WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

INFORMATION TECHNOLOGIES & TELECOMMUNICATIONS INDUSTRY PARTNERSHIP

The Contribution of ICT to Climate Change Mitigation

Working Paper

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The widespread adoption of information and communications technologies (ICT) solutions in all parts of society in the last 25 years has led to tremendous productivity improvement while reducing energy consumption. The application of ICT solutions can enable a transformation towards a resource efficient and services-based society, and deliver CO_2 emissions reduction in particular in those sectors where the opportunities are largest: building, transport and manufacturing. The ICT sector holds great potential for mitigating climate change through the decoupling of economic growth from energy consumption. This has been shown in the past with the introduction of the PC, the Internet and mobile telecommunications.

From national and macro perspectives, as market- and policy-based approaches to reduce greenhouse gas (GHG) emissions are implemented, the market will demand new, innovative and large responses in the form of new technologies and social approaches. These responses will spur new markets, R&D and industries (whether energy management, bio-, geo- or behaviour-based) and serve as significant economic drivers for countries and innovation hubs throughout the 21st century.

> **"The ICT industry is responsible for approximately 2% of global CO_2 emissions. ICT solutions have the potential to be an enabler to reduce a significant part of the remaining 98% of total CO_2 emitted by non-ICT industries."**
>
> **Source:** Gartner/HP/McKinsey/WWF

Introduction

There is significant need for the ICT sector to collaborate with leading think tanks and NGOs on elucidating a clear message on the role of ICT in mitigating climate change. There remains no single, unified message that is being delivered to senior-most decision-makers from governments and in other industries.

This work will be of significant value to these decision-makers at a time when positive action needs to be taken and when winners in a low-carbon economy need to step forward.

The World Economic Forum is pleased to have partnered with so many respected institutions to synthesize the leading thinking on the role of ICT. The work is focused on the role of ICT in mitigating climate change as an enabler within many other sectors and industries, and is not primarily focused on the carbon footprint of the ICT industry. While the carbon footprint is not the focus of this work, it is obviously an important issue that also needs to be addressed, as any serious actor taking steps forward will have to "put its own house in order".

The following work represents the synthesis of feedback from a large number of institutions on the ICT contributions with the most impact on mitigating climate change. This impact may be measured in absolute terms (reduction in energy usage) in the short term and/or long term, or indirectly through strategic results (visible and symbolic impact on people's lives/corporations' behaviour supporting wider, positive behavioural change and improved regulatory frameworks).

Summary of Structure

Seven contributions of ICT to mitigating climate change are laid out in this paper and can be grouped into the following three logical categories:

1) **Infrastructure innovation**: This section addresses the area where many of the most significant and immediate impacts can be made on energy savings and reduction of GHGs[1]. This includes the large-scale physical environment consuming the most energy, which includes buildings, public utilities and infrastructure, and manufacturing. It also captures opportunities for innovation within the energy grid and efficiencies for energy distribution.

2) **Behavioural change and green enablement**: This section focuses on the need for global measurement and tracking of carbon reduction, as well as tools that affect positive behavioural change. This includes software tools for carbon impact measurement, and the use of innovative technologies and opportunities that reduce travel and transportation, such as those for virtual meetings, telecommuting and online services (e.g. eHealth, eTaxation and eBanking).

3) **Energy efficiency of ICT products and solutions**: This section covers energy efficiency of data centres, electronic devices and solutions. Even if ICT products themselves have only a marginal environmental impact, there is a great risk that the public will judge the whole sector as environmentally unfriendly if the sector does not address its own carbon footprint. First, this would impact ICT's credibility, making it difficult to deliver on the points above. Second, the rapid increase and penetration of ICT products can, if no action is taken, result in increased energy demand.

Project Overview

Problem Statement

While significant opportunity exists for ICT products and services to enable climate change mitigation, the opportunity is far from realizing its potential. With climate change now one of the top issues at the global, intergovernmental level, a unified, clear message on the role of ICT is urgently required. This message needs to be delivered outside the ICT sector. Otherwise, uninformed legislation and investment decisions would probably only focus on ICTs direct climate change impact and thereby limit both the overall positive impact of ICT, as well as reduce the total green technology market opportunity for the ICT sector.

A unified and clear message would allow the ICT sector to establish itself as a leading contributor that sees reduction of CO_2 as a driver for innovation and profit. It would also allow the sector to claim a leadership role as a winner in a low-carbon economy.

The status quo is determined by a number of factors:

1) **The contribution by the ICT sector has, until now, focused on the sector's own carbon footprint**. The approach of business, policy-makers, media and NGOs has contributed to this situation (as business has traditionally been seen as part of the problem, not the solution). This is now changing as the understanding of the ICT sector's potential role is slowly gaining acceptance.
2) **Industry messaging has largely been internally focused**. Many leading experts and organizations have spent significant time and resources in developing clear views on the role of ICT in climate change mitigation. These efforts have, in most cases, aimed at regional and ICT industry audiences.
3) **External messaging by the ICT sector remains fragmented as a whole**. The ICT industries have thus far focused on reducing their own footprint and are relatively new to the broader global debate on climate change. They have only recently shifted from internal problems to external opportunities, and are still optimizing their positions and perspectives, something the automotive and energy sectors have long ago achieved.
4) **ICT is still positioned only as a productivity enhancer, not as an energy efficiency driver**. ICT solutions are generally positioned in the market as enablers of productivity improvements and cost reductions (doing more with less). The link between productivity improvements and energy savings is new, and is a message that the ICT industry is not yet clearly quantifying and communicating.
5) **Policy-makers lack information on the potential contribution of ICT**. Largely as a result of the above, policy-makers and decision-makers outside the ICT sector are only slowly becoming aware of the potential contribution of ICT, and are currently more likely than not to create approaches that do not fully leverage this potential.

Question to Be Resolved

How can the ICT sector unify its messaging and create the first clear, global statement on the role of ICT in mitigating climate change – to better inform regulatory and investment decisions globally over the next five years?

Aims of This Work

The aims of this work are to:

1) **Formalize a clear set of statements on the contribution of ICT to climate change mitigation**.
   This will synthesize the best thinking by leading global ICT companies and independent experts on the role of ICT in climate change mitigation, and act as the unifying effort needed and asked for by the ICT sector.
2) **Provide the basis for a two-page executive summary for review and approval by CEOs and ICT ministers at the World Economic Forum Annual Meeting**. This will serve as a tool to gain agreement at the highest level of decision-making with the ICT industry globally.
3) **Elevate any ICT industry-wide consensus as a message to the highest decision-makers globally**.
   This will clarify the role of ICT within the broader context of climate change and sustainability initiatives, strengthen global dialogue and understanding, as well as promote more focused public policy action.

Collaborators

The role of the World Economic Forum is one of neutral orchestrator of collaboration. This work has been achieved in collaboration with the following organizations:

- **The IT & Telecoms Industry Partners of the World Economic Forum**: *Accenture, Akamai Technologies, Alcatel-Lucent, AMD, Amdocs, Applied Materials, AT&T, Autodesk, Avaya, BMC Software, BT, CA, China Mobile, Cisco, Deutsche Telecom, EMC, France Telecom, Freescale Semiconductor, Google, HCL, HP, HTC-VIA, Huawei, Infosys, Intel, Lenovo, Liberty Global, Microsoft Corporation, Motorola, Pitney Bowes, Qualcomm, Salesforce.com, SAP, SAS, Satyam, SK Telecom, Silver Lake, Telia Sonera, Telstra, Vimpelcom, Vodafone, Wipro and Fujitsu (non-partner)*
- **Expert organizations**: *American Electronics Association (AeA), Business for Social Responsibility (BSR), The Climate Group Gartner, Global e-Sustainability Initiative (GeSI), Information Technology Industry Council (ITIC), ITU and the World Wide Fund for Nature (WWF)*

Further intellectual content for this work comes from the synthesis of other work from:

- *ABB, Arup, BP, EMPA, European Network Operators (ETNO), European Commission, Forum for the Future, GE, IKEA, International Energy Agency (IEA), McKinsey & Co., Ministries of Commerce in China and India, Toyota, Pew Centre on Global Climate Change, United Nations Foundation, UNDP, United Nations Information and Communication Technologies Task Force, UNCTAD, United States Environmental Protection Agency, Vattenfall, Volvo and World Business Council on Sustainable Development (WBCSD)*

Audience

It is important to note that this document is written for ICT industry insiders. It assumes clear understanding of the scale and urgency of the climate change challenge, as well as the extent to which further enhancement and deployment of ICT and other advanced technologies can provide the foundation for the many new innovations that can set a trajectory for a low-carbon path to the future.

Definitions

The relevance of ICT to discussions on a low-carbon future is regarded as significant by many. It is important to clarify what this work is concerned with and what it is not:

1. **Focus on climate change, not broader environmental sustainability**
   The focus is on climate change, not the broader issue of environmental sustainability. The scope covers actions and contributions that reduce GHG emissions. While tackling many of the sources of GHG emissions also has implications for other environmental issues such as biodiversity, waste management and sustainable use of resources, this report only relates to those issues insofar as they are connected to climate change. It does, however, take into account economic sustainability, as it is built on the understanding that the ICT sector can be a winner in a low-carbon economy.
2. **The role of ICT as an enabler of a low-carbon future, not the ICT industry's efforts to reduce its own carbon footprint**
   The expansion of new devices and appliances in homes and businesses has increased energy consumption – and especially the use of electricity. Gartner estimates the ICT industry accounts for approximately 2% of global CO2 emissions, and this is expected to increase. On the other hand, the potential for ICT to address the other 98% is striking. Most studies have based their assumptions on business-as-usual scenarios developed by experts focusing on the supply side. While the potential is significant even under a business-as-usual scenario, it is a shift towards a low-carbon economy with focus on the demand side that will allow for ICT's truly important contribution (see studies by IPCC, EMPA, WWF, Booz Allen Hamilton, ACEEE, EuroACE and Vattenfall internal papers).

Next Steps

This document was approved in Davos, January 2008, by the IT and Telecoms Governors. Their subsequent mandate was for the World Economic Forum to clarify the economic rationale behind the adoption of greener technologies, This work will be completed over 2008

Summary of the Contributions of ICT to Mitigating Climate Change

Infrastructure Innovation

1. Increase energy efficiency of buildings/infrastructure through intelligent systems and design
2. Reduce the energy use of the manufacturing sector through intelligent systems, design and change of business models
3. Enable smarter management of energy supply and demand
4. Sustainable energy production

Behavioural Change and Green Enablement

5. Enable carbon accounting and the tracking of GHG emissions through the supply chain
6. Enable virtual meetings

Energy Efficiency of ICT Products and Solutions

7. Increase energy efficiency of data centres and electronic devices

Contribution 1:

Increase Energy Efficiency of Buildings/Infrastructure through Intelligent Systems and Design

Description

Rapid urbanization in emerging economies is set to increase the population of the world's cities by almost 2 billion over the next 25 years. In this context, there is significant demand on urban planners to maximize energy efficiency of buildings. Within the EU, buildings are responsible for 40% of GHG emissions. This is approximately 48% in the US. The majority of energy-inefficient features in buildings are designed into them. Two key areas of focus to generate greater energy efficiency in buildings are:

1) *Existing buildings*: Greater smart management of energy use through building energy management systems (BEMS). These schedule the operations of major equipment including chillers, boilers, packaged air conditioners, heat pumps and lights according to need, reducing unnecessary use and minimizing wear and tear on equipment. Features could include demand limiting, load shifting, advanced meters that record and communicate actual electricity use and then adjust electricity use based on time-of-day, on peak/off peak or other billing rates.
2) *New buildings*: Built-in energy supply and improved and ICT-enabled energy-efficient design in buildings, including greater use of efficiency principles in position and shape of the building as well as designing windows, lighting, shading and insulation. New buildings can also be linked and deliver integrated solutions where energy production and energy use are optimized.

Potential Impact

The potential carbon savings provided through the adoption of BEMS have been estimated to be as high as 20%.[2] When it comes to new buildings, it is possible to turn many from large energy consumers to net producers. With approximately 50% of CO_2 emissions coming from buildings, this might be the single biggest opportunity towards a low-carbon economy.[3]

Today's Situation

Data from the US Energy Information Administration illustrate that buildings are responsible for almost half (48%) of all energy consumption and GHG emissions annually; globally, the percentage is even greater. Of all power plant-generated electricity, 76% is used just to operate buildings.[4] Technology and knowledge exists to enable buildings to be zero-carbon or even net producers of electricity.[5]

To deliver significant reductions of GHG emissions it is important to start from the planning phase and include the surroundings in the equation.[6] Energy savings potential from water heating, cooling or hot water production can be up to 10%, which represents up to 7% of the total energy consumption of the domestic residential and commercial sectors.[7]

Office buildings and hotels have begun integrating sensors and wireless technology to monitor and control lighting and electronics in unoccupied hotel rooms and offices. For example, after learning that hotel rooms were left unoccupied for an average of 11.5 hours per day, some hotels began installing small infrared sensors to detect when no one is in the room. After 30 minutes, the temperature is automatically reduced by three degrees; these technologies have saved as much as 37% of hotel heating costs.[8]

Heating Examples[9]

- Temperature control: protection against freezing or frost protection generally involves running heating system pumps and boilers when external temperature reaches a set level (0°C)
- Compensated systems: control flow temperature in the heating circuit relative to external temperature. This raises the circuit flow temperature when the outside temperature drops
- Thermostatic radiator valves: sense space temperature in a room and throttle the flow accordingly through the radiator or convector to which they are fitted

- Proportional control: involves switching equipment on and off automatically to regulate output
- Other methods can include thermostats, occupancy sensing passive infrared sensors (PIRs) and manual user controls

Lighting Examples[10]

Different control systems exist, enabling time- and parameter-based control (where a level of luminance or particular use of lighting is required). Energy savings can be up to 75% of the original circuit load, which represents 5% of the total energy consumption of residential and commercial sectors. Examples include:

- Zones: lights are switched on corresponding to the use and layout of lighted areas, to avoid lighting a large area if only a small part needs it
- Time control: to automatically switch lights on and off in each zone on a preset schedule
- Passive infrared (PIR) occupancy sensing: in areas that are occupied intermittently, sensors can be used to indicate whether or not anyone is present and switch the lights on or off accordingly
- Light level monitoring: this consists of switching or dimming artificial lighting to maintain a light level measured by a photocell

Role of Government

1) Develop and implement policy measures, such as financial incentives, efficiency-related tax legislation, low interest loans, or performance standards (e.g. California's Building Standards Title 24) to mobilize efforts to increase energy efficiency in buildings (home and office)
2) Encourage manufacturers and suppliers of equipment and services to make their products visibly display information about their real-time environmental behaviour[11]
3) Ensure that sustainable solutions are developed with the global need in mind and support technology transfer and technology exchange between nations
4) Support innovative solutions that allow buildings to become net supporters
5) Launch global competitions where cities compete to become the first zero-carbon city on the planet
6) Support information sharing that allows entrepreneurs to engage in sustainable building solutions[12]
7) Adopt greater design efficiency measures in all public buildings, including increased focus on energy-efficient public procurement decisions (e.g. fixtures and fittings)

ICT Industry Next Steps

1) BEMS: design easy to install systems that optimize energy usage; partner with building developers to ensure the longer-term financial benefits of these systems
2) Efficient design: building design (software) tools incorporating energy efficiency (e.g. LEED) at design stage
3) Support integrated building solutions with focus on the demand side
4) Develop solutions that allow commercial and residential buildings to become net producers of electricity
5) Develop solutions that allow trading between buildings and cities
6) Use expansion of offices, server parks and suppliers to develop new innovative solutions that can be integrated into new business opportunities
7) Develop standards and benchmarks allowing for easy comparison of energy-efficient data centres
8) Collaborate more closely with decision-makers involved in urban planning to ensure greater awareness and optimal use of technology solutions
9) Develop voluntary, open standards to allow interoperability of end devices and management controls

Contribution 2:

Reduce the Energy Use of the Manufacturing Sector through Intelligent Systems, Design and Change of Business Models

Description

Carbon dioxide emissions from industrial energy use have been rising as a consequence of increasing product demand and appear to be on a growing pathway. However, this trend can be reversed through energy efficiency measures. Contrary to common belief, industry is not always efficient in its energy use.[13]

ICT can provide more and better information as well as tools to design teams and product managers to improve the energy impact of products. It can also support a shift in business models where companies can, for example, dematerialize their services (such as in the entertainment industry) or move from product to service.[14]

1) Enabling easier design of products with lower energy requirements, reduced emissions, improved recyclability/reuse, longer life, lower maintenance or support needs
2) Enabling "dematerialization" of any products or services that may be delivered virtually, especially those with high "embedded energy". Dematerialization refers to the absolute or relative reduction in the quantity of materials required to serve economic functions
3) Product life cycle management (PLM); manufacturing process controls (MPC) – integrated measurement devices linked to intelligent control systems and process automation to improve plant energy efficiency while boosting productivity by increasing throughput, yield and product quality
4) Sensors and controls to significantly improve energy efficiency, providing significant reductions in total energy consumption
5) ICT support for decentralized, on-demand production systems
6) Development of systems that can help companies move from a product to a service approach

Potential Impact

A new study by the IEA, *Tracking Industrial Energy Efficiency and CO_2 Emissions*, suggests a technical efficiency improvement potential of 18-26% for the manufacturing industry worldwide if best available technology were applied. These savings would equal 5-7% of total energy use and reduce CO_2 emissions by 8-12% worldwide. These are conservative estimates based on proven technology.[15]

Today's Situation

Globally, approximately 36% of all CO_2 emissions are from manufacturing, 40% from buildings and appliances, and 24% from transport. Approximately half of the transport sector emissions are from freight haulage. On a global scale, manufacturing is buoyed by GDP growth that is concentrated in emerging economies, notably China, where the rising middle classes are just starting to buy automobiles and increasing their consumption of manufactured items commonly found in the developed world. Last year, China's automobile production overtook that of Germany. Over the last 25 years, China has accounted for four-fifths of the growth in industrial energy use and CO_2 emissions. Today, China accounts for more than half of world cement production and is the largest producer of key energy intensive commodities, such as aluminium, ammonia and steel.[16]

With few energy efficiency programmes in this sector aside from notable individual approaches, there is significant room for improvement.

Role of Government

1) Support and fund energy (and carbon) labelling on manufactured products and reward lower impact products. Adopt complementary approaches to incentivize rapid adoption of superior solutions
2) Sponsor R&D into building energy toolsets and simulations of product life cycle management tools
3) Use public procurement to support innovation and energy efficiency measures by including CO_2 footprint and energy use over the life cycle in procurement criteria for manufactured goods. It is important that these criteria also include the positive contribution of products such as meters, servers and videoconference equipment on energy usage behaviour
4) Review the taxation system to promote dematerialization and a shift from product to service where this is delivering a reduction of GHG emissions

ICT Industry Next Steps

1) Demonstrate existing, and invest in new, product life cycle management tool (PLM) functionality that enables enterprises to analyse, simulate, model and design lower energy products (throughout the life cycle) and products (and packaging) with lower environmental impact
2) Continue focus on enabling "dematerialization" of any products or services that may be delivered virtually, especially those with high "embedded energy"
3) Continue development and application of MPCs and other ICT-based manufacturing technologies, such as automated, self-correcting production systems (smart sensors and machine-to-machine communications)
4) Develop communication systems between all required devices that incorporate technical capability to adapt to a renewable energy resource (such as photovoltaics or wind resources)
5) See Contribution 3: ICT to provide information on energy consumption and saving
6) Support the development of software that enables measurement of GHG emissions for procurement purposes
7) Collaborate more closely with decision-makers in the manufacturing supply chain to ensure greater awareness and optimal use of technology solutions

Contribution 3:
Enable Smarter Management of Energy Supply and Demand

Description

Many of today's energy systems were built during a time when oversupply was the only way to ensure that enough power was available. Years of underinvestment in the electric grids of many nations have resulted in aged, inefficient and environmentally wasteful energy systems. In the US, for example, the result is a very inefficient electricity generation and distribution system that converts only one-third of the total energy it consumes into useful electricity.[17]

Recognizing these inefficiencies, the energy community is starting to marry information technology with renewable energy to significantly improve how electric power is generated, delivered and consumed. Technology allows the electric grid to be become "smart". Near real-time information allows utilities to manage the entire electricity grid as an integrated system – actively sensing and responding to changes in power demand, supply, costs and emissions across various locations and devices. Similarly, better information allows consumers to manage their energy use to best meet their needs. "Just as a robust information economy was triggered by the introduction of the Internet, a dynamic new renewable energy economy can be stimulated by the development of an electranet or *Smart Grid*," noted Nobel Peace Prize-winner Al Gore.[18]

The main principles include:

1) **Demand Management**: Reducing electricity consumption in homes, offices and factories
Demand response: Alerting consumers during periods of peak usage to reduce consumption[19]
Smart meters and variable pricing: Replacement of traditional meters with "smart" meters that charge variable rates based upon demand[20]
Smart buildings with smart appliances: Use of IT systems to coordinate energy consumption by key appliances (heating, ventilation, air, etc.)[21]
Energy dashboards: Online energy dashboards offering real-time visibility into individuals' energy consumption, while offering suggestions on how to reduce consumption[22]

2) **Distributed Energy Generation**: Encouraging home and business-owners to install their own renewable sources of energy
Micro-generation: Cost-effective production of electricity locally using small renewable devices designed for home or office, such as wind generators, photovoltaics and solar thermal, as well as non-renewable devices, such as natural gas generators with heat reclamation. Micro-generation technologies are becoming affordable for residential, commercial and industrial customers.[23]
Storage and hybrid electric vehicles: Plug-in hybrid vehicles offering the ability to buy energy when it is inexpensive, store it in their batteries and sell it back to the grid when the price goes up. Drivers see these vehicles as a viable means to arbitrage the cost of power, while some utilities may envision fleets of these vehicles supplying power to reduce peaks in electricity demand.

3) **Supply-side Efficiency**: Utility companies use information technology to provide near real-time monitoring and control of the electric grid. These solutions prolong the useful life of the existing grid, delaying major investments to replace its infrastructure.
Grid monitoring and control: Power outages are very expensive, but some can be avoided if proper action is taken immediately to isolate the fault. Utilities are installing sensors to monitor and control the grid in near real-time (milliseconds or nanoseconds) to detect faults early to provide time to respond. These systems are increasingly being automated into utility's existing SCADA control systems.

Potential Impact

A technology-enabled electric grid will be more efficient, reduce GHG emissions and improve power reliability. The potential environmental and economic benefits of smart grid are significant.[24] Specifically, smarter electricity grids would:

- Reduce peaks in power usage by automatically turning down appliances in homes and offices
- Reduce waste by providing instant feedback on how much energy is being consumed

- Encourage home and business owners to install their own renewable sources of energy
- Encourage manufacturers to produce "smart" appliances to reduce energy use
- Sense and prevent power blackouts before they occur

Enhancing the role of technology to make electricity grids "smart" could help offset some of the expected increases in $C0_2$ emissions in three ways:

1. **Reduce growth in demand for electricity**

   Electricity consumers
   - Inform consumers and enable them to better monitor their own energy consumption to be more efficient and promote energy efficiency
   - Provide more accurate and timely information to consumers on electricity variable pricing signals, allowing them to invest in load shedding and load shifting solutions
   - Provide more accurate information to consumers on electricity variable pricing signals, allowing them to dynamically shift among several competing energy providers based on price, GHG or social goals

   Power utility companies and regulators
   - Broadcast demand response alerts to reduce peak energy demand and need to start up dirty, inefficient reserve generators
   - Provide remote energy-management services and energy control operations to advise consumers and remotely reach into their homes to reduce their energy usage
   - Enable utilities to increase their focus on creating "save-a-watts" instead of only producing kilowatts. That is, offsetting a watt of demand through energy efficiency measures is more cost effective than generating an extra watt of electricity. In fact, some utilities believe they can earn more profit by selling "save-a-watts" instead of kilowatts[25]

   Equipment manufacturers
   - Provide incentives to building control systems companies to standardize data communications protocols across building systems – eliminating proprietary and non-standard protocols that inhibit integration and management
   - Provide incentives to manufacturers to produce goods (air conditioners, freezers, washer/dryers) that better monitor and manage their power usage and that are able to communicate and coordinate among themselves. For example, a refrigerator and air conditioner compressor could "talk among themselves" to ensure they don't start up at same time, thus reducing peak electricity demand
   - Enable and encourage electrical equipment manufacturers to build energy efficiency, management and data integration capabilities and interfaces into their equipment

   Building architects and owners
   - Accelerate construction of new buildings that are built with an integrated approach, incorporating smart, connected building communication technologies to manage and synchronize operations of appliances, turn off lighting in rooms not in use, turn on reserve generation when price effective and manage overall energy use

2. **Accelerate adoption of renewable sources of electricity generation**
   - Provide local energy grid infrastructure that accepts distributed power production, and thus accelerates the growth of opportunities for micro-generation
   - See Contribution 4 for more details on the contribution of ICT companies here

3. **Delay construction of new electricity generating and transmission infrastructure**
   - It is estimated that the cost to renew the world's ageing transmission and distribution grid will exceed US$ 6 trillion over next 25 years.[26] Utility companies that implement electronic monitoring and management technologies will prolong the useful life of the electric grid and delay this investment. This delay could reduce new construction and installation costs for the grid and accompanying carbon emissions

Today's Situation

Practically speaking, most of the technologies required to create smarter electric grids are already available today.

Forward-looking utilities are already offering demand-response technologies to customers. Such technologies detect the need for load shedding, communicate the demand to participating users, automate load shedding, and verify compliance with demand-response programmes.

Many utilities are implementing large numbers of smart electric meters to offer variable pricing to consumers and to reduce manual meter reading costs[27]. However, several competing communication protocols[28] are still vying to become the standard to which all building devices can intercommunicate. Delay in agreeing a common industry standard has delayed the vision of having every electric device connected and has spawned several middleware and gateway companies. As expected, many manufacturers of white goods are making appliances that can connect to the building network.

Many public and private organizations have implemented energy consumption dashboards. Typically, these are custom designed internally or provided by small software integrators.[29]

IT systems integration is provided by several large technology firms. A host of other technology companies provides network communications required to make the smart grid smart.

Role of Government

While the technologies for smart grid solutions are mainly available today, the real challenge to accelerating adoption stems from the various industries that need to work together to create a viable, integrated system. For example, smart grids require utility companies to work with technology companies, and building owners to work with energy technology companies. Bringing together their various perspectives to design and build complex systems often proves challenging.

Given this complexity, the role of government is to create the working organizations and policies to provide incentives to open partnerships. Five of the most important steps for government to accelerate smart grids would be:

1) Financial incentives to drive smart grid adoption. This includes electric regulatory policy that decouples utility sales from profits and protects utilities from high initial investment costs. California, for example, has led regulation to encourage utilities to help consumers reduce the amount of electricity they consume by basing utility profits on energy savings, not on electricity sold or generating capacity.
2) Quickly develop critical communication standards. The connected building industry, in particular, has been battling among several standards for the past 10 years.
3) Encourage utilities to offer variable time-based pricing for electricity tariffs to their customers.
4) Allow increased competition among utilities, giving consumers the ability to choose among several energy providers using the smart meter to purchase electricity from the most efficient provider.

ICT Industry Next Steps

The ICT sector can help accelerate the smart grid in the following ways:

1) *Partnering for systems integration*: From an ICT perspective, building the smart grid is a fairly straightforward technical challenge – most of the core technologies already exist and have been proven However, the real challenge in smart grid is integrating the various technologies together into a single, working solution – it is a significant systems integration challenge to tie various devices, constituencies and telecommunication protocols together to operate in a seamless manner. No single company has all the capabilities to implement smart grids; rather, each industry brings a piece of the solution. The challenge, especially for ICT companies, is to build the alliances and partnerships needed to ensure their technology fits into the larger cross-industry ecosystem that will become the smart grid.
2) *Increase risk taking*: In a recent discussion with technology companies, James E. Rogers, Chairman, President and Chief Executive Officer, Duke Energy Corporation, USA, said that, because smart grid ideas are evolving so quickly, technology companies need to become more comfortable taking risks and applying their technologies to new applications. Rather than wait for the perfect IT solution or comprehensive standard to be developed, companies need to rapidly get their solutions into the marketplace to be tested and vetted.[30]
3) *Companies make markets – markets don't make companies*: Technology companies need to make a return on their investments. Large, successful, established companies often pursue a "fast follower" strategy, waiting for the market to be proven and large numbers of customers to be identified. This often makes sense before investing significant R&D resources; however, the smart grid may evolve in a way that makes the fast follower strategy suboptimal. The core technology and communications standards that will enable a widespread smart grid are currently being established. Once open protocols are established, they will be built into a capital infrastructure (power plants, substations, buildings and power lines) that have a useful life of 20+ years.

Contribution 4:
Sustainable Energy Production

Description

According to the International Energy Administration's (IEA) World Energy Outlook 2007, the world's primary energy needs are projected to grow by 55% between 2005 and 2030 at an average annual rate of 1.8%.[31]

This rising global energy demand poses real and growing threats not only to the world's energy security, but also to strategies to limit rising CO_2 and other GHG emissions and mitigate climate change. To meet this growing demand, an estimated US$ 22 trillion of investment in supply infrastructure is required. The ICT sector can impact most directly the electricity generating sector, which the IEA projects to double in usage by 2030, rising to 22% of total energy consumption (up from its current 17% level). The ICT sector can make more modest contributions to other areas as well.

ICT solutions are:
1) *Electricity generation*: In addition to ICT's contribution to better grid management (see Contribution on Energy Supply and Demand), ICT companies are increasingly entering the alternative energy production sector, bringing R&D capital, technical skills and production economies of silicon to this potential market.
2) *Transport*: Using materials, battery technology and other ICT-derived innovations, hybrid vehicles can contribute to limiting the growth in demand of oil for transportation.

Potential Impact

- Reduction of need for fossil fuels, with attendant benefits to both energy security and climate change mitigation
- Creation of potential for economic development from distributed power generation (analogy to countries bypassing landlines and installing wireless telephony to bring modern communications capabilities – and the resulting economic opportunities – to regions previously excluded)
- Home and building owners invest in high efficient and low emissions micro-generation technologies to supply some of their own energy needs and offset the peak demand on the electric grid – to offset the need for new large-scale power plants
- Creation of virtual power plants that include distributed power production and energy efficiency measures
- Acceleration of the introduction of plug-in hybrid vehicles to act as temporary electricity storage, as well as provide incremental energy generation to offset peak demand on the grid

Today's Situation

The IEA estimates that the bulk (84%) of the world's growing energy appetite until 2030 will be met by fossil fuels. Despite its great promise, non-hydro renewable electricity today supplies less than 5% of global electricity and its share is dropping as new coal-fired generating capacity is being developed worldwide. The major reason for this situation is the cost of renewable electricity – with photovoltaic-generated electricity, for example, roughly five times the cost of coal-fired power, geothermal about two to three times more expensive, and wind at least 50% more.

Alternative energy solutions offer a game-changing scenario if the price can be reduced. This is only possible through greater investment and the construction of a proper policy framework. Today, alternative energy production is a checkerboard of policy initiatives that often hinder as much as help.

Role of Government

1) Create supportive policy frameworks to encourage adoption of sustainable energy production systems and remove artificial barriers to integration into existing energy networks and grids; governments should agree on realistic cost/pricing structures and factor in externalities when comparing all types of energy production systems (fossil fuels, nuclear, solar, wind, etc.)
2) Provide long-term incentives for sustainable energy production that will decline as technologies mature and become commercially viable
3) Accelerate investment and research into new materials, technologies and infrastructure improvements for increased and more efficient sustainable energy production

ICT Industry Next Steps

1) Develop technology that can lower the cost of critical renewable electricity sources, e.g. advanced semiconductors for photovoltaics and improved generators and inverters for wind turbines
2) Advance "smart grid" technology that can enable more significant penetration of renewable electricity – both central station and distributed generation – into the electricity grid without destabilizing effects
3) Be a test bed for new renewable technologies through demonstration projects and power purchase agreements to meet facility electricity needs

Contribution 5:

Enable Carbon Accounting and the Tracking of GHG Emissions through the Supply Chain

Description

Provide systems to measure and report GHG emissions and track these through the supply chain down to the individual product's use. This includes accounting on the carbon footprint of:

- An organization's operations
- A product (from production through to distribution at point of sale)

This includes software tools, reporting standards and enhanced public awareness of the relative carbon efficiency of products.

Potential Impact

Consistent calculation and visibility of carbon impact would give investors, management teams, buyers and consumers the ability to make more informed choices about activities, processes, products and services. This would allow investors to set benchmark targets, government to drive informed public procurement, and customers to choose lower carbon lifestyles. For example:

- Greater consumer information on the carbon footprint of foods would reduce the climate impact of dietary choices. Cattle-rearing generates more GHG, as measured in CO_2 equivalent, than transportation.[32] The indirect effect of enhancing consumer awareness is even more important with its broader impact on behaviour and markets in general
- The impact on manufactured product purchases is described in Contribution 4

Today's Situation

CO_2 footprints are mostly invisible to investors, management teams, buyers and consumers. While there has been some progress in the development of carbon accounting protocols, there are no consistently applied standards and systems for tracking and reporting carbon footprints. Software tools are appearing on the market, however, the lack of agreement on measurement and reporting standards is slowing progress. Further research is needed on what specifically must be measured, and how differences between consumption by individuals and industries can be recognized.

Role of Government

1) Working with existing bodies such as the World Resources Institute, World Business Council for Sustainable Development, Climate Disclosure Standards Board and Global Reporting Initiative (GRI) to establish appropriate guidance and regulation on measuring, tracking, reporting and accounting for GHG emissions at an enterprise and eventually at a product and service level
2) Support initiatives that make the CO_2 emissions visible throughout the supply chain
3) Fund greater research into what the scope of carbon accounting might be and into technologies that can help track GHG emissions
4) Introduce the need for carbon impact reporting for publicly procured goods and services

ICT Industry Next Steps

1) Collaborate with governments and NGOs (World Business Council for Sustainable Development, Carbon Disclosure Standards Board, GRI and Carbon Disclosure Standards Board) on creating widely acceptable and implementable standards
2) Provide business with easy-to-use measurement and reporting systems that comply with existing GHG protocols and new standards
    - Create (software) tools for measuring and converting CO_2 emissions using the GHG protocol, to allow for reporting, tracking and managing of emissions (i.e. user-friendly tools such as "Quicken" for CO_2 measurement and management)
    - Automate the CO_2 accounting rules and processes as per financial reporting and accounting (i.e. more powerful software such as "TurboTax" for CO_2 financial report)
    - Support development of software that makes it possible to distinguish between high-carbon and low-carbon services as well as the shift from using a product to using a service
    - Collaborate with sectors that are interested in helping customers choose low-carbon services, e.g. retail, transportation, restaurant and energy sectors.
3) Champion better carbon accounting and reporting, raising the importance of this issue with all stakeholders

Contribution 6:
Enable Virtual Meetings

Description

Travel Substitution: remote collaboration and telecommuting (home to office, inter-office travels); use of ICT to enable and encourage remote collaborations as a substitute for some travel activities. In many cases, the value of these virtual meetings far exceeds what would be possible without ICT. For example, the latest reports of the Intergovernmental Panel on Climate Change were the work of 450 lead authors, 800 contributing authors and 2,500 scientific expert reviewers from 130 countries – an undertaking impossible to imagine without the collaboration and communication tools provided by the ICT sector.

Potential Impact

- Reduction in the number of total kilometres travelled
- Reduction in traffic congestion (and therefore time spent idling in traffic)
- Reduction in the amount of building-related energy used by reducing the amount of office space required to house employees
- A study completed by the European Telecommunications Network Operators Association (ETNO) and the World Wildlife Fund (WWF) concluded that, if 20% of business travel in the EU were replaced by non-travel means through audio-conferencing, videoconferencing or telepresence, by 2010 around 25 million tonnes of CO_2 might be saved annually. That same study also noted that if just 10% of EU employees became telecommuters or flexitime workers, another 22 million tonnes of CO_2 might be saved annually.[33]

Today's Situation

While some organizations have embraced distributed working models, there are still significant barriers preventing widespread adoption. Greater effort is required to maximize the social and environmental benefits of telework and, where possible, increase productivity.

Role of Government

1) Use incentives to encourage the use of remote collaboration technologies. Adjust tax schemes that encourage travel (deductions on travel costs, company car allowances) to reward and encourage travel displacement
2) Encourage video-capable broadband deployments to all areas, especially emerging markets where the infrastructure is being shaped
3) Favourable tax treatment for investments in conferencing technologies for companies that agree to use them to displace travel
4) Encourage the public sector to adopt telepresence and similar technologies to reduce the need for work-based travel, and lead the way in allowing staff to work from home
5) Use virtual meetings at high-level conferences and meetings when possible to set an example
6) Fund research into cultural, management and behavioural issues, resistance and barriers that get in the way of, or reduce, the efficacy of remote working
7) Continue to promote and deploy broadband infrastructure to better enable technologies that enable virtual meetings and collaboration technologies

ICT Industry Next Steps

The potential to save energy and reduce traffic congestion will only be realized when employees can work flexibly.
1) Introduce and encourage flexible working models, such as flexible hours and work from home options to employees
2) Encourage greater understanding by managers of the benefits of distributed working practices
3) Enable and enhance mobile working environments through interoperability of devices over networks
4) Collaborate in creating cross-industry value with key stakeholders such as travel agencies, airlines, airports, hotels and event organizers
5) Enhance general awareness of key decision-makers by demonstrating virtual meeting tools at key events such as climate meetings, the World Economic Forum Annual Meeting, WTO meetings
6) Increase investment in making technology attractive as an alternative to individual travel: publicize best practices in getting people to use the technology; improve ease of use and address privacy issues; reduce infrastructure resources needed to deploy VoIP and video
7) Improve the efficiency and effectiveness of citizen-centric services

Contribution 7:

Increase Energy Efficiency of Data Centre Technologies and Electronic Devices

Description

The ICT industry has for a long time been focused on delivering productivity enhancements in and through its products and solutions. Energy efficiency has only recently become a critical issue. There continue to be improvements to individual devices; however, it is important to note that individual parts of a total solution may actually increase in energy intensity as they combine to produce more value (e.g. one device doing the job of two). As such, two important areas of focus exist: increasing the energy efficiency of the products and services offered by ICT companies; and progress in educating society on the economic and environmental value that ICT solutions such as data centres provide. Thus, energy efficiency of any device providing a stated value (perhaps measured in bits per watt) should be reduced.

Potential Impact

- Prove commitment to providing leadership on climate change mitigation by investing time and resources to improve the energy efficiency of the ICT sector's own products and services
- Increase of thought leadership and commitment to GHG reduction by the ICT industry through investment in time and resources to increase electrical efficiency
- Improved distribution of technology resources by other industries and government through increased awareness of efficient data centre technologies and efficient practices

Today's Situation

The use of electronic devices from mobile phones to laptops is exploding globally. This is a function of many new users in emerging and developing economies, as well as an increase in the number of devices. Parallel to this rise is the increase in use of the Internet and, thus, data centres by businesses and governments. The increasing demands made by society to provide greater productivity of ICT devices and data centres naturally lead to rising energy cost of these tools (for example, the growing demand in video and voice communications via the Internet). Individual companies are doing much to increase the overall energy efficiency of individual devices; however, the greatest impact will be achieved through greater ICT sector collaboration to ensure that the total energy cost of connected systems is reduced.

Commercial use of energy management systems is increasing and is expected to significantly increase in the next few years. It is important that these are increasingly installed. In addition to optimizing device and system energy efficiency in this way, human processes provide an important additional improvement in energy efficiency. Increasing implementation of best practices will continue to be an important factor. Significant progress is being made on the development of standardized metrics for data centres and the energy efficiency of electronic devices; however, it is important to note that this progress must be intensified if the ICT sector is to adopt a leadership role in climate change mitigation. Even if ICT products themselves have only a marginal environmental impact (when compared to overall statistics), there is a great risk that the public will judge the whole sector as environmentally unfriendly if the sector does not address its overall carbon footprint. First, this would impact ICT's credibility, making it difficult to deliver on the points above. Second, the rapid increase and penetration of ICT products may, if no action is taken, result in increased energy demand.

Role of Government

1) Collaborate with industry to develop measurement and efficiency metrics
2) Collaborate with industry on promoting efficient technologies, applications and practices, particularly in power provisioning, computing and cooling resources of data centres
3) Encourage industry partnerships to address vendor-neutral solutions to enhance data centre productivity
4) Collaborate with industry to define future objectives for data centre optimization
5) Facilitate regulatory changes in deprecation allowance to provide an incentive to remove

inefficient legacy equipment and install new energy-efficient equipment
6) Identify and promote best regulatory standards globally to increase device efficiency, such as US Energy Star
7) Stimulate greater research and development in electrical efficiency

ICT Industry's Next Steps

1) Define and promote the value of a holistic approach, rather than component-level efficiency, to improving the efficiency of data centres
2) Lead development of reporting efforts on environmental impact of data centres
3) Continue to create new products and services to enhance energy efficiency, and share those improvements with a broader audience
4) Collaborate with data centre users to develop efficiency models best practices, such as virtualization, and develop other ICT management applications
5) Join industry partnerships (e.g. the Climate Savers Computing Initiative) aimed at increasing the use of energy-efficient PCs, servers, components and software

Endnotes

1 Furthermore:
- International Energy Agency (IEA) estimates the world economy will need to invest US$ 20 trillion (in 2005 dollars) between now and 2030 to maintain current energy-related infrastructure as well as build new supply facilities to meet growing energy demands.
- McKinsey Global Institute suggests that the right set of investments in the development and application of new technologies could increase energy productivity by 25% or more over standard projections during the next two decades. In addition to reducing energy use and CO_2 emissions, the estimated productivity gains would generate a 10% or better net positive return on investment.
- Vattenfall, the Swedish electric utility, suggests that cost-effective efficiency investments could reduce overall GHG emissions by 25%.
- The United Nations Foundation now refers to energy efficiency as "the resource of first choice" and called on the G8 to double the historical rate of energy efficiency improvements by 2012 through 2030.

2 Paul Ashford, Caleb Management Services, *Assessment of Potential for the Saving of Carbon Dioxide Emissions in European Building Stock*, Prepared for EUROACE – Building Energy Efficiency Alliance, 1998.

3 Many different projects exists and many construction companies and architects have initiatives:
- http://www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=2&CategoryID=58, http://www.zerocarbonhouse.com/,
- http://www.arup.com/europe/newsitem.cfm?pageid=10639,
- http://uk.ihs.com/news/earthships-building-zero-carbon-future-for-homes.htm,

4 http://www.architecture2030.org/current_situation/building_sector.html

5 http://www.zerocarbonhouse.com/

6 http://www.architect-vzy.au.com/Free/climate.htm

7 http://www.businessballs.com/intelligentbuildingsdesign.htm

8 AeA Report "Advanced Electronics and Information Technologies: The Innovation-Led Climate Change Solution", September 2007, P. 13

9 http://www.businessballs.com/intelligentbuildingsdesign.htm

10 http://www.businessballs.com/intelligentbuildingsdesign.htm

11 http://www.fatspaniel.com/

12 http://www.sf.solarmap.org/

13 http://environmentalresearchweb.org/cws/article/opinion/30580

14 For example white ware producers transitioning from selling washing machines and fridges to providing clean clothing and cold food services.

15 http://environmentalresearchweb.org/cws/article/opinion/30580

16 http://environmentalresearchweb.org/cws/article/opinion/30580

17 In more detail:
- That equates to 1,500 teragrams of CO2 emissions wasted during the production and delivery of electricity in the US each year (Environmental Protection Agency, Inventory of US Greenhouse Gas Emissions & Sinks, 1990 to 2005, Page 45. "in 2005, the electricity generation in US resulted in 2,381 Tg of CO2 equivalent" (a Tg = teragram = 1012) http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf
- Energy Information Administration, US Dept. of Energy, Annual Energy Review, 2006, Page 221 (Page 2 of Section 8) "41 quadrillion BTU's of raw energy are consumed to generate 13 quadrillion BTU's of usable electricity" http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8.pdf
- In fact, most of the existing infrastructure (wires, transformers, substations and switches) that make up the US electric grid have been in use 25 years or more (National Electric Delivery Technologies Roadmap, US Dept. of Energy, Office of Electric Transmission & Distribution, Jan 2004, Page 5).

18 Al Gore speech at NYU Law School, Sept. 2006, http://thinkprogress.org/gore-nyu

19 During emergency periods of peak energy usage, utility companies could send electronic messages to alert consumers to reduce their energy consumption by turning off or down non-essential appliances. Often, alert signals automatically pass directly to the end-appliance, eliminating the consumer's need for manual intervention. If enough consumers comply, the utilities may not need to start up a reserve generator (which is typically inefficient with high CO_2 emissions). In return, consumers may receive cash payments above and beyond their energy savings.

20 In many areas, electricity pricing is dynamic, rising and falling based on the demand at that moment. Utilities are replacing traditional mechanical electric meters outside buildings with "smart meters" that charge the variable rate based on the time the electricity is used. Consumers respond accordingly, shifting their energy consumption from high price times (days) to low price times (nights), called *load shifting*, or by turning off appliances altogether, called *load shedding*. This reduces consumer costs while reducing peak demand on utilities.

21 Buildings are becoming smarter in their ability to reduce energy usage. Traditional standalone, complex systems that manage the various appliances (heating, ventilation, air conditioning, lighting, etc.) are now converging onto a common IT infrastructure that allows these devices to "talk" to each other, coordinating their actions and reducing waste. For example, a manager of 500 commercial buildings was able to reduce energy consumption nearly 20% simply by ensuring heaters and air conditioners were not running simultaneously (State of Missouri, Dave Mosby, Director of Facilities, December 2007). Individual appliances will include passive displays and single pixel interfaces, such as the ambient orb, which exploit pre-attentive processing to display subtle hints to consumers.

22 Recent university studies have found that simple dashboards can encourage occupants to reduce building energy usage by up to 30% (2005 Dormitory Energy Competition at Oberlin College, Cleveland, OH. "On average, dorms reduced electricity use by 32% during the competition. The two dorms with real-time feedback won with 56% reductions in electricity") http://www.oberlin.edu/dormenergy/news.htm

23 Analysis by Dept of Energy NREL found that many micro-generation technologies cost about the same per KwH as the local power company while producing less GHG. Furthermore, using new ICT solutions the smart grid allows consumers to sell back any surplus energy for a profit, reducing investment cost and accelerating adoption. These

distributed technologies can help consumers to become an "active part of the grid'" rather than "go off the grid", and may integrate with, not replace centralized generation.

24 A recent PNNL study provided homeowners smart grid technologies to monitor and adjust the energy consumption in their homes. The average household in the US reduced their annual electric bill by 10%. This could reduce peak loads on utility grids up to 15% annually, avoiding need to build 30 large coal-fired power plant over next 20 years in the US alone. This could save US$ 70 billion in capital expenditures (CAPEX) on new plant investments, and take the equivalent of 30 million autos off the road (Department of Energy putting power in the hands of consumers through technology, Pacific Northwest National Laboratory, Jan. 2008), http://www.pnl.gov/topstory.asp?id=285

25 Jim Rogers, CEO of Duke Energy, briefing to Gridwise Alliance meeting, Charlotte, NC, Dec. 2007

26 World Energy Outlook, 2006

27 In more detail:

- European utilities, in particular, are leading in implementing this technology. For example, ENEL the Italian utility has already installed 33 million smart meters at a cost of 2 billion euros. Total power consumption from households has decreased 5% since installing smart meters, and ENEL is saving 500 million euros annually on reduced operational costs (Website Low Carbon Life http://www.lowcarbonlife.net/default.asp?page=79).
- In 2006, California approved a PG&E plan to roll out smart meters to 9 million residents in northern California over five years (Website Wikipedia http://en.wikipedia.org/wiki/Smart_meter).
- The major building automation companies, all have smart building solutions that integrate their various HVAC systems.

28 BACnet, LONnet, oBIXa, etc.

29 Oberlin College has an interesting example of an online energy dashboard showing energy consumption at its college dormitories (2005 Dormitory Energy Competition at Oberlin College, Cleveland, OH. "On average, dorms reduced electricity use by 32% during the competition. The two dorms with real-time feedback won with 56% reductions in electricity" http://www.oberlin.edu/dormenergy/).

30 Jim Rogers, CEO of Duke Energy, briefing to Gridwise Alliance meeting, Charlotte, NC, Dec. 2007

31 Worldwide demand for electric energy is estimated to rise 82% by 2030. Unless revolutionary new fuels are developed, this demand will primarily be met by building many new coal and natural gas electricity generation plants. Not surprisingly, world carbon dioxide emissions are estimated to rise by 59% by 2030 as a result (International Energy Outlook 2007, Energy Information Administration, US Dept. of Energy, Figure 6, "World carbon dioxide emissions continue to increase steadily in the IEO2007 reference case, from 26.9 billion metric tons in 2004 to 33.9 billion metric tons in 2015 and 42.9 billion metric tons in 2030, an increase of 59% over the projection period" http://www.eia.doe.gov/oiaf/ieo/highlights.html).

32 http://www.un.org/apps/news/story.asp?NewsID=20772&Cr=global&Cr1=environment

33 AeA Report "Advanced Electronics and Information Technologies: The Innovation-Led Climate Change Solution", September 2007, P. 10

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Working Paper

INFORMATION TECHNOLOGIES & TELECOMMUNICATIONS INDUSTRY PARTNERSHIP

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