications) network using GPRS (General Packet Radio Service). These additional services provide access to e-mail, instant messenger services, and basic Internet browsing at rates of up to 40kbit/s[71] which could provide much needed information on education, health, and adaptation to climate change. More applications could be developed with the introduction of wired and wireless broadband, which could provide connection rates of up to 14 Mbit/s (mobile) and 100 Mbit/s (fixed).

Reducing the ICT sector's GHG emissions, in the face of a booming industry sector growth, is the major challenge addressed in this report.

1.2 The situation today

With 21.2 million mobile phone subscriptions among a population estimated to be 24.2 million[72], there is an estimated take-up rate by subscription of up to 71 per cent of the population. Dual SIM (Subscriber Identity Module) mobile phones, where one person subscribes to more than one TSP, are very popular for extending coverage while roaming, which means that the number of separate subscriptions will in practice be significantly lower than 71 per cent of the population. The breakdown by TSP is given in Table 1 for December 2011.

Table 1. The breakdown of mobile phone subscriptions in Ghana in December 2011

Telecom service provider	Million lines	Market share %
SCANCOM (MTN)	10.2	47.35
VODAFONE MOBILE	4.3	19.93
MILLICOM TIGO	3.9	18.28
AIRTEL MOBILE	2.6	12.24
EXPRESSO	0.2	0.87
Total mobile	**21.2**	

Source: National Communications Authority of Ghana.

Examples of coverage maps for mobile TSPs Vodafone Ghana, Scancom[73], and Airtel Mobile are shown in Figures 1, 2 and 3.

Figure 1. Vodafone coverage.

Figure 2. Scancom coverage.

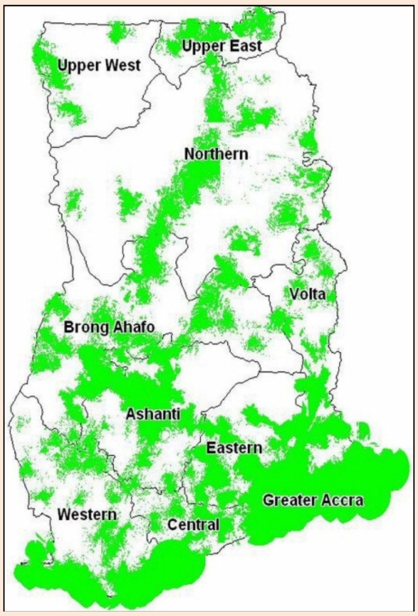
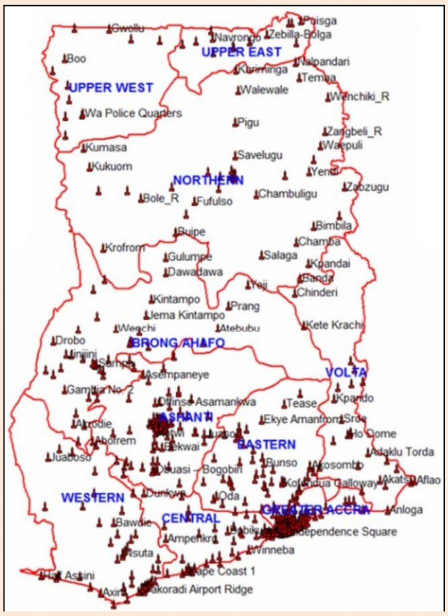


Figure 3. Airtel coverage



Suggested action: It would be useful to be able to refer to a map showing the overall coverage of mobile services in Ghana, taking into account the coverage of each TSP. However, no such coverage map currently exists. It is recommended that the NCA should commission or mandate the provision of such a map that would help to identify gaps in coverage of mobile services.

It can be observed that there are many areas of Ghana which are not served by these three TSPs. Unserved areas are likely to be those with small population centres or areas difficult to access for which TSPs cannot economically support the installation of a base station.

Table 2. Take-up of ICT services in the region around Ghana

	Côte d'Ivoire	Ghana	Togo	Benin	Nigeria	Burkina Faso
Population Millions	20.1	**25.0**	6.1	9.1	162.4	17.0
GDP $B	23	**32**	3.2	6.6	202	8.8
Fixed telephone %	1.33	**1.14**	3.90	1.68	0.44	0.83
Mobile cellular %	86.42	**84.78**	50.45	85.33	58.58	45.27
Mobile broadband %	0	**23.0**	0.43	0	2.83	0
Internet users %	2.20	**14.11**	3.50	3.50	28.43	3.00
Fixed broadband %	0.08	**0.25**	0.08	0.04	0.13	0.08
Households with computer %	2.00	**10.23**	3.81	2.80	9.30	2.80
Households with Internet %	1.20	**4.00**	3.0	1.80	4.60	2.40

Source: ITU World Telecommunication/ICT Indicators database.[74]

Internet access is the second ICT service most used in Ghana, used by an estimated 14 per cent of the population. Wireline subscriptions, which once represented the main telecommunication network, are only available to 1.14 per cent of the population. Table 2 presents a comparison of the ICT sector in Ghana compared to other countries in the region (in approximate geographical order from West to East along the coast).

1.3 Key stakeholders

The following key stakeholders for the actions proposed by this report should endorse them via membership and participation in action plans of the proposed Green ICT Council:

- The Ministry of Communications in Ghana (MoC)[75] has the mission "to facilitate the development of a reliable and cost effective world class communication infrastructure and services, driven by appropriate technological innovations to enhance the promotion of economic competitiveness in a knowledge based environment". Growing interest in environmental issues was shown in MoC's recent hosting in Ghana of the ITU-organised Sixth Symposium on ICTs, the Environment and Climate Change, 7-8 July 2011, which concluded with the Accra Call to Action[76].
- The National Communications Authority of Ghana (NCA)[77], under a mandate from the MoC, is responsible for regulating the ICT sector in Ghana, including telecommunications and broadcast licensing via public consultations. It includes a policy for the realization of the vision to transform Ghana into an information rich knowledge-based society and economy through the development, deployment, and exploitation of ICTs within the economy and society. One of its strategies is to "Promote R&D programmes relating to alternate energy sources such as nuclear energy, solar energy, biomass, wind and other renewable energy sources, to supplement the current traditional energy sources".
- The Environmental Protection Agency (EPA) of Ghana[78] has the mission to co-manage, protect, and enhance the country's environment as well as to seek common solutions to global environmental problems. The accomplishment of the mission of the EPA is to be achieved, for example, through "An integrated environmental planning and management system established on a broad base of public participation, efficient implementation of appropriate programmes and technical services, giving good counsel on environmental management as well as effective and consistent enforcement of environmental laws and regulations. The EPA is an implementing Agency, a regulatory body and catalyst for change towards sound environmental stewardship. Its vision for Ghana is a country in which all sections of the community value the environment and strive to attain sustainable development, with sound and efficient resource management, taking into account social and equity issues".
- The Ministry of Energy[79] has a mission to develop and ensure a reliable supply of high quality energy services at minimum cost to all sectors of the economy through the formulation, implementation, monitoring, and evaluation of policies.
- The Ministry of Environment, Science and Technology (MEST) is responsible for coordinating climate change activities across Ministries, Departments and Agencies (MDAs). MEST hosts the National Climate Change Committee (NCCC) which has a mandate to advise MEST on issues related to climate policy. In 2010, the NCCC initiated the development of a National Climate Change Policy Framework (NCCPF) which resulted in the publication of a discussion document by MEST, "Ghana Goes for Green Growth", in advance of the international climate conference in Cancun in November 2010.
- The Energy Commission of Ghana (previously National Energy Board) is a major stakeholder regarding energy efficiency and alternative energy sources. For example, it promotes safe energy and the use of energy-saving lamps.
- The Ghana Network Operators Group (GhNOG) is the local chapter of the African Network Operators Group (AFNOG). This has as its members the TSPs providing networks and services in Ghana, which

include mobile TSPs Vodafone, Scancom, Airtel, Millicom, and Expresso, and fixed TSPs Vodafone and Airtel.

- The Ghana Internet Services Providers Association (GISPA)[80] is a professional, non-profit trade association, representing the interests of local ISPs and other Internet providers. It currently has 23 members. It runs the facility of routers and switches known as the Ghana Internet eXchange (GIX), which allows local ISPs and TSPs to easily exchange Internet traffic within Ghana, while improving connectivity and services for their customers.

The following key international stakeholders should have a consultative status on the proposed Green ICT Council:

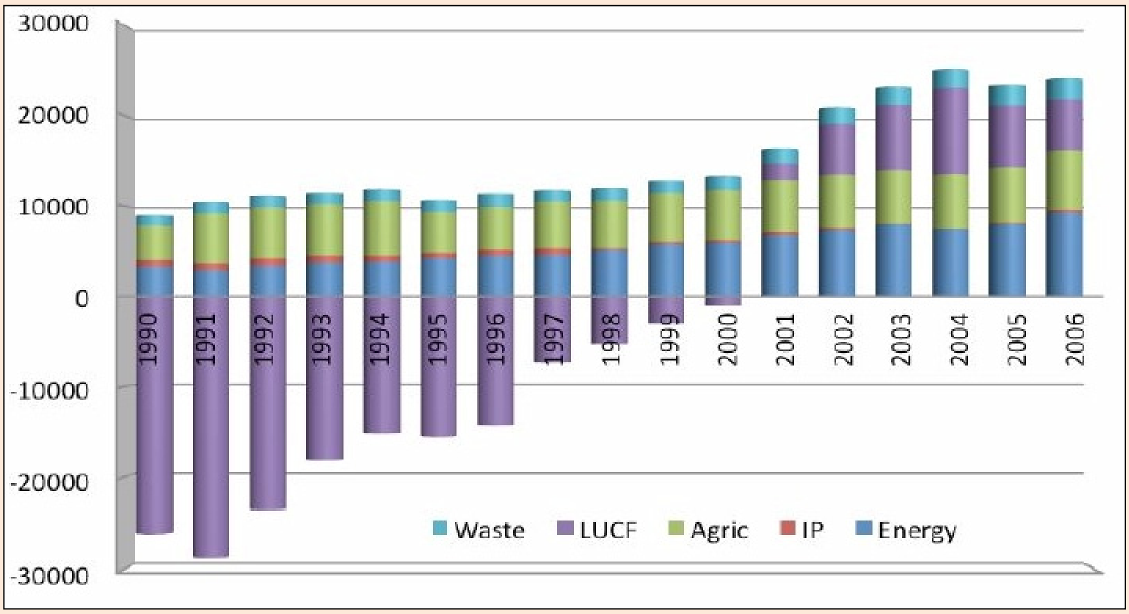
- The International Telecommunication Union (ITU). ITU has a key role in global telecommunication regulation and standardization. ITU is the UN specialized agency responsible for telecommunications and information and communication technologies (ICTs). Its membership, comprising 193 governments, over 700 private companies, and 40 academic institutions, has called for ITU to take the lead in engaging the global community (including countries, the UN system, and the ICT industry, as well as academia and NGOs) to address climate change through the use of ICTs.
- The United Nations Framework Convention on Climate Change (UNFCCC). UNFCCC is the UN secretariat responsible for supporting the operation of the Framework Convention on Climate Change, an international environmental treaty produced at the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 and updated by the Kyoto Protocol.
- Economic Community Of West African States (ECOWAS)[81]. The ECOWAS Commission and the ECOWAS Bank for Investment and Development, more often called 'The Fund', are its two main institutions designed to implement policies, pursue a number of programmes and carry out development projects in Member States. Such projects include intra-community road construction and telecommunications; and agricultural, energy and water resources development. ECOWAS may be able to assist in getting fibre into urban and rural areas (some rural areas also have a need for power lines).

2. The sources of ICT GHG emissions in Ghana

It would be useful to identify the total GHG emissions from Ghana, including those arising from ICTs. The total GHG emissions reported by Ghana were 24 Mt CO2e in 2006, which is equivalent to approximately 1 tonne per capita[82].

In addition to CO2, there are a number of other GHGs emitted by the ICT industry. These include sulphur hexafluoride (SF_6) which has approximately 40 thousand times the impact of CO2 per gramme emitted[83]. SF_6 plasma is used in the semiconductor industry as an etchant[84]. SF_6 is also used to pressurize waveguides in radar systems. The gas insulates the waveguide preventing internal arcing[85] and is also applied in transmission waveguides for medical X-ray equipment. The impact of SF_6 in Ghana is considered to be small. However, the relatively high radiative forcing[86] of SF_6 indicates that it needs to be monitored; for example, it might arrive unexpectedly in Ghana as part of e-waste.

Figure 4. Trend in total GHG emissions, including LUCF (land use change and forestry) in GgCO2e



If ICT-related emissions in Ghana followed global averages, then 2.5 per cent of GHG emissions in Ghana would come from ICT networks and devices, including wireline and mobile networks, broadcasting networks, and consumer electronic devices (in both homes and businesses), and this would equate to about 0.6 Mt CO2e. ICT is included in the energy sector. This estimate does not include emissions from sectors such as transport and manufacturing which are discussed in Section 3.

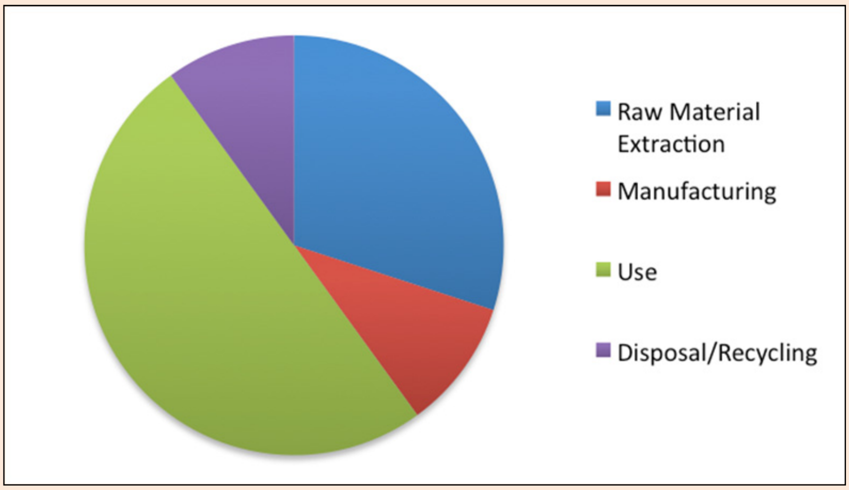
The sources of ICT-related GHG emissions may be traced from a life cycle assessment (LCA) of ICT devices. The life cycle phases (for any product or service including telecommunications) are defined in ISO14040/44 as:

- Raw material extraction and conversion
- Manufacture
- Use (or consumption)
- End-of-life (re-use, recycling of materials, energy recovery and ultimate disposal)

Transport and energy supply are included in each life–cycle phase.

The proportion of emissions from each phase is illustrated in Figure 5. Every ICT product will have a different apportionment. A more exact apportionment of emissions for Ghana is recommended for further study.

Figure 5. Approximate proportions of emissions from each phase



2.1 Raw material extraction phase

ICT products, such as mobile phones, can contain over 40 base metals which all need to be mined[87]. A handset generally contains around 40 per cent of metals by weight. Aluminium compromises up to 20 per cent, copper around 15 per cent and nickel 10 per cent (mainly in the battery). Although gold makes up less than 0.1 per cent by weight of a mobile phone, it has the highest recycled value, and so is covered first below.

GHG emissions arise from the extraction of raw materials because of the energy used to power the extraction and refinement processes. There is a view that raw material extraction is not in the ICT sector but rather in the mining industry. However, a significant proportion of raw materials, especially rare metals, are used in ICT products. It is therefore necessary to examine whether raw material extraction is a significant contributor to GHG emissions in Ghana.

It should also be recognised that a large proportion of the raw materials extracted in Ghana are sent to other countries for use in the manufacture of ICT products to be sold and used worldwide. Should the resultant CO2 emissions be accounted for as part of Ghana's GHG emissions or should they be counted as Scope 3 emissions from other countries/industries? This report does not enter this debate. However, measures to reduce the GHG emissions from this mining are discussed below.

Gold

The global electronics industry used over 300 tonnes of gold in 2010. This represents 14 per cent of world production of 2 350 tonnes[88]. A small amount of gold is used in almost every electronic device, including TV sets, monitors, printers, cell phones, calculators, personal digital assistants, global positioning system (GPS) units and other small electronic devices. Gold is used by many manufacturers in the production of desktop and laptop computers, as it is an efficient and reliable conductor that provides the rapid and accurate transmission of digital information needed by modern equipment. The importance of high quality and reliable performance justifies the high cost. Edge connectors used to mount microprocessor and memory chips onto motherboards and the plug-and-socket connectors used to attach cables, all contain gold. The gold in these components is generally electroplated onto other metals and alloyed with small amounts of nickel or cobalt to increase durability.

The mining industry of Ghana accounts for 1.5 per cent of the country's GDP and minerals make up 41 per cent of total exports, of which gold contributes over 90 per cent of the total mineral exports[89]. Most of Ghana's exports are raw materials. Gold is the most valuable export and is predominantly used in jewellery and the electronics industry.

Gold production is incredibly energy and labour intensive. Recently, rising crude oil prices and demands for higher wages, have significantly increased global gold production costs[90]. For example, in South Africa where there have been power supply shortages, labour disputes, and other issues, the average cash cost rose to USD 869/ounce. Oil prices rose to USD 145 per barrel (159 litres) in July 2008 and although they have reduced since, they were again approaching USD 100 as this report was being prepared in August 2011. Fossil fuel, up to 5 000 times the weight of the gold yielded, is used to produce it.

Ghana produced 2.9 million ounces (82 tonnes) of gold in 2009[91]. It can be estimated that it could emit approximately 82 thousand tonnes CO2[92]. The electronics industries worldwide will use approximately 14 per cent of all gold produced and so 1 442 tonnes of fossil fuel and 3 780 tonnes of CO2e are emitted in the production of gold for the ICT industry in Ghana. This represents 0.016 per cent of the GHG emissions in Ghana.

Suggested action: As far as is known, there are no standard publicly available inventories showing the impact on energy and emissions (CO2e) of extracting and processing raw materials such as gold. The EPA could consider taking a lead on establishing such tables, specifically for Ghana.

As more gold is extracted, the gold that remains is often harder to discover and mine; and could require more energy per gram to remove and process. By recycling worn-out or obsolete goods such as mobile phones, rare metals such as gold can be extracted and recycled. This maintains materials in circulation, and reduces the demand for raw materials and the energy needed for extraction. Although the amount of gold is small in each device, their enormous numbers translate into a lot of unrecovered gold[93].

Given the importance to Ghana's economy of the extraction and processing of gold for export, it may be necessary to explore ways of making this industry less dependent on fossil fuels. There may also be an economic benefit to Ghana in developing methods for recovering gold (and other materials) from e-waste, which can then be re-exported. (See more below under Recycling). Whereas 5g of gold may be extracted from 1t of ore, 400g of gold may be extracted from 1 t of mobile phones.

Suggested action: The EPA and the Ministry of Communications should check emerging legislation on e-waste to maximise the recovery of gold and other rare metals for the electrical industry, and to ensure the safe disposal of ICT equipment in line with the recommendations of the Basel Convention which are designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries[94]. The categories of hazardous wastes are listed in Annex I of the Convention. E-waste can also be covered if it is defined or considered to be a hazardous waste under the laws of: the exporting country, the importing country, or any country of transit.

Aluminium

Aluminium became a significant export from Ghana following the construction of the Akosombo hydro-electric dam to supply the industry, and the creation of Lake Volta, the world's largest man-made lake. Lake Volta was formed between the years of 1962 and 1966, and necessitated the relocation of about 80,000 people. There is a huge demand for aluminium worldwide as it has many uses, including high voltage electrical transmission in place of copper, as it is the most cost-efficient power-line material[95]. Aluminium's other electrical applications include TV aerials, satellite dishes, CDs, DVDs, chassis, and instrument cases.

In Africa, seven per cent of the mined aluminium is used in the production of electronic equipment[96]. Assuming that Ghana's aluminium production is powered by a non-fossil fuel source, hydroelectricity, GHG emissions are small in comparison with other countries, such as Australia where aluminium smelting is fuelled by coal, consuming about 15 per cent of all electricity produced and emitting 6-7 per cent of total CO2e emissions.

The emissions released in the generation of hydropower are less, but hydropower is far from emission free and has not come without a massive environmental cost. Dam construction and maintenance, continuous lake dredging, building and strengthening of the power grid to cope with the power being produced, and manufacture and maintenance of the turbines, are just a few examples of damage to the environment.

2.2 Manufacturing phase

Manufacturing of ICTs causes GHG emissions because energy is used in factories to process and assemble materials and to transport goods and supplies to and from assembly plants.

Ghana is not currently a significant producer of ICT-based products but there is a growing business in the assembly of handsets. Overall, the manufacturing industry is growing and may make a significant contribution to GHG emissions in the future.

2.3 Use (consumption) phase

Electricity is the primary source of power for the use phase of ICTs. Approximately 50 per cent of Ghana's electricity comes from renewable sources with nearly all of this coming from hydroelectric generation. The rest is made up of thermal (oil, diesel and natural gas) powered generation[97].

As in other countries, electricity is used in Ghana to operate wireline, mobile and broadcasting networks, and the end equipment used to provide the services. The ICT sector is powered by a mixture of on-grid and off-grid supplies. Significant energy users include:

- The legacy fixed network (e.g. now part of Vodafone Ghana)
- Private communication systems including Ghana government systems
- The mobile TSPs
- Consumer networks (customer premises equipment such as TVs, monitors and PCs)
- Service providers (broadcasters and Internet service providers, especially those using data centres in Ghana)

To provide an accurate estimate of the energy requirement for Ghana's ICT sector requires a detailed analysis of the significant energy users listed above. A methodology to accomplish this is provided in the Annex. The first advised step is to monitor the electricity used by large corporations as published in their report and accounts.

Specific opportunities for energy reduction in the ICT sector are discussed in Chapter 4.

2.4 End of life/recycling phase

Although there are some environmental impacts and GHG emissions associated with recycling, the benefits far outweigh other options. More energy is needed to recycle an obsolete product than leaving it in-situ or sending it to landfill. However, assuming that there is a constant demand for new products, the energy needed to recycle a product is far less than that needed to extract new material from raw material.

For example, aluminium has been dubbed 'liquid electricity'. Ghana may be able to do more in the area of recycling aluminium, especially from the electronics industry. As an example, it is estimated that the energy saved by recycling one aluminium drink container could be used to operate a TV set for 3 hours, and is the equivalent to almost 2 litres of petrol[98]. One of the industry's main incentives for recycling has been the reduced amount of energy it takes to produce one tonne of secondary aluminium compared with one tonne of primary aluminium. This involves a saving of 95 per cent of the energy required to produce molten aluminium from bauxite[99].

Electronic equipment also contains, in aggregate, significant quantities of gold, and other rare metals which can also be recovered for re-use, thus reducing some of the GHG emissions associated with mining of gold.

A 'cradle-to-cradle' or 'closed loop' approach to manufacture and recycling is becoming increasingly widespread with China taking the lead by producing legislation in this area. It has been recognised that recovering the materials from e-waste is beneficial in many ways: less landfill; less hazardous waste to cause human and environmental problems; less resource depletion; re-using the materials is less energy intensive than extraction and processing of raw materials. This last point is particularly relevant to this report which addresses how Ghana's GHG emissions can be reduced.

Suggested action: The EPA together with MoC or other appropriate agency in Ghana should consider, and if necessary promote, legislation on a 'cradle to cradle' or 'closed loop' approach to manufacture and recycling.

Recycling or disposal of e-waste contributes to GHG emissions because energy is required to transport the ICTs to waste sites and to reprocess it. To maximise the environmental benefit, e-waste should be recycled efficiently by expert reprocessing units. An example of bad practice in Ghana is where ICT circuit boards or transformers are currently burned to extract electronic components or copper. Without proper controls, GHGs and toxins enter the environment causing pollution of the atmosphere and water supplies and the contamination of land.

Ghana is preparing an e-waste management policy which should become law in 2012. Ghana's Energy[76] Commission has also recently taken moves to ban used refrigerators and air-conditioners from coming into the country from 1 January 2013 which will reduce electronic waste (e-waste). Ghana wants to use state-of-the-art ICT technology, and does not want to be sent electronic products "for re-use" which are more than three years old. However, it is self-evident that any electronic equipment currently in use in Ghana, or manufactured/imported in future, will in time become e-waste.

Suggested action: The MoC in cooperation with EPA in Ghana should promote legislation to ban the import of e-waste more effectively as it may contain unknown and unspecified toxins.

Suggested action: Ghana lacks an effective infrastructure for handling e-waste. The EPA and the MoC or other appropriate agency in Ghana should take a lead role in setting one up.

Suggested action: The principle of producer responsibility (producer pays to clean up waste) should be applied in Ghana to help to minimise e-waste streams. New legislation is required in this area. The EPA and MoC are in a position to advise on the drafting of this legislation.

It is understood that the Ghanaian Government is addressing the problem of the management of e-waste, with the legislation expected in 2012. Consideration also needs to be given by policy-makers or advisors, such as the EPA and MoC, to the appropriate disposal or recycling processes. A policy to maximise the economic and environmental benefits of recycling e-waste produced within Ghana would complement the mining and export of raw materials, which are an important part of Ghana's economy.

The GSM Association (GSMA) has reported that "*In developing countries, the informal repair sector tries to reuse phone parts as spares and only components that can't be recycled in this way will become available for collection. A pilot recycling project was run by Vodafone in Kenya and collected, on average, half a kilogram of waste per week from each repairer. Nearly a quarter of the waste collected was phone casings, 22 per cent batteries and 20 per cent chargers*".

Box 1: ICT rare metal components recommendation

ITU-T Study Group 5 identified the recycling of ICT rare metal components as an area demanding attention, and has responded with the new Recommendation ITU-T L.1100 detailing the procedures to be employed when recycling these metals. The Recommendation outlines key considerations in all phases of the recycling process, and provides guidelines as to how organizations may fairly and transparently report on rare metal recycling. Rare metals are essential to the high-end functionality of ICT products, and the ICT industry has reached the point where it is not possible to omit these metals from product design. A mobile phone contains no less than 20 rare metals, and to further illustrate the need to recycle rare metals, consider that a tonne of gold ore yields 5 g of gold, compared to a staggering 400 g yielded from a tonne of used mobile phones.

It is well known that natural stocks of some semiconductor compounds such as CIGS (copper, indium, gallium, selenide) or CdTe (cadmium, tellurium) will be entirely depleted in the near future. It is almost unique to have such strong environmental and economic incentives for recycling.

3. How ICTs can help to reduce GHG emissions in other sectors

This section identifies how the ICT sector can help reduce GHG emissions in other sectors in Ghana through improvements in energy efficiency and mitigation. Adaptation to climate change and the ICT infrastructure needed to support this is not addressed, as adaptation is covered extensively in the companion report.

3.1 Improvements in energy efficiency

The use of ICT equipment, networks, and services makes it possible to:

- improve energy efficiency,
- reduce power consumption,
- reduce emissions throughout the whole life cycle of goods, networks, and services,
- use materials sustainably and eliminate hazardous materials,
- use fewer components and materials, including packaging,
- lower impacts with converged, multi-functional goods[100].

One example of minimising the 'in use' emissions is the Ghanaian Government project to replace five million incandescent lamps with compact fluorescent lamps[101] which use one fifth of the energy to produce the same illumination. This action would also reduce the peak load on the electricity grid by 124 MW. When calculating the benefit in terms of GHG emissions, the emission factor of the electricity source needs to be included. The ratio of emissions can be calculated to be 0.35 kg CO2e/kWh in Ghana. By incorporating more renewable sources into the energy mix and/or making the energy supply more efficient, this figure could be further reduced. For comparison, the emission factor in the UK is higher at 0.59 kg CO2e/kWh[102] due to less renewable sources of power being used to produce electricity.

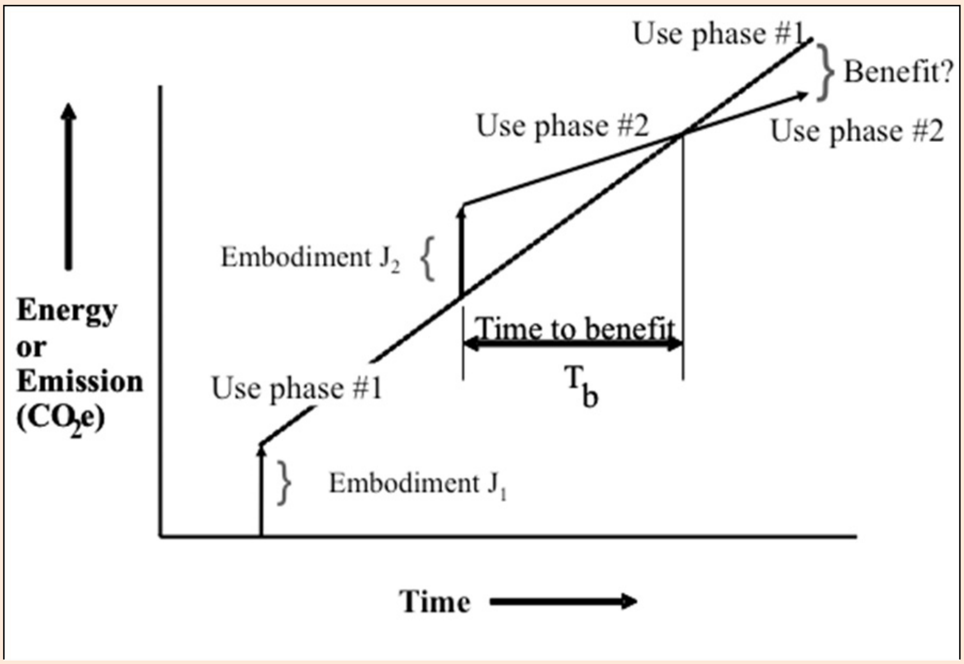
Similar measures of mass change-out may be considered in the ICT industry in Ghana. One example is changing from cathode ray tube (CRT) to liquid crystal or light emitting diode (LED) displays for computer and TV screens. Some companies or government departments may consider doing this voluntarily to save energy cost over the life cycle. An energy saving of 63 per cent has been measured in one example[103]. An alternative saving of 40 per cent for LED backlighting is claimed by one manufacturer[104]. It should be noted that the process of change-out itself has the potential to generate a large amount of e-waste and this should be dealt with effectively.

Suggested action: The MoC, NCA, EPA or other appropriate agency in Ghana should coordinate at the global level with institutions such as the ITU to identify a set of best practices and standards that could be undertaken within the ICT sector to reduce GHG emissions. It is important that these are based on solid evidence and compiled by a neutral organization such as the ITU and not simply based on claims of specific manufacturers.

Initiatives to be undertaken should prioritize those actions that will produce higher savings in energy consumption. However, some actions to reduce GHG emissions do not produce a cost benefit, as the savings obtained in electricity consumption are not significant.

In general terms, for equipment that introduces limited improvements in energy efficiency, it may make more economic sense to wait for the equipment to reach the end of its life before procuring a more efficient replacement. Figure 6 illustrates this. Note that the use of recycled materials instead of raw materials reduces the embodied carbon in a new product.

Figure 6. Use of recycled materials to reduce embodied carbon in a product[105].



The key question for purchasers is: "Will the purchase of a more energy-efficient device genuinely reduce GHG emissions?" Figure 6 illustrates that this is only true if the intercept in phase 2 occurs before the new device reaches end of life. By recycling, the energy used in embodiment can be reduced and so the 'break-even' time will be reduced.

Suggested action: The MoC and EPA or other appropriate agency in Ghana should coordinate at the global level with institutions such as the ITU and draft new recommendations on a sustainable procurement policy and best practises, taking the whole life cycle into account.

Suggested action: The EPA and MoC or other appropriate agency in Ghana should investigate whether it is possible within the current legislative and regulatory framework to limit the sales of new models that make existing ICT products prematurely obsolete. An example of this would be a printer which will not print after 10 000 sheets have been printed.

The new infrastructure that will allow Ghana to improve energy efficiency and reduce GHG emissions while allowing further growth is addressed in Section 4.

3.2 Mitigation in other sectors

So far we have shown how GHG emissions increase because of the introduction and use of ICTs. However there are ways in which the services can be exploited to save energy and so mitigate GHG emissions. There are significant opportunities to reduce GHG emissions in other sectors by using ICT equipment and services to replace activities with large GHG emissions, as shown in Table 1.

Table 1. Reductions in the environmental load through use of ICTs[106].

Categories	Effects
Consumption of materials	By reducing materials (dematerialization), the environmental load related to goods production and disposal as well as waste generation can be reduced.
Power / energy consumption	By enhancing the efficiency of power and energy use to reduce consumption, the environmental load related to power generation, power transmission, etc. can be reduced.
Movement of people	By reducing the movement of people, the environmental load required for transportation can be reduced.
Movement of materials	By reducing the movement of materials, the environmental load required for transportation can be reduced.
Storage of goods	By reducing storage space of goods, power consumption for lighting, air conditioning, etc. can be reduced, thus reducing the environmental load.
Improved work efficiency	By enhancing work efficiency, the environmental load can be reduced.
Waste	By reducing waste emissions, the environmental load required for environmental preservation as well as for waste disposal can be reduced.

The Smart 2020 report[107] provides examples of how the use of ICTs can reduce emissions in other sectors, including:

- Smart motor systems – through changes to the design of electric motors to allow them to run at speeds optimised to the task.
- Smart logistics – through efficiencies in transport and storage.
- Smart buildings – through better building design, management and automation.

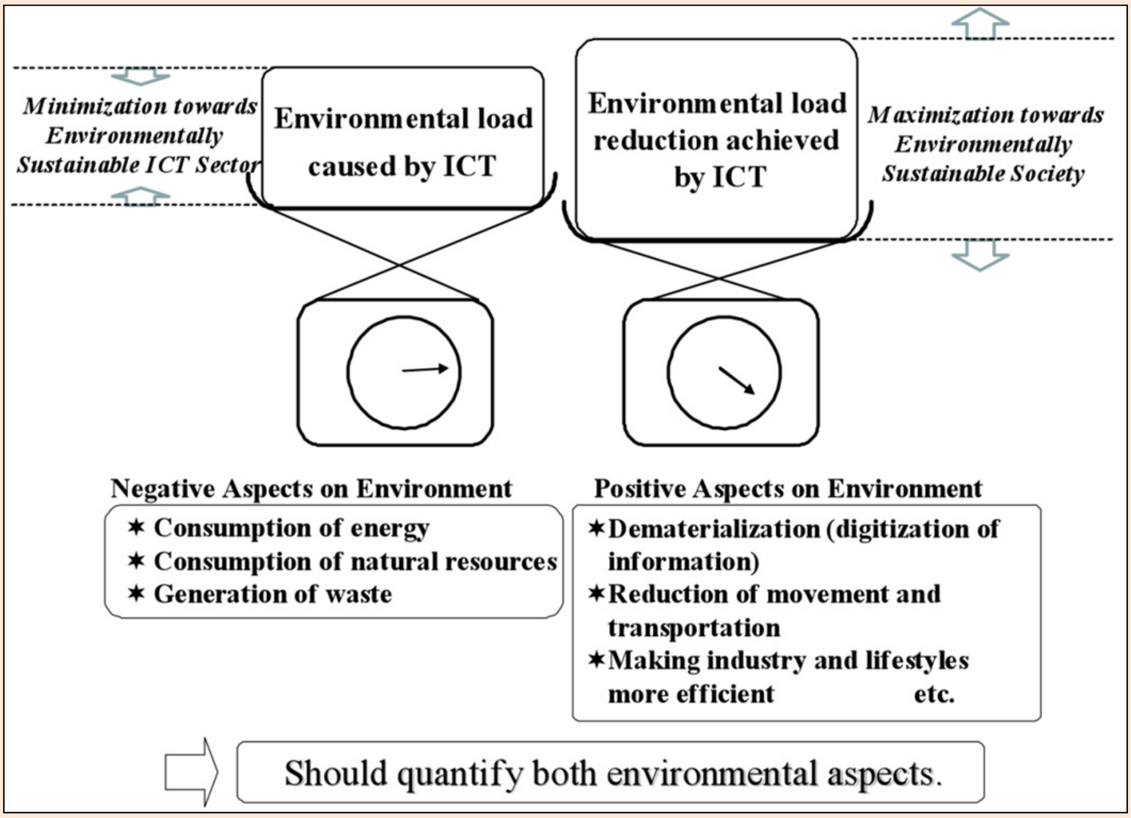
- Smart grids – which would be of most benefit to countries such as India where reductions in emissions could be as high as 30 per cent.

According to the Smart 2020 report, the use of ICTs to mitigate emissions in other sectors can be shown to reduce emissions globally by up to seven times the emissions arising from the energy consumption of the ICTs themselves. Therefore, a priority for investment should be infrastructure that will enable mitigating technologies such as videoconferencing to be deployed, rather than investment in infrastructure such as road transport. Major investment decisions, such as expansion into rural areas, need cost saving considerations such as maximising shared resources where coverage is non-existent.

Suggested action: The EPA and MoC should investigate the use of ICTs to mitigate emissions in other sectors to find out if the seven-fold savings of the Smart2020 report are applicable to Ghana, and whether speeding up investment in telecommunications would bring economic and emissions benefits more quickly than similar investment in other infrastructure, such as road and rail.

Figure 7 reminds us that ICT can have both positive and negative effects on the environment. There will be an increased environmental load caused by the ICT devices themselves, including increased consumption of energy and natural resources and generation of e-waste. Therefore, it is important that both the positive and negative impacts are quantified before going ahead with deployments such as a new broadband infrastructure.

Figure 7. Environmental aspects of ICT (weighing scale illustration)[108]



Specific examples of how the roll out of a broadband infrastructure could reduce GHG emissions in other sectors are given in the following sections.

3.2.1 Using ICTs to improve waste management

Globally, energy savings of the order of 46 GJ per tonne can be made by recycling ICT hardware and avoiding the need to mine/extract raw materials, especially highly energy intensive materials such as rare metals in personal computers[109]. Greater use of recycling and the safe disposal of e-waste can therefore assist in reducing the amount of GHGs released and therefore the effects of climate change, and introduce greater sustainability of supply to the ICT industry.

An example of how to do this is through the development of smartphone applications to help users to locate recycling and garbage bins. For example, the winning smartphone application of the first ITU's Green ICT Application Challenge, produced by Lis Lugo Colls from Spain, enables users to locate their closest recycling points so helping to reduce pollution and GHG emissions caused by e-waste[110].

Suggested action: The EPA and MoC or other appropriate agency in Ghana should support the adoption of intelligent systems for recycling and other forms of recovery, thereby decreasing the waste fraction that goes to final disposal and incineration.

3.2.2 Using ICTs to increase energy-efficient supply and maximize the use of renewable sources

ICTs can be used to maximise the efficiency of power systems. Their computing and communication capabilities are essential if power from renewable resources such as geothermal, solar, wind, wave and tidal are to be harnessed efficiently and fed into the electricity grid in a smart way.

Ghana is already providing 50 per cent of its electricity from renewable sources, although the production from predominantly hydroelectric schemes can be variable and unreliable. ICTs could play a useful role in controlling the load on the grid and so maximise the utilisation of available power from other renewable sources.

3.2.3 Using ICTs in education to raise awareness and build capacity on climate change

Educational content can be delivered via ICT networks and services to students in their home communities thus saving travel costs and increasing the penetration of information. Teleconferencing and audio conferencing are now used extensively in education. A study carried out by the Open University in the United Kingdom, which focuses on distance learning, shows that "On average, the production and provision of the distance learning courses consumed nearly 90 per cent less energy and produced 85 per cent fewer CO2 emissions than the conventional campus-based university courses[111]". Universal broadband access would allow educational content to be delivered direct to local schools and homes thereby limiting the need for travel to distant schools or cybercafés. ICTs can also be used for building capacity on climate change issues and sharing knowledge between professionals.

The challenge is to build a national broadband infrastructure and offer convenient access for every Ghanaian.

Suggested action: See action under paragraph 3.2.4.

3.2.4 Using ICTs in healthcare

Use of ICTs in healthcare is known as e-Health (or Health Informatics). Healthcare practice can be supported by electronic processes and communication. ICT tools used in e-Health include not only computers but also clinical guidelines, formal medical terminologies, and information and communication systems. E-Health can apply to nursing, clinical care, dentistry, pharmacy, public health and (bio) medical research[112].

Remote health monitoring enables individuals to continue to lead independent lives in their own homes. Telemedicine can also provide patients with access to specialists outside their geographical area using a broadband network. This can remove the need for all patients to travel to a medical centre and therefore has the potential to reduce GHG emissions. This technology is especially valuable in remote rural communities where travel to clinics or hospitals may otherwise be lengthy and impractical for patients.

Suggested action: To fully realise the benefits of mitigation in other sectors, it is recommended that Ghana sets up a broadband infrastructure to complement the mobile infrastructure that is already widely used for narrowband voice communications. This would bring benefits in terms of education, health care and waste management, as well as the capability to monitor the impact of climate change and reduce its worst effects. (The broadband infrastructure is explored more fully in Section 4).

Suggested action: It is also recommended that a Broadband Applications Stakeholder Group (BASG) is also set up in conjunction with the proposed Green ICT Council. This would monitor the implementation of broadband applications and ensure value for money from any new broadband infrastructure. It should explore how Ghana can benefit from broadband applications before setting up a potentially costly broadband infrastructure.

Suggested action: The appropriate agency in Ghana should assist and set targets for TSPs to deploy mitigating technologies such as travel substitution to reduce GHGs in other sectors.

4. How to make broadband infrastructure available to all Ghanaians without adding to GHG emissions

This section identifies specific ways to save energy and reduce GHG emissions in Ghana. Actions suggested for an evolution path for Ghana are provided in the green boxes.

To reduce the energy use per customer connected to either a wireless or wireline network, it is necessary to make networks and systems that are more energy efficient. If the use of renewable energy sources could be increased and the dependency on fossil fuels reduced, then networks and services could be expanded without increasing GHG emissions overall. This should be the aim of the NCA guided by the EPA to allow growth of telecommunication services in Ghana without increasing overall GHG emissions.

Energy costs are one of the largest operating expenses borne by TSPs, whether fixed or mobile. Therefore, there is a great incentive to reduce energy consumption in their networks and most TSPs have programmes to do so. Achieving this is also seen to deliver non-pecuniary environmental benefits which are reported either in the Annual Report or in a separate Corporate Social Responsibility (CSR) report to bring brand and reputation benefits.

Smarter use of ICTs and the incorporation of smart ICTs can help cut emissions by:

- Reducing the power consumption of ICTs
- Turning equipment off when not in use
- Using standby modes
- Requiring low-carbon equipment in procurement specifications

- Sharing equipment between utilities and TSPs
- Having a longer equipment life cycle before replacement

The above principles can be applied to both wireline and mobile networks. In Ghana, mobile networks have many times more users than wireline networks and user adoption is growing at a much faster rate, therefore these are covered first in the sections below as measures taken here have the potential to have a more significant impact on reducing emissions. However, the use of fibre optic networks is increasing as broadband services are rolled out, and so the energy efficiency of these must also be considered. Broadcast services and private circuits are also growing rapidly and emissions from these could become significant in the future.

4.1 Mobile services and energy efficiency

"*Irbaris estimates that mobile industry emissions were 90 mega-tonnes of carbon dioxide equivalent (Mt CO2e) in 2002 rising to 245 Mt CO2e by 2009. During this period, the industry grew from 1.1 billion to 4.6 billion connections, whilst GSM network coverage increased to over 90 per cent of the world's population in 2009 from 50 per cent in 2002 and a new generation of mobile broadband networks, 3G HSPA (High-Speed Downlink Packet Access), began to be built out. Emissions per connection actually fell by 30 per cent from 2002 to 2009*[113]".

The use of the network accounted for 71 per cent of emissions, and devices for 4 per cent. Embodied (i.e. non-use phase) emissions of the network component were 13 per cent whilst embodied emissions of the devices were 12 per cent. The embodied emissions are understood to be an annualised figure with handsets being replaced every two years. Some effort has been made to use recycled materials, including plastics. However, the report notes that the take-back rates are low as research shows that old mobile phones are typically kept by customers.

Base Transceiver Stations (BTS or base stations) typically consume around 65 per cent of a mobile TSP's energy usage (e.g. for Vodafone globally it is 62 per cent[114]). However, the type and level of demand for mobile services is key to the energy demand of the base station.

With 2G (International Mobile Telecommunications 2000), it was normal for a base station to run at around 800W power consumption. In 2011, this has been typically reduced to around 500W-650W (38-19 per cent reduction). Vodafone has shown that the adoption of a number of power-reduction techniques, such as remote radio heads, optimising the design of the antenna and radio frequency stages, and use of free air cooling, can reduce this to around 200W for a 2 transceiver GSM site[115] (75 per cent reduction from average rates in the year 2000).

International Mobile Telecommunications-Advanced (IMT-Advanced) have much higher power consumption due to growing demand for bandwidth for mobile data and applications. The advent of smartphones implies that data usage is likely to grow from around 700MB/month/user in 2010 to 2.5GB/month/user in 2015. Therefore, base stations will be running at full demand for a greater period of time and will normally consume up to 1000W per base station (25 per cent more than an average 2G base station). IMT-Advanced base stations are required to run at maximum power for at least 50 per cent of the time due to LTE data throughput requirements. LTE was designed with a higher modulation complexity and the peak power consumption increases as a result. Fortunately, there are potential solutions to this through, for example, high accuracy tracking enabling high efficiency power amplifiers[116].

If the energy consumption of a BTS could be reduced to 200W or less, then it would be practical to run a BTS from off-grid renewable sources for at least part of the day. This would reduce demand on the electricity grid and would decrease CO2 emissions. With totally off-grid electricity, it would also be possible to site the BTS where they will best serve populations without the additional cost of connecting to the grid.

4.1.1 Example of a base station run solely on renewable energy

To run a BTS wholly on off-grid renewable energy, it would currently be necessary to reduce power consumption to approximately 100W per BTS (87 per cent reduction in comparison with 2G base stations). This is due to the current size and cost of solar and/or wind powered electricity generators, which means that the current generation only practically provides around 100W of electricity. As technology improves significantly higher powers may become available, but it would still be useful to identify improvements in energy efficiency from BTSs to make them more cost effective to deploy.

Reduction to 100W per BTS has been achieved in remote locations such as the Isle of Bute in Scotland where connection to the electricity grid is currently not possible. Here the Hopscotch project[117] has reduced the energy demand of a 2G BTS down to 80W by:

- Switching off BTS functions that are not being used.
- Using predicted demand from users together with the predicted renewable energy that will be available.
- Combining solar and wind power. The availability curves for these seem to be mutually exclusive on the Isle of Bute as, normally, there is sun when there is no wind and vice versa.

The average wind speeds on the Isle of Bute range from 12-22 kph (3.3m-6.1 m/s) depending on the month of the year[118]. The average wind speed in Ghana ranges from 2-3 on the Beaufort scale (2.5-4.5m/s) according to the month of the year[119]. Therefore, the average wind speed in Ghana is only 66 per cent of that in Bute. The power output of a wind generator is proportional to the cube of the wind speed and so a wind turbine in Ghana will only deliver, on average, 29 per cent of the power in Bute. However there may be sites (e.g., on the coast) which are much more favourable to wind generation, and so studies should be undertaken at each site to identify the potential power outputs for a wind turbine.

It will not be feasible to supply 3G mobile BTSs consuming up to 1000W of energy wholly from non-grid electricity without the extensive use of diesel generators. An incentive based scheme could be established to ensure that TSPs in Ghana use of renewable energy sources where possible to reduce dependence on fossil fuels and therefore CO2e emissions..

Suggested action: The proposed Green ICT Council should consider a strategic plans to extend the coverage of 2/2.5G mobile networks to rural areas (the 50 per cent Ghanaians without coverage) by adopting the best available technology for low density applications (e.g. high antenna location, high antenna gain, with solar arrays and wind turbines to provide power).

Suggested action: TSPs should be incentivised to provide a target percentage of BTSs using non-fossil fuels.

Suggested action: Mobile TSPs who are unable to supply their BTSs wholly from off-grid electricity should be required to construct or purchase renewable sources of electricity which are delivered via the electricity grid. TSPs in Ghana who provide off-grid electricity from renewable resources should then receive regulatory and financial relief.

4.2 Mobile base-station generators

In developing countries, a significant proportion (approximately 30 per cent) of emissions from a mobile TSP's carbon footprint comes from the use of diesel (or other fossil fuel powered) generators. These are commonly used where there is no connection to the electricity grid. One example of an efficient diesel generator achieves 38 per cent efficiency at full load and 27 per cent efficiency at half load[120]. However, combined-cycle turbines as are now used in the electricity generation industry are in the 50 per cent to 60 per cent thermal efficiency range[121]. It will therefore be more energy efficient to use grid electricity unless a local non-fossil fuel feedstock, micro-hydro or solar power can be provided.

Developing countries are leading the way in turning waste biomass into energy[122] and this technology could be used to supply legacy generators using internal combustion (IC) engines. Methane, petroleum, wood gas and biodiesel are examples of fuels which have been used successfully in internal combustion engines. Biofuels have the potential to become carbon neutral and so reduce GHG emissions significantly, although this is heavily dependent on the farming, processing and transport methods.

A promising source of feedstock for future biodiesel production is algae, and this could be considered for Ghana. An obstacle preventing widespread mass production of algae for biofuel production has been the equipment and structures needed to begin growing algae in large quantities. Open-pond systems for the most part have been given up for the cultivation of algae with high-oil content, as contamination by other organisms blown in by the air is a problem. A closed system (not exposed to open air) avoids this but the problem then is finding a cheap source of sterile CO2. Several experimenters have found that CO2 emitted from a power station promotes algae growth, which therefore has the two-fold benefit of helping to scrub CO2 from power generation while producing biodiesel at the same time.

Biodiesel may also be produced from coconut oil[123]. This has the advantage of being readily available in Ghana and could be retrofitted to existing base-station diesel generators. More work is needed to establish the best choice of feedstock and whether sufficient land can be allocated to growth of this without reducing food supply.

Suggested action: The EPA, Energy Commission, or other appropriate agency in Ghana should consider paving the way for the deployment of biodiesel technology in Ghana. This could be used as a substitute for fossil fuel in mobile telecommunications base stations. The danger that the balance of land use will be moved from food production towards production of biodiesel can be avoided by using alternative feed-stocks such as the production of algae, and these should be explored.

A further technology being widely adopted in other African countries is 'micro-hydro' or micro scale hydropower. This can offer a higher power output than solar photovoltaic (PV) at lower cost. Studies in Kenya[124] have shown that hydro stations in the pico range (less than 5kW) can supply electricity to households at a fraction of the cost compared with solar PV.

They are also less vulnerable to changes in water availability than large-scale hydropower as they only use part of the water in rivers. The potential for the exploitation of micro-hydro in Ghana should be assessed.

Figure 8. Tungu-Kabiri 18kW crossflow turbine.

4.3 *Mobile infrastructure sharing*

Mobile networks can be made more energy efficient through sharing of resources between competing mobile service providers. Network sharing can significantly reduce costs, increase capacity and lower the network's environmental impact.

There are two levels of infrastructure sharing: passive and active. Passive sharing involves components such as the tower mast or pylons, cables, physical site or rooftop, shelter cabinets, power supply, air conditioning, alarm systems, etc. Active sharing includes antennas, antenna systems, backhaul transmission systems, and BTS equipment. Passive sharing at BTS sites is becoming increasingly common and reduces the environmental footprint of mobile networks by cutting the number of BTS sites required by each company to provide overall coverage.

Network infrastructure can be shared between:

- TSPs
- Technologies, e.g. LTE, UMTS and GSM
- Multiple radio frequency (RF) modules for capacity upgrades

and can occur at different levels:

- Location only
- Sharing the electricity supply
- Mast (Tower)
- Antenna system
- BTS (cell site)
- Signal

Examples of these are described below. Figure 9 shows a base station with multiple TSPs using the same mast but with separate antenna systems. Figure 10 shows multiple TSPs using a shared antenna system as well as a shared mast and electricity supply:

Figure 9. Mast sharing

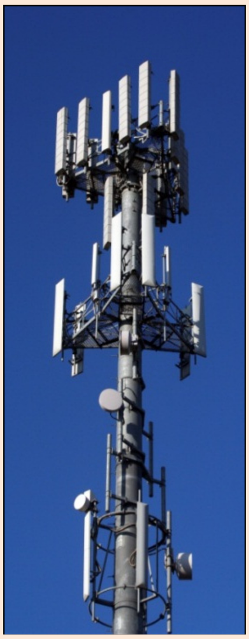


Figure 10. Mast and antenna sharing.

In Europe, in 2011 it has been estimated that two TSPs sharing a single network could save approximately €400m in CAPEX and €138m per year in OPEX compared with deploying separate networks[125]. In addition, the use of a technology called MORAN (Multi Operator Radio Access Network) can save 500W per site compared to hybrid combining. In this case, filter combiners are used to allow separate RF modules to share a common antenna system[125].

Active sharing agreements include T-Mobile and 3 Group in the UK, Telstra and 3 Group, as well as Vodafone and Optus, in Australia, Tele2 and Telia, as well as Tre and Telenor, in Sweden. In the Republic of Korea, all three TSPs, KT, SK Telecom, and LGT invested in KRTnet Corporation in 1996 to construct and manage base-station sites jointly used by all TSPs, leading to co-location of sites and tower sharing.

In Africa, Ghana and Nigeria lead the way on mobile infrastructure sharing. "*In December 2010, MTN entered into an agreement with American Tower Company to establish a joint venture in Ghana called TowerCo Ghana. American Tower, through a wholly owned subsidiary, took a 51 per cent stake in TowerCo Ghana, while MTN Group held a 49 per cent share*"[126].

The guidelines for the deployment of communication towers issued by the NCA[127] include the process for application for a licence to erect and operate a tower. An applicant "*must demonstrate that all reasonable steps have been taken to investigate tower sharing before applying to the permitting agencies to construct a new tower within a specified radius of 400m of the proposed site.*" A licence can allow an independent infrastructure provider to offer service providers access to towers on a shared basis provided that the charges are fairly shared[128]. The guidelines include reference to energy saving measures such as solar panels. The guidelines refer to Recommendation ITU-T K.52[129] on safety levels for persons in electromagnetic fields near towers.

Mobile infrastructure sharing is an effective way to reduce both costs and GHG emissions. It could also contribute to the wider deployment of mobile services in Ghana as many mobile TSPs are yet to move into remote rural areas. "*People are sparsely scattered over wide areas and most believe that the investment will not match the returns. Operators do not want to take the risk alone. Tower sharing is the answer to this as the risk is effectively shared by the service providers*"[130].

Suggested action: The NCA or other appropriate agency in Ghana should investigate how much energy could be saved by sharing of infrastructure (both passive and active) between mobile TSPs.

Suggested action: Passive sharing of infrastructure such as masts and antennas is already the preferred solution in Ghana. Sharing of the electricity supply and site electronics should also be encouraged by NCA and should not be prevented by competition rules.

4.4 Wireless and fibre-based broadband networks compared

The deployment of a broadband infrastructure would help to realise the NCA vision of an information rich knowledge-based society and economy through the development, deployment and exploitation of ICTs and could help to achieve UN Millennium Development Goals (MDGs)[131] such as improving literacy rates, improving maternal health, ensuring environmental sustainability, and facilitating development as described in Section 3.2.

For high-speed broadband communications, optical fibre provides the highest capacity, and the majority of broadband plans in developed countries are defining goals of between 10 to 100 Mbit/s[132]. An optical fibre system such as Gigabit Passive Optical Network (G-PON) can provide this capacity at less than 1mW in the light path per location. To provide this capacity over a mobile network would require the user to be within 100 metres of a base station (as is currently the case for all high-speed WiFi) and for that base station to be emitting more than 1 Watt. A further problem for mobile TSPs is how to deliver sufficient radio power inside buildings. Building materials in walls typically reduce the signal power by a factor of 10 or more[133]. To provide nationwide broadband roaming at this capacity per user would be highly energy intensive with current technologies and therefore is currently considered an unnecessary goal. It is more economic and energy efficient to provide one fibre to each termination point (building or pole top) and use the best available customer premises network e.g. WiFi to allow roaming within the area of the subscriber premises and connect to the user's device. It is strongly recommended that Ghana invests in fibre access technology whenever an infrastructure investment opportunity arises.

When comparing fixed access and wireless for broadband services, Franco Bernabè, CEO and President of Telecom Italia said in his address at the ITU Workshop "Moving to a Green Economy through ICT Standards" on 6th September 2011 that wireless is 100 times more energy intensive than fixed[134]. In his presentation at NOC 2009, Valladolid, Spain, Lowell Lamb showed that WiMAX per subscriber power is 52.6 Watts (for up to 3.5 Mbit/s capacity near the base station) whereas a state-of-the art PON is 3.2W per user (for up to 1 Gbit/s capacity)[135]. Note that the PON operates with 16 times less power per subscriber and can deliver 30 times the capacity. More can be read about the state-of-the-art of wireless and fibre access systems in these References[136, 137].

Mobile networks need to coexist with fibre networks in the information society. They satisfy different needs. Mobile networks are mainly used for communications on the move and fixed networks are used mainly for deskwork or entertainment. In Ghana, mobile networks have many times more subscribers than the fixed network, and so despite the additional energy consumption of mobile networks, it is considered that the many benefits of a basic broadband service require that attention is given to upgrading mobile networks to expand the reach of this service. Ideally, this would be achieved without adding fill-in base stations to achieve the necessary capacity. Investment in new infrastructure should focus on providing sufficient fibre capacity to put Ghana on a path to compete with and enjoy the benefits of richer economies. An upgrade path which aims to provide superfast services over wireless alone will lead to a future with greatly reduced energy-efficiency and higher GHG emissions than with fibre.

4.5 Next generation networks (NGNs)

A key differentiator between legacy and next generation networks is the type of switching used. Legacy networks use circuit switching optimised for voice communications, whereby the user pays for the time the circuit is maintained. NGNs use packet switching, whereby the user pays for the amount of information which is carried.

The growing demand for ICTs for new multimedia services, and the resulting expansion of digital traffic, is leading the telecommunications industry towards the convergence and optimization of traditional networks. The goal is the coming together of existing networks (fixed, mobile, Internet, broadcast, etc.) into a unitary network architecture which has been termed Next Generation Networks (NGNs). This emerging technology is a packet-based network able to make use of multiple broadband technologies, providing telecommunication services to users, with independence of service-related functions from transport technologies.

NGNs are more energy efficient than the current generation of public fixed networks, and the principles should be adopted[138].

Introduction of NGNs could provide at least a 40 per cent reduction in energy use due to:

- A significant decrease in the number of switching centres required.
- More tolerant temperature range for NGN equipment.
- Use of more advanced technologies such as passive optical networks (PONs).

National Broadband Plans are being implemented in many countries around the world, including Ghana. The elements of Ghana's National Broadband Plan are already being implemented through the "Wiring Ghana" project which started in 2007 to provide a 4,000 km fibre backbone network, and the agreement with Huawei Technologies in 2009 to supply an advanced telecommunication infrastructure to ensure that broadband Internet access is available countrywide by the end of 2011. However, this needs extending to homes, businesses and schools in Ghana.

A significant investment in infrastructure would be needed to bring Ghana up to the standard of developed countries where the availability of a wireline or fibre connection is the norm. For example, according to the Fibre-to-the-Home (FTTH) Council Europe, the cost of a fibre home connection in Holland is between €750 (urban) and €1,100 (rural)[139]. The cost of labour is a significant part of this and further work is needed to estimate the potential costs for Ghana. The choice of infrastructure will be critical in minimising GHG emissions and other environmental impacts and there is a significant difference between emissions from fixed access Next Generation Networks (NGNs) and mobile broadband networks.

When calculating the final impact of either technology, a life cycle analysis (LCA) of the construction and operation of infrastructure should be performed. The inventory could yield a net carbon sequestration benefit in the case of the fibre access network. There will be captured carbon in approximately two million of the wooden poles needed for a distribution network in Ghana. Utility poles have a typical life of 40-60 years and the material may be reused (e.g. for fence posts) in a cradle-to-cradle recycling scheme[140].

The carbon captured in the wood may be accounted for in different ways. One LCA analysis claims back the sequestered carbon at end of life. This compares the energy input in the manufacture and installation of steel, concrete and wooden poles and shows that wood has the lowest embodied carbon[141]. In this analysis the sequestered energy in the pole is not claimed until the pole is converted into carbon at the end of its life cycle.

A utility company may be able to claim carbon sequestration if it produces its poles from a forest regeneration project and locks away the carbon at end of life in an environmentally friendly way such as conversion to biochar. A typical wooden pole weighs 0.5 tonnes[142] the sequestered carbon may be shown to be equivalent to 900kg CO2. The total sequestered carbon captured for a 'fibre to the pole' system in Ghana would be approximately 1.8Mt CO2e. Note that this is a 'one-off' saving and does not go far towards offsetting the annual emissions of Ghana, 24Mt CO2e.

Suggested action: There is a case for constructing modern fixed access broadband networks, based on an NGN, in Ghana. This would replace growing demand for energy from mobile networks that would otherwise make increasing use of IMT data. A modern broadband fixed infrastructure would help to meet targets for literacy and health that can only be met using advanced technology, as described in Section 3.

It is important that Ghana rolls out an ICT infrastructure following a model based on its own circumstances and to satisfy demand from Smartphone users' wireless broadband IMT, IMT-Advanced and WiFi would be the preferred technology choice for most end users. However this will be more energy intensive than FTTP with WiFi to make the final user connection. Energy efficiency over the whole life cycle should be a key criterion when rolling out new infrastructure (and selecting a new technology) and it will be essential to perform a life cycle analysis to make sure that overall the deployment and operation of any new infrastructure would actually reduce GHGs and not increase them.

Suggested action: Any implementation of new broadband infrastructure should be subject to the oversight of the proposed Green ICT Council.

4.6 Utility pole sharing

It has been estimated that 45-47 per cent of Ghanaians have access to grid electricity[143]. A telecommunication infrastructure project to provide fibre to the premises or (pole top) with WiFi distribution would require electricity for the end devices. The supply of electric power along with the fibre cable would allow sharing of infrastructure such as utility poles. Such sharing offers the prospect of using the poles for other purposes such as street lighting and for pole-top mounted WiFi hotspots.

WiFi distributed from the pole top could offer the benefit of being 'always on', and to allow emergency calls to be made a micro USB connection could be made available to power a handset. The total power consumption of an efficient optical network termination, including WiFi with 1W transmitter output power (the FCC maximum), should be significantly less than the maximum 7.5W specified in the European Union (EU) Code of Conduct V.4.

Suggested action: The proposed Green ICT Council should consider utility pole sharing to connect access to grid electricity, and a broadband fibre/WiFi network for the remaining 50 per cent of Ghanaians without access to grid electricity.

4.7 Fibre sharing

MTN Ghana has reported[144]:

> *"To reduce its impact on the environment, as well as manage capital and operational costs, MTN Ghana continues to work toward greater sharing of fibre infrastructure with other mobile operators. It is pleased to report some important successes in this regard in 2009, with more sharing agreements expected to be sealed in 2010".*

For example, in the case of the UK it has been recognised by the Ofcom that a single infrastructure provider can be used for fixed access networks provided that the services are made available to TSPs on the basis of 'equivalence' down to the level of the individual subscriber. Following public consultation[145], the fixed access network of BT was split into a separate operating and accounting division 'Openreach'. Sharing includes copper lines and equipment space in the telephone exchanges.

In Ghana, sharing of infrastructure facilities is beneficial where there is a natural monopoly such as in the area surrounding a mobile phone base station. This can save both cost and energy. Provision is made for this in the 'Guidelines for the deployment of communication towers' as discussed in Section 4.3.

Tight regulation on prices is recommended so that the local monopoly provider does not exceed costs by more than an agreed margin. It is important that incentives are given to invest in new infrastructure.

The deployment of a fibre access network can be staged so that key buildings such as libraries and schools are connected first to make information available to communities. Access can be made cost and energy efficient using WiFi at the terminal stations. Micro-payments for the service provider can be made using systems such as Skype or FON WiFi.

4.7.1 Example of a base station run solely on renewable energy

In the future it is anticipated that circuit-switched voice calls over the fixed access network will become obsolete. Mobile networks and voice over Internet protocol (VoIP) services are replacing the need for traditional voice communications using a dedicated energy-intensive public switched telecommunications network (PSTN).

Developed countries are keeping their copper lines and circuit switched legacy network because they were expensive to install, have a long service and life, and allow emergency calls with power provided over the line from the telephone exchange. Although there are areas in Ghana without mobile coverage, as described in Section 1.2., there is up to 77 per cent mobile penetration by subscription which is expected to rise to 95 per cent by 2015[146]. Due to the inherent increase in locational flexibility of mobile devices it could be argued that they are generally better suited as an emergency communication device when compared to fixed line services. Users are already aware of the need to keep phones charged up and have access to small-scale off-grid supplies, such as solar panels, that can be used when needed. The case for expanding copper-based wireline communications in Ghana is weak.

4.7.2 Backhaul networks

The GSMA reports the importance of local authorities in providing backhaul networks for both fixed and mobile network broadband upgrade[147]:

> *"Local authorities play a key role at sector level in the development and usage of new services, broadband coverage and bandwidth expansion. Local communities are in the best position to aggregate public services (e-education, e-health, etc) and ensure their availability to citizens through the internet. Local authorities also have a direct interest in broadband coverage to attract enterprises and particularly small manufacturing enterprises. Existence of public initiative networks enables local operators to offer business services and challenge national operators. Fibre-based backhaul networks are crucial to enable such offers. Fibre-based backhaul networks also play an important role in achieving broadband coverage and prepare the migration from high to very-high speed fixed and mobile services – fibre-based backhaul networks are necessarily independent of access technology. Local authorities can also lower market entry barriers for the roll out of next generation access networks by adopting master plans (e.g. duct installation in waiting mode, dark fibre roll-out) and mapping available*

infrastructures to support the deployment of next generation access networks (creating a "digital registry")".

In the case of Ghana, the EPA and the NCA should push to encourage the sharing of infrastructure when expanding the network to deliver capacity to key places such as new base stations (for wireless broadband), schools and libraries (for fixed access) and individual homes (for full rollout).

Suggested action: The NCA or other appropriate agency in Ghana should investigate opportunities to extend fibre backhaul networks to public access points such as schools when increasing the number of mobile phone base stations to expand coverage.

4.8 Digital broadcasting and telecommunication networks

4.8.1 Digital terrestrial TV (DTT) versus analogue broadcast TV

Globally, the changeover from analogue to digital TV distribution is predicted to raise emissions initially by around 10 watts per user as they will require a digital to analogue convertor, as a set-top box. However this additional power load will reduce as TV sets are replaced by more energy-efficient devices with an integral digital TV tuner[148].

The best example of a study to compare the emissions from analogue and digital transmission systems has been carried out in the UK[149]. This shows that analogue transmitter power (effective radiated power- ERP) of the 5 terrestrial channels is approximately 75MW. The total ERP post switchover is estimated be 18.2MW. This is a reduction in power of approximately 75 per cent. When antenna gain (10dB) and transmitter efficiency are taken into account, the DC power to the transmitters is estimated to be 13MW for the UK.

Box 2. ITU digital broadcasting plan for 120 countries

ITU has developed technical standards and approved the Digital Broadcast Plan, which reduces by ten times, the consumption of hundreds of thousands of powerful transmitters.

Suggested action: Ghana's digital broadcasting switchover timetable started in January 2010 and will be completed in July 2015[150]. Opportunities should be investigated to accelerate this exercise to save energy and further reduce GHG emissions.

4.8.2 A comparison of the carbon footprint of digital terrestrial television with video-on-demand

The Internet is being increasingly used to distribute entertainment services that would have traditionally been carried by broadcast networks. It is therefore relevant to make a comparison of the respective carbon footprints of digital terrestrial TV (over a radio frequency broadcast network) and video-on-demand (telecommunications network).

It is estimated[151] that television and related equipment account for 1.8 per cent of GHG emissions and ICTs are responsible for two per cent of global GHG emissions. Both these sectors are forecast to grow as the developing world increases its uptake of technology.

A study by the British Broadcasting Corporation (BBC) estimates the carbon footprint of two different ways of watching television: using terrestrial broadcast DTT and video-on-demand (VoD) over the Internet. It compares the two distribution methods and the corresponding consumer equipment. The carbon footprints are derived using a bottom-up analysis of the system applied to the BBC's television services. This was the only environmental impact considered and was mainly from electricity use. Equipment manufacturing was not included.

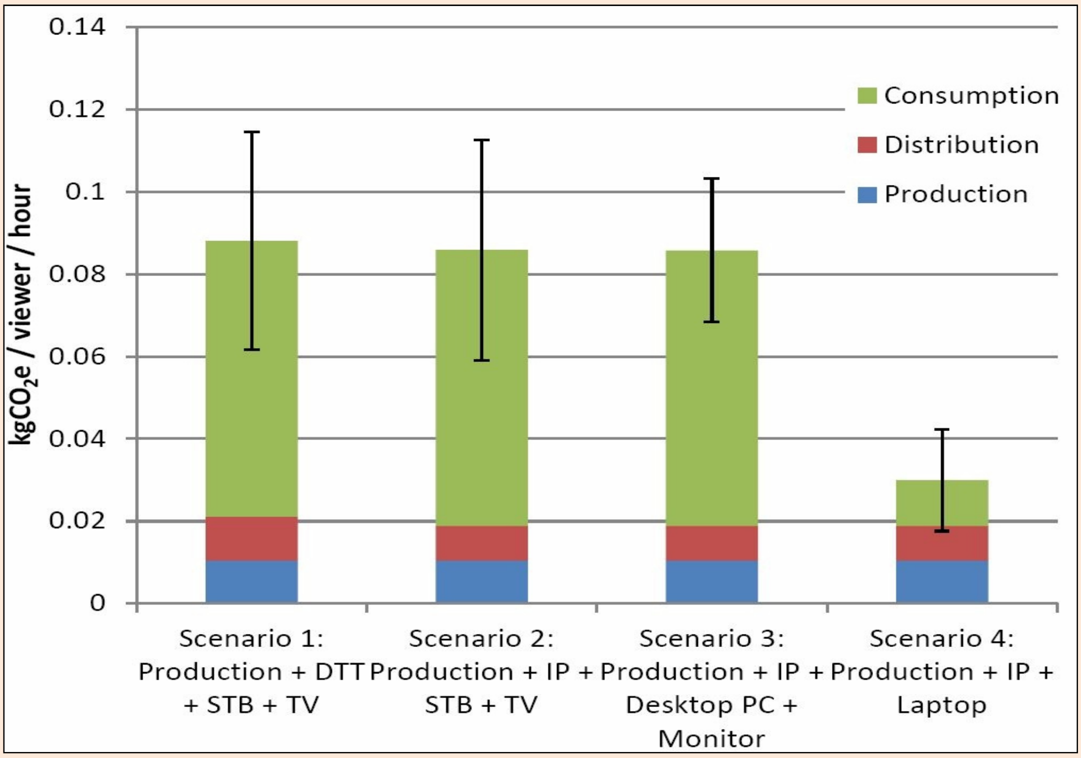
The main results showed that broadcast DTT has a smaller carbon footprint per viewer-hour than VoD for average sized audiences, but not with small audiences or for homes using an aerial amplifier. The largest environmental impact from watching television is from the consumer equipment. This amounts to 76 per cent of the total for DTT and 78 per cent and 37 per cent for VoD using desktop and laptop computers respectively. The trend for larger screens could increase this, although there is a parallel increase in viewing on small mobile devices. Programme-making contributes 12 per cent to 35 per cent.

Results were sensitive to the viewer numbers per display. Doubling the number of viewers per display reduces the carbon footprint by 44 per cent for digital terrestrial television. For VoD, there was large uncertainty in the energy consumption data for the content delivery network and the Internet. However, this does not affect the main outcomes.

Figure 11 shows the results for the full end-to-end chain with the same four scenarios. The production component, which is common to all, has the same value in all scenarios. The DTT distribution component includes an aerial amplifier and the average value for DTT distribution was used. Scenarios 1-3 have a carbon footprint of 0.088 kg CO2e/viewer-hour, 0.086 kg CO2e/viewer-hour and 0.086 kg CO2e/viewer-hour respectively whereas Scenario 4 has a carbon footprint of only 0.030 kg CO2e/viewer-hour.

The consumption component is the largest in all scenarios although the lower average energy consumption of laptop PCs is reflected in the results.

Figure 11. Overall comparison of four different scenarios. The error bars show the 95 per cent confidence interval.



The trend to watching TV on laptops or smartphone displays rather than TV sets may become more popular in the future as viewing habits change from 'family' to 'personal' viewing. Such personal devices are less energy intensive than a conventional family room size TV.

An energy-saving technology for Ghana to consider is the use of smartphones or equipped tablets or laptops for TV entertainment. In the absence of fixed access networks, most Ghanaians will need to rely on a broadband wireless system to access entertainment services such as YouTube.

Suggested action: The appropriate agency in Ghana should investigate how the trend towards single-user alternatives, such as laptops and smartphones, to traditional family TV sets will increase personal choice whilst adopting a less energy-intensive lifestyle.

4.9 Facility sharing to save costs: digital broadcasting and telecommunications networks

The opportunity to increase the coverage of DTT in Ghana together with the coverage of mobile telecommunications should be explored. This would save cost as the infrastructure facilities can then be shared. This would mean that several services can be brought to sparser and poorer populations than would be affordable by one service provider acting alone. By making public service DTT channels available to a wider population, more channels can be made available than is possible using analogue transmission, including those which carry information about the environment worldwide such as The Community Channel[152]. A detailed study in this area would need to take account of the gaps in coverage, the need for DTT relay stations, the risk of radio frequency interference between services, and the experiences of mast sharing elsewhere.

A report published in 2011[153] states that "*The current geographic extent of TV signal is 80 per cent coverage of the land area and 70 per cent of the population is covered. The uncovered areas are due to gaps caused by an uneven distribution of the transmitters. Included in the plans for the digital rollout, are future plans to extend coverage and close the gaps. A tentative schedule shows digital coverage will be completed by 2012*".

Suggested action: The NCA should investigate opportunities for facility sharing which would improve the coverage of DTT and mobile phone services.

4.10 A telecommunications evolution plan for Ghana

This Chapter has examined options for extending the coverage of telecommunication networks without increasing GHG emissions. A summary of the key findings is presented here.

- Extend the coverage of mobile networks to rural areas by adopting the best available technology for low-density applications (e.g. high antenna location, high antenna gain), with use of solar arrays and integral wind turbines to provide power.
- Upgrade the existing mobile infrastructure with a view to offering basic Internet access from all BTS with, for example, smartphones and a switch to renewable energy sources in the process.
- Adopt infrastructure sharing (e.g. utility poles) to reduce the cost of connecting grid electricity and a broadband fibre/WiFi network for the 50 per cent Ghanaians without access to telephony (mobile or fixed) and grid electricity.

5. How global ICT standards will help reduce GHG emissions in Ghana

International standards are fundamental to delivering benefits in terms of energy efficiency because their use will result in:

- Lower energy usage of all ICT equipment that meets the standard, particularly where the standard is referenced in procurement directives.
- Lower equipment costs through commoditization of equipment, leading to greater deployment of the most energy-efficient equipment available.
- Lower costs will also lead to greater deployment of equipment in support of mitigation and adaptation.
- Common measurement and assessment methods so that the performance of different ICT-based solutions can more readily be compared and evaluated.

Some examples are given below of where international standards have helped to improve energy efficiency of products and services.

However, standards will not be sufficient on their own to bring about reductions in energy usage. Targets also need to be set to provide a stimulus and motivation for improvements in energy efficiency. For example, the European Union Codes of Conduct (CoC) could play a significant role here as described below.

5.1 Example: EU Codes of Conduct (CoCs)

The European Union (EU) CoCs are European Community action to improve the energy efficiency of ICT equipment. They are not standards and although they set targets for energy efficiency, sign-up is invited and compliance is voluntary. CoCs are published by the EU Joint Research Centre (JRC) and include:

- CoC for Data Centres
- CoC for Digital TV Services
- CoC on Energy Consumption of Broadband Communication Equipment
- CoC on Efficiency of External Power Supplies2
- CoC on AC Uninterruptible Power Systems (UPS)

Since these CoCs were introduced, significant numbers of vendors have signed up to them on a voluntary basis. They are therefore helping to reduce GHG emissions globally and it is estimated that they could reduce ICT GHG emissions by around ten per cent over five years.

Although not all ITU members agree to the establishment of energy-reduction targets, a question for Ghana or African regional ICT administrators is whether a similar set of CoCs is needed, or whether the EU framework should be followed or supported in this area.

It could be argued that Ghana should not embrace the EU Codes of Conduct, but rather contribute to the development of similar frameworks at regional (African) level, although harmonisation would be essential so that manufacturers can continue to produce equipment cost-effectively for global markets. With the support of regional or international organizations, such as the ITU, Ghana could provide a country case for the adoption of the CoCs or for the development of a compatible regional framework for the African region.

Note that if the African region does not specify power levels when procuring equipment there is a risk that suppliers will supply higher power products which are outside the EU CoC specifications.

Suggested action: The NCA or other appropriate agency in Ghana should consider which CoCs with voluntary or mandatory reductions in equipment energy consumption should be introduced to vendors supplying equipment to TSPs in Ghana.

Suggested action: The NCA or other appropriate agency in Ghana should require annual improvements to the energy efficiency of base stations through the adoption of CoCs or international standards, for example, based on the experience provided by the EU framework or ITU.

Suggested action: The EPA should support the development of CoCs or standards for energy efficiency. Suppliers would then be more motivated to provide Ghana with their lowest energy consumption products.

Suggested action: The NCA and EPA should investigate the need for development of similar frameworks (CoCs) at regional (African) level. These could be developed with the support of regional or international organizations such as the ITU. The EPA could provide a country case for either the adoption of the EU CoCs or for the development of a compatible regional framework for the African region. Harmonisation with international standards such as Recommendation ITU-T L.1300 "Best practices for Green Data Centers" or the EU CoCs would be essential so that manufacturers can continue to produce equipment cost effectively for global markets.

5.2 Life cycle assessment

A life cycle assessment (LCA) as defined in ISO 14040/44 is a technique to assess the environmental impacts associated with all the stages of a product's life from cradle to grave. It is valid for any product, not only for ICT equipment. The phases of an LCA have been internationally standardized by ISO in the ISO14040 series of LCA standards. Publication of this standard has ensured that all phases of the life cycle of ICT equipment are accounted for (not just the use phase) in any assessment of GHGs arising from the use of that equipment. This has made it much easier to compare different ICT-based solutions.

5.3 Recommendation ITU-T L.1000

The recently published Recommendation ITU-T L.1000 for a universal energy-efficient mobile phone charger will save up to 82,000 tonnes of redundant chargers a year and at least 13.6 million tonnes of CO2 annually. It has been estimated that the widespread adoption of ITU-T L.1000 will result in a 50 per cent reduction in standby energy consumption and approximately 14 Mt of GHG emissions reduction each year.

This is one of the many standards developed by ITU to reduce e-waste and reduce energy consumption.

Suggested action: The MoC, EPA, and the Energy Commission should lead the process of adoption of Recommendation ITU-T L.1000 in Ghana.

5.4 ITU-T methodologies for assessing the environmental impact of ICT

Methodologies for assessing the environmental impact of ICT are currently being developed by ITU-T Study Group 5 (ITU-T SG5) in close cooperation with the UNFCCC, and other standards organizations. Cooperation with the UNFCCC is particularly important for the assessment of the environmental impacts of ICT projects and the assessment of the environmental impacts of ICT in countries or groups of countries.

ITU-T SG5 is developing a set of methodologies for the assessment of the environmental impact of:

- ICT goods, networks, and services (approved)
- ICT in organisations (approved)
- ICT projects (under development)
- ICT in cities (under development)
- ICT in countries or groups of countries (under development)

The following environmental impacts will be assessed:

- Energy consumption
- Global warming potential or GHG emissions
- Raw material depletion
- Water depletion
- Ozone depletion
- Air toxic emissions
- Photochemical ozone creation
- Air acidification
- Water eutrophication
- Water toxic emissions
- Hazardous waste generation

In the first phase, the focus of the Recommendations will be on energy consumption. This should be sufficient to meet the immediate needs of Ghana for improvements in energy efficiency.

The assessment of GHG emissions covers the whole life cycle phases as described in Recommendation ITU-T L.1410 Methodology for environmental impacts assessment of ICT goods, networks and services:

- Raw material acquisition
- Production
- Use
- End of Life Treatment

Any assessment should identify the embodied carbon in the raw material acquisition and production phases as well as the emissions arising from the use and end of life treatment phases.

Suggested action: The MoC, EPA (or African Region) should contribute to the ITU-T SG5 work on ICTs and Climate Change in order to ensure that the methodologies being developed meet the specific requirements of Ghana (or African Region). In addition, the EPA and MoC could provide leadership for a case study of a pilot test of the new ITU-T methodologies to assess the carbon footprint of the ICT sector and the reduction of GHG emissions in other sectors.

5.5 What energy efficiency metric should be used in Ghana?

An energy efficiency metric needs to be defined which allows Ghana to expand its ICT market to the whole population whilst minimising overall energy usage. This metric should provide a meaningful indication of progress towards the target level (to be set by regulators). The most appropriate metric could be considered to be:

"average power per customer connected".

However, this does not take into account the desirability of moving to non-fossil fuels and the use of renewable sources of energy. Therefore this metric can be amended to take into account the use of renewable energy sources. Therefore, a better metric in these circumstances could be:

"average power originating from fossil fuels per customer connected".

This number needs to be as low as possible, and TSPs could be challenged by the NCA to make annual reductions. This would give TSPs in Ghana the incentive to develop renewable sources of energy which would allow faster expansion of its telecommunications market (without increasing GHG emissions) than would be possible using energy efficiency measures alone.

To use this proposed metric it would be necessary for regulators to verify the number of customers connected to each TSP's network and the energy used by the TSP. One way of obtaining this information would be to obtain reports from TSPs of how many users have accessed the network during the previous year together with reports of the fossil fuel or electricity usage during that period.

It would also be necessary for TSPs in Ghana to identify and report their GHG emissions to the EPA so that these can be assessed.

Suggested action: The NCA or other appropriate agency in Ghana should request figures from TSPs providing *"average power originating from fossil fuels per customer connected"* when assessing the progress of TSPs towards set targets.

6. The role of policy-makers and regulators in reducing GHG emissions in Ghana

In Ghana, the NCA (with a mandate from the MoC) is responsible for promoting competition between TSPs and ensuring infrastructure development. The EPA is responsible for protecting the environment, including responding to the threat of climate change. These distinct roles must be taken into account in addressing the actions proposed by this report.

The ITU also has a key role to play in global telecommunication regulation. The ITU develops international standards and hosts the annual Global Symposium for Regulators (GSR)[154] and has developed a global portal on "ICTs, the Environment and Climate Change" intended for policy-makers and regulators around the world.

6.1 Principles of regulation

Regulation of telecommunications service providers is normally set up to achieve an open market, fair competition for service, more investment in infrastructure, more innovation, a wider range of (different types of) services and more choice of services for consumers[155]. This does not normally include energy efficiency considerations.

The possible principles for regulation to encourage energy efficiency were discussed at the 10th ITU Global Symposium for Regulators[156]. These included the questions of:

> *"whether the responsibilities of ICT sector regulators should be broadened to encompass environmental objectives, particularly policies and interventions that relate to climate change"*

and:

> *"should GHG reduction measures be incorporated into existing regulatory mechanisms or is there a need to devise specific regulatory interventions".*

To ensure a reduction in GHG emissions from the ICT sector in Ghana, it will be beneficial to include measures to ensure "a reduction in GHG emissions down to a sustainable level" as part of the regulatory framework. However such regulation should not stifle the processes of liberalisation, increasing efficiency and continuous innovation that ensure a diverse and growing market.

Suggested action: The EPA and MoC should promote legislation to reduce GHG emissions caused by ICTs and identify ways to reduce emissions according to an agreed national strategy.

Alternative methods of achieving this would be:

- A Carbon Tax: a tax on the burning of fossil fuels assessed according to their carbon content. Renewable energy, such as solar and hydro, does not convert hydrocarbons to CO2 and so is favoured by not taxing them.
- Cap-and-Trade: which would cap GHG emissions at existing levels by allocating a fixed number of 'permits to emit'. To be able to emit more CO2, a company would have to buy more permits on the open market.

A carbon tax would be simplest to implement but does not guarantee to keep emissions at current levels or reduce them. Cap and Trade allows for reductions to be achieved by progressively withdrawing permits from the market. Examples of both of these are given in the following sections.

6.2 Regulation in developed countries

The Kyoto Protocol (KP) to the UNFCCC provides the sole global binding agreement defining specific targets for the reduction of GHG emission in a limited group of countries. During the Durban Climate Change Conference held in 2011, parties to the UNFCCC agreed a second commitment period under the Kyoto Protocol to start 2013. Additionally, Durban cemented mitigation plans of 89 countries from now until 2020, and identified the path toward the future legal framework that will cover all nations of the world, remarkably departing from the past[157].

As countries advance in the negotiation of a universal legal agreement under which all countries will mitigate their emissions in the long run (aiming at concluding these negotiations by 2015 for the agreement to enter into force in 2020), there are valuable examples of regulations that developed countries have implemented at the national level, as shown below.

6.2.1 Example from the United Kingdom (UK)

As part of a national strategy to reduce overall GHG emissions, the UK has adopted the Climate Change Act 2008[158] which sets a target date of 2050 for the reduction of targeted GHG emissions. This is legally binding.

It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80 per cent lower than the 1990 baseline.

In the UK, Ofcom[159] is the independent regulator and competition authority for the UK communications industries. These include broadcasting and telecommunications. It has a statutory duty to act in the interests of citizens and consumers by promoting competition, and protecting consumers from what might be considered harmful or offensive material. Some of the main areas Ofcom presides over are licensing, research, codes and policies, complaints, competition, and protecting the radio spectrum from abuse. Ofcom has not taken on responsibility for measures to reduce GHG emissions arising from energy use in the communications sector although it has commissioned reports which include sections on energy demand changes arising from analogue to digital conversion. These are cited in Section 4.8.

The Department of Energy and Climate Change (DECC) is the UK government lead department on climate change mitigation. DECC is responsible for managing the combined risk of climate change and a shortfall in the supply of safe, affordable energy. This includes managing electricity supplies generated by renewable energy and power stations fitted with carbon capture and storage, reducing GHG emissions arising from heating and cooling systems in buildings and transport. DECC is the designated national entity with overall responsibility for the national inventory which is reviewed by the UNFCCC[160].

The Department for Environment, Food and Rural Affairs (DEFRA)[161] is responsible for GHG emissions mitigation in agriculture, forestry, land management, waste, fluorinated gases and non-CO2 emissions from industrial processes, and treatment and use of water. In many of these areas, DEFRA determines policy in England. It also publishes annual reports on carbon emissions across all sectors.

In England, the Environment Agency (EA)[162] is responsible for ensuring that policies are carried out including running some of the main trading schemes to reduce GHG emissions, regulating important low-carbon technologies such as hydropower, nuclear power, and carbon capture and storage. The EA has a major role in managing adaptation to climate change through flood and coastal risk management, for the water and wetland environment, and as an advisor in the land-use planning system.

In the UK, ICT industries report in the same way as other industries. If they use more than 1GWh electricity per annum they are required to produce a report[163]. Organizations with emissions over this limit are required to purchase carbon credits as a tax incentive/burden to reduce emissions. Year-on-year lower thresholds will be set which if not followed will result in a gradual rise in this taxation bill and set industry competitors with lower emissions on a path to higher profitability.

The UK also has a tax on carbon emissions from motor vehicles applied through the annual road tax on vehicles emitting over 100g/km.

6.2.2 Example from Canada

Canada has made a commitment to cut GHG levels by 20 per cent by 2020. This will be done by establishing a cap-and-trade system, i.e. setting a market price for carbon and setting up a market in carbon emissions trading.

Some Canadian states have also introduced carbon taxes. For example, in 2008 British Columbia implemented a carbon tax of USD 10 per tonne of CO2e emitted (2.4 cents per litre of petrol). The tax increases each year until it reaches a final price of USD 30 per tonne (7.2 cents per litre of petrol).

Canada is also imposing mandatory carbon capture and storage (CCS) for all new fossil-fuelled power stations by 2012.

6.2.3 Example from Japan

In Japan, a mandatory cap-and-trade programme has just been set up in Tokyo. Around 60 million tonnes of GHG emissions were emitted in Tokyo in 2006 and this had risen by three per cent since 1990. The cap-and-trade programme is unique in that it focuses on large office buildings concentrated in the city centre as these emit around 40 per cent of the CO2 emitted from the commercial sector. The cap is an absolute cap; not an intensity target as used in other countries.

Installations under the cap are required to reduce CO2 emissions by six per cent between 2010 and 2014 and this is intended to lead to an overall reduction of GHG emissions in Tokyo by 25 per cent over 2000 levels by 2020. More detail is available here[164].

6.3 Regulation in developing countries

The Kyoto Protocol does not establish reduction targets for developing countries such as Ghana, which ratified the treaty on 1995. However, significant progress has achieved during the 2011 Durban Climate Change Conference, where, according to the UNFCCC[165],

> *"Under the Convention, all industrialized countries plus 49 developing countries have made mitigation pledges covering the time period from now until 2020. These pledges cover 80% of global emissions and were affirmed in Durban. Additionally, agreement was reached on how and by when both developed and developing countries will report on these mitigation efforts, as well as on the details of verifying these efforts. Countries now need to quickly clarify their publicly announced mitigation targets and actions, so that there is mutual understanding"*

The EPA and the Ministry of Communications have shown leadership in the area of climate change, but has so far focussed on adaptation rather than emissions reduction. EPA has involved the TSPs and their suppliers in partnerships, workshops, and awareness outreaches to widen their understanding of climate change and to bring this knowledge within reach of all communities and individuals in Ghana[166]:

> *"Cellphone giant Vodafone (which partly owns Verizon) paired up with Ghana's EPA to form and lead a Climate Change Adaptation campaign in Ghana. The EPA has learned that solar panels and clean energy investments do not stop floods or property losses. Currently, Ghana suffers from extreme climate shifts. There are longer dry season droughts, and subsequent cycles of severe flooding. High temperatures force near constant influxes of pests and diseases. Climate change is exacerbating these impacts, which destroy property and takes the lives of thousands every year. Economically, agricultural losses reach into the millions".*

6.3.1 Example from South Africa

A tax on carbon emissions from motor vehicles was introduced in 2010. Unlike the UK, this applies on first purchase. ZAR 75 is added to the price for every gram of CO2 per km the vehicle emits over 120 g/km.

6.3.2 Example from China

China uses a measure called 'carbon intensity' instead of the absolute level of carbon emissions to assess its GHG emissions. This is the amount of CO2 produced per unit of economic growth instead of an absolute emissions cap. However, China has pledged to reduce GHG emissions from 2005 levels per unit GDP by 40-45 per cent by 2020[167].

6.3.3 Example from Brazil

Brazil is anxious to bring broadband services to more areas of the country. The Brazilian government has announced that it proposes to waive certain taxes in the hope of attracting TSPs to build out USD 44 billion in new fibre networks.

Any TSP that registers for a tax break will have to be willing to build out fibre networks in areas where there is currently limited coverage. The government will forfeit around USD four billion in taxes to help achieve this.

This comes soon after the Brazilian government's National Broadband Plan that would provide users with a 1Mbps connection for around USD 22 per month.

Suggested action: The EPA, MoC, and other appropriate agencies in Ghana should promote legislation to ensure that TSPs who make investment decisions that will benefit capacity building, literacy and e-health objectives should receive regulatory relief.

6.4 What more could be done in Ghana?

The examples of appropriate regulation in developed and developing countries show how policy-makers and regulators can act to mitigate climate change and how ICT fits within the reporting methods adopted by the UNFCCC. Developed countries have much higher emissions per capita than Ghana and report under a stricter commitment within the Kyoto Protocol. The negotiations currently taking place in the UNFCCC process under in the newly formed 'Durban Platform', are defining the terms of a new agreement that will enter into force in 2020.

To be successful in combating climate change, leadership is needed from the President downwards and there must be the political will to enact legislation to fight climate change. Legislation will move the action from 'voluntary' to 'mandatory and enforceable'.

Such leadership was demonstrated in the Vice President's opening address to the Sixth Symposium on ICTs, the Environment and Climate Change on 7-8 July in Ghana. In his address[168] H.E. Mr. John Dramani Mahama referred to legislation on the management of e-waste which is being prepared and due to come into effect in 2012. He also emphasised the role of the ICT technologies in 'the protection of the environment, management of natural resources and disaster prevention as they support sustainable development".

The situation in Ghana is different from developed countries in that economic growth is needed to allow people to enjoy a higher standard of living. However, Ghana has the opportunity to achieve this on a different evolution path to the one chosen by developed countries. Ghana needs affordable access to ICTs to be able to understand and take measures to combat and adapt to climate change. While this is recognised by the MoC and EPA, the big question is how it can put telecommunications on a 'lower energy per user' evolution path. A key objective of this report has been to show how this might be done.

7. The way forward: suggested next steps

The analysis presented thus far suggests the important role that ICTs can play in the reduction of GHG emissions through improvements in the energy efficiency of the ICT sector and other key sectors, including smart-buildings, transportation, logistics, manufacture and forestry, among others. The analysis has also suggested that, in order to effectively achieve those savings and realise ICT's mitigation potential, developing country stakeholders and decision makers need to design effective policies and strategies that tackle the challenges and opportunities at hand.

The companion study to this report, "Climate Change Adaptation and Information Communication Technologies (ICTs): The Case of Ghana", suggests that there are three main components that should be in place for the formulation and implementation of effective policies and strategies at the intersection of the ICTs and climate fields, namely (a) content, (b) structures, and (c) processes.

Thus, the development of ICT and climate change mitigation *content*, the provision of adequate *structures* to implement policy decisions and strategies, as well as the adoption of a *process-oriented* approach to ensure coherence throughout the policy cycle (i.e. from policy design to implementation), are important aspects to consider in the effective use of ICTs towards climate change mitigation in developing countries.

This section presents a series of suggested 'next steps' aimed at fostering the role of ICTs in mitigation actions and national strategies, considering the development of policy content, and the provision of effective structures and processes focused on ICTs and mitigation. The first part of the analysis suggests the actions that are considered a priority within developing countries like Ghana. The second part presents specific suggestions in regards to 5 main areas of action: (a) extraction of raw materials, e-waste and recycling, (b) infrastructure and coverage, (c) mitigation in other sectors, (d) international standards and energy-saving codes of conduct, and (e) regulation.

Although the suggestions provided below are aimed at key stakeholders in Ghana (such as MoC, MEST, NCA, and/or EPA), they constitute relevant steps for other developing countries that wish to leverage ICT's mitigation potential and improve energy efficiency across multiple sectors.

The suggestions provided below are based on the recognition that Ghana is advancing in the development of a National Climate Change Policy Framework (NCCPF) through the Ministry of Environment, Science and Technology in coordination with the Ministry of Communications. The NCCPF is aimed at achieving a climate-resilient and climate compatible economy, and one of its main pillars is low carbon economic growth. Thus, for the case of Ghana, some of the suggestions provided below may have already been integrated as part of NCCPF's functions, while others could be considered in support of its mandate, or could provide guidance to other developing countries in this field.

ICT and climate change mitigation: priority areas

- To set up a national Green ICT Council to support the mandate of the NCCPF, providing expertise and technical know-how on issues of low-carbon growth, and aimed at ensuring that any new build out of ICT infrastructure in Ghana considers energy efficiency and the use of renewable energy sources as key criteria when choosing a certain technology. As is shown in this report, this will expand access to ICTs, reducing the digital divide, and help to ensure that GHG emissions are minimised while laying the best possible foundations for realising the NCA vision of an information rich knowledge-based society and economy through the development, deployment and operation of ICTs.

  The proposed Green ICT Council could provide support in the implementation of strategic plans to:

  ◊ Extend the coverage of mobile networks to rural areas by adopting the best available technology for low-density applications (e.g. high antenna location, high antenna gain), with use of solar arrays and integral wind turbines to provide power.

- ◊ Upgrade the existing mobile infrastructure with a view to offering basic Internet access from all BTS with, for example, smartphones and a switch to renewable energy sources in the process.
- ◊ Adopt infrastructure sharing (e.g. utility poles) to reduce the cost of connecting grid electricity and a broadband fibre/WiFi network for the 50 per cent Ghanaians without access to telephony (mobile or fixed) and grid electricity.

- To create a regulatory framework which encourages energy efficiency and emission reductions for existing and future telecommunication service provider (TSP) infrastructure and equipment. This would include incentives for infrastructure sharing while imposing penalties for exceeding emissions targets. It will also be necessary to encourage the introduction of technology to mitigate emissions in other sectors. Regulatory easements to TSPs or an appropriate carbon-trading scheme could be used to achieve this.
- To support legislation to tackle the e-waste problem in Ghana. The Energy Commission has recently taken moves to ban used refrigerators and air-conditioners from coming into the country from 1 January 2013. This will reduce the dumping of electronic waste (e-waste) but not stop it. There is a clear link between the management of e-waste and climate change as described in Section 2, and actions are proposed that would limit this. Ways to assess the carbon footprint of the ICT sector as a whole are given in the Annex.

ICTs and climate change mitigation: next steps

a) Extraction of raw materials, e-waste and recycling

- As far as is known, there are no standard publicly available inventories showing the energy and emissions (CO2e) impact of extracting and processing raw materials such as gold. The EPA and MoC should consider taking a lead on establishing such tables, specifically for Ghana.
- The EPA and MoC should check emerging legislation on e-waste to maximise the recovery of gold and other rare metals for the electrical industry, and to ensure the safe disposal of ICT equipment in line with the recommendations of the Basel Convention designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries. The categories of hazardous wastes are listed in Annex I of the Convention. It is also covered if it is defined or considered to be a hazardous waste under the laws of the exporting country, the importing country, or the countries of transit.
- The EPA together with MoC or other appropriate agency in Ghana should consider, and if necessary promote, legislation on a 'cradle to cradle' or 'closed loop' approach to manufacture and recycling.
- The MoC and EPA or appropriate agency in Ghana should promote legislation to ban the import of e-waste more effectively as it may contain unknown and unspecified toxins.
- Ghana lacks an effective infrastructure for handling e-waste. The EPA and the MoC or other appropriate agency in Ghana should take a lead role in setting one up.
- The principle of producer responsibility (producer pays to clean up waste) should be applied in Ghana to help to minimise e-waste streams. New legislation is required in this area. The EPA and MoC are in a position to advise on the drafting of this legislation.
- The MoC, NCA, EPA or other appropriate agency in Ghana should coordinate at the global level with institutions such as the ITU to identify a set of standards and best practices that could be undertaken within the ICT sector to reduce GHG emissions. It is important that these are based on solid evidence and compiled by a neutral organization such as the ITU and not simply based on claims of specific manufacturers.
- The MoC and EPA or other appropriate agency in Ghana should coordinate at the global level with institutions such as the ITU and draft new Recommendations on a sustainable procurement policy and best practices, taking the whole life cycle into account.

- The EPA and MoC or other appropriate agency in Ghana should investigate whether it is possible within the current legislative and regulatory framework to limit sales models that make ICT products prematurely obsolete with little or no retained value. An example of this would be a printer which will not print after 10 000 sheets have been printed.
- The EPA and MoC or other appropriate agency in Ghana should support the adoption of intelligent systems for recycling and other forms of recovery, thereby decreasing the waste fraction that goes to final disposal and incineration.

b) Infrastructure and coverage

- It would be useful to be able to refer to a map showing the overall coverage of mobile services in Ghana taking into account the coverage of each TSP. However, no such coverage map currently exists. It is recommended that the NCA should commission or mandate the provision of such a map that would help to identify gaps in coverage of mobile services.
- To fully realise the benefits of mitigation in other sectors, it is recommended that Ghana sets up a broadband infrastructure to complement the mobile infrastructure that is already widely used for narrowband voice communications. This would bring benefits in terms of education, health care and waste management, as well as the capability to monitor the impact of climate change and reduce its worst effects.
- It is recommended that a Broadband Applications Stakeholder Group (BASG) is set up in conjunction with the proposed Green ICT Council. This would monitor the implementation of broadband applications and ensure value for money from any new broadband infrastructure. It should explore how Ghana can benefit from broadband applications before setting up a potentially costly broadband infrastructure.
- The proposed Green ICT Council should consider a strategic plan to extend the coverage of 2/2.5G mobile networks to rural areas (the 50 per cent Ghanaians without coverage) by adopting the best available technology for low-density applications (e.g. high antenna location, high antenna gain, with solar arrays and wind turbines to provide power).
- TSPs should be incentivised to provide a target percentage of BTSs using non-fossil fuels.
- Mobile TSPs who are unable to supply their BTSs wholly from off-grid electricity should be required to construct or purchase renewable sources of electricity which are delivered via the electricity grid. TSPs in Ghana who provide off-grid electricity from renewable resources should then receive regulatory and financial relief.
- The EPA, Energy Commission, or other appropriate agency in Ghana should consider paving the way for the deployment of biodiesel technology in Ghana. This could be used as a substitute for fossil fuel in mobile telecommunication base stations. The danger that the balance of land use will be moved from food production towards production of biodiesel can be avoided by using alternative feed-stocks such as the production of algae, and these should be explored.
- The NCA or other appropriate agency in Ghana should investigate how much energy could be saved by sharing of infrastructure (both passive and active) between mobile TSPs.
- Passive sharing of infrastructure such as masts and antennas is already the preferred solution in Ghana. Sharing of the electricity supply and site electronics should also be encouraged by NCA and should not be prevented by competition rules.
- There is a case for constructing modern fixed access broadband networks, based on an NGN, in Ghana. This would replace growing demand for energy from mobile networks that would otherwise make increasing use of 3G data. A modern broadband fixed infrastructure would help to meet targets for literacy and health that can only be met using advanced technology.

- It is important that Ghana rolls out an ICT infrastructure following a model based on its own circumstances and to satisfy demand from smartphone users' wireless broadband IMT, IMT-Advanced and WiFi would be the preferred technology choice for most end users. However this will be more energy intensive than FTTP with WiFi to make the final user connection. Energy efficiency over the whole life cycle should be a key criterion when rolling out new infrastructure (and selecting a new technology) and it will be essential to perform a life cycle analysis to make sure that overall the deployment and operation of any new infrastructure would actually reduce GHGs not increase them.
- Any implementation of new broadband infrastructure should be subject to the oversight of the proposed Green ICT Council.
- The proposed Green ICT Council should consider utility pole sharing to connect access to grid electricity and a broadband fibre/WiFi network for the remaining 50 per cent Ghanaians without access to grid electricity.
- The NCA or other appropriate agency in Ghana should investigate opportunities to extend fibre backhaul networks to public access points such as schools when increasing the number of mobile phone base stations to expand coverage.
- Ghana's digital broadcasting switchover timetable started in January 2010 and will be completed in July 2015. Opportunities should be investigated to accelerate this exercise to save energy and further reduce GHG emissions.
- The appropriate agency in Ghana should investigate how the trend towards single-user alternatives, such as laptops and smart-phones, to traditional family TV sets will increase personal choice whilst adopting a less energy intensive lifestyle.
- The NCA should investigate opportunities for facility sharing which would improve the coverage of DTT and mobile phone services.

c) Mitigation in other sectors

- The EPA and MoC should investigate the use of ICTs to mitigate emissions in other sectors to find out if the seven-fold savings of the Smart2020 report are applicable to Ghana and whether speeding up investment in telecommunications would bring economic and emissions benefits more quickly than similar investment in other infrastructure such as road and rail.
- The appropriate agency in Ghana should assist and set targets for TSPs to deploy mitigating technologies such as travel substitution to reduce GHGs in other sectors.

d) International standards and energy-saving codes of conduct

- The NCA or other appropriate agency in Ghana should consider which international stanadrds or Codes of Conduct with voluntary or mandatory reductions in equipment energy consumption should be introduced to vendors supplying equipment to TSPs in Ghana.
- The NCA or other appropriate agency in Ghana should require annual improvements to the energy efficiency of base stations through the adoption of international standards or Codes of Conduct, for example, based on the experience provided by the EU framework.
- The EPA should support the development of international standards or Codes of Conduct for energy efficiency. Suppliers would then be more motivated to provide Ghana with their lowest energy consumption products.
- The NCA and EPA should investigate the need for development of similar frameworks (CoCs) at regional (African) level. These could be developed with the support of regional or international organizations such as the ITU. The EPA could provide a country case for either the adoption of the European Union Codes of Conduct or for the development of a compatible regional framework for the African region.

Harmonisation with the EU CoCs would be essential so that manufacturers can continue to produce equipment cost effectively for global markets.

- The MoC, EPA, and the Energy Commission should lead the process of adoption of Rec. ITU-T L.1000 in Ghana.
- The NCA and EPA (or African Region) should contribute to the ITU-T SG5 work on ICTs and Climate Change in order to ensure that the methodologies being developed meet the specific requirements of Ghana (or African Region). In addition, the EPA and MoC could provide leadership for a case study of a pilot test of the new ITU-T methodologies to assess the carbon footprint of the ICT sector and the reduction GHG emissions in other sectors.
- The NCA or other appropriate agency in Ghana should request figures from TSPs providing "*average power originating from fossil fuels per customer connected"* when assessing the progress of TSPs towards set targets.

e) Regulation

- The EPA and MoC should promote legislation to reduce GHG emissions caused by ICTs and identify ways to reduce emissions according to an agreed national strategy.

The EPA, MoC, and other appropriate agencies in Ghana should promote legislation to ensure that TSPs who make investment decisions that will benefit capacity building; literacy and e-health objectives should receive regulatory relief.

Conclusions

This report has shown that there are many ways to reduce GHG emissions in Ghana. The key action proposed is to set up a Green ICT Council to explore ways of implementing the other actions proposed by this report. It is also recommended that a national broadband infrastructure is set up to enable capacity building for adaptation to climate change and emissions savings in other sectors, but that this should be done in the most cost-effective and energy-efficient way possible.

There is a crucial role for governance agencies to steer TSPs and other ICT users to go greener. The EPA, MoC, and the NCA need to be aware of emerging new technologies and anticipate evolutionary changes in the area of energy efficiency of ICT networks, products and services. Each TSP must be in a position to take account of emerging needs to improve energy efficiency and reduce GHG emissions both in its own facilities and operations and in that of its customers. A key driver here is cost reduction and this should be reinforced by a robust regulatory environment that mandates GHG emissions reporting, year-on-year energy savings, and the use of renewable energy.

Incentives should continue to be put in place to promote a switch to renewable energy sources. Mechanisms should also be put in place to deal effectively with e-waste, especially that coming into Ghana from other countries.

Glossary

2.5G	2G with GPRS providing data rates from 56 Kbit/s up to 115 Kbit/s
2G	2nd Generation mobile networks (e.g. GSM)
3.5G	3G with HSPA providing data rates of up to 14 Mbit/s downstream and 5.76 Mbit/s upstream
3G	3rd Generation mobile networks providing data rates of at least 200 Kbit/s
4G	4th Generation mobile networks that conform to the ITU IMT Advanced standards
ADSL	Asymmetric Digital Subscriber Line
BASG	Broadband Applications Stakeholder Group
BSP	Broadcasting Service Provider
BTS	Base Transceiver Station (or cell site)
CAPEX	Capital Expenditure
CCS	Carbon Capture & Storage
CO2e	Carbon dioxide equivalent – a standardised measure of GHG emissions designed to account for the different global warming potentials of GHGs
CoC	Code of Conduct
CRC	Carbon Reduction Commitment
CRT	Cathode Ray Tube
CSR	Corporate Social Responsibility
DEFRA	Department for Environment Food and Rural Affairs (UK)
DTT	Digital Terrestrial Television
EA	Environment Agency (UK)
EC	European Commission
ECOWAS	Economic Community Of West African States
EDGE	Enhanced Data Rates For Global Evolution
EPA	Environmental Protection Agency (Ghana)
ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
EU	European Union
e-waste	electronic waste (waste arising from the disposal of ICTs at end of life)
GDP	Gross Domestic Product
GeSI	Global eSustainability Initiative
GHG	Greenhouse Gas
GIX	Ghana Internet eXchange
G-PON	Gigabit Passive Optical Network
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
GSMA	GSM Association
GSR	Global Symposium for Regulators
HSPA	High-Speed Packet Access
IC	Internal Combustion
ICT	Information and Communications Technology
IMT	International Mobile Telecommunications – the standard underlying 3G mobile telecommunications

ISO	International Standards Organization
ISP	Internet Service Provider
ITU	International Telecommunication Union
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LTE	Long Term Evolution
MDG	UN Millennium Development Goals
MEST	Ministry of Environment, Science and Technology (Ghana)
MORAN	Multi Operator Radio Access Network
Mt	Million tonnes (of CO2e)
MTN	Mobile Telephone Networks (company offering telecommunications services in a number of African countries)
NCA	National Communications Authority (Ghana)
NCCC	National Climate Change Committee (Ghana)
NCCPF	National Climate Change Policy Framework (Ghana)
NGA	Next Generation Access
NGN	Next Generation Network
Ofcom	Office of Communications (UK) – Regulator for telecommunications, media and broadcasting
Ofgem	Office of the Gas and Electricity Markets (UK)
OPEX	Operating Expenditure
PON	Passive Optical Network
PSTN	Public Switched Telephone Network
PV	Photovoltaic (solar array)
RF	Radio Frequency
SDO	Standards Developing Organization
SF_6	Sulphur Hexafluoride
SIM	Subscriber Identity Module
TSP	Telecommunications Service Provider
TV	Television
UMTS	Universal Mobile Telecommunications System
UNCED	UN Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
VoD	Video on Demand
VoIP	Voice Over Internet Protocol
WCDMA	Wideband Code Division Multiple Access
WiFi	Wireless Fidelity (Wireless Local Area Network)
WiMAX	Worldwide Interoperability for Microwave Access

Annex: How GHG emissions in the ICT sector should be reported by organizations in Ghana

1 *The GHG reporting hierarchy*

A GHG reporting hierarchy is first described here so that a consistent set of results may be presented at a global level.

Global

It is recommended that any organization reporting on emissions should collect data in a form which can feed into a National Inventory Report for an Annex 1 party. Even though Ghana, as a developing country, is not required to report as an Annex 1 party, many organizations operating in Ghana will be multinationals and so need to be aware of and control their Global GHG impact. Under UNFCCC guidelines, the two sectors on which ICT organizations have most impact are energy (as a user of off grid electricity or fossil fuel) and industrial processes (as a manufacturer of electronic products). Tables 1 and 2 detail the data which needs to be gathered.

Organizational

At the organizational level, Recommendation ITU-T L.1420[169] is the ITU-T methodology for energy consumption and GHG emissions impact assessment of ICT in organizations. This refers to both ISO 14064[170] and the GHG Protocol[171] and provides a method of carbon accounting for ICTs in line with the UNFCCC guidelines and the Kyoto Protocol.

ITU-T L.1420 defines an ICT organization as "an organization, the core activity of which is directly related to the design, production, promotion, sales or maintenance of ICT goods, networks or services". This Recommendation can be used to assess energy consumption and GHG emissions generated over a certain period of time for two different purposes; to produce an inventory of GHG impact from ICT organizations and for assessment of GHG impact from ICT related activities in non-ICT organizations. This Recommendation covers:

- The assessment of the environmental impact of an ICT organization ("ICT organizations") based on ISO 14064-1 and the GHG Protocol
- The assessment of the life cycle environmental impact of ICT Goods, Networks and Services used by a non-ICT organization based on the Recommendation ITU-T L.1410 and the aggregation to an organizational level for first and second order effects
- The interpretation of these impacts
- The reporting of these impacts to ensure a fair and transparent communication.

According to ITU-T L.1420 when assessing the impact of the use of ICT, an organization shall:

- Identify the concerned ICT goods, networks or services of which the organization would like to better understand the impact.
- Perform an assessment of these product systems in accordance with Part I of the Recommendation ITU-T L.1410, in order to calculate the life cycle impact of the product systems.
- Scale up the result to an organizational level.

ISO 14064[170] is integral to the use of ITU-T L.1420 and details principles and requirements for designing, developing, managing and reporting organization- or company-level GHG inventories. It includes requirements for determining GHG emission\boundaries, quantifying an organization's GHG emissions and removals, and identifying specific company actions or activities aimed at improving GHG management. It also includes requirements and guidance on inventory quality management, reporting, internal auditing and the organization's responsibilities for verification.

ITU-T L.1420 also references the GHG Protocol Corporate Accounting and Reporting Standard[172] that helps companies and other organizations to identify, calculate, and report GHG emissions. It is designed to set the standard for accurate, complete, consistent, relevant and transparent accounting and reporting of GHG emissions by companies and organizations, including information on setting organizational and operational boundaries, tracking emissions over time, and reporting emissions. It also provides guidance on GHG accounting and reporting principles, business goals and inventory design, managing inventory quality, accounting for GHG reductions, verification of GHG emissions, and setting a GHG target.

ICT products and services

At the level of ‘ICT goods, networks, and services’ (ICTs-as part of the everyday activity of a typical organization) Recommendation ITU-T L.1410 provides a method of performing a life cycle analysis of ICT goods, networks, and services. The LCA results for a particular item, such as a laptop computer, should be requested by the purchaser of ICT goods, networks, and services from the supplier. The supplier is in a position to trace back the GHG emissions at each step of the manufacturing process, down through the supply chain to the raw material.

2 Categorising an organization’s GHG emissions

ITU-T L.1420 defines direct and indirect emissions as follows:

- Direct GHG emissions are emissions from sources that are owned or controlled by the reporting entity
- Indirect GHG emissions are emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity

The direct and indirect emissions are categorized into three broad scopes:

- **Scope 1:** All direct GHG emissions (e.g. natural gas, petroleum, or diesel).
- **Scope 2:** Indirect GHG emissions from consumption of purchased electricity, heat, or steam.
- **Scope 3:** Other indirect emissions such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. transmission and distribution losses) not covered in Scope 2, outsourced activities, waste disposal, etc.

Companies do not generally formally report on Scope 3 emissions yet as they do not have the data needed under their control, and the method of reporting ICT products and services is currently being drafted[173]. However, before letting contracts some service providers and national agencies now ask their suppliers if they can provide information to enable their Scope 3 emissions to be calculated. In this case, TSPs could be asked what their emissions per product item are.

3 The benefits to TSPs of reporting GHG emissions

Large TSPs such as Verizon[174], Vodafone, and BT have taken a lead in reporting their annual energy demand and emissions of GHGs with a view to:

- Saving energy costs.
- Complying with national requirements (e.g. legal or voluntary commitments) to reduce emissions of GHGs year on year.
- Improving their corporate social responsibility.

Steps being taken include:

- Switching off electrical equipment when not in use.
- Reducing the amount of cooling needed in central offices (e.g. operating equipment up to the rated temperature limit).
- Adopting more efficient power supplies (higher voltage).
- Looking for lower in-use energy when purchasing new products.

4 How organizations in Ghana should report GHG emissions

Once a GHG reporting requirement is in place in Ghana, all TSPs should be required to report their GHG emissions. The following procedure should be followed:

1. Decide if you need to report:
   - As mandated e.g. by law (not applicable yet in Ghana).
   - As preparation for mandatory reporting; e.g. if reporting is likely to be necessary in the next two or three years
   - To improve customer relations by participating in voluntary reporting[175]
2. Understand what is required, including the necessary training for staff.
3. Download the appropriate standard and reporting form. To conform to ITU-T L.1420, download the corporate standard from the GHG Protocol website[176].
4. Determine who needs to see the report:
   - National Agencies, e.g. EPA or MoC Ghana.
   - An organization administering a carbon trading scheme (e.g. UNFCCC).
   - A voluntary organization that is able to offer disclosure, accreditation or other services to members (e.g. The Carbon Disclosure Project[177] has 50 supply chain members).
   - If a wide range of stakeholders need to see the report, publication via the organization's website should be considered.
5. Establish a base year (e.g. 2011). Have your emissions' report independently verified.

5 Helping customers reduce their costs and emissions

The running costs of an ICT network are significant, and are set to rise year on year as fossil fuel supplies become depleted, and with the introduction of carbon taxes to reduce GHG emissions. This presents a unique challenge to an industry which is at the same time trying to expand its service sets, coverage and capacity.

The energy required for mobile base stations in developing countries represents 70 per cent of a mobile TSP's energy requirement. For wireline access, network equipment represents around 70 per cent of each TSP's electricity load, principally via line termination equipment. By making networks more energy efficient, considerable savings in operational costs can be made.

New approaches are needed to enable carbon-saving opportunities both in network infrastructure and derived services.

The MoC and NCA, in collaboration with the EPA, have the opportunity to help customers reduce their costs and emissions by:

- Improving the network's traffic efficiency by identifying and deleting unnecessary traffic, ensuring links are able to run close to full capacity, and deferring investment in higher capacity infrastructure and equipment.
- Ensuring links run to full capacity by allowing some traffic types to be identified for alternative routing when traffic demand is high. This also defers investment cost.
- Reducing energy consumption of TSPs' products and services through better energy efficiency and resource sharing (e.g. optical switching of input signals from probes in the customer network).

6 Working with the supplier chain

Equipment vendors are increasingly looking to reduce emissions, not only downstream (towards customers) but also upstream towards the suppliers of subsystems and, ultimately, the extractors of the raw materials. To present a full inventory of GHG emissions, all suppliers to TSPs should be required to report their emissions on products and services so that TSPs can accurately report and hence reduce their own emissions.

7 Actions to reduce the GHG emissions in the ICT sector

When a GHG assessment is completed, opportunities should be identified to reduce GHG emissions and save energy costs. An 'actions list' should be compiled and the cost of the intervention assessed along with the payback period. The responsibility for taking action rests with the organization being audited. However, in cases where the payback period is longer than the organization's (e.g. the TSP) investment norm (e.g. two years) the EPA and NCA should investigate shaping the regulations to favour implementation of the GHG/energy-saving reduction scheme.

Overall report conclusions

Developing countries are facing unprecedented challenges and opportunities in the face of climate change. The analysis presented in this report evidences that the close linkages that exist between ICTs and climate change adaptation and mitigation are gaining momentum in the policy, the research and the practice agendas, from the international to the local levels. Within vulnerable environments affected by more frequent and intense climatic events, the increasing diffusion of Information and Communication Technologies (ICTs) is enabling new ways to withstand, recover and adapt to climatic impacts, as well as to improve energy efficiency and mitigate GHG emissions in a variety of sectors.

The two reports presented in this publication provide distinctive, yet complementary approaches to the use of ICTs in the climate change field. The suggestions provided in both documents evidence the need for developing countries to adopt innovative ICT-enabled strategies to tackle climate change adaptation and mitigation, while ensuring a long-term, coordinated approach to the integration of ICT tools into broader climate change strategies.

The reports identifies key areas of action to be considered in the design of ICTs and climate change adaptation and mitigation strategies, including the development of policy content, and the establishment of adequate structures and processes. The document builds upon the experiences and progress being achieved by Ghana, an African country that has being a pioneer in the integration of ICTs and climate change strategies. While there are still challenges to overcome, Ghana's experience provides valuable principles and suggested actions that have been reflected throughout this document. It is expected that the suggestions provided in the report will help to guide the actions of other developing countries in this field, as well as to raise the awareness of policy and decision-makers, and ultimately encourage the design of new policies strategies and standards that foster ICT's adaptation and mitigation potential.

As the experience of Ghana demonstrates, ICT and climate change policies should be designed based on a holistic perspective, and as a collaborative, long-term process of continuous learning and interaction among a varied set of stakeholders and levels. Leadership, articulation of efforts, active participation in international climate change processes, partnerships with key stakeholders and local engagement in the design of technology solutions, are among the key components of effective ICT and climate change strategies.

As ICTs continue to play an increasing role in climate change networking and decision-making, information and knowledge sharing, capacity building, livelihoods strengthening, and low-carbon/resource-efficient economies, so will their potential as part of a more resilient future.

The resources, events and actions that have been undertaken by the International Telecommunication Union (ITU) and other key stakeholders working at the intersection of ICTs and climate change, provide a solid basis for future actions in this field.

Notes and references

1 Contribution of Working Group III to the Fourth Assessment Report of the IPCC, 2007. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

2 Ospina, A. V. & Heeks, R (2010) *Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study*, Centre for Development Informatics (CDI), Institute for Development Policy and Management (IDPM), University of Manchester, www.niccd.org/ScopingStudy.pdf

3 IPCC TAR (2001 a). Climate Change 2001: Impacts, Adaptation and Vulnerability. IPCC Third Assessment Report, Cambridge University Press.

4 UNDP (2004) Adaptation Policy Frameworks (APF) for Climate Change: Developing Strategies, Policies and Measures, Cambridge University Press, www.undp.org/climatechange/adapt/apf.html#about

5 UNFCCC. (2007) *Assessing Climate Change Impacts and Vulnerability: Making Informed Adaptation Decisions*, United Nations Framework Convention on Climate change (UNFCCC), http://unfccc.int/files/adaptation/application/pdf/11unf051_nwp-was-web[1].pdf

6 UNFCCC, 1992. United Nations Framework Convention on Climate change (UNFCCC) http://unfccc.int/resource/docs/convkp/conveng.pdf

7 "Report on the analysis of existing and potential investment and financial flows relevant to the development of an effective and appropriate international response to climate change". August 2007, UNFCCC. http://unfccc.int/files/cooperation_and_support/financial_mechanism/financial_mechanism_gef/application/pdf/dialogue_working_paper_8.pdf

8 Articles 3 (principles) and 4 (commitments) of the convention.

9 http://unfccc.int/files/meetings/cop_10/adopted_decisions/application/pdf/01_cp_l_16.pdf

10 UNFCCC, 2012, http://unfccc.int/adaptation/items/4159.php

11 www.itu.int/ITU-T/studygroups/com05/sg5-q23.html

12 "ICTs and Climate Change" ITU-T Technology Watch Report #3 (2007). www.itu.int/oth/T2301000003/en

13 For further references see www.itu.int/climate

14 UNFCCC. (2007) *Assessing Climate Change Impacts and Vulnerability: Making Informed Adaptation Decisions*, United Nations Framework Convention on Climate change (UNFCCC), http://unfccc.int/files/adaptation/application/pdf/11unf051_nwp-was-web[1].pdf

15 For further sources of research in this area see www.itu.int/ITU-T/worksem/climatechange/resources.html

16 Ospina, A.V. & Heeks, R. (2012) *Making Policy on ICTs and Climate Change in Developing Countries*, Centre for Development Informatics, University of Manchester, UK, www.niccd.org/ICCD_Policy_Guidance_Paper.pdf

17 ITU (2008) ICTs and Climate Change: ITU Background Report, ITU Symposium on ICTs and Climate Change Hosted by CITIC, Quito, Ecuador, 8-10 July 2009. www.itu.int/dms_pub/itu-t/oth/06/0F/T060F00600C0004PDFE.pdf

18 Ibid, p.2.

19 Republic of Ghana. (2011) Ghana's Second National Communication to the UNFCCC, http://unfccc.int/resource/docs/natc/ghana_second_nationalcommunication_final_version.pdf

20 http://esa.un.org/unpd/wpp/unpp/p2k0data.asp

21 http://data.worldbank.org/about/country-classifications/country-and-lending-groups

22 UN Data (2008) http://data.un.org/CountryProfile.aspx?crName=Ghana

23 Ghana High Commission, Ottawa. www.ghc-ca.com/frm-e-location-maps.html

24 Republic of Ghana. (2011) *Ghana's Second National Communication to the UNFCCC*, http://unfccc.int/resource/docs/natc/ghana_second_nationalcommunication_final_version.pdf

25 Republic of Ghana. (2011) Ghana's Second National Communication to the UNFCCC, http://unfccc.int/resource/docs/natc/ghana_second_nationalcommunication_final_version.pdf

26 The World Bank (2010), *Economics of Adaptation to Climate Change*, http://climatechange.worldbank.org/content/ghana-economics-adaptation-climate-change-study

27 P. 42 in ITU (2011) *Measuring the Information Society*. ITU. http://www.itu.int/pub/D-IND-ICTOI-2011/en

28 ITU World Telecommunication/ICT Indicators database (2011).

29 Ghana Government Official Portal (2011) *Factor Local Content in National ICT Policy*, 12 May 2011,

www.ghana.gov.gh/index.php?option=com_content&view=article&id=5859:factor-local-content-in-national-ict-policy-&catid=28:general-news&Itemid=162

[30] ITU Statshot, August 2011 www.itu.int/net/pressoffice/stats/2011/03/index.aspx see also, Killian Fox, Africa's mobile economic revolution The Observer, 24 July 2011 www.guardian.co.uk/technology/2011/jul/24/mobile-phones-africa-microfinance-farming

[31] www.modernghana.com/news/215536/1/vodafone-to-invest-700m-in-telecom-infrastructure-.html

[32] Republic of Ghana, Ministry of Communications, National Telecommunications Policy: www.nca.org.gh/downloads/Ghana_Telecom_Policy_2005.pdf

[33] See David Faulkner and Keith Dickerson, (2011) "How the ICT sector in Ghana can reduce its own GHG emissions and improve energy efficiency." ITU/Climate Associates

[34] See David Faulkner and Keith Dickerson, (2011) "How the ICT sector in Ghana can reduce its own GHG emissions and improve energy efficiency." ITU/Climate Associates

[35] P. 41 in ITU (2011) *Measuring the Information Society*. ITU http://www.itu.int/pub/D-IND-ICTOI-2011/en

[36] Table 4.1 in ITU (2011) *Measuring the Information Society*. ITU, http://www.itu.int/pub/D-IND-ICTOI-2011/en

[37] For an analysis of the economic impact on capacity prices when there is a dramatic increase in the supply of international submarine capacity, albeit in different geographies, during the bandwidth boom of the late 1990s, see Young, S., and Flanigan, B. (1999) *The Bandwidth Explosion.* London: Ovum. ISBN190256619X.

[38] www.gixa.org.gh/

[39] http://www.nita.gov.gh

[40] WB. (2011). *Vulnerability, Risk Reduction and Adaptation to Climate Change: Ghana,* The World Bank, Washington D.C., http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_GHA.pdf

[41] World Bank study of the Economics of Adaptation to Climate Change Study (looking at the 2010-2050 periods) and the 2000 UNDP Climate Profile of Ghana (looking at the 2060-2090 periods).

[42] WB. (2011). *Vulnerability, Risk Reduction and Adaptation to Climate Change: Ghana,* The World Bank, Washington D.C., http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_GHA.pdf

[43] Yaro, J. (2010) *The Social Dimensions of Adaptation to Climate change in Ghana,* Discussion Paper No 15, The World Bank, Washington D.C., http://climatechange.worldbank.org/sites/default/files/documents/Ghana-EACC-Social.pdf

[44] UNEP (2010) *Climate Change Adaptation and Development Initiative* (CC DARE), National Climate Change Adaptation Strategy, United Nations Environment Programme (UNEP). www.ccdare.org/Countries/Ghana/tabid/6763/Default.aspx

[45] http://prod-http-80-800498448.us-east 1.elb.amazonaws.com/w/images/2/29/GhanaGreen.pdf

[46] Ministry of Environment, Science and Technology, Republic of Ghana (2010) *Ghana Goes for Green Growth.* November 2010, http://cdkn.org/wp-content/uploads/2011/04/NCCPF-Summary-FINAL.pdf

[47] p.8 in Ministry of Environment, Science and Technology, Republic of Ghana (2010) *Ghana Goes for Green Growth*. November 2010, http://cdkn.org/wp-content/uploads/2011/04/NCCPF-Summary-FINAL.pdf

[48] p.32 in Ministry of Environment, Science and Technology, Republic of Ghana (2010) *Ghana Goes for Green Growth*. November 2010, http://cdkn.org/wp-content/uploads/2011/04/NCCPF-Summary-FINAL.pdf

[49] For further examples see "*Climate Change, ICTs and Innovation*" at www.niccd.org

[50] Prasad Pant, L. & Heeks, R. (2011) *ICT-Enabled Development of Capacity for Climate Change Adaptation*. Centre for Development Informatics (CDI), University of Manchester, UK, www.niccd.org/PantHeeksClimateChangeAdaptationICTs.pdf

[51] Ospina, A. V. & Heeks, R. (2011) *ICTs and Climate Change Adaptation: Enabling Innovative Strategies*, Strategy Brief, Centre for Development Informatics, University of Manchester, UK, www.niccd.org/ICTs_and_Climate_Change_Adaptation_Strategy_Brief.pdf

[52] www.itu.int/ITU-T/worksem/climatechange/201107

[53] www.itu.int/ITU-T/worksem/climatechange/index.html

[54] Ospina, A.V. & Heeks, R. (2012) *Making Policy on ICTs and Climate Change in Developing Countries*, Centre for Development Informatics, University of Manchester, UK, www.niccd.org/ICCD_Policy_Guidance_Paper.pdf

[55] Ibid.

[56] Ibid.

57 Heeks, R. (2010) 'Coherent ICT-for-Development Policies', paper presented at the workshop *Policy Coherence in the Application of Information and Communication Technologies for Development*, Organisation for Economic Co-operation and Development (OECD) and infoDev, Paris, France, 10-11 September. www.oecd.org/dataoecd/18/8/43762187.pdf

58 Ospina, A.V. & Heeks, R. (2012) *Making Policy on ICTs and Climate Change in Developing Countries*, Centre for Development Informatics, University of Manchester, UK, www.niccd.org/ICCD_Policy_Guidance_Paper.pdf

59 www.niccd.org/Helen_Asiamah_Poster.pdf

60 Asiamah, H. (2012) *'Ghana experiences in National Planning for ICTs, Climate Change and Development*', Presentation at the Workshop ICTs, Climate Change and Development, University of Manchester and Association for Progressive Communications (APC), Johannesburg, South Africa, 23-25 January. www.niccd.org/workshop2012.htm

61 Ospina, A.V. & Heeks, R. (2012) *Making Policy on ICTs and Climate Change in Developing Countries*, Centre for Development Informatics, University of Manchester, UK, www.niccd.org/ICCD_Policy_Guidance_Paper.pdf
Ibid.

63 P.14 and p.32 in Ministry of Environment, Science and Technology, Republic of Ghana (2010) *Ghana Goes for Green Growth.* November 2010. http://cdkn.org/wp-content/uploads/2011/04/NCCPF-Summary-FINAL.pdf

64 Ospina, A. V. & Heeks, R. (2011) *ICTs and Climate Change Adaptation: Enabling Innovative Strategies*, Strategy Brief, Centre for Development Informatics, University of Manchester, UK, www.niccd.org/ICTs_and_Climate_Change_Adaptation_Strategy_Brief.pdf

65 Internet Research (2011), 'Information Management and Technology for Forest Governance in Ghana', http://www.profor.info/sites/profor.info/files/Ghanacasestudy.pdf

66 World Bank, World Development Report 2010, supra note 66 at 19.

67 ITU *"Radiocommunications and Climate Change: Mitigation"* www.itu.int/ITU-R/index.asp?category=information&rlink=climate-change&lang=en

68 See, for example: L. Brand et al., Data Centres And Telecoms Hotels: After The Space Race (London: Ovum, 2002) and S. Young et al., Telecoms Hotels, Co-location And Data Centres (London: Ovum, 2000).

69 ITU World Telecommunication/ICT Indicators database.

70 Republic of Ghana, Ministry of Communications, National Telecommunications Policy: www.nca.org.gh/downloads/Ghana_Telecom_Policy_2005.pdf

71 GSMA website: http://www.gsma.com/

72 Ghana Government Official Portal: http://www.ghana.gov.gh/

73 MTN Ghana website: Our Coverage: http://corpnet.mtn.com.gh/index.php/mtn-ghana-website

74 ITU World Telecommunication/ICT Indicators database, 2010.

75 Mission statement from the Ministry of Communications of Ghana. www.ghana.gov.gh/index.php?option=com_content&view=article&id=326:ministry-of-communications-&catid=74:ministries&Itemid=224

76 Address delivered by H.E. Mr. John Dramani Mahama, Vice President of Ghana at the Sixth ITU Symposium on ICTs and the Environment & Climate Change, Accra, Ghana, 7-8 July 2011, www.itu.int/ITU-T/worksem/climatechange/201107

77 Official website of the NCA: www.nca.org.gh

78 Official website of the EPA: www.epa.gov.gh

79 Ministry of Energy official site: www.ghana.gov.gh/index.php?option=com_content&view=article&id=327:ministry-of-energy&catid=74:ministries&Itemid=224

80 Ghana Internet Service Providers Association: www.gispa.org.gh

81 ECOWAS website: www.comm.ecowas.int/sec/index.php?id=about_a&lang=en

82 Ghana's Second National Communications to the UNFCCC http://unfccc.int/resource/docs/natc/ghana_second_nationalcommunication_final_version.pdf

83 UK Ofgem website: The marginal impacts of CO2, CH4 and SF6 emissions: www.ofgem.gov.uk/Sustainability/Environment/Policy/Documents1/3281-hope_report.pdf

84 ScienceDirect: Alternative etching gases to SF6 for plasma enhanced chamber cleaning in silicon deposition systems: www.sciencedirect.com/science/article/pii/S0257897205004093

85 Fluorocarbons and Sulphur hexafluoride website: http://www.fluorocarbons.org/

86 IPCC Fourth Assessment Report: www.ipcc.ch/publications_and_data/ar4/wg1/en/tssts-2-5.html

87 UNEP/StEP "Recycling from e-waste to resources", page 7: www.unep.org/PDF/PressReleases/E-Waste_publication_screen_FINALVERSION-sml.pdf

88 World Gold Production (2010): www.resourceinvestor.com/News/2010/5/Pages/World-Gold-Production-2010.aspx

[89] OECD: The Role of Foreign Direct Investment (FDI) in the Mining Sector of Ghana and the Environment: www.oecd.org/dataoecd/44/12/1819492.pdf

[90] China Business News: Climbing mining costs to hit gold: http://cnbusinessnews.com/climbing-mining-costs-to-hit-gold/

[91] MBendi Information Services Web Page: http://www.mbendi.com/indy/ming/gold/af/gh/p0005.htm

[92] UNEP/StEP "Recycling from e-waste to resources", page 10: www.unep.org/PDF/PressReleases/E-Waste_publication_screen_FINALVERSION-sml.pdf

[93] The Many Uses of Gold: http://geology.com/minerals/gold/uses-of-gold.shtml

[94] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal: www.basel.int

[95] International Aluminium Institute (IAI) website: www.world-aluminium.org

[96] Carbon Trust: www.carbontrust.co.uk/policy-legislation/international-carbon-flows/aluminium/Pages/3.aspx

[97] Guide to Electric Power in Ghana (2005): www.beg.utexas.edu/energyecon/IDA/USAID/RC/Guide_to_Electric%20Power_in_Ghana.pdf

[98] Carbon Credit Specialists: Statistics & Facts: www.carboncreditspecialists.com/stats-facts/66

[99] Australian Government: Geoscience Australia: Aluminium Fact Sheet: http://www.australianminesatlas.gov.au/education/fact_sheets/aluminium.html

[100] ITU-T Technology Watch report on ICTs and Climate Change (December 2007): www.itu.int/oth/T2301000003/en

[101] Ghana Energy Foundation: www.ghanaef.org/

[102] UK DEFRA 2011 GHG Conversion Factors for Company Reporting: http://archive.defra.gov.uk/environment/business/reporting/pdf/110707-guidelines-ghg-conversion-factors.pdf (see Annex 3)

[103] CNET Energy Efficiency Guide: http://reviews.cnet.com/green-tech/monitor-power-efficiency/

[104] Samsung Technical Support website: www.samsung.com/us/computer/monitors/LS23B5HVFH/ZA-features

[105] ITU Symposium on ICTs and the Environment & Climate Change, Accra, Ghana, 7-8 July 2011: E-waste and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal: www.itu.int/dms_pub/itu-t/oth/06/0F/T060F00601E0051PPTE.ppt

[106] ITU-T Draft Rec. L.1410 "Methodology for environmental impacts assessment of Information and Communication Technology (ICT) goods, networks and services".

[107] SMART 2020: Enabling the low carbon economy in the information age www.smart2020.org/_assets/files/02_Smart2020Report.pdf

[108] ITU-T Recommendation L.1400 "Overview and general principles of methodologies for assessing the environmental impact of ICT".

[109] US Environmental Protection Agency: Waste Management and Energy Savings: Benefits by the Numbers: www.epa.gov/climatechange/wycd/waste/downloads/Energy%20Savings.pdf

[110] ITU Green ICT Application Challenge – 2011 Edition www.itu.int/ITU-T/climatechange/greenict/index.html

[111] Towards Sustainable Higher Education: Environmental impacts of campus-based and distance higher education systems http://design.open.ac.uk/roy/documents/F10HEPh1and2FinalRptCover_000.pdf

[112] Gartner Newsroom: Gartner Estimates ICT Industry Accounts for 2 Percent of Global CO2 Emissions: www.gartner.com/it/page.jsp?id=503867

[113] "Adoption of Green Technology and Safety of Wireless Network", Slide 14.

http://www.docstoc.com/docs/72640416/Adoption-of-Green-Technology-and-Safety-of-Wireless-Network

[114] Vodafone *Sustainability Report* March 2010, www.vodafone.com/content/index/about/sustainability/publications.html

[115] Vodafone Green Technology, Mobile World Congress (MWC), Jan 2010, www.vodafone.com/content/dam/vodafone/about/sustainability/green%20technology%20demo%20MWC%202010_PUBLIC.pps

[116] OpenET Alliance: www.open-et.org

[117] Steepest Ascent website: www.steepestascent.com/content/

[118] Weather2 website: Climate Profile for Abhainn Mh r, Argyll and Bute: www.myweather2.com/City-Town/United-Kingdom/Argyll-and-Bute/Abhainn-Mh-r-Argyll-and-Bute/climate-profile.aspx

[119] Ghana Climate Guide to the Average Weather & Temperatures with Graphs Elucidating Sunshine and Rainfall Data & Information about Wind Speeds & Humidity: www.climatetemp.info/ghana/

[120] Slow-Turning 5 kW Yanmar Diesel Generator www.generatorsales.com/order/yanmar_4kw.asp?page=yanmar_4kw

[121] GE Gas Turbine Performance Characteristics http://143.107.98.150/Silvio/PME2517/GEgasTurbine.pdf

[122] Biomass Energy in India: Transition from Traditional to Modern www.decisioncraft.com/energy/papers/ecc/re/biomass/bti.pdf

[123] Coconut Oil as a Biofuel in Pacific Islands: www.unesco.org/csi/smis/siv/Forum/CoconutOilFuelPacific_JanCloin.pdf

[124] Maher Smith & Williams (2003) Assessment of pico hydro as an option for off-grid electrification in Kenya", Renewable Energy, vol. 28, no 9, pp1357-1369

[125] Radio Design (Experts in Base Station Filtering) website: www.radiodesign.eu

[126] Infrastructure sharing 'to shape telecoms sector' www.businesslive.co.za/businessexchange/2011/07/11/infrastructure-sharing-to-shape-telecoms-sector

[127] www.nca.org.gh/downloads/Communications_Towers_Guidelines.pdf

[128] NCA Communications Infrastructure (Communication Tower) Licence: http://www.nca.org.gh/downloads/TOWER_LICENCE.pdf

[129] ITU-T Recommendation K.52 "Safety levels for persons in electromagnetic fields near towers (Basic Limits for Public and Occupational Exposure)"

[130] ibid

[131] UN Millennium Development Goals www.un.org/millenniumgoals/poverty.shtml

[132] ITU/UNESCO Broadband: A Platform for Progress: http://www.broadbandcommission.org/Reports/Report_2.pdf

[133] Indoor Radio Propagation http://sss-mag.com/indoor.html#tutorial

[134] ITU Workshop "Moving to a Green Economy through ICT Standards" www.itu.int/ITU-T/climatechange/gsw/201102/programme06-08.html

[135] Lowell Lamb, "Energy Consumption of Broadband Access Networks: Challenges and Opportunities", Proc. NOC 2009, University of Valladolid Spain, 10-12 June 2009, pp. 51-59.

[136] ITU G-PON Gigabit-capable Passive Optical Network: www.itu.int/itudoc/gs/promo/tsb/85155.pdf

[137] iPhone Usage Characteristics From Real Outdoor Wi-Fi Networks www.tropos.com/pdf/whitepapers/iPhone_Usage_Characteristics.pdf

[138] ITU-T Technology Watch Report "NGNs and Energy Efficiency": www.itu.int/oth/T2301000007/en

[139] The Guardian (UK): The numbers on fibre to the home just don't add up: www.guardian.co.uk/technology/2008/nov/27/ffth-high-speed-broadband

[140] Australian Timber Pole Resources for Energy Networks: www.ena.asn.au/udocs/dpiandena_timber_pole_review06.pdf

[141] The Environmental Impact of Utility Poles: http://engineering.dartmouth.edu/~cushman/courses/engs171/UtilityPoles.pdf

[142] Utility Pole Material Comparison: www.powertrusion.com/Literature/Pole%20-%20Crossarm%20Material%20Comparison%20(PPL08).pdf

[143] Guide to Electric Power in Ghana: www.beg.utexas.edu/energyecon/IDA/USAID/RC/Guide_to_Electric%20Power_in_Ghana.pdf

[144] MTN Ghana website: www.mtn-investor.com/mtn_ar09/book1/or_ghana.html

[145] UK Ofcom Strategic Review of Telecommunications Phase II Consultation Document: http://stakeholders.ofcom.org.uk/binaries/consultations/telecoms_p2/responses/olswang.pdf

[146] Ghana Telecommunications Report Q4 2011 www.marketresearch.com/Business-Monitor-International-v304/Ghana-Telecommunications-Q4-6574272/

[147] GSMA: Mobile's Green Manifesto: www.gsmworld.com/documents/mobiles_green_manifesto_11_09.pdf

[148] UK Ofcom Cost and Power Consumption Implications of Digital Switchover: http://stakeholders.ofcom.org.uk/market-data-research/tv-research/dsoind/cost_power/

[149] Eftec/Plextek: Understanding the Environmental Impact of Communication Systems: http://stakeholders.ofcom.org.uk/binaries/research/technology-research/environ.pdf

[150] Ghana Business & Finance: Prospects bright for meeting digital TV deadline in Ghana: www.ghanabizmedia.com/ghanabizmedia/april-2011-digital-tv/257-prospects-bright-for-meeting-digital-tv-deadline-in-ghana.html

[151] BBC Research White Paper: http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP189.pdf

[152] Community Channel: http://communitychannel.mediatrust.org/info/

[153] Ghana Research Report on Digital Broadcast Migration in West Africa: www.apc.org/en/system/files/apcpublicationdigitalmigrationghanaen.pdf

[154] Global Symposia for Regulators: www.itu.int/ITU-D/treg/Events/Seminars/GSR/

[155] ITU/InfoDev ICT Regulation Toolkit: www.ictregulationtoolkit.org/en/index.html

[156] 10th Global Symposium for Regulators (GSR10), 10-12 November 2010, Discussion Paper, Stephen Young: www.itu.int/ITU-D/treg/Events/Seminars/GSR/GSR10/documents/GSR10-paper5.pdf and the presentation: www.itu.int/ITU-D/treg/Events/Seminars/GSR/GSR10/documents/GSR10-ppt5.pdf

[157] UNFCCC (2012). Summary on the Durban Outcome for United Nations System Organizations and Specialized Agencies.

158 UK Climate Change Act 2008: www.legislation.gov.uk/ukpga/2008/27/introduction

159 UK Ofcom website: www.ofcom.org.uk/about/

160 Review of UK Annual Emissions to UNFCCC (2010): http://unfccc.int/resource/docs/2011/arr/gbr.pdf

161 UK DEFRA web site: www.defra.gov.uk/environment/climate/mitigating/

162 UK Environment Agency website: What we are doing to tackle climate change: www.environment-agency.gov.uk/homeandleisure/climatechange/44074.aspx

163 UK Environment Agency: Source list: www.environment-agency.gov.uk/business/topics/pollution/127436.aspx

164 C40 Cities: Tokyo Cap-and-Trade Program: http://www.c40cities.org/c40cities/tokyo/case_studies

165 UNFCCC (2012). Summary of the Durban Outcome for United Nations System Organizations and Specialized Agencies.

166 Climate Adaptation website: www.climateadaptation.tumblr.com/post/5641097338/ghana-adaptation-partnership-epa-vodafone

167 From Copenhagen to Climate Action www.nrdc.org/international/copenhagenaccords/

168 ITU website: Address by H E John Dramani Mahama: www.itu.int/dms_pub/itu-t/oth/06/0F/T060F00601E0004PDFE.pdf

169 ITU-T Rec. L.1420 "Methodology for energy consumption and greenhouse gas emissions impact assessment of Information and Communication Technologies (ICT) in organizations". Currently TD 947rev3 (GEN/5)

170 ISO 14064-1:2006, Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals

171 GHG Protocol web site: www.ghgprotocol.org

172 A Corporate Accounting and Reporting Standard http://pdf.wri.org/ghg_protocol_2004.pdf

173 Greenhouse Gas Protocol Initiative: New initiative announced to help ICT industry measure carbon footprint: www.ghgprotocol.org/feature/new-initiative-announced-help-ict-industry-measure-carbon-footprint

174 Verizon 09/10 Corporate Responsibility Report: http://responsibility.verizon.com/images/vz_uploads/verizon_cr_report_2009-2010.pdf

175 The Climate Registry: General Reporting Protocol Version 1.1: www.theclimateregistry.org/downloads/GRP.pdf

176 Greenhouse Gas Protocol Initiative: Corporate Standard: www.ghgprotocol.org/standards/corporate-standard

177 Carbon Disclosure Project website: www.cdproject.net/en-US/Programmes/Pages/CDP-Supply-Chain.aspx

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