ICTs and Climate Change Mitigation in Developing Countries

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Urgent action is required to reduce greenhouse gas emissions. Developing countries overall are significant emitters, and they must maximise use of ICTs in three ways:

- Green ICT: reducing the emissions from production and use of ICTs themselves.
- Smart ICT: using ICTs in other sectors – energy, buildings, transportation, logistics, manufacture and forestry – to shrink their carbon footprint.
- Community ICT: applying ICTs at community level to reduce energy consumption and substitute for journeys.

Developing countries have an opportunity to leapfrog to low-carbon solutions, and to reduce operating costs alongside carbon emissions by investing in e-mitigation. However, they face important challenges: lack of awareness, capital, skills, appropriate technology, and appropriate market/policy regimes.

Action is therefore needed by:

- International organisations: to incorporate ICTs more clearly into low-carbon technology transfer and financing.
- Governments: to build capacity and partnerships, and to create a business environment that incentivises both innovation and adoption of e-mitigation applications.
- Businesses: to develop new e-mitigation solutions appropriate to developing countries, and to drive adoption of such solutions within their entire supply chain.

Carbon dioxide emissions are growing at a rate that is consistent with the worst-case scenario for global warming[4]. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change[5] along with the Stern Review[6] predict that unless this trend is reversed, it will have dire consequences, including catastrophic changes to key earth systems.[7]

Although historically associated with the world's developed countries, greenhouse gas (GHG) emissions are fast becoming a developing country issue. Developing countries already account for 50% of global GHG emissions and by 2030 this figure is expected to rise to 65%.[8] At present, the least developed countries are minor contributors – responsible for just 0.5% of cumulative emissions between 1995 and 2008.[9] The major sources are the "emerging economies", particularly Brazil, China, India and South Africa – the largest emitters on their continents.[10]

On average (see Figure 1), developing countries have a different emissions profile to developed countries: lower emissions from energy but higher emissions from manufacturing, construction, deforestation, and agriculture. And within developing countries, profiles differ: China's emissions come mainly from energy and manufacturing, Brazil's and Indonesia's from deforestation and agriculture.[11] Developing countries also have particular needs – alleviating poverty, bridging the digital divide, building institutions – that are less of a priority in the world's richer nations.

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

non-Annex I

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

Figure 1: GHG Emissions by Sector in Developing/Emerging Countries[12]

Excepting the ambitious (and, some argue, highly risky and unlikely) route of geo-engineering, then climate change mitigation via the reduction of carbon emissions is essential if the predicted catastrophe is to be avoided. Given their contributions, developing countries must play a key role in mitigation, and ICTs – information and communication technologies – will have a central part to play. ICTs can be used in numerous ways to mitigate climate change by providing solutions that help measure, monitor, manage, and enable more efficient use of resources and energy. ICTs provide immense opportunities to improve the operation of infrastructure and systems and can contribute to dematerialisation, transport substitution, and smarter ways to live, work and spend our leisure time.

What follows in this Brief is an outline of the ways in which ICTs can make a contribution. This breaks down into three main areas (see Figure 2):

- Green ICT: the reduction of carbon emissions from ICT production and consumption.
- Smart ICT: the application of ICT in other sectors to save both money and emissions.
- Community ICT: the use of ICTs within developing country communities in which, as yet, green and smart ICT applications play little role.

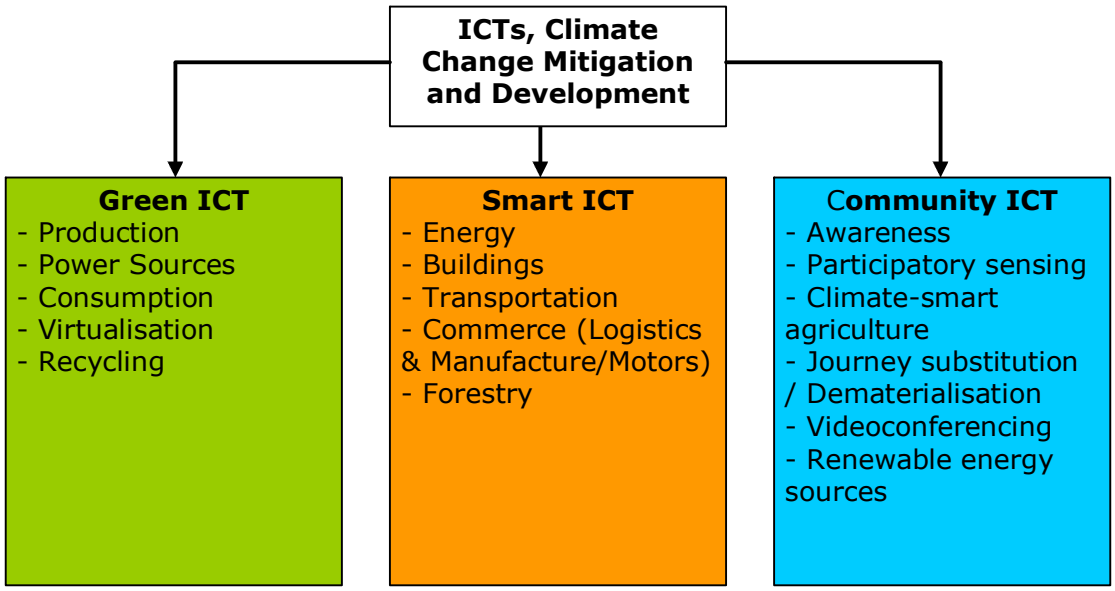

Figure 2: Mapping ICTs' Contribution to Climate Change Mitigation

1a. Green ICT

According to Gartner, the ICT industry "accounts for 2% of global CO_2 emissions".[13] This is expected to increase by 6% each year until 2020.[14] 40% of these emissions come from the operation of PCs and monitors, and 23% from data centres.[15] Emissions from data centres are rising particularly rapidly and the proliferation of mobile devices in developing countries is also making an increasing contribution.

To address this problem, nations, organisations and individuals need to adopt a green ICT strategy that seeks to minimise emissions from ICT production and consumption. Measures include[16]:

- Adoption of ICT components that are as energy-efficient as possible, including the incorporation of green criteria into ICT procurement.
- Innovation by ICT firms of new components that use even less energy.
- Transfer of data centres to cooler locations and/or close to greener energy sources such as hydropower, and more effective management of data centre energy design and use.
- Lifecycle analysis and planning of ICT production including the minimisation of e-waste and maximisation of component recycling.[17]
- Use of smart technologies within ICT production and logistics.
- Virtualisation: moving both server and desktop services to the cloud.
- Use of renewable energy sources to power ICT-related infrastructure, with a significant potential contribution relating to green, off-grid mobile base stations in developing countries.[18]

1b. Smart ICT

Although carbon emissions from ICT itself are growing, use of "smart" ICT applications in other sectors could far more than outstrip this growth:

> *ICTs could reduce global carbon emissions by 7.8 $GtCO_2e$ by 2020 (from an assumed total of 51.9 $GtCO_2e$ if we remain on a BAU trajectory), an amount five times larger than its own carbon footprint. Savings from avoided electricity and fuel consumption would reach €600 billion.* (The Climate Group/GESI 2008)[19]

ICT applications in various sectors are outlined below (see also Figure 3) but a cross-cutting point is that the majority of these will arise in urban areas. Cities generate up to 60 per cent of GHG emissions. Urban energy consumption per capita is estimated to be three times higher than that of rural areas, and this will be exacerbated as the world urbanises, with expectations that the urban population of developing countries will reach 50 percent by 2020.[20]

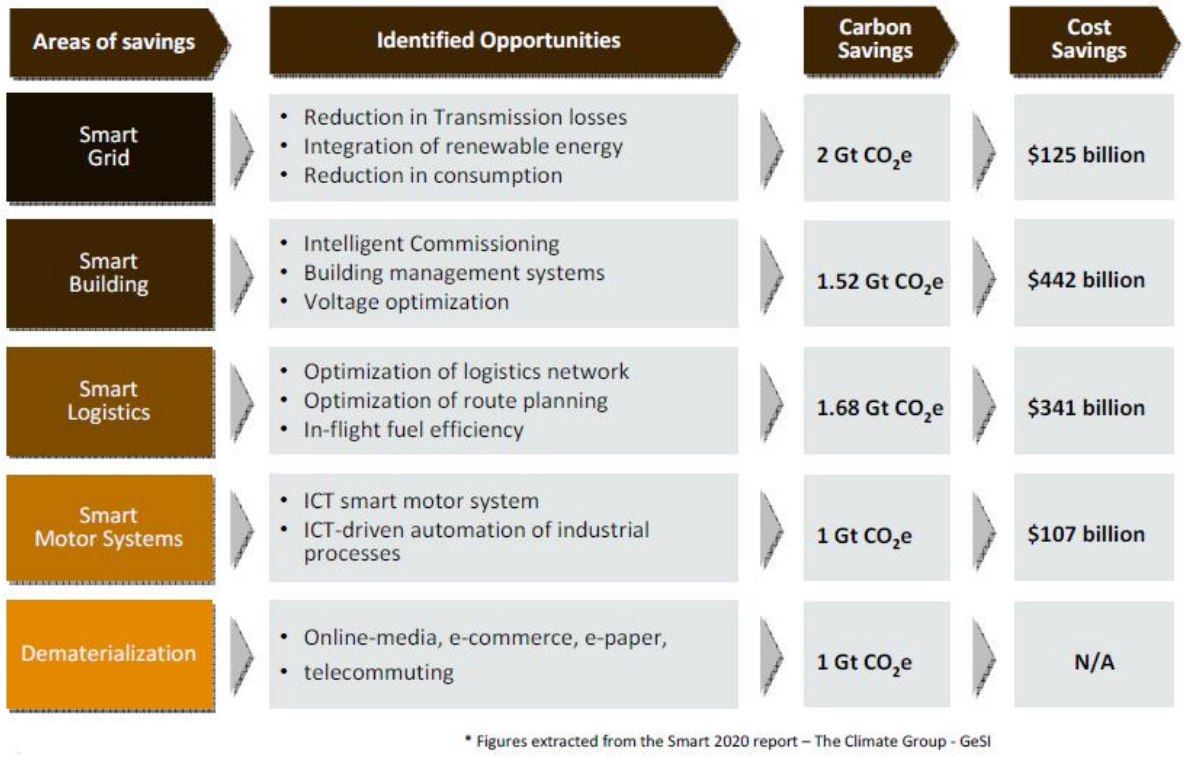

Figure 3: Smart ICT Solutions and Impact[21]

Smart Energy

It is estimated that the world's primary energy needs will grow by about 45 percent from 2006 to 2030, and that this growth will largely occur in developing countries (about 87 percent) where carbon-intensive fossil fuels remain the dominant source of primary energy. Developing countries need to meet their growing energy needs in order to maintain robust socio-economic development,[22] but therefore also need urgently to find ways to decarbonise energy supply and use.[23]

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

- ***Energy generation***: This includes using smart grids that will allow the monitoring of power consumption and use over the electricity grid. The goal is to allow more efficient power distribution and power use by the grid itself, including the possibility of making greater use of renewable and non-GHG emitting sources of energy.
- ***Energy transmission and distribution***: These include remote measurement and monitoring of energy use, remote grid element management and energy accounting, which together would help utilities monitor energy use across the grid better and allow them to trace the source of energy losses.[24] Energy transmission and distribution monitoring is the most significant single carbon reduction opportunity and can significantly reduce the share of electricity losses; a key problem for developing countries.
- ***Efficient end-use technologies***: These technologies are expected to play a fundamental role in the transition to low-carbon societies[25] and include smart meters which can influence consumer energy-use patterns.
- ***Decentralised energy production***: This could allow renewable energy such as solar and micro-hydro sources to be integrated into the grid, reducing carbon-intensive generation. Decentralised energy sources use ICTs for both control and connection, and could also allow the grid to respond to local power surges and shortages, making it easier to manage.[26]

Smart Buildings

According to the International Energy Agency, direct emissions from buildings account for around 10 per cent of global CO_2 emissions, while indirect emissions from the use of electricity by systems and appliances within buildings increase this share to almost 30 per cent.[27] Yet demand for new buildings is high – in Asia, for example, 20,000 new housing units are needed every day, which creates large demand for construction materials (the sector uses 40% of all raw materials).[28]

Several ICT-based technologies have an important role to play in enhancing the efficient use of energy in buildings, with the green building technology market in India alone forecast to touch US$100bn in 2012.[29] Applications include:

- Building information modelling (BIM) to facilitate building design and to optimise energy and material use in a sustainable fashion throughout the life cycle of a new building or retrofit. BIM also streamlines the building process and facilitates sustainable building certifications such as Leadership in Energy and Environmental Design.
- Wireless sensor networks to connect and potentially control everything that consumes or affects the consumption of energy in the building and its envelope and to monitor environmental variables including the surrounding microclimate to allow the building to adapt its energy balance accordingly and instantaneously.
- Building management systems (BMS) to automatically manage and reduce energy consumption and control heating, ventilation and air conditioning systems, lighting systems, and the sensors and smart motors / variable rate motors that control and operate them.
- Integrated BMS systems extending over a larger area via the Internet and integrated with the smart grid via wide area situational awareness technology.

Smart Transportation

ICT-driven applications across transportation have the potential to achieve a reduction in total global emissions of 1.68 $GtCO_2e$.[30] Many industries already rely on software systems to optimise transportation systems to reap big energy savings.

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

New ICT-based technologies and services are also being developed in relation to areas such as systems integration (smart charging and vehicle-to-grid systems), vehicle navigation and driving assistance, fees and bill payment systems, vehicle fleets, and mobility services. Finally, ICTs are also core to the greater use of electric vehicles.

Smart Commerce

Although the globalisation of trade and manufacturing has brought significant economic benefits to a number of developing countries, it has also increased their carbon emissions. For example, during the mid-2000s, 50 per cent of the growth in China's emissions was attributable to the production and international trade of goods exported for consumption in other countries.[31]

Addressing this requires progress on two fronts.

First, in development of "smart logistics". Part of this relates to transportation: it is estimated that optimising logistics using ICT could result in a 16 percent reduction in transport emissions and a 27 percent reduction in storage emissions globally.[32]

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.[33] Various machine-to-machine technologies can help improve operational efficiency including onboard telematics, loading monitoring devices, and tracking systems.[34]

Second, "smart manufacturing" solutions can be used to

- increase manufacturing process efficiency by automating communications between production sub-processes,
- support predictive maintenance by remotely monitoring machinery to improve maintenance planning and overall service management, and
- optimise order fulfilment by integrating order capture in production planning, output and dispatch, and increasing the intensity of batch production to reduce continuous production.[35]

Smart motors will also be an important part of the solution (since motors constitute up to 70% of industrial electricity consumption), including:

- Variable speed drives: VSDs control the frequency of electrical power supplied to the motor, thereby adjusting the rotation speed to the required output and are the most effective means of saving energy – up to 25-30 percent.
- Intelligent motor controllers: IMCs monitor the load condition of the motor and adjust the voltage input accordingly. They offer minor efficiency gains (3-5 percent), but have the benefit of extending the motor lifespan, which reduces the number of new motors required and therefore the associated manufacturing emissions.[36]

Smart Forestry

One third of total emissions of developing countries is caused by land-use change and forestry – primarily deforestation – with the largest contributors being Indonesia and Brazil (others include Malaysia, Myanmar and the Democratic Republic of Congo).[37] Reducing or preventing deforestation is "the mitigation option with the largest and most immediate carbon stock impact in the short term".[38] It is estimated that reducing deforestation by 50 percent over the next century would help prevent 500 billion tonnes of carbon from being released into the atmosphere per year.

The primary ICT application is data capture via remote sensing, typically via satellite, displayed on a geographic information system. These may be used in combination with earth-based data sources e.g. wireless sensor networks to detect plant status, and "participatory sensing"[39] by local citizens or activists, for example using mobile devices.

These systems can be used by government regulators – for example to monitor and then intervene on illegal deforestation.[40] The systems can also be used by local NGOs, for example:
"– Satellite data to identify areas of forest loss where urgent reforestation or tree planting should be carried out.
– GIS and remote sensing to … delineate the extent of specific potential community-based tree planting project sites.
– Field measurements to estimate baseline biomass and carbon stocks for community tree planting project sites.
– Mapping and field based-monitoring using GIS to ensure high survival of the planted trees.
– Web-based mapping application for and analysis and reporting of project progress to management and project partners".[41]

1c. Community ICT

Most of the applications listed above lie outside the scope of use of community members within developing countries. Given their limited contribution to climate change – at least if we focus on poor rural communities – the impetus for action may seem limited.

However, there are many examples of ways in which community members can be users of ICT applications that may make some contribution to climate change mitigation:

- Awareness raising, using broadcast and narrowcast media to make individuals and groups aware of climate change issues and mitigation strategies.
- Local contributions to deforestation: the type of participatory sensing noted above, but also use of ICTs such as community radio to encourage replanting and more efficient use of wood burning for heating and cooking.[42] In many cases, these initiatives must be put in place alongside alternative sources of income and fuel for the community.
- Obtaining information and guidance on "climate-smart agriculture", which may include attempts to reduce methane and related emissions.[43]
- Journey substitution and other energy savings through use of dematerialised services such as e-government, e-commerce and e-health initiatives.
- Use of videoconferencing (including Skype) to substitute for journeys that require meetings with government or other officials.[44]
- Use of renewable energy sources such as solar chargers and panels to power ICT devices within the community.

2. Opportunities and Challenges in Developing Countries

As noted above, each individual developing country has a unique carbon emissions profile, and this will shape their particular "e-mitigation" priorities. However, there are some generalisations we can put forward.

Developing countries face an important opportunity as regards ICTs and mitigation: for technological "leapfrogging", whereby they can overleap emissions-intensive intermediate technology in favour of cleaner technologies.[45] Thus they would implement low-carbon strategies from the outset and avoid the legacy infrastructures and technology lock-ins that constrain available options in richer economies.[46]

Most of the mitigation applications outlined above also have a dual benefit for developing countries. Not only do they reduce carbon emissions – they also save money, typically energy costs – a significant attraction given the limitations on availability of capital.

However, such limitations are a reminder that the roll-out of green, smart and community ICT solutions faces a number of specific challenges in developing countries, which include:

- Lack of awareness of technological developments and their potential for more carbon- and energy-efficient solutions.[47] A challenge for many organisations and individuals is to take informed decisions on ICT adoption (or non-adoption), as they are not familiar with ICT options and the carbon-/cost-saving opportunities they offer.[48]
- 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.[49]
- High or uncertain costs of new technologies and no proven commercial viability for large-scale investments, in particular for smart grids and smart cities.[50]
- Limited or uncertain suitability of technologies for local conditions: there is a challenge of ensuring technology compatibility across countries or even within single organisations (e.g. with smart grids and smart logistics). To ensure compatibility and accelerate technology

adoption there is a need for technology and telecommunication providers and affected industries to collaborate and develop common operating standards.[51]

- Limited resources, capacity or technical and managerial skills to identify suitable technologies, adapt them for specific local application, and conduct installation and maintenance services.[52]
- Unpropitious regulatory and political circumstances such as market distortions and subsidies in favour of fossil fuels[53] on the one hand and lack of policies and incentives to encourage investment in green, smart and community ICT solutions on the other.[54]

3. Strategic Action Steps

Action steps for **international organisations**[55]:

1. ***Extend existing technology transfer and finance schemes*** under the United Nations Framework Convention on Climate Change to include broader deployment of ICT in developing and emerging economies. Cap-and-trade and offset mechanisms that result in the transfer of ICT technology to developing countries need to be further promoted and new mechanisms may need to be added to drive inclusive low-carbon growth by utilising the opportunities ICT could bring if technology were widely available and effective implementation viable.

2. ***Identify e-mitigation applications from existing ICTs***: mitigation is strongly associated with ICT innovation – and much-beloved of ICT firms and ICT engineers as a result. However, a critical success factor in a number of e-mitigation projects has been the use of existing ICTs, which are already in use within developing countries. International organisations can usefully map out the e-mitigation application opportunities from such technologies.

Actions steps for **governments in developing countries** include:

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

2. ***Raise awareness and build a knowledge base*** about the relevance of climate change mitigation to developing countries, and about the relevance of ICTs in delivering mitigation goals. At the same time, developing training initiatives to ***build capacity*** within government and other organisations for understanding and dealing with e-mitigation. Such capacity-building should include the capacity to conduct ICT-related assessments such as energy audits and e-environment readiness studies, which provide baseline carbon emissions and related data.

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

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

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

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

7. ***Incorporate a sector-based approach*** which focuses on key carbon-emitting sectors of the economy, and identifies what green, smart and community ICT applications have to offer for that sector, and what specific measures are required to spur innovation and adoption.

8. ***Develop multi-stakeholder partnerships*** that integrate across sectors – public, private and civil society – and that integrate across levels – local, national, global – in order to maximise the access to resources, the sharing of knowledge, and the potential for scalability and sustainability of initiatives.

Actions steps for **private firms** based in or trading with developing countries include:

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

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

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

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

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

6. ***Engage in policy advocacy*** at international and national levels to promote the regulatory and policy reforms needed for better investment opportunities and the removal of market barriers, and to encourage greater incorporation of ICTs within international climate change technology transfer schemes.

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