ICTs and Climate Change Mitigation in Emerging Economies

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Executive Summary

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

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

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

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

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

1. Introduction

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

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

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

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

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

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

The share of greenhouse gases emitted by the world's developing countries is increasing and, in total terms, emissions of developed and developing countries are converging. Developing countries already account for 50 percent of global GHG emissions and by 2030 this figure is expected to rise to 65 percent.[1]

Emissions from fossil fuel combustion increased by 41 percent between 1990 and 2008 – an increase significantly driven by emerging economies where fossil fuel emissions more than doubled during that period. The growth of fossil fuel emissions in emerging economies can largely be ascribed to the use of coal as the primary energy source and the production and international trade of goods and services.[2] Emerging countries are expected to be leading source of future growth in GHG emissions as robust economic growth further drives an increase in energy use from industrialisation, new buildings, increased traffic and deforestation. It is predicted that between 2005 and 2030, 50 percent of the increase in world primary energy demand will come from China and India alone.[3]

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

- China and India are the largest emitters of GHGs in the Asia/Pacific region, contributing 51 percent and 15 percent of the region's emissions.
- Brazil is the largest emitter in the Latin America/Caribbean region accounting for 32 percent of the region's GHG emissions.
- South Africa is the largest emitter in Africa, responsible for 24 percent of emissions.[4]

Average GHG emissions per capita are still comparatively low in these countries. But due to rapid economic development, per capita emissions are increasing and in particular in China quickly approaching levels common in the industrialised countries. Per capita emissions reached 6.1 tonnes in China in 2009, up from only 2.2 tonnes in 1990. In comparison, per capita emissions in 15 nations of the European Union were 7.9 tonnes in 2009 (down from 9.1 tonnes in 1990) and in the United States the figure was 17.2 tonnes (down from 19.5 tonnes in 1990).[5] South Africa's per capita emissions are already among the highest at 9.25 tonnes in 2008.[6]

The world's least developed countries are a minor contributor to global climate change. They contributed only 0.5 percent of the cumulative GHG emissions between 1995 and 2008[7]. The majority of the least developed countries have emissions of less than 2 tonnes CO_2 per capita with, for example, countries such as

[1] Tan, X. and Seligsohn, D., 2010.
[2] Le Quere et al., 2009.
[3] WWF, 2008.
[4] UNFCCC, 2005.
[5] Kanter, J., 2010.
6 Union of Concerned Scientists, 2010.
[7] UN-OHRLLS, 2010.

Rwanda exhibiting per capita emissions of 0.3 tonnes, Bangladesh 0.9 tonnes, and Cambodia 1.6 tonnes CO_2 per capita in 2005[8].

Major differences in GHG emission accounts between developed and developing countries reflect challenges related to economic growth, industrial development and access to modern energy services in many developing and emerging economies. While the challenge to mitigate climate change is global, developing countries face the urgent need to expand provision of affordable energy services to the world's poor. Experts argue that "energy services play a critical role not just in supporting economic growth and generating employment, but also in enhancing the quality of people's lives".[9]

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

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

- An opportunity for technological 'leapfrogging', whereby developing countries can overleap emissions-intensive intermediate technology in favour of cleaner technologies.[10] Thus they would implement low-carbon strategies from the outset and avoid the legacy infrastructures and technology lock-ins that constrain available options in more advanced economies.[11]

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

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

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

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[8] Climate Analysis Indicators Tool Version 7.0., World Resources Institute, 2010.
[9] UNDP, 2007.
[10] Metz, B., et al., 2007
[11] WWF, 2008.

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

GHG Emissions by Sector in 2005
CO_2, CH_4, N_2O, PFCs, HFCs, SF_6
(includes land use change)

Annex I

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

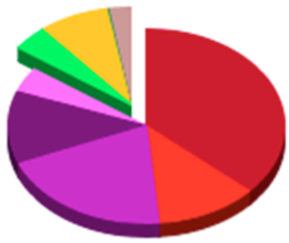


Figure 1: GHG Emissions by Sector in 2005 in Annex I (industrialised) Countries.
Source: Climate Analysis Indicators Tool Version 7.0., World Resources Institute, 2010[12].

GHG Emissions by Sector in 2005
CO_2, CH_4, N_2O, PFCs, HFCs, SF_6
(includes land use change)

non-Annex I

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

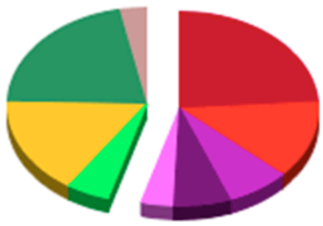


Figure 2: GHG Emissions by Sector in 2005 in non-Annex I (Developing/Emerging) Countries.
Source: Climate Analysis Indicators Tool Version 7.0., World Resources Institute, 2010.

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

Box 1: The Climate Analysis Indicators Tool

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

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

To explain CAIT emission sector categories further:

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

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

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

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

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

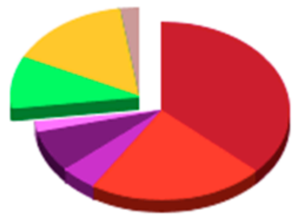
- In China and India, the largest sources of GHG emissions in 2005 came from sources related to electricity and heat, manufacturing and construction, and agriculture.

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

- In contrast, GHG emissions in Brazil and Indonesia were dominated by land-use change and forestry activities, which contributed 64.4 percent of emissions in Brazil and 71.5 percent of emissions in Indonesia.[13]

China

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



* Represents shares of total emissions excluding LUCF.

Figure 3: China GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010[14].

India

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

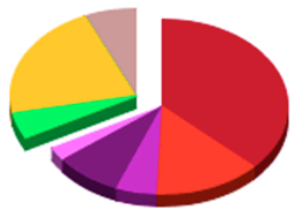


Figure 4: India GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

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

South Africa

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

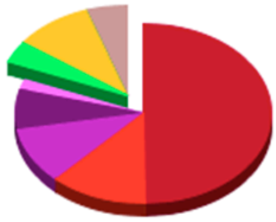


Figure 5: South Africa GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

Brazil

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

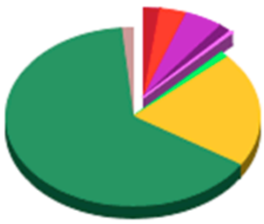


Figure 6: Brazil GHG Emissions by Sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

Indonesia

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

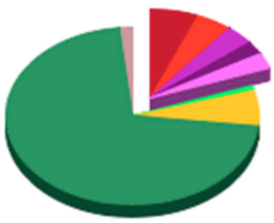


Figure 7: Indonesia GHG emissions by sector in 2005.
Source: Climate Analysis Indicators Tool Version 7.0, World Resources Institute, 2010.

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

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

- India seeks to significantly increase the share of renewable energy and aims for a increased deployment of solar pholtovoltaic and hydropower sources.

- South Africa aims to accelerate energy efficiency and conservation across all sectors and targets to reduce transport emissions.[15]

- Brazil aims to reduce deforestation by 30 percent during 2013-2017 and to double the area of forest plantation to 11 million ha by 2020.

- In Indonesia, which has not developed a strategy yet, the exploitation of geothermal power and efforts targeting the land-use change and forestry sector (e.g. reducing deforestation, promoting reforestation, conserving peat land, and preventing fires) are key mitigation options being explored.[16]

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

2. ICT-based Climate Change Mitigation in Emerging Economies

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

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

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

The ICT sector has the potential to play a powerful role in tackling climate change by enabling other sectors (such as transport, construction, power and industry) to become more efficient. In fact, ICT-enabled emission reduction potential far exceeds the ICT sector's own carbon footprint.[17] A report published by The Climate Group and the Global e-Sustainability Initiative (GESI) found that

> *ICTs could reduce global carbon emissions by 7.8 $GtCO_2e$ by 2020 (from an assumed total of 51.9 $GtCO_2e$ if we remain on a BAU trajectory), an amount five times larger than its own carbon footprint. Savings from avoided electricity*

[15] WRI, 2009
[16] Indonesian Ministry of Finance, 2009
[17] For example The Climate Group and GESI, 2008 and ITU, 2009

and fuel consumption would reach € 600 billion. (The Climate Group and GESI, 2008)[18]

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

- Dematerialisation by replacing physical goods, processes or travel with 'virtual' alternatives, such as video-conferencing or e-commerce (online shopping).[19]
- Machine-to-machine (M2M) communication, which enables a large share of GHG emission savings by means of process optimisation. These include for example smart grids, smart logistics, smart buildings, or smart motor systems.[20]
- Systemic impacts, i.e. behavioural effects such as new habits and consumption patterns that humans develop as a result of ICT use.[21] This is an important area of intervention since consumers control or at least influence 60 percent of all GHG emissions (through their own consumption and use consumers directly control 35 percent of these emissions). Thus, consumer targeted carbon reduction measures can result in significant reductions in global GHG emissions.[22]

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

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

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

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

12

[18] BAU means "business as usual" and refers to emission levels that would occur if emissions grew at the same rate as has accompanied economic growth in the past and no actions to reduce emissions were taken.

[19] Vodafone and Accenture, 2009

[20] Ibid.

[21] Pamlin and Szomolanyi, 2005

[22] IISD, 2008

To date, discussions on ICT-based climate change mitigation strategies have largely focussed on the general opportunities. With the exception of an ITU draft paper[23], discussions have not considered how far the enabling effect of ICTs will be influenced by the development status of a country - which in turn helps determine the investment climate and the state of ICT diffusion and applicability – and influenced by the specific pattern of carbon emissions to be mitigated. They have also not focussed much on the application of ICT-enabled mitigation solutions in the specific high-carbon sectors dominant in these countries such as agriculture or forestry.

The marked growth in ICT uptake in emerging economies[24] will result in an increased share of these countries in ICT-related GHG emissions from increased energy demand. At the same time it provides the opportunity to deploy smarter solutions as technologies become deeply embedded into the socio-economic fabric.[25]. There is an urgent need to develop and adopt IT architectural paradigm shifts (e.g. virtualisation across all ICT assets) to counter the increased energy demand for ICTs in countries such as India and China (see Box 2). In these countries we are seeing a roll-out of mobile networks, a larger share of the population being able to afford ICT devices as well as a rapid growth in data centres.[26]

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

There is a risk of further broadening the 'digital divide' if technology-based mitigation efforts are solely devised for developed countries. This would exclude developing countries from the new wave of developments and trends towards 'cleaner', 'smarter' and more efficient technologies[27] crucial in achieving sustainable economic growth and leave them at risk to carbon being "locked in" to their infrastructures, networks and operations.

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

Developing and emerging economies face numerous challenges in the provision of infrastructure as economic growth progresses, with demand rapidly increasing for reliable electricity supply, transport infrastructure and commercial buildings. Some experts argue that difficulties faced in meeting this demand are driving investments

[23] ITU, 2009
[24] ITU, 2008
[25] Ospina, A.V. and Heeks, R, 2010
[26] The Climate Group and GESI, 2008
[27] Ospina, A.V. and Heeks, R, 2010

towards more energy efficient solutions.[28] As major infrastructure investments are taking place in the world's emerging economies there is a great opportunity to "leapfrog" to smarter infrastructures and processes and to avoid the carbon-intensive development stages experienced by developed countries. In developing countries, much of the energy efficiency potential in life-long assets such as buildings, energy grid and industry stock is associated with greenfield opportunities, i.e. new constructions. Infrastructure investments not taking advantage of this opportunity can lock in energy- and emissions-intensive infrastructure for at least the next 40 years. Retrofit opportunities to partially reverse this situation tend to be more expensive than energy efficient investments in the greenfield.[29]

A small number of emerging economies have already successfully deployed low-carbon technologies in certain industry sectors and thus partially avoided the high-carbon investments made in developed economies. Examples include the substitution of 40 percent of gasoline fuel with sugar cane-based ethanol in Brazil's transport sector[30] and the rapid development of wind power in China which has made the country the fourth largest wind power generator in the world[31].

The opportunity for technological leapfrogging is increasingly being seen and realised by the private sector which expects substantial financial savings from investments in smarter solutions. For instance, North Delhi Power Limited (NDPL), which distributes electricity to approximately five million people in the Delhi metropolitan area, has invested in a host of technologies for a smarter grid which has already reduced energy losses from 54 percent to less than 18 percent over a five-year period through the company's automation strategy. Technological investments included an Outage Management System which allows the control room to pinpoint the location of a failure and trigger a repair operation - a solution that allows faster restoration of power.[32]

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

[28] OECD, 2009
[29] The Secretary General's Advisory Group on Energy and Climate Change (AGECC), 2010
[30] ESMAP, 2010 Brazil case study
[31] WRI, 2010b
[32] GE, 2009

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

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

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

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

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

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

2.2. ICT-enabled Carbon Reductions in an Urban Context

In emerging economies, cities are an important engine for economic growth and socio-economic development. They are the main driver behind increased energy consumption and related GHG emissions.[33] But experts argue they also have the greatest potential for reducing GHG emissions through ICT.

To date, one-third of the world's population, i.e. 2.6 billion people, live in emerging-market cities and by 2030 the number is likely to increase by an additional 1.3 billion.[34] It is expected that the urban population of developing countries will reach 50 percent in 2020. By 2030, Asia and Africa will both have higher numbers of urban dwellers than any other area of the world.[35] In China 43.6 percent of the population lived in urban areas by the end of 2006. This rate is rapidly increasing, with 75 percent of the population estimated to live in cities by 2050.[36]

[33] See for example WWF and Ericsson, n.d.
[34] WW, n.d.
[35] UN Habitat, n.d.
[36] WWF, n.d.

The massive growth in size and number of emerging-market cities, alongside the burgeoning middle-class households within them, drives housing and infrastructure investments and brings with it a rapid increase in energy consumption and related GHG emissions. Urban energy consumption per capita is estimated to be three times higher than that of rural areas, and this will be exacerbated as rural populations continue to migrate to urban areas: a flow which, in China alone for example, is estimated at 10 million people annually.[37]

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

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

There is great potential for ICTs to help reduce direct emissions in cities resulting from cars, buildings and energy production by by finding smart, less carbon-intensive ways to provide the same services.[38] Among such solutions are smart transportation, which is explained further in Box 3.

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

Energy efficiency can offer practical solutions to budget-constrained cities to meet their energy needs without sacrificing their development priorities. Energy-efficient activities are generally cost-effective as the higher upfront investment is offset in the long-term by lower energy costs.[39] This is explored further in the next section including the example of smart grids (albeit in non-urban settings) in Box 5: Smart Micro-grids for Remote Areas.
Another area to tackle is imported emissions, i.e. reducing the emissions resulting from products and services imported to or exported from a city such as emissions from the production of steel and other construction materials (outside a city's boundaries) used in a city's building developments. Here, ICTs can play a role in developing smart solutions to logistics, motor systems, energy production and consumption, and industrial processes.[40]

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

[37] Ibid.
[38] WWF and Ericsson, n.d.
[39] Energy Sector Management Assistance Program, n.d.
[40] WWF and Ericsson, n.d.

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

Box 3: Smart Transportation – ICTs and Electric Vehicles

ICT-driven applications across transportation have the potential to achieve a reduction in total global emissions of 1.52 $GtCO_2e$. Many industries already rely on software systems to optimise transportation systems to reap big energy savings.

Transport challenges faced by emerging markets include increasing urbanisation (especially in the mega cities) and worsening congestion leading to adverse economic, health and safety impacts. An increasing number of emerging economy cities are rethinking their transportation systems to better meet these challenges. This represents a huge potential for ICT-driven solutions including software to improve the design of transport networks with specific levers such as intermodal shift, eco-driving, route optimisation, inventory reduction, or moving to the most efficient type of transport.

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

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

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

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

Box 4: Smart Buildings

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

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

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

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

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

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

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

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

2.3. Decarbonising Energy Supply and Demand

It is estimated that the world's primary energy needs will grow by about 45 percent from 2006 to 2030, and that this growth will largely occur in developing countries (about 87 percent) where carbon-intensive fossil fuels remain the dominant source of primary energy. Developing countries need to meet their growing energy needs in order to maintain robust socio-economic development.,[41] but therefore also need urgently to find ways to decarbonise energy supply and use.[42]

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

- **Energy generation**: This includes using smart grids that will allow the monitoring of power consumption and use over the electricity grid. The goal is to allow more efficient power distribution and power use by the grid itself, including the possibility of making greater use of renewable and non-GHG emitting sources of energy.[43]

- **Energy transmission and distribution**: These include remote measurement and monitoring of energy use, remote grid element management and energy accounting, which together would help utilities monitor energy use across the grid better and allow them to trace the source of energy losses.[44]Energy transmission and distribution (T&D) monitoring is the most significant single carbon reduction opportunity and can significantly reduce the share of electricity losses; a key problem for developing countries.

- **Efficient end-use technologies**: These technologies are expected to play a fundamental role in the transition to low-carbon societies[45] and include smart meters which can influence consumer patterns.

- **Decentralised energy production**: This could allow renewable energy such as solar and micro-hydro sources to be integrated into the grid, reducing carbon-intensive coal-based generation. Decentralised energy sources could also allow the grid to respond to local power surges and shortages, making it easier to manage.[46]

The Climate Group and GESI (2008) found smart grid technologies to be the largest opportunity for GHG emission reduction with a potential to reduce 2.03 $GtCO_2e$ globally.[47] Moreover, smart ICT solutions for optimised electricity grids hold various other benefits for emerging economies with rapidly increasing energy demands and large T&D losses such as in India or South Africa.

The energy systems in many developing and emerging economies' cities face substantial challenges related to a rapidly rising demand for energy, high carbon intensity of supply, high grid losses, rising energy costs, and the need for large investments in infrastructural development in the coming years. This is the case for

[41] International Energy Agency, 2008.
[42] See for example Ockwell et al., 2009.
[43] ITU, 2009.
[44] The Climate Group and GESI, 2008.
[45] Ockwell et al., 2009.
[46] The Climate Group and GESI, 2008.
[47] Ibid.

India in particular. Smart grids, therefore, are of key relevance in driving down energy-related GHG emissions in emerging economies to prevent them from becoming locked-in to high emissions trajectories for the next 30 years. Incorporating smart ICT solutions not only helps tackle energy losses and improve efficiency but can also reduce power generation investment costs and contribute to energy security.

In India, the private sector and the Indian government are expected to invest significantly in the energy sector.[48] This presents an opportunity to put in place a "best in class" system early and leapfrog to smart grid technology. The Climate Group and GESI (2008) argue that T&D losses in India's power sector can be reduced by 30 percent through better monitoring and management of electricity grids, first with smart meters and then by integrating more advanced ICTs into the so-called "energy internet". This will lead to significant financial savings and emissions reductions from prevented T&D losses; creating a potential economic and environmental win-win.[49]

ITU (2009) sees great potential for energy demand side management in emerging economies, as important energy savings for consumers and electrical utilities can be realised through ICT applications to even out energy loads and reduce brown outs. ITU notes that "in some cases, this practice may be the only alternative to help existing electrical utilities avoid black outs and brown outs without adding to existing energy generation capacity".[50] Energy efficiency measures are seen as "no regrets" (i.e. as producing economic benefits regardless of their environmental necessity) and highly cost-effective options even in a pricing regime where tariffs do not reflect costs as is the case in many emerging economies and developing countries. Energy efficiency measures help increase megawatt capacity without necessitating the buying or building of new plants.[51]

In Bangladesh, for example, the World Bank invested US$15 million to replace customer incandescent bulbs with high efficiency compact fluorescent lamps to help reduce peak hour deficits and improve power supply reliability in particular in rural areas. It was found that lighting coincides with the peak load hours and contributes over 20 percent of the demand. The investment compared very favourably to the alternative of installing a comparable amount of new peak generation capacity at an estimated cost of US$235 million.[52]

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

[48] Chadha, M., 2010.
[49] The Climate Group and GESI, 2008.
[50] ITU, 2009.
[51] Sarkar, A. and Singh, J., 2009.
[52] Ibid.

Box 5: Smart Micro-grids for Remote Areas

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

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

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

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

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

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

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

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

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

2.4. Export of Manufacturing-based Emissions

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

Overall, around one-quarter of the growth in developing country emissions (including emerging economies) since 2000 was associated with international trade.[53] More specifically, 30 percent of the growth in emissions in China between 1990 and 2002 was attributable to the production and international trade of goods exported for consumption in other countries. This figure increased to a staggering 50 percent in the following three years (2002 to 2005). Over half of the exported products were destined for developed countries where consumption-based emissions – those linked to in-country consumption of goods irrespective of their production site – have also been on the increase. For example, in the UK between 1992 and 2004, within-country emissions decreased by 5 percent, but consumption-based emissions rose by 12 percent.[54]

This issue highlights the shared responsibilities of developed and emerging economies in reducing global GHG emissions and in realising low-carbon development paths. There is a need to develop and transfer low-carbon technologies from advanced to emerging economies, which would serve two goals – reduce international trade related emissions and support catch-up growth in those economies. Reducing global GHG emissions can not only depend on the international coordination of carbon emissions trading and carbon tax schemes (as indicated by the carbon leakage problem[55]), but will also largely depend on the success of technology transfer to improve the performance of energy- and carbon-intensive industries in emerging economies.

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

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

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

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

The transport sector is a large and growing emitter of GHGs, responsible for 14 percent of global GHG emissions. Optimising logistics using ICT could result in a 16 percent reduction in transport emissions and a 27 percent reduction in storage emissions globally. Efficiency gains come with significant economic benefits since the sector operates a high-value market, with the global logistics industry estimated to be worth $3.5 trillion in 2005.[56]

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

"Smart logistics" solutions include software enabling improved design of transport networks, running of centralised distribution networks and of management systems facilitating flexible home delivery services (see Box 3 for further examples).[57] Various machine-to-machine (M2M) technologies can help improve operational efficiency including onboard telematics, loading monitoring devices, and tracking systems such as Helveta's supply chain software introduced in Box 6.[58]

In emerging economies, we are witnessing rapid growth in consumption as well as manufacturing, for both domestic and foreign markets, which results in a continuous increase of GHG emissions. The logistics sector is already contributing a large part of these emissions and they are set to rise further with manufacturing increasing for both domestic and overseas markets. A major challenge in tackling these emissions is the fact that in emerging economies the logistics sector is largely fragmented. ICTs hold the promise to address this challenge but have not been widely deployed in emerging economies and developing countries. As trade and transportation grow, thereby further exacerbating the need to devise innovative low-carbon solutions, there is a need for governments in these countries to incentivise the deployment of smart solutions. Moreover, underdeveloped trade and logistics infrastructure not only contribute to excessive GHG emissions but also adversely affect GDP. It has been estimated that underdeveloped trade and logistics infrastructure costs India 13 percent of its GDP.[59] Some leading logistics and transport companies are therefore already adopting smart logistics solutions for network tracking and monitoring.

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

- increase manufacturing process efficiency by automating communications between production sub-processes,

- support predictive maintenance by remotely monitoring machinery to improve maintenance planning and overall service management, and
- optimise order fulfilment by integrating order capture in production planning, output and dispatch, and increasing the intensity of batch production to reduce continuous production.[60]

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[56] The Climate Group and GESI, 2008.
[57] Ibid.
[58] Accenture, 2009.
[59] Youngman, R., n.d..
[60] Vodafone and Accenture, 2009.

In particular, energy-intensive motor systems, largely used in China's manufacturing sector, hold significant efficiency potential through the adoption of smart technologies (see Box 7). Within manufacturing, a particular focus will also be on the cement sector – an industry expected to double by 2030 and which is already responsible for about 5 percent of the world's CO_2 emissions.[61] Cement production and demand are increasing rapidly in developing countries where already 80 percent of global cement production takes place, and application of ICTs in cement production in the developing world thus form an important path of new ICT-enabled development patterns.[62]

Box 6: Helveta's Supply Chain Software

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

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

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

Source: Youngman, R., n.d.

[61] GreenBiz Group, 2009.
[62] World Business Council for Sustainable Development, 2009.

Box 7: Smart Motor Systems, China

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

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

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

Source: The Climate Group and GESI, 2008

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

Emissions from land-use change and forestry (LUCF emissions including deforestation, logging and intensive cultivation of cropland soils) are the second largest source of global anthropogenic GHG emissions (estimated between 15 to 20 percent).[63] The largest driver of LUCF emissions is deforestation caused by the conversion of forest to agricultural lands, primarily in developing countries.[64] One third of total emissions of developing countries is caused by LUCF with the largest contributors being Indonesia and Brazil (other countries include Malaysia, Myanmar and the Democratic Republic of Congo).[65]

The Intergovernmental Panel on Climate Change (IPCC, 2007) notes that reducing and/or preventing deforestation is "the mitigation option with the largest and most immediate carbon stock impact in the short term".[66] It is estimated that reducing deforestation by 50 percent over the next century would help prevent 500 billion tonnes of carbon from being released into the atmosphere per year.[67]
ICTs can help monitor land-use change and deforestation and enhance data collection on the condition of forests. Satellites are now able to take images through

[63] IPCC, 2007.
[64] Baumert, a. et al., 2005
[65] Ibid.
[66] IPCC, 2007.
[67] ITU, 2009.

clouds and at night making remote sensing applications a critical and effective tool in monitoring deforestation and illegal logging (see also Box 6). For example, Google maps are being used to present illustrations, satellite images and photographs that depict human impacts on the environment (both past and present).[68] Alongside illegal logging such impacts include forest loss from the construction of road networks, and from establishing farms, plantations and pastures.

ICT solutions can make data collection on the ground more efficient at lower cost and environmental impacts. Remote sensing technologies and communication networks, for example, enable more efficient monitoring and resource management.[69] This is critical in emerging and developing countries where environmental protection agencies and organisations are usually understaffed and underfunded.

However, for effective monitoring remote sensing data need to be complemented by in-situ ground data and geolocation information. Team Networks, for example, works with local groups based in developing country field sites using mobile technologies (smart phones and EcoPDAs) to facilitate the collection of data. Once this data has been stored in servers and databases, it is disseminated globally, in a timely manner and free of charge.[70] Through such applications ICT can encourage better land use planning and contribute to more informed land use decision making.

Moreover, by facilitating information gathering and dissemination, ICTs can contribute to capacity building including efforts to increase public awareness of critical environmental issues, the development of professional staff, involvement of and collaboration among relevant stakeholders, and the integration of environmental content into education and policy enforcement. The increasing availability of satellite data imagery data has spurred the establishment of NGO imagery activities around the world. The Global Forest Watch (GFW) programme by the World Resources Institute (WRI), for example, urges better forest management by monitoring and publicising information on forest loss around the world. This information combines reports from ground observers with satellite imagery data and GIS. Members of the Indonesian Forest Monitoring Network (IFMN) are sharing information via the Internet and developing a database of satellite imagery and information on local forests in an effort to influence government policy on illegal deforestation.[71]

ICT applications can also contribute to empowering groups and supporting them in efforts around environmental conservation. For instance, Amazon Indians in South America combine use of ICT solutions like Google Earth and Global Positioning System (GPS) mapping, with traditional knowledge of the rainforest to help detect illegal activities and thus fight deforestation.[72]

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[68] Ibid.
[69] SPIDER, n.d.
[70] TEAM, 2010.
[71] Baker, J.C., and Williamson, R. A., n.d.
[72] Brahic, C., 2007.

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

The rural societies of Brazil, China, India and South Africa constitute one fourth of the world's population. They are the world's largest producers of food, are involved in the management of millions of hectares of land and forest, and significantly contribute to the global economy. But for all that they constitute about one third of the world's poor and almost half of the world's rural poor, and are challenged by one of the lowest levels of human development.[73]

In emerging economies we are now seeing a rapid and deep economic, social, demographic, cultural and political transformation of rural areas. While such transformation is necessary and even indispensable for the sustainable development of these countries, it is putting enormous pressures on the environment. Because of the scale of rural societies and of the resources involved - be they "forests in Brazil, water resources in India, biodiversity in South Africa, or the pressures on land for urbanisation in China" - these pressures have global implications.[74]

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

In relation to agriculture, ICTs are currently seen to have only low potential to enable GHG emissions reductions in the rural areas of poorer countries[75] However, given the high share of GHG emissions in emerging and developing economies related to the agricultural sector there is need to further explore opportunities for ICT-enabled emissions reductions on a country-by-country basis.

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

Introducing low-cost energy-efficient user devices, online services and travel replacement technologies in rural and remote areas will not lead to significant impacts in terms of energy saved and GHG emissions prevented at a national level. But the enabled socio-economic benefits can be significant to the individuals involved and their families.[76] With judicious technology selection, carbon emissions could also be minimised. An example (albeit not specific to the rural poor) is the deployment of virtual desktops for schools in all of Brazil's municipalities (see box 8 below). This initiative has contributed to improving the student-to-computer ratio at minimal economic and environmental costs.

The rapid proliferation of mobile communications in rural areas will demands efforts to reduce ICTs' own carbon footprint, for example through greater use of renewable energy. In 2008 Celtel in Uganda started converting all diesel-driven radio base station sites outside the power grid to a hybrid energy solution developed by

[73] Planning Commission of India and Institute for Human Development, 2009.
[74] Ibid.
[75] See, for example, GESI, n.d.
[76] ITU, 2009

Ericsson. The new off-grid system replaces one of the two previously-used diesel generators by a battery bank with specially designed batteries and a photo-voltaic array. The batteries can handle the large number of charge/discharge cycles required for connection to solar panels. The hybrid solution enables a less carbon-intensive energy supply at sites too large to be economically viable for a solely renewable energy based solution. In this way the hybrid energy system contributes to increased network reliability in remote areas while also reducing GHG emissions related to energy generation.[77]

Box 8: Virtualised Desktops for Schools, Brazil

In 2009, the Brazilian Ministry of Education realised the world's largest virtual desktop deployment in order to provide computer access to schools in all of Brazil's 5,560 municipalities. The initiative also achieved a record low-cost for PCs with the deployed PC-sharing hardware and software costing less than US$50 per seat.

Compared to traditional PC-per-workstation solutions, the virtual workstations achieve savings of up to 60 percent in up-front costs and 80 percent in annual power demand. The Desktop Virtualisation Deployment created 356,800 workstations by transforming one PC to support up to ten simultaneous monitors, keyboards and users which are all managed at once through a central website.

This initiative has demonstrated the potential of simultaneous developmental and environmental benefits, by significantly increasing the availability of ICTs in schools but at relatively low cost both financially and in terms of carbon emissions.

Source: Userful, 2009

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

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

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

[77] Ericsson, 2008

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

- Lack of awareness of technological developments and their potential for more carbon- and energy-efficient solutions.[78] A challenge for many small firms is to take informed decisions on ICT adoption (or non-adoption), as they are not familiar with ICT options and the business opportunities they offer.[79]

- Limited access to capital as the result, for example, of a conservative banking sector and scarce as well as highly sector-specific venture capital and private equity sources.[80]

- High or uncertain costs of new technologies and no proven commercial viability for large scale investments, in particular for smart grids and smart cities.[81]

- Limited or uncertain suitability of technologies for local conditions: There is a challenge of ensuring technology compatibility across countries or even single companies (e.g. with smart grids and smart logistics). To ensure compatibility and accelerate technology adoption there is a need for technology and telecommunication providers and affected industries to collaborate and develop common operating standards.[82]

- Limited resources, capacity or technical and managerial skills to identify suitable technologies, adapt them for specific local application, and conduct installation and maintenance services.[83]

- Unpropitious regulatory and political circumstances such as market distortions and subsidies in favour of fossil fuels[84] on the one hand and lack of policies and incentives to encourage investment in smart ICT solutions on the other.[85]

Barriers to successful deployment of low-carbon technologies in developing and emerging economies are frequently compounded by the lack of a central organisation acting as the focal point and bringing together the academic, business and government communities to address the low-carbon innovation challenge in a co-ordinated manner.[86]

It has to be noted that the challenge of a broader deployment of low-carbon solutions in emerging and developing economies goes beyond technology-related barriers as outlined above. As pointed out in Box 9, technology is only one part of

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[78] ITU, 2009.
[79] European Commission, 2010.
[80] Carbon Trust, 2008.
[81] Vodafone and Accenture, 2009.
[82] Vodafone and Accenture, 2009.
[83] ITU, 2009 and Carbon Trust, 2008.
[84] Carbon Trust, 2008.
[85] ITU, 2009.
[86] Carbon Trust, 2008.

the equation. There is a risk that efficiency gains can potentially be offset by a change in consumption patterns triggered by the very same technology.

Box 9: Rebound Effect

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

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

To date, rebound effects from energy efficiency improvements in developing and emerging economies have not been well studied. Some experts expect these to be larger in these economies as energy demand has not yet been saturated.

The discussion on rebound effects stresses that energy savings do not result from technology itself but instead from how it is deployed and used, noting that policies play a crucial role in encouraging desired behaviours.

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

4. Conclusions and Recommendations

The barriers outlined in the previous section indicate the need to extend existing technology transfer and finance schemes under the United Nations Framework Convention on Climate Change (UNFCCC) to include broader deployment of ICT in developing and emerging economies. Cap-and-trade and offset mechanisms that result in the transfer of ICT technology to developing countries need to be further promoted and new mechanisms may need to be added to drive inclusive low-carbon growth by utilising the opportunities ICT could bring if technology were widely available and effective implementation viable.[87]

More importantly, there is a need for mechanisms that support technology transfer to focus on how to constructively build innovation capacity in developing and emerging economies, rather than simply conceiving a one-way flow of technology from global North to global South. This would have the potential to transform developing countries from being consumers of technologies and dependent on continued imports to being low-carbon technology producers and innovators in their own right. In turn this will foster competitiveness of local industries and create new

[87] Vodafone and Accenture, 2009

business opportunities.[88] Creating centres of low-carbon innovation in selected developing countries would catalyse domestic capacity to adapt and develop technologies and help diffuse innovations.[89] It would also help enhance the political and economic justifications for a low-carbon development path.

While globally the pace of technology deployment has dramatically accelerated over recent decades, technology deployment and low-carbon technology deployment in particular, remains slow in low- and middle-income countries. An exception is China where the deployment has accelerated over recent decades transforming the country into a major manufacturer of a number of low-carbon technologies.[90] In looking for ways to build low-carbon innovation capability in and diffusing climate-smart technologies across developing countries there is a need to look at experiences in China and other success stories in emerging economies (e.g. low-carbon energy in Brazil) to capture the lessons learned that have enabled these economies to leap-frog into the global elite of low-carbon innovators, if only in certain sectors.

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

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

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

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

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

5. Expand local lending capabilities and access through local commercial banks and micro-finance institutions to scale up investments. The existing systems could be adapted to the emerging challenges, e.g., by adding special incentives for off-

[88] Ockwell et al., 2009
[89] The Carbon Trust, 2008
[90] World Resources Institute, 2010b

grid areas or the deployment of renewable energy, and making access to funding mechanisms more conducive to the needs of SMEs in these countries.[91]

Sector-based approaches can be an effective tool in emerging economies. Some experts argue that national development paths do not result from integrated policy programmes but rather emerge from fragmented decisions made by numerous private actors and public agencies. Moreover, critical decisions are being made in carbon-intensive sectors by ministries and companies that do not regularly attend to climate risks.[92] Mainstreaming low-carbon development within the national policy making process will represent a major challenge in those emerging economies that lack sufficient institutional and regulatory capacity. Against this background a national sector-based approach focussing on key industry sectors can be more effective in streamlining efforts and enabling stakeholders to bring about a low-carbon growth in that particular area. Focused efforts at the sector level have significant potential to spur national level growth.

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

Recommendations to **business**:

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

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

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

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

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

[91] Recommendations were derived from various studies and include UN, 2010 and WRI, 2010b
[92] See for example Metz, B., et al. (2007)

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

A discussion on the potential for ICT-enabled climate change mitigation in an emerging country context has to take into consideration the specific development needs in these countries and has to help contribute to a low-carbon development trajectory. To reiterate, then, analysis of national carbon footprints suggests that a sectoral approach might be most effective in cutting national greenhouse gas emissions. This sectoral approach needs to focus on carbon intensive sectors crucial for economic growth in emerging and developing countries such as the manufacturing, transport, forestry and potentially agricultural sector. A major objective should be the building of innovative capacity within emerging and developing economies rather than a solution whereby these countries depend on technology transfer from industrialised countries.

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

Box 10: Priorities for Future Research

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

The research paper also indicates key priorities for future research as follows:

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

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

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