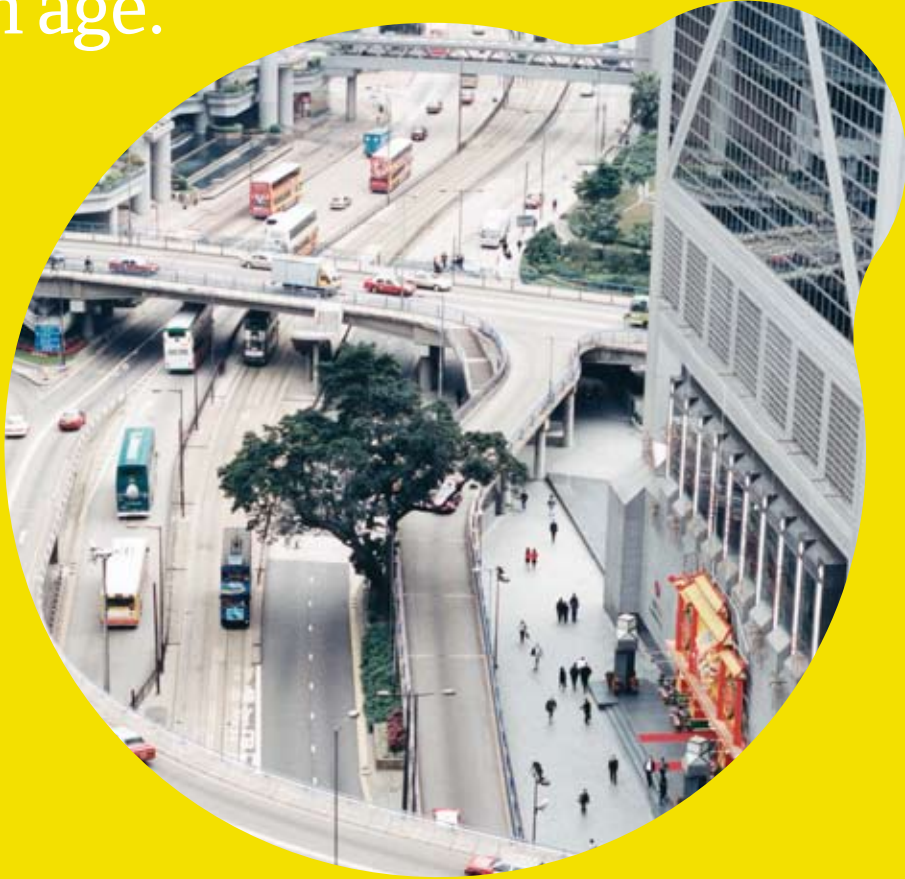


SMART 2020: Enabling the low carbon economy in the information age.



A report by The Climate Group on behalf of the Global eSustainability Initiative (GeSI)

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Support for the Report

This rigorous assessment underlines that the world can realise a green economy and make the transition to a low carbon economy. It also underlines the crucial importance of the international community reaching a deal on a new climate agreement at the climate convention meeting in Copenhagen in 2009. This partnership between GeSI (convened under UNEP) and The Climate Group, with analytical support from McKinsey, gives us yet another platform for action and yet another compelling reason for reasoned optimism [Achim Steiner, UN Under-Secretary General and Executive Director, UN Environment Programme \(UNEP\)](#)

Nowhere is ICT's vast potential more apparent than India where it is driving opportunity and development and transforming our economy and society. This important report makes clear the exciting opportunity that exists for industry to significantly contribute to climate change abatement, as well as expand into new markets. [Nandan Nilekani, Co-Chairman, Infosys Technologies Limited](#)

The ICT industry has a very significant role to play in reducing greenhouse gas emissions, especially in a rapidly developing country such as China. Future development in China should not follow the wrong path taken by developed countries. Many industries can make use of modern ICT technology to move into higher efficiency low carbon markets. If we are to better use ICT technology to move away from existing energy-intensive work habits and lifestyles, we need government policy innovations, incentives for companies and the active participation of consumers. [Tang Min, Deputy Secretary-General, China Development Research Foundation](#)

This report gives a clear picture of the key role that the ICT industry plays in addressing climate change globally and facilitating efficient and low carbon development. The role of ICT not only includes emission reduction and energy savings in the ICT sector itself, but also benefits from the adoption of ICT technologies to influence and transform the way our society works and the way people behave. By using our huge network and over 400 million customers, China Mobile is doing its best to promote this transformation and to realise real sustainable development for human beings and the environment. [Wang Jianzhou, Chief Executive, China Mobile Communications Corporation](#)

Unlocking the universal potential of clean technology in the information systems sector is a critical step toward a low carbon future. Silicon Valley innovators and the growing support of clean tech investors in California place the state in a unique position to lead the effort to combat global warming. [Linda Adams, Secretary, California Environmental Protection Agency](#)



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Forewords

A force for change

The most recent results presented by climate scientists are alarming. The accumulation of greenhouse gases (GHG) in the atmosphere is growing faster than originally predicted. Scientists, economists and policy makers are calling for emissions targets of at least 20% below 1990 levels in 2020.

It is our responsibility to estimate the GHG emissions from the information and communications technology (ICT) industries and to develop opportunities for ICT to contribute to a more efficient economy.

“SMART 2020 – Enabling the low carbon economy in the information age” presents the case for a future-oriented ICT industry to respond quickly to the challenge of global warming.

We now have evidence demonstrating that the ICT industry is a key player in creating a low carbon society and could do a lot more to help push the world in this direction by 2020.

The ICT sector's own emissions are expected to increase, in a business as usual (BAU) scenario, from 0.53 billion tonnes (Gt) carbon dioxide (CO₂) in 2002 to 1.43 GtCO₂ in 2020. But specific ICT opportunities identified in this report can lead to emission reductions five times the size of the sector's own footprint, up to 7.8 Gt carbon dioxide equivalent (CO₂e), or 15% of total BAU emissions by 2020.

This report has identified many opportunities for the ICT industry, to replace goods and services with virtual equivalents and to provide technology to enable energy efficiency. The ICT sector must act quickly to demonstrate what is possible, get clear messages from policy makers about targets and continue to innovate radically to reduce emissions. The publication of this report is not an end but a beginning and GeSI is committed to continue to work across the industry as a force for change. In particular GeSI will:

1. Develop an agreed ICT industry-wide methodology for the carbon footprinting of ICT products and services

2. Put more emphasis on climate change issues in our supply chain work so we influence the end-to-end manufacturing process for electronic equipment
3. Ensure that energy and climate change matters are fully considered by the organisations that set the technical standards for our industry
4. Work with organisations in the key opportunity areas – travel/transport, buildings, grids and industry systems – to help turn potential CO₂ reductions into reality. This will include a strong emphasis on the significant opportunities offered by dematerialisation
5. Work with public policy makers to ensure that the right regulatory and fiscal frameworks are in place to move us all in the right direction.

We will do this by involving appropriate partners drawn from the business and NGO worlds.

In particular we aim to continue our successful partnership with The Climate Group. We will also continue to work collaboratively with the International Telecommunication Union (ITU) and the World Business Council for Sustainable Development (WBCSD).

In conclusion

The ICT sector has both a profitable opportunity and a critical role to play with other sectors to design and deploy solutions needed to create a low carbon society. I urge you to review this report and focus your efforts on improving energy efficiencies wherever possible, to collaborate with us in steering regulations to be more productive and to move boldly forward with technologies to improve our global climate. Acting now will be good for business, good for the economy and good for the world.

Luis Neves
Chair, GeSI



About GeSI

GeSI (www.gesi.org) is an international strategic partnership of ICT companies and industry associations committed to creating and promoting technologies and practices that foster economic, environmental and social sustainability and drive economic growth and productivity. Formed in 2001, GeSI fosters global and open cooperation, informs the public of its members' voluntary actions to improve their sustainability performance and promotes technologies that foster sustainable development. It partners with the UNEP and the ITU. These partners help shape our global vision regarding the evolution of the telecommunications sector and how we can best meet the challenges of sustainable development.

The SMART solution

Putting a man on the moon was one of the greatest technological challenges of the 20th century. In the 21st century we face an even greater test – tackling climate change. In contrast to the space race, the solutions required today must encompass us all. This is not just about one man walking on the moon, but about 7 or 8 billion people, the population of 2020, living low carbon lifestyles in harmony with our climate.

How can a mission of this size be achieved? This report illustrates for the first time the scale of the opportunity for ICT to drive efficiency across the economy and deliver emission savings of 15% - 7.8 GtCO₂e - of global BAU emissions in 2020.

Recently, Lord Stern revised his targets for safe levels of GHG emissions reductions to 2 tonnes per capita by 2050 (20 GtCO₂e). The ICT-enabled solutions in this report would make possible savings of 1 tonne per capita in 2020, a significant step in the right direction.

When we started the analysis, we expected to find that ICT could make our lives 'greener' by making them more virtual – online shopping, teleworking and remote communication all altering our behaviour. Although this is one important aspect of the ICT solution, the first and most significant role for ICT is enabling efficiency.

Consumers and businesses can't manage what they can't measure. ICT provides the solutions that enable us to 'see' our energy and emissions in real time and could provide the means for optimising systems and processes to make them more efficient. Efficiency may not sound as inspirational as a space race but, in the short term, achieving efficiency savings equal to 15% of global emissions is a radical proposition. The breadth of solutions will span motor systems, logistics and transport, buildings and electricity grids – across all key economies in the world.

Mature economies will be able to upgrade and optimise entrenched systems and infrastructures. Developing countries could 'leapfrog' inefficient mechanisms and integrate state-of-the-art solutions into their evolving societies.

Companies that implement the solutions will capture part of the potential global savings of €600 billion (\$946.5 billion), once again showing that tackling climate change is not only good for the climate but good for the economy.

Given the unpredictable nature of technological innovation, there is always uncertainty in estimating future impacts and this report has identified a number of hurdles that must be overcome if the large savings highlighted are to be realised. Furthermore, the ICT sector will have to focus on reducing its direct footprint as the demand for its products and services grows. But this is the first time that the potential of ICT to reduce emissions has been put on the same plane as other climate change solutions, such as carbon capture and storage (CCS).

This sends a clear message to industry leaders and policy makers around the world that, through collaboration, ICT solutions can unlock emissions reductions on a dramatic scale.

To get things moving forward, this report launches our new SMART framework, a guide for developing ICT solutions. Through standards, monitoring and accounting (SMA) tools and rethinking (R) and optimising how we live and work, ICT could be one crucial piece of the overall transformation (T) to a low carbon economy.

The Climate Group, along with GeSI, will be taking the report findings to the USA, China, India and Europe to work with decision makers and leading companies to develop a set of scenarios – the vision – focused on how to turn the ideas presented here into a global reality.

Putting a man on the moon was once thought impossible. The next "giant leap for mankind" is within our reach, but only if we act now.



Steve Howard
CEO, The Climate Group



About The Climate Group

The Climate Group is an independent, not-for-profit organisation that works internationally with government and business leaders to advance climate change solutions and accelerate a low carbon economy. Its coalition of proactive leaders – from government, business and civil society – has demonstrated that emissions reductions, essential to stop climate change, can be achieved while boosting profitability and competitiveness. More companies, states, regions and cities around the world are realising there are significant economic as well as environmental advantages from taking decisive action now. The Climate Group was founded in 2004 and has offices in the UK, USA, China, India and Australia. A European office is planned for 2008.



Report Summary

¹ The Stern Review suggested that developed countries reduce emissions 20-40% below the 1990 levels would be a necessary interim target based on IPPC and Hadley Centre analysis. Source: Stern, N (2008), *Key Elements of a Global Deal on Climate Change*, London School of Economics and Political Science, http://www.lse.ac.uk/collections/climateNetwork/publications/KeyElementsOfAGlobalDeal_30Apr08.pdf

² All currency conversions to US\$ based on exchange rate €1=\$ 1.57757, obtained at <http://xe.com> on 9th June 2008.

³ Exact figures: €553 billion (\$872.3 billion) in energy and fuel saved and an additional €91 billion (\$143.5 billion) in carbon saved assuming a cost of carbon of €20/tonne, for a total of €644 billion (\$1,015 billion) savings.

⁴ All value figures here include a cost for carbon of €20/tonne. See Appendix 3 for detailed assumptions.

The ICT sector has transformed the way we live, work, learn and play. From mobile phones and micro-computer chips to the internet, ICT has consistently delivered innovative products and services that are now an integral part of everyday life. ICT has systematically increased productivity and supported economic growth across both developed and developing countries. But what impact does pervasive information and communication technologies have on global warming? Is it a sector that will hinder or help our fight against dangerous climate change?

To answer these questions, this report has quantified the direct emissions from ICT products and services based on expected growth in the sector. It also looked at where ICT could enable significant reductions of emissions in other sectors of the economy and has quantified these in terms of CO₂e emission savings and cost savings.

Aside from emissions associated with deforestation, the largest contribution to man-made GHG emissions comes from power generation and fuel used for transportation. It is therefore not surprising that the biggest role ICTs could play is in helping to improve energy efficiency in power transmission and distribution (T&D), in buildings and factories that demand power and in the use of transportation to deliver goods.

In total, ICTs could deliver approximately 7.8 GtCO₂e of emissions savings in 2020. This represents 15% of emissions in 2020 based on a BAU estimation. It represents a significant proportion of the reductions below 1990 levels that scientists and economists recommend by 2020 to avoid dangerous climate change¹. In economic terms, the ICT-enabled energy efficiency translates into approximately €600 billion (\$946.5 billion²) of cost savings.³ It is an opportunity that cannot be overlooked.

Our analysis identifies some of the biggest and most accessible opportunities for ICT to achieve these savings.

- **Smart motors:** A review of manufacturing in China has identified that without optimisation, 10% of China's emissions (2% of global emissions) in 2020 will come from China's motor systems alone and to improve industrial efficiency even by 10% would deliver up to 200 million tonnes (Mt) CO₂e savings. Applied globally, optimised motors and industrial automation would reduce 0.97 GtCO₂e in 2020, worth €68 billion (\$107.2 billion).⁴
- **Smart logistics:** Through a host of efficiencies in transport and storage, smart logistics in Europe could deliver fuel, electricity and heating savings of 225 MtCO₂e. The global emissions savings from smart logistics in 2020 would reach 1.52 GtCO₂e, with energy savings worth €280 billion (\$441.7 billion).
- **Smart buildings:** A closer look at buildings in North America indicates that through better building design, management and automation 15% of North America's buildings emissions could be saved. Globally, smart buildings technologies would enable 1.68 GtCO₂e of emissions savings, worth €216 billion (\$340.8 billion).
- **Smart grid:** Reducing T&D losses in India's power sector by 30% is possible through better monitoring and management of electricity grids, first with smart meters and then through integrating more advanced ICTs into the so-called energy internet. Smart grid technologies were the largest opportunity found in the study and could globally reduce 2.03 GtCO₂e, worth €79 billion (\$124.6 billion).

While the sector plans to significantly step up the energy efficiency of its products and services, ICT's largest influence will be by enabling energy efficiencies in other sectors, an opportunity that could deliver carbon savings five times larger than the total emissions from the entire ICT sector in 2020.

These are not easy wins. There are policy, market and behavioural hurdles that need to be overcome to deliver the savings possible. For example, Chinese factory managers find it difficult to stop producing long enough to implement more efficient industrial processes because they risk losing revenue and competitiveness.

Logistics efficiency is hampered by fragmentation in the market, which makes it difficult to coordinate across the sector to achieve economies of scale. Even with the latest technologies implemented, buildings are only efficiently if managed properly. In India, there is no coordinated national roadmap for smart grid implementation and more needs to be done to build the cross-functional and cross-sectoral capabilities needed to design and implement innovative business and operating models and deliver new technology solutions.

In addition to the savings possible by supporting other sectors to become more energy efficient, there are also potential energy savings from dematerialisation or substitution – replacing high carbon physical products and activities (such as books and meetings) with virtual low carbon equivalents (e-commerce/e-government and advanced videoconferencing). Our study indicates that using technology to dematerialise the way we work and operate across public and private sectors could deliver a reduction of 500 MtCO₂e in 2020 – the equivalent of the total ICT footprint in 2002, or just under the emissions of the UK in 2007. However, these solutions would need to be more widely implemented than they are today to realise their full abatement potential.

This is the opportunity the ICT sector has in the fight against climate change. But it does come at a cost. Emissions from the sector are estimated to rise significantly over the coming years – from 0.5 GtCO₂e today to 1.4 GtCO₂e in 2020 under BAU growth.⁵ This growth assumes that the sector will continue to make the impressive advances in energy efficiency that it has done previously. However, meeting the sheer scale of demand for products and necessary supporting services in emerging markets such as China and India and continuing to deliver the services to increase productivity growth in the developed world will effectively outweigh the adoption of the current wave of efficiency benefits per product or service. There is also the possibility that the speed of introduction and the impact of new ICT technology or the mass adoption of social networking could cut carbon emissions in ways currently impossible to predict.

While the sector plans to significantly step up the energy efficiency of its products and services, ICT's largest influence will be by enabling energy efficiencies in other sectors, an opportunity that could deliver carbon savings five times larger than the total emissions from the entire ICT sector in 2020.

Getting SMART

The scale of emissions reductions that could be enabled by the smart integration of ICT into new ways of operating, living, working, learning and travelling makes the sector a key player in the fight against climate change, despite its own growing carbon footprint. No other sector can

⁵ The scope of this analysis includes whole life emissions from PCs and peripherals, data centres, telecoms devices and telecoms networks.

supply technology capabilities so integral to energy efficiency across such a range of other sectors or industries.

But with this potential comes with responsibility. Emissions reductions in other sectors will not simply present themselves; the ICT sector must demonstrate leadership on climate change and governments must provide the optimum regulatory context. This report outlines the key actions needed.

These actions can be summarised as the SMART transformation. The challenge of climate change presents an opportunity for ICT to first standardise (S) how energy consumption and emissions information can be traced across different processes beyond the ICT sector's own products and services. It can monitor (M) energy consumption and emissions across the economy in real time, providing the data needed to optimise for energy efficiency. Network tools can be developed that allow accountability (A) for energy consumption and emissions alongside other key business priorities. This information can be used to rethink (R) how we should live, learn, play and work in a low carbon economy, initially by optimising efficiency, but also by providing viable low cost alternatives to high carbon activities. Although isolated efficiency gains do have an impact, ultimately it will be a platform - or a set of technologies and architectures - working coherently together, that will have the greatest impact. It is through this enabling platform that transformation (T) of the economy will occur, when standardisation, monitoring, accounting, optimisation and the business models

that drive low carbon alternatives can be developed and diffused at scale across all sectors of the economy.

The ICT sector can't act in isolation if it is to seize the opportunity it has to tackle climate change. It will need the help of governments and other industries. Smart implementation of ICTs will require policy support including standards implementation, secure communication of information within and between sectors and financing for research and pilot projects.

This report demonstrates the potential role the ICT sector could play in mitigating climate change. It is now up to policy makers, industry leaders and the sector itself to make sure this potential is realised. The stakes couldn't be higher. ●

01: The time for change

The science

As stated in the Intergovernmental Panel on Climate Change's (IPCC) 2007 *Synthesis Report*: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."⁶

The global warming debate has now shifted from whether or not man-made climate change is occurring to what atmospheric levels of GHG are 'safe' and what can be done to prevent them from exceeding this threshold.

Current BAU scenarios predict that global emissions will rise from 40 GtCO₂e (referred to as both 'carbon' and 'GHG' emissions in this report) emitted each year in 2002 to nearly 53 GtCO₂e annually by 2020.⁷ Current atmospheric GHG levels stand at 430 parts per million (ppm) and are rising at approximately 2.5ppm every year, leading us beyond levels of 450-500 ppm (roughly twice pre-industrial levels).

The specific figures for what can be considered 'safe' are not universally accepted⁸ and will continue to be debated as new information becomes available. Whichever benchmark is used, the magnitude of cuts required will be challenging.

The economics

Former UK Government and World Bank Chief Economist Lord Stern, author of the Stern Review,⁹ makes it clear that to ignore rising carbon emissions that will result in dangerous climate change now, will damage economic growth in the future. According to the report, if no action is taken, the overall costs and risks of climate change will be equivalent to losing at least 5% of global gross domestic product (GDP) each year. Not acting now

would incur a wider range of risks and impacts and the estimates of damage could rise to 20% of global GDP or more. In contrast, the costs of action – reducing GHG emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.

The review predicts that failure to act today and in the future could cause possibly irreversible economic and social disruption "on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century".

Lord Stern has recently joined scientists in outlining the worsening nature of the problem. His report on the economics of climate change should have issued a bleaker warning when it was published 18 months ago, he said recently "We underestimated the risks... we underestimated the damage associated with the temperature increases... and we underestimated the probabilities of temperature increases."¹⁰

Society currently needs to reduce emissions to about 20 GtCO₂e per year by 2050, according to Stern, about two tonnes per person in 2050. Given that the current underlying rate of decrease in carbon intensity, defined as tonnes of carbon dioxide equivalent (tCO₂e)/GDP, is 1% per year and that the world economy continues to grow by 3-4% per year, carbon emissions will continue to grow at 2-3% per year under a BAU scenario. So to reduce emissions by 20 GtCO₂e per year, as recommended by Stern, implies that a dramatic change is needed in production and consumption profile.¹¹

Both policy makers and industry must initiate the rapid implementation of climate solutions before average global temperatures move beyond a "tipping point" of no return.

⁶ Pachauri, R.K and A. Reisinger (eds.) (2007) *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Intergovernmental Panel on Climate Change, Geneva, Switzerland.

⁷ McKinsey analysis for this report, based on IPCC (2007) *Fourth Assessment Report* and International Energy Agency (IEA) (2007) *World Energy Outlook*.

⁸ Recent analysis suggests that 450ppm may be too high and that we should be aiming to reduce emissions more quickly: King D. and G. Walker (2008), *The Hot Topic: How to Tackle Global Warming and Still Keep the Lights On*, Hansen J., M Sato, P Kharecha, D Beerling., V Masson-Delmotte, M Pagani, M Raymo, D Royer and J Zachos (2008); *Target Atmospheric CO₂: Where Should Humanity Aim?*, http://www.columbia.edu/~jeh1/2008/TargetCO2_20080331.pdf

⁹ Stern, N (2006), *Executive Summary*, Stern Review on the Economics of Climate Change, HM Treasury.

¹⁰ Harvey, F and J. Pickard, "Stern takes bleaker view on warming", *Financial Times*, 17 April 2008, http://www.ft.com/cms/s/0/d3e78456-0bde-11dd-9840-0000779fd2ac.html?nclink_check=1

¹¹ Stern, N. (2008), *Key Elements of a Global Deal on Climate Change*, London School of Economics and Political Science, http://www.lse.ac.uk/collections/climateNetwork/publications/KeyElementsOfAGlobalDeal_30Apr08.pdf

¹² EU Spring Summit, Brussels (March 2007).

¹³ UK Climate Change Bill (April 2008).

¹⁴ Germany's Integrated Energy and Climate Programme (December 2007).

¹⁵ China's 11th Five-Year Economic Plan, www.gov.cn/english/special/115y_index.htm

¹⁶ Roeller, Lars H. and Leonard Waverman, (2001), 'Telecommunications Infrastructure and Economic Growth: A Simultaneous Approach', American Economic Review, Volume 91, Number 4, pp. 909-23.

¹⁷ Analysis includes data from Global Insight (www.globalinsight.com).

¹⁸ Waverman, Meschi and Fuss (2005) 'The Impact of Telecoms on Economic Growth in Developing Countries, Africa: The Impact of Mobile Phones', Vodafone Policy Paper Series 2.

¹⁹ Eggleston K., R. Jensen and R. Zeckhauser (2002), 'Information and Communication Technologies, Markets and Economic Development', Discussion Papers Series, 0203, Department of Economics, Tufts University.

²⁰ Jensen R. (2007), 'The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries sector', Quarterly Journal of Economics, cited in: Economist, 'To do with the Price of Fish', 10 May 2007, http://www.economist.com/finance/displaystory.cfm?story_id=9149142.

²¹ Member companies of GeSI: Alcatel-Lucent, Bell Canada, British Telecommunications plc, Cisco Systems, Deutsche Telekom AG, Ericsson, European Telecommunication Network Operators Association (ETNO), France Telecom, Fujitsu Siemens Computers, Hewlett-Packard, Intel, KPN, Motorola, Microsoft, Nokia, Nokia Siemens Networks, Nortel, Sun Microsystems, Telecom Italia, Telefónica SA, US Telecom Association, Verizon, Vodafone plc. Associate members: Carbon Disclosure Project (CDP), WWF. Supporting Organisations: ITU, Telecommunication Development Bureau, UNEP Division of Technology, Industry and Economics.

The political response

Thirty-four countries have signed up to the legally binding Kyoto Protocol, the agreement negotiated via the United Nations Framework Convention on Climate Change (UNFCCC), which sets a target for average global carbon emissions reductions of 5.4% relative to 1990 levels by 2012. Discussions for a post-2012 agreement are currently underway.

Individual regions and countries have also developed their own targets. In 2007, the European Union (EU) announced a 20% emissions reduction target compared to 1990 levels by 2020 and will increase this to 30% if there is an international agreement post-2012.¹² The UK is aiming for a reduction of 60% below 1990 levels by 2050, with an interim target of about half that.¹³ Germany is aiming for a 40% cut below 1990 levels by 2020,¹⁴ while Norway will become carbon neutral by 2050. California's climate change legislation, known as AB 32, commits the state to 80% reductions below 1990 levels by 2050. China's latest five-year plan (2006-2010) contains 20% energy efficiency improvement targets¹⁵ to try to reduce the impact of recent fuel shortages on its economic growth.

As governments across the world wake up to the urgency of rising temperatures, they are increasingly focusing on how business is responding to both reduce their carbon footprints and to develop and supply the required innovations for a low carbon world.

What does this mean for business?

Companies must adapt quickly to the political, social, economic and fiscal drive towards a global low carbon economy. Businesses that can turn this challenge into an opportunity, by developing business models to enable adoption of low carbon solutions, will be in a stronger position to mitigate rising carbon emissions and adapt to a world dealing with the impacts of climate change. A radical approach is required that incorporates different ways of thinking, living, working, playing, doing business and developing solutions. Action is no longer an option; it has become an urgent necessity.

What does this mean for the ICT sector?

The terms "the new economy", "the knowledge economy" and "the information society" all refer to the world's increasing reliance on ICT to provide services and solutions that ultimately generate

wealth. A number of studies have linked the growth of ICT to global GDP growth and globalisation. One analysis¹⁶ suggests that a third of the economic growth in the Organisation for Economic Cooperation and Development (OECD) countries between 1970 and 1990 was due to access to fixed-line telecoms networks alone, which lowered transaction costs and helped firms to access new markets.

Globally, the ICT sector contributed 16% of GDP growth from 2002 to 2007 and the sector itself has increased its share of GDP worldwide from 5.8 to 7.3%. The ICT sector's share of the economy is predicted to jump further to 8.7% of GDP growth worldwide from 2007 to 2020.¹⁷

In low income countries, an average of 10 more mobile phone users per 100 people was found to stimulate a per capita GDP growth of 0.59%.¹⁸ In China, improved communication has helped increase wealth by driving down commodity prices, coordinating markets and improving business efficiency.¹⁹ In Kerala, India, the introduction of mobile phones contributed on average to an 8% rise in fishermen's profits and a 4% fall in consumer prices.²⁰

Scope, process and methodology

The study was undertaken by a unique partnership between not-for-profit organisation The Climate Group and ICT sector group GeSI.²¹ The supporting analysis was conducted independently by international management consultants McKinsey & Company. Input was provided by GeSI member companies and the global experts consulted for each of the case studies.

The combined knowledge and experience of this group has enabled us to identify and quantify specific ICT impacts and opportunities, in the context of carbon emission savings and potential economic value. In addition, the analysis drew on additional data from the ICT companies involved in the study. It estimated the likely growth of the ICT sector's carbon footprint and, more importantly, the carbon emissions savings and business opportunities that are possible when ICT is deployed across the economy. A detailed methodology can be found in Appendix 1. ●

This demonstrates that the ICT sector continues to play a vital role in the growth of the global economy and international development. As the imperative to develop zero carbon growth solutions becomes stronger, society needs to lower emissions while continuing to serve the needs of people in emerging economies, to develop poverty reduction schemes and enable multiple sectors across the world. What, therefore, are the next steps for ICT? Could it apply its creativity and skills to help reduce carbon emissions by massively enabling efficiency or behaviour change? How big an impact could it have? And how will that affect its carbon footprint?

The SMART way

In order to understand and compare the direct impact of ICT products and services and its enabling role in climate change solutions, the analysis set out to answer three main questions:

1. What is the direct carbon footprint of the ICT sector?
2. What are the quantifiable emissions reductions that can be enabled through ICT applications in other sectors of the economy?
3. What are the new market opportunities for ICT and other sectors associated with realising these reductions?

Because of growth in demand for its products and services, mainly from emerging economies and the rapid adoption in the developed world, the ICT sector's own carbon footprint is likely to grow under BAU conditions to 1.4 GtCO₂e by 2020, three times what it was in 2002. Chapter 2 looks at the reasons for this growth, assesses what can be done to reduce it and the hurdles that need to be overcome for the sector to attain maximum efficiency.

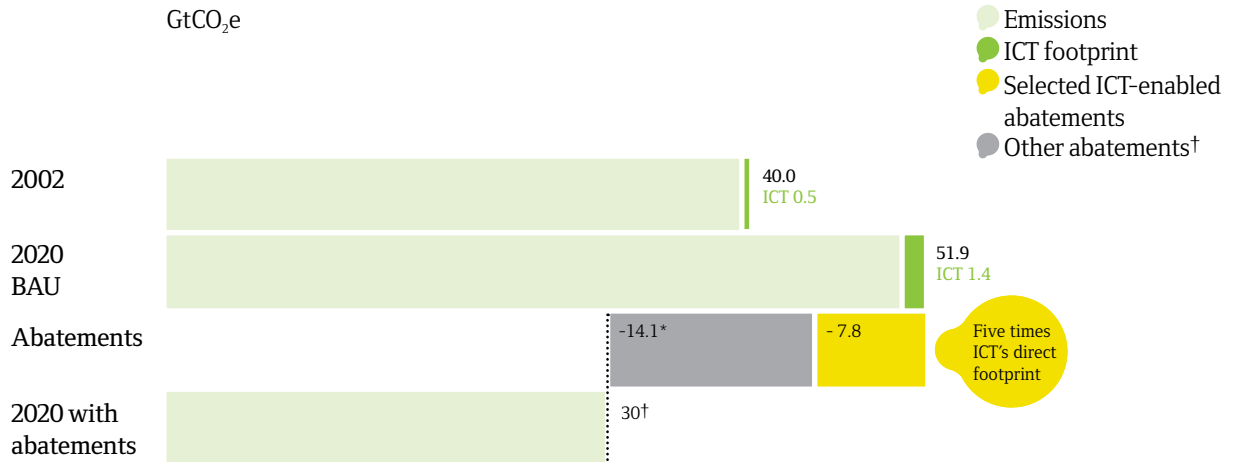
In order to approach the second and third questions, it was important to know which sectors are responsible for producing the highest levels of carbon emissions and therefore where ICT might enable reductions. Of the total emissions from human activity in 2002, 24% was from the power sector, 23% from industry, 17% from agriculture and waste management, 14% from land use, 14% from transport and 8% from buildings. Taking another view of the same data – at the point where electricity is consumed and fuel is used – sharpens the focus further. In 2005, manufacturing was 33% of end use energy consumption, transport was 26% and households 29% (other services and construction made up the final 12%).²²

The findings of the analysis are highly illuminating. Because of its pervasiveness, ICT is a key, though often unrecognised, enabling infrastructure in the global economy. The sector can enable smart development opportunities for CO₂e reductions and participate in the new sources of value of low or zero carbon solutions markets at the same time as restricting the growth of its own carbon footprint.

Even as the sector tackles its own carbon footprint, the need to mitigate climate change presents opportunities for ICT to deliver low carbon energy efficiency solutions. The sector has a unique ability to make energy consumption and GHG emissions visible through its products and services. Radical transformation of infrastructure is possible only if it is known where inefficiency occurs throughout the processes and workflows of various sectors in the economy. ICT can provide this data which can be used to change behaviours, processes, capabilities and systems. Although isolated efficiency gains do have an impact, ultimately it will be a platform – or a set of technologies – working coherently together, that will have the greatest impact.

²² IEA (2008), *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis*, IEA/OECD, Paris.

Fig. 1 ICT impact: The global footprint and the enabling effect



* For example, avoided deforestation, wind power or biofuels

† 21.9 GtCO₂e abatements were identified in the McKinsey abatement cost curve and from estimates in this study. Source: Enkvist P., T. Naucler and J. Rosander (2007), 'A Cost Curve for Greenhouse Gas Reduction', The McKinsey Quarterly, Number 1

This report has identified global emissions reductions of 7.8 GtCO₂e in 2020, five times its own footprint (**Fig.1**).

The ICT sector can enable emission reductions in a number of ways:

- **Standardise:** ICT can provide information in standard forms on energy consumption and emissions, across sectors.
- **Monitor:** ICT can incorporate monitoring information into the design and control for energy use.
- **Account:** ICT can provide the capabilities and platforms to improve accountability of energy and carbon.
- **Rethink:** ICT can offer innovations that capture energy efficiency opportunities across buildings/homes, transport, power, manufacturing and other infrastructure and provide alternatives to current ways of operating, learning, living, working and travelling.
- **Transform:** ICT can apply smart and integrated approaches to energy management of systems and processes, including benefits from both automation and behaviour change and develop alternatives to high carbon activities, across all sectors of the economy.

In Chapter 3, the report looks at five of the most important "levers" or mitigation opportunities: dematerialisation; smart motor systems in China; smart logistics in Europe; smart buildings in North America; and smart grids in India. It considers the impact of ICT on local and global emissions, where ICT could have the most influence on emissions reductions, current markets, regulatory context and hurdles that need to be overcome if its potential to reduce emissions is to be realised.

In parallel with the ICT reducing its own carbon footprint, governments need to do more to create a fiscal and regulatory environment that will encourage faster and more widespread adoption of ICT. Crucially new partnerships between governments and the private sector are required. Chapter 4 develops a framework for understanding the enabling opportunity of ICT solutions. ●



02: Taking direct action

²³ Gartner, 'Green IT: The New Industry Shockwave', Presentation at Symposium/ITXPO conference, April 2007.

²⁴ Of course a range of figures are possible, but the report took a BAU scenario with the best information available from companies and public sources. See Appendix 1 for detailed methodology and Appendix 2 for the direct footprint assumptions.

²⁵ CIA (2007): World Factbook website, <https://www.cia.gov/library/publications/the-world-factbook/print/ch.html>

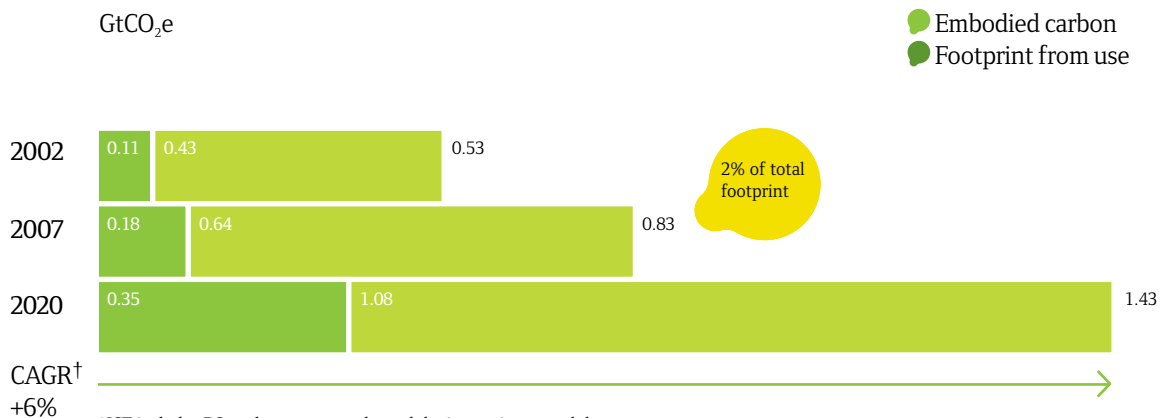
In 2007, analyst Gartner released a statistic that the ICT sector was responsible for 2% of global carbon emissions²³ and this figure has since been widely cited. The analysis conducted for this report came to similar conclusions. This chapter sets out in some detail how today's 2% figure was calculated and the assumptions behind the growth in emissions expected in 2020, taking into account likely efficient technology developments that affect the power consumption of products and services or their expected penetration in the market in 2020. Not all technology developments can be predicted and therefore further possible abatements are discussed, but not calculated. The chapter concludes with a brief section on what more could be done.

In 2007, the total footprint of the ICT sector – including personal computers (PCs) and peripherals, telecoms networks and devices and data centres – was 830 MtCO₂e, about 2% of the estimated total emissions from human activity released that year. Even if the efficient technology

developments outlined in the rest of the chapter are implemented, this figure looks set to grow at 6% each year until 2020. The carbon generated from materials and manufacture is about one quarter of the overall ICT footprint, the rest coming from its use (**Fig. 2.1**).

Although there is expected growth in mature developed markets, the most significant growth is attributable to increasing demand for ICT in developing countries (**Fig. 2.2**). Just one in 10 people own a PC in China today; by 2020, that will rise to seven in 10, comparable to current ownership rates in the US. In just 12 years time, one in two Chinese people will own a mobile phone and half of all households will be connected by broadband. It will be a similar story in India. By 2020, almost a third of the global population will own a PC (currently one in 50), 50% will own a mobile phone and one in 20 households will have a broadband connection.²⁴ Considering that the populations of China and India are currently 1.3 billion²⁵ and

Fig. 2.1 The global ICT footprint*



*ICT includes PCs, telecoms networks and devices, printers and data centres.
†Compounded Annual Growth Rate

1.1 billion respectively²⁶ and that consumption in the Indian economy is expected to quadruple in the next four years and the middle class in China is expected to grow to over 80% of the population by 2020,²⁷ these are potentially huge growth areas.

By 2020, when a large fraction of developing countries' populations (up to 70% in China) will be able to afford ICT devices and will have caught up with developed countries' ownership levels, they will account for more than 60% of ICT's carbon emissions (compared to less than half today), driven largely by growth in mobile networks and PCs. But these are not the fastest-growing elements of the footprint. Despite first-generation virtualisation and other efficiency

measures, data centres will grow faster than any other ICT technology, driven by the need for storage, computing and other information technology (IT) services. Though the telecoms footprint continues to grow, it represents a smaller share of the total ICT carbon footprint in 2020 as efficiency measures balance growth and as data centres rise to take a larger share of the total (Fig. 2.3).

The analysis below took a deeper look at three main areas of the direct footprint: PCs and peripherals, data centres, telecoms networks and devices, outlined below. Appendix 1 provides more information about what was included in the scope of the analysis and Appendix 2 outlines the assumptions behind each in more detail.

²⁶ Ibid

²⁷ McKinsey Global Institute 'China Consumer Demand Model, V2.0'.

Fig. 2.2 The global ICT footprint by geography

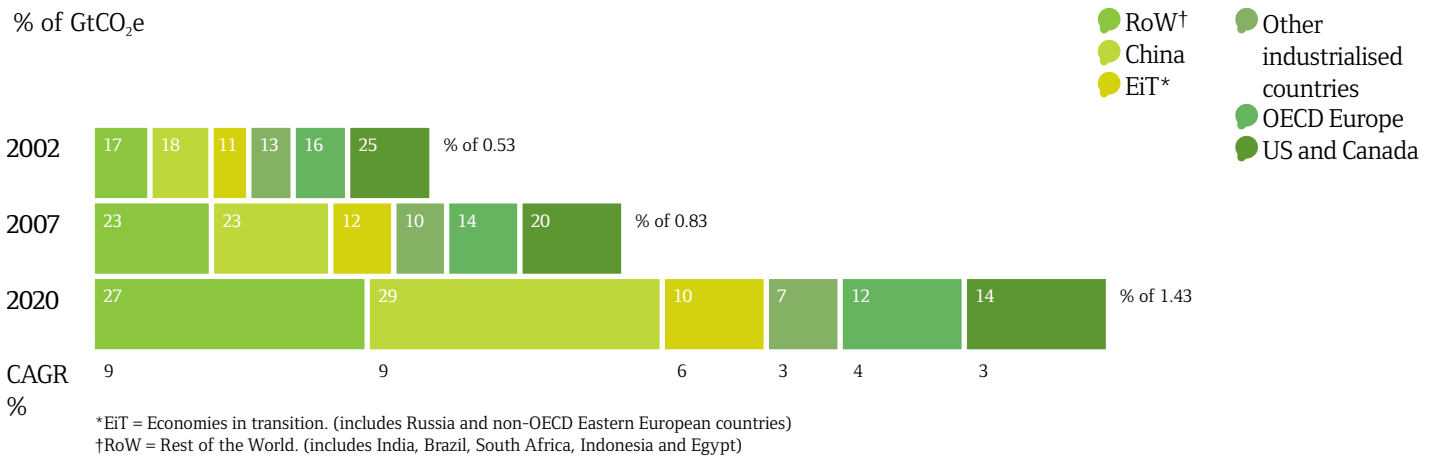


Fig. 2.3 The global footprint by subsector

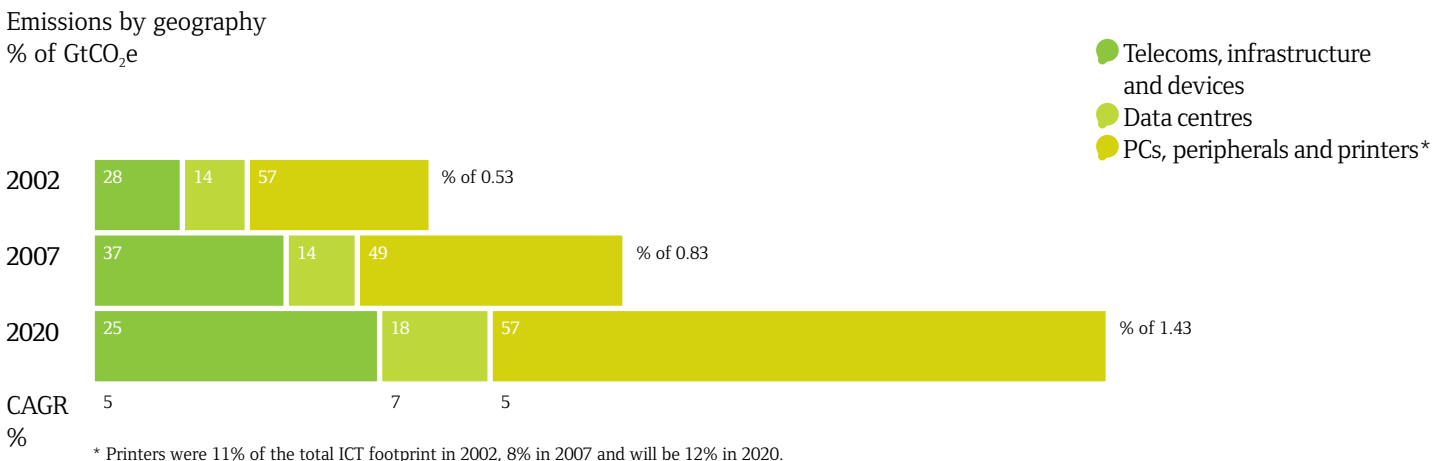
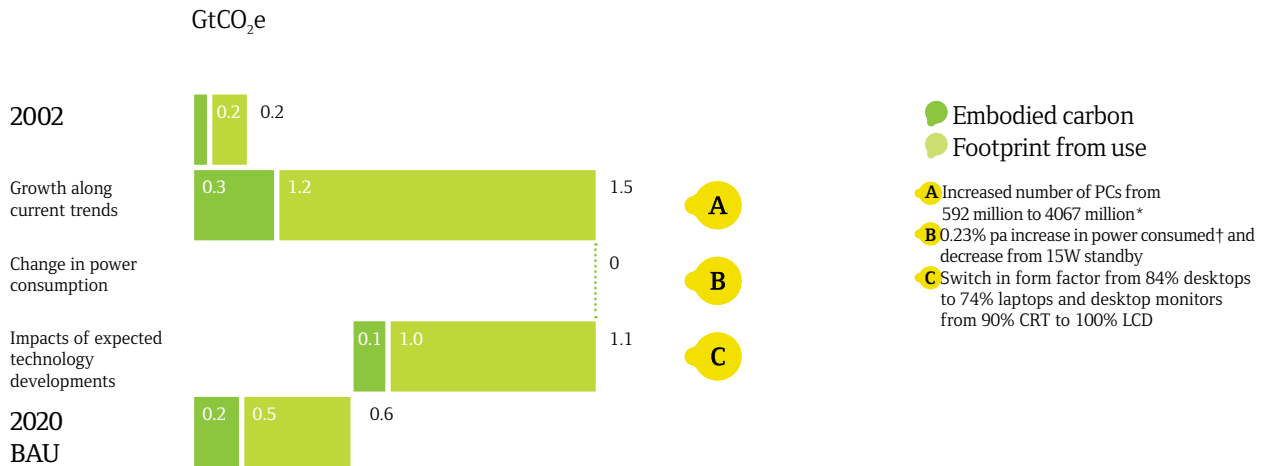


Fig. 3.1 The global footprint of PCs – desktops and laptops



* Based on Gartner estimates until 2011 and trend extrapolation to 2020.
 † Based on McManus, T (2002), 'Moore's Law and PC Power' presentation to Tulane Engineering Forum.

²⁸ Printers were included in the overall analysis of the ICT footprint, but are not broken down further in this section.

²⁹ Analysis includes data from Shiffler, G III. (2007), *Forecast: PC Installed Base Worldwide, 2003-2011*, Gartner.

PCs and peripherals

In the developed world today, PCs (workstations, desktops and laptops) are almost as ubiquitous in people's homes as televisions (TVs). This is not yet the case in the developing world, but the explosion in the number of internet cafés demonstrates that the demand is there. Growing middle classes in emerging economies, whose newfound wealth will allow them to start buying PCs at developed country rates, will substantially increase the global carbon footprint of these technologies.

In 2002, the PC and monitors' combined carbon footprint²⁸ was 200 MtCO₂e and this is expected to triple by 2020 to 600 MtCO₂e – a growth rate of 5% per annum (pa) (**Fig. 3.1**).

Calculating the PC footprint in 2020

The number of PCs globally is expected to increase from 592 million in 2002 to more than four billion in 2020. Row **A** of **Fig. 3.1** shows the expected footprint if this growth used today's PC technology. Since 1986, the power demand for PCs has only increased at 0.23% pa, a low rate considering there has been a 45% pa improvement in computational power. This success has been achieved by the exploitation of multi-core processors and more efficient power supply units. By 2020, further advances in power management

are expected to compensate for the increase in PC computing demand, represented by Row **B**, so that overall power consumption is not expected to grow.

However, two major technology developments are expected by 2020. First, the desktop PCs that dominate today's market (84%) will be largely replaced by laptops if adoption materialises as forecasted – by 2020, 74% of all PCs in use will be laptops. Second, all cathode ray tube (CRT) screens will be replaced by low energy alternatives, such as liquid crystal display (LCD) screens by 2020. These two factors explain the reduction in carbon footprint in Row **C**.

Taking Rows **A**, **B** and **C** together shows that the 2020 footprint will rise to three times the emissions in 2002.²⁹

By 2020, laptops will have overtaken desktops as the main source of emissions (**Fig. 3.2**) and will make up the largest portion (22%) of the global ICT carbon footprint. Desktops with LCD monitors will represent 20% of the total ICT footprint in 2020, an increase of 16% since 2002.

Reducing PC emissions further

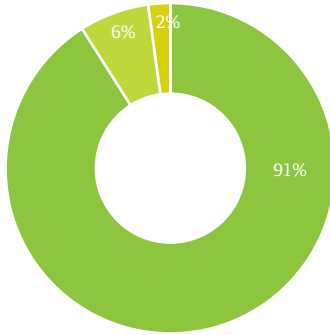
To reduce the total carbon emissions of PCs predicted for 2020 to below 2002 levels would require a 95% efficiency improvement in the overall impact from PCs. This cannot only be

Fig. 3.2 Composition of the PC footprint

MtCO₂e

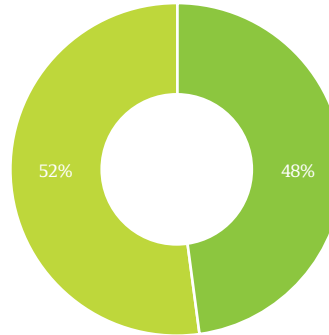
2002
100% = 247
MtCO₂e

- Laptops (6 MtCO₂e)
- Desktops with LCD monitors (16 MtCO₂e)
- Desktops with CRT monitors (226 MtCO₂e)



2020
100% = 643
MtCO₂e

- Desktops with CRT monitors (0 MtCO₂e)
- Laptops (333 MtCO₂e)
- Desktops with LCD monitors (309 MtCO₂e)



Desktops with CRT monitors represented 44% of the total ICT footprint (91% of 49%).

Desktops with LCD monitors and laptops represented 4% of the total ICT footprint (8% of 49%).

Laptops will represent 22% of the total ICT footprint (52% of 42%).

Desktops with LCD monitors will represent 20% of the total ICT footprint (48% of 42%).

Fig. 4.1 The global data centre footprint

MtCO₂e

2002



Growth along current trends



Power consumption

0

Impacts of expected technology developments



2020
BAU



- Use
- Embodied

- A** Increased number of servers and their necessary power and cooling from 18 million to 122 million*
- B** No increase in power consumption due to new generation technologies across server classes†
- C** Savings from expected adoption of measures (27% efficiency due to virtualisation and 18% due to smart cooling and broad operating temperature envelope)

*Based on IDC estimates until 2011 and trend extrapolation to 2020, excluding virtualisation.
†Power consumption per server kept constant over time.

³⁰ This category includes blade servers.

³¹ Assessments based on data made available by GeSI companies for the purposes of this report.

³² The net zero increase shown in Row B is due to the adoption of volume servers which incorporate technologies such as multi-core/multi-threading microprocessors with more sophisticated power-state sensing and management. Additionally, the rapid adoption of newer processor micro-architectures has refreshed the installed base of servers with a more power-efficient silicon transistor technology.

³³ IDC analysis predicts 83 million servers will be needed in 2020 if virtualisation effects are included.

achieved through a combination of increased energy efficiency and longer product life, but will necessitate changes comparable in scale to that enabled by the shift from desktops to laptops.

There could also be breakthrough technologies around the corner that would transform how PCs use energy. Examples include solid state hard drives, which could reduce energy consumption by up to 50%, cholesteric LCD screens that reduce monitor consumption by up to 80% and direct methanol fuel cells that can deliver 20% savings for power supplies.

Other areas of research such as quantum and optical computing could also have a substantial impact. These have not been factored into the carbon emission calculations because their impact within the timeframe is uncertain.

Data centres

In the “information age” there is a vast amount of data that is stored and instantly made available upon request. Users of these data range from companies complying with the recent Sarbanes–Oxley accounting data legislation to consumers watching YouTube videos, to the processing and storage capabilities required for climate change modelling. This has led to a vast increase in the number of data centres – buildings that house a

collection of servers, storage devices, network equipment, power supplies, fans and other cooling equipment – which provide information at our fingertips, supplying business, government, academia and consumers around the world.

In 2002, the global data centre footprint, including equipment use and embodied carbon, was 76 MtCO₂e and this is expected to more than triple by 2020 to 259 MtCO₂e – making it the fastest-growing contributor to the ICT sector’s carbon footprint, at 7% pa in relative terms (**Fig. 4.1**).

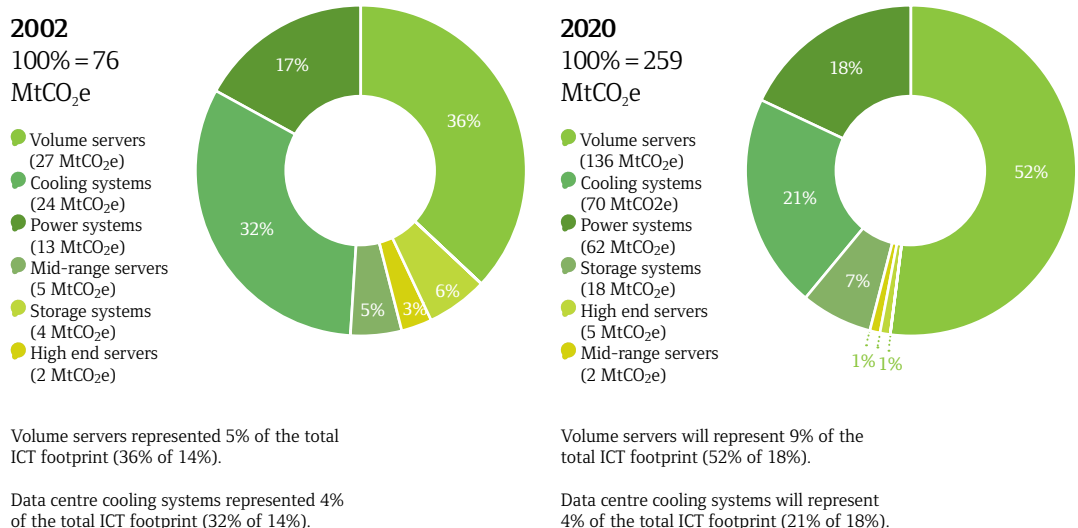
Calculating the data centre footprint in 2020

If growth continues in line with demand, the world will be using 122 million servers in 2020, up from 18 million today. In addition to this 9% pa increase in server numbers, there will be a shift from high-end servers (mainframes) to volume servers,³⁰ the least expensive kind of server that can handle much of the computational needs of businesses. Row **A** of **Fig. 4.1** shows the increase in footprint that would be expected by simply scaling up today’s data centre technology without the application of virtualisation technologies in data centres.

Power consumption differs by server type but, like PCs, no increase in overall

Fig. 4.2 Composition of data centre footprint

Global data centre emissions %



consumption is expected in the coming years, in spite of increased processing demand.³¹ This is due mainly to new technologies in all types of servers³² and explains the net zero change in Row B.

A major trend driving down the overall growth in the footprint of data centres (Row C) is virtualisation – pooling assets such as computing and storage where utilisation is low, so they can be used across the enterprise and beyond. Virtualisation represents a radical rethinking of how to deliver the services of data centres, pooling resources that are underutilised and could reduce emissions by 27% – equivalent to 111 MtCO₂e.³³ Technologies are also available to detect where within the data centre temperatures are running high and to direct cooling to those areas thus delivering a 12% reduction in cooling costs. By 2020, the analysis predicted that these measures could achieve an approximate 18% reduction (55 MtCO₂e) in consumption.

Only about half of the energy used by data centres powers the servers and storage; the rest is needed to run back-up, uninterruptible power supplies (5%) and cooling systems (45%).³⁴ There are a number of ways to reduce this energy overhead, some of which are expected to be adopted by 2020. The simplest way is to turn

down the air conditioning. Similarly, in climates where the outside temperature allows, simply directing external air into the data centre can save cooling costs for much of the year. By allowing the temperature of the data centre to fluctuate along a broader operating temperature range, a 24% reduction in energy consumption from cooling is possible. Distributing low voltage direct current (DC) into the data centre would eliminate the need for mechanical back-up, uninterruptible power supply units.

By 2020, the net footprint for data centres is predicted to be 259 MtCO₂e. At this point, volume servers will represent more than 50% of the data centre footprint (174 MtCO₂e) and cooling systems for data centres alone will amount to 4% of the total ICT footprint (**Fig. 4.2**).

Reducing data centre emissions further

Additional emission reductions not included in the current 2020 BAU scenario are possible. Complete adoption of the cooling technologies noted above would result in additional savings of 65 MtCO₂e in 2020.

Higher adoption rates of virtualisation architectures and low energy cooling would help achieve step changes in efficiency. Current utilisation rates of servers, storage and other

³⁴ Estimates based on Koomey, J.G. (2007), 'Estimated Total Power Consumption by Servers in the U.S. and the World', <http://enterprise.amd.com/Downloads/svrprwusecompletefinal.pdf>.

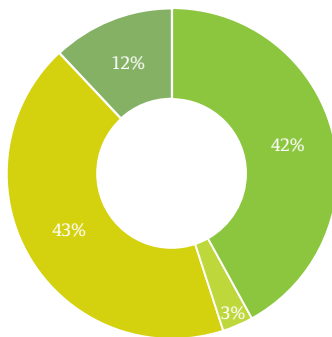
³⁵ Uptime Institute and McKinsey & Company (2008), *Revolutionizing Data Center Efficiency—Key Analyses*, <http://uptimeinstitute.org/content/view/168/57>

Fig. 5 Global telecoms footprint (devices and infrastructure)

Global telecoms emissions %

2002
100% = 151
MtCO₂e

- Mobile (66 MtCO₂e)
- Fixed narrowband (64 MtCO₂e)
- Telecom devices (18 MtCO₂e)
- Fixed broadband (4 MtCO₂e)

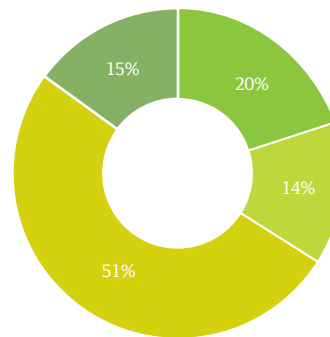


Mobile phones represented 3% of the total ICT footprint (11% of 30%).

Fixed broadband represented 1% of the total ICT footprint (3% of 30%).

2020
100% = 349
MtCO₂e

- Mobile (179 MtCO₂e)
- Fixed narrowband (70 MtCO₂e)
- Telecom devices (51 MtCO₂e)
- Fixed broadband (49 MtCO₂e)



Mobile phones will represent 1% of the total ICT footprint (6% of 25%).

Mobile phones will represent 13% of the total ICT footprint (51% of 25%)

Fixed broadband will represent 4% of the total ICT footprint (14% of 25%)

assets in the data centre worldwide are low (6% average server utilisation, 56% facility utilisation) and vary dramatically depending on the installation.³⁵ If, for example, a 20% reduction below 2002 emission levels were to be achieved, this would entail an increase in efficiency of 86% globally. Though it may be possible to achieve 86% efficiency in one data centre by more efficient virtualisation architectures and changing the data centre location to reduce cooling needs, adoption of best practice has its challenges. And although the cost of energy is high, companies are not often organised so that the person paying for the IT equipment is also paying for the energy consumption of that equipment.

However there is a significant consolidation trend that may help in dealing with the existing or legacy data centre impact. Also, organisational attitudes are changing as costs of operating a data centre surpass the initial investment in equipment and as the data centre operation becomes a larger share of a company's overall energy costs. Companies now have a number of options for computing services, which shift costs from the enterprise to an external provider that can potentially deliver these capabilities with economies of scale and at higher energy efficiency. The "software as a service" business model allows companies to access key enterprise applications such as customer relationship management databases or collaboration tools via a web browser, with no need to host their own data centre facilities. Companies can also pay to use server space on demand to build their own applications and websites, the way one would pay monthly for electricity or water, known as 'utility computing'. These are both simple examples of what is more generally called 'cloud computing', centralised and highly scalable services that could lead to further capacity to virtualise or consolidate resources with breakthrough gains in energy efficiency.

Predicting the pace and intensity of these virtualisation trends is difficult, but the industry is well aware of the huge efficiency opportunity. Initiatives such as the Green Grid, a global consortium dedicated to data centre efficiency and information service delivery, working towards new operating standards and best practices, has attracted support from the industry.³⁶

³⁶ Green Grid data centre efficiency metrics such as power usage effectiveness (PUE) and data centre infrastructure efficiency (DCiE) can help operators improve efficiency and reduce costs, <http://www.thegreengrid.org/>

³⁷ Cable accounts providing broadband but not cable TV.

³⁸ Mobile analysis includes both voice and data. It includes a range of existing technologies, GSM, CDMA, EDGE, 3G, etc.

Telecoms infrastructure and devices

Increased mobile phone and internet use over the past few years has driven a parallel increase in telecoms infrastructure. Fixed-line, narrowband and voice accounts are expected to remain fairly constant overall, but the number of broadband accounts – operated by both telecoms and cable operators³⁷ – will more than double 2007–2020 and mobile accounts³⁸ will almost double during the same period. From 2002, the growth in telecoms emissions has grown from 150 MtCO₂e in 2002 to 300 MtCO₂e in 2007 and is expected to reach 350 MtCO₂e in 2020.

The relative share of telecoms devices remains fairly constant, but the mobile network will come to dominate the overall telecoms footprint by 2020 (**Fig. 5**).

Telecoms devices

The use of mobile phones, chargers, internet protocol TV (IPTV) boxes and home broadband routers is set to increase over the next 12 years, due in the most part to growth in China and India, where the middle classes will catch up with the current telecoms penetration of developed countries. The telecoms devices global footprint was 18 MtCO₂e in 2002 and is expected to increase almost threefold to 51 MtCO₂e by 2020,³⁹ driven mainly by rises in the use of broadband modems/routers and IPTV boxes, which will expand from a small user base (**Fig. 6**).

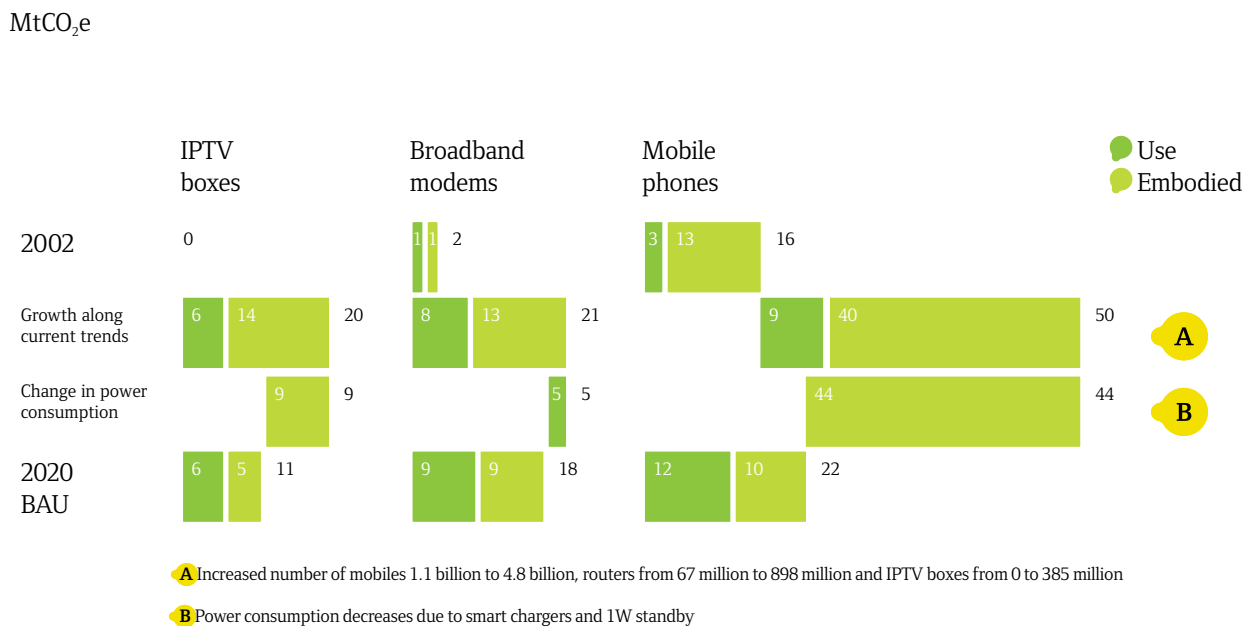
Calculating the telecoms devices' footprint in 2020

In 2002, there were 1.1 billion mobile accounts. This is set to increase to 4.8 billion in 2020 and is the largest source of global telecom footprint emissions. Increased access to broadband will also have an impact – the number of routers will grow from 67 million in 2002 to 898 million in 2020. Increasingly, broadband is also accessed over IPTV boxes. Although none of these was sold in 2002, if current trends continue 385 million may be in use by 2020.⁴⁰ The total impact of these increases is set out in Row **A** of **Fig. 6**.

The majority of emissions from mobile devices come from standby mode, the power (sometimes known as phantom power) used by chargers that are plugged in but not in use.

Unlike PCs and data centres, the overall consumption of telecoms devices is set to decrease over the 2020 timeframe because 'smart chargers'

Fig. 6 The global telecoms devices footprint



(those that turn off when a device is not connected) and 1W (or lower) standby standards are rapidly becoming commonplace. The footprint of mobile phones therefore increases 4%, given that a sharp decrease in charger consumption offsets the growth in number of accounts. Broadband routers and IPTV boxes increase their footprint comparatively more thanks to higher penetration from a small base today (Row **B**).

Mobile phones will contribute a smaller share of the telecoms devices' footprint in 2020, if predicted power consumption reductions from smart chargers and standby modes materialise.

Reducing telecoms devices' emissions further

The footprint of telecoms devices can be reduced further if devices produce fewer emissions in manufacturing, or if less – and greener – electricity is used by the device during its lifetime. Attractive offers that allow service upgrades without trading the phone in are already increasing the life of the mobile device itself. Some companies have announced that they will experiment with more custom ordering of phones, so that only the requested features are built into the physical device, lowering the carbon emissions that are due to manufacturing.

Telecoms infrastructure

As the demand for telecoms devices grows so, inevitably, will the need for the infrastructure that supports it. This growth is due not only to increases in the number of broadband and mobile accounts in emerging economies, but is also to the sharing of videos and games and other peer-to-peer content exchange.

The telecoms infrastructure footprint, including ongoing energy use and carbon embodied in the infrastructure, was 133 MtCO₂e in 2002. This is expected to more than double to 299 MtCO₂e by 2020, a growth rate of 5% pa⁴¹ (Fig. 7).

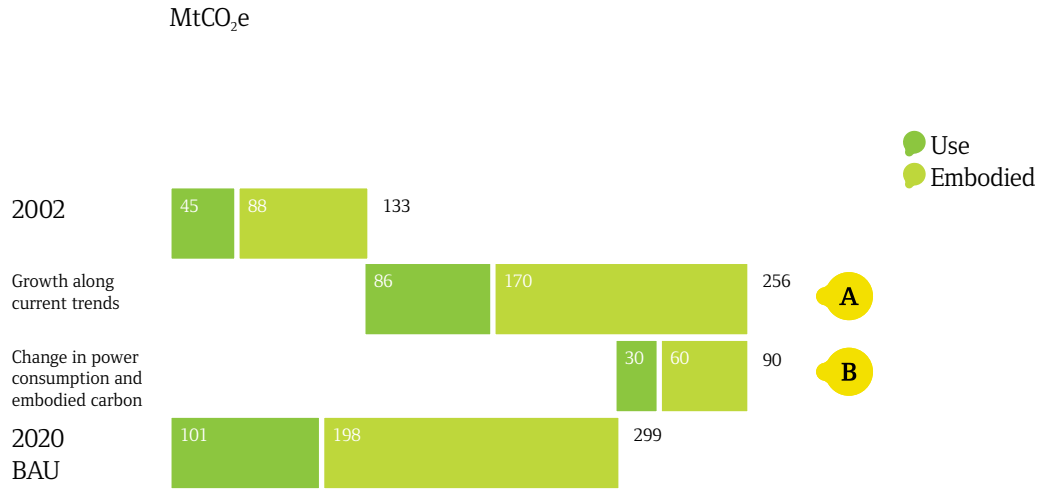
Calculating the telecoms infrastructure footprint in 2020

A key contributor to carbon emissions in 2020 will be mobile networks, driven largely by the increase in base stations and mobile switching centres. However, emissions from networks cannot be calculated based on the hardware used in the network alone, nor were data available from each provider on specifically how much energy their networks consumed. Therefore, the analysis used the reported energy consumption of eight telecoms providers and the increased number of mobile, fixed and broadband accounts – from 2.3 billion in 2002 to 7 billion in 2020 –

³⁹ Analysis included data from; Schaefer C., C. Weber and A. Voss (2003), 'Energy usage of mobile telephone services in Germany', Energy, Volume 28, Issue 5, pp411-420; Bertoldi, Paulo (2007), 'European Code of Conduct for Broadband Equipment', European Commission DG JRC, http://www.itu.int/dms_pub/itu-t/oth/09/05/T09050000010004PDFE.pdf

⁴⁰ Figures based on Yankee Group and IDC estimates and McKinsey trend extrapolation. Embodied carbon from manufacturing and distribution estimated from manufacturer studies for mobile phones and from laptop comparisons for other devices.

Fig. 7 The global telecoms infrastructure footprint



A Increased number of accounts from 2.3 billion to 7 billion (fixed, broadband and mobile)*

B Decrease in power consumption and embodied carbon due to expected adoption of efficiency measures

*Based on Yankee estimates until 2011 and trend extrapolation to 2020.

to calculate the overall footprint of the network. The total was 256 MtCO₂e: see Row **A** of Fig. 7.

The uncertainty in the telecoms figures is worth noting. Looking at the eight providers, the analysis found a wide range in the energy consumed per subscriber per year – anywhere from 23 kWh to 109 kWh, even when the composition of services offered by the operator was similar.⁴²

There could be a number of reasons for this. First, the operators offering similar services may configure their networks differently. They may also outsource parts of the network that consume energy, including the entire transmission and switching components of the network in the case of virtual operators and therefore don't report on the energy consumption of external providers along their value chain. In addition, the energy consumption of some network providers is dominated by services offered to businesses and governments rather than consumers.

In general, the distribution of energy consumption within the telecoms network is poorly understood and the impact of further adoption of interconnected devices is unknown. However, telecom operators are beginning to use new network management tools to better understand the distribution of energy consumption within the telecoms network,

the impact of the adoption of interconnected devices and the network services they deliver. This will enable them to plan for significant energy efficiency improvement. The analysis therefore took expected growth in the number of consumer connections as a proxy for growth across the entire telecoms network.

Overall, a decrease in power consumption of telecoms networks per user is expected, owing to the adoption of efficiency measures and is included in the 2020 footprint. For example, mobile infrastructure technologies currently available include network optimisation packages which can reduce energy consumption by 44% and solar-powered base stations, which could reduce carbon emissions by 80%.⁴³ The expected adoption of these measures by 2020 would lead to the avoidance of almost 60 MtCO₂e in 2020 (Row **B**).

Figures from one European telecoms company show that electricity use per information unit decreased between 2003 and 2005 by 39% pa but this has been more than negated by an increase in bandwidth requirements of 50% annually.

This will continue to be the case: expected significant improvements in the energy efficiency of base stations, routers, switches and other network infrastructure equipment are

⁴² A figure of 50kWh per year per subscriber was therefore used to calculate the footprint.

⁴³ Abatements included network optimisation packages (44% reduction in energy consumption possible, 80% expected adoption by 2020), more efficient base station amplifiers (9% reduction in energy consumption possible, 50% expected adoption by 2020), advanced standby power management (15% reduction in energy consumption possible, 50% expected adoption by 2020), night battery operation (50% reduction in energy consumption possible, 10% expected adoption by 2020) and solar-powered base stations (81% reduction in energy consumption possible, 10% expected adoption by 2020).

unlikely to compensate for the increase in overall demand. Therefore, though total energy use and associated emissions will continue to rise, it is decoupled from the growth in users of the equipment.

Reducing telecoms infrastructure emissions further

Further abatements are possible that are not included in the current 2020 BAU scenario. For example, if the technologies discussed above were 100% adopted, an additional saving of 42 MtCO₂e could be achieved in 2020. However, it is not always possible to implement these technologies at scale. For example, it is not currently cost effective to implement night battery operation and solar-powered base stations can be used only in certain climates.

Natural ventilation is already being used by some operators and would reduce the need to cool the base station and core network equipment. In addition, companies are experimenting with “network sharing”, which reduces the need to construct new networks, and tracking the energy consumption reduction benefits. Clarification on best practices in these areas is expected.

Green power generation

The direct carbon footprint of the ICT sector is dominated by electricity consumption, so an obvious way to reduce emissions is to use as much electricity as possible from renewable sources.

ICT companies can do this by purchasing renewable electricity, by installing renewable generation on their sites and by making renewable electricity integral to their products.

The sector can also encourage policy makers to create the right regulatory and fiscal environment to encourage investment in large-scale renewable generation as this will ultimately lead to a reduction in the ‘in use’ phase of the ICT product life cycle.

In fact, as outlined in Chapter 3 (smart grids), the sector is uniquely placed to partner with power companies to optimise the existing electricity grid to allow more efficient power distribution and enable the use of more renewable or green power. ●

Next generation networks (NGN) were not explicitly included in the analysis as there was little consistent data globally on NGN energy reductions. But in some countries, NGN will be rolled out before 2020, which could change the projections in this section. In addition, there is currently a lot of discussion over next generation access (NGA). This essentially means providing faster fixed-line access over fibre optics, rather than copper, all the way to customer premises. Again there was insufficient whole life data to include this in the analysis. Over time both these technologies could deliver further carbon reduction, but there could be an increase in emissions over the transition period.

Additional emissions abatement could be realised by changing the network design to optimise overall network consumption and by rolling out the most energy and carbon-efficient network architecture available today. Older networks in developed countries continue to be supported; however, this is not the case in the emerging markets where greenfield and “leapfrogging” technology adoption needs to be geared to low carbon infrastructure. The full potential of the best available technology today is unlikely to be realised without cost incentives for consumers or other types of policy intervention.

The challenge of reducing the ICT sector's footprint

The invention of the transistor in the 1950s marked the dawn of the digital age. It introduced personal computing on the one hand and high-capacity, fixed and mobile telecommunications on the other. The convergence of these technologies is most evident in the ubiquitous internet.

In 1965 Gordon Moore observed that the density of transistors in integrated circuits was doubling every 18 months. Now famously known as Moore's Law, this phenomenon has continued to the present day and has meant that the energy consumption per bit of information processed or transmitted has fallen by many orders of magnitude.

However, absolute growth in the use of digital technologies in developed world economies has led to an ever - increasing carbon footprint. And, as this analysis shows, without major paradigm shifts in technological development, the growth in both usage and footprint is likely to continue as more and more people worldwide enter the digital age.

As this analysis shows, without major paradigm shifts in technological development, the growth in both usage and footprint is likely to continue as more and more people worldwide enter the digital age.

⁴⁴ Green Electronics Council's standard for PCs that goes beyond Energy Star.

In the course of this study it became apparent that it is easier to identify the carbon footprint of an individual piece of ICT hardware such as a mobile phone, or even a dedicated collection of technology capabilities, such as a data centre, than it is complex and converged network services – such as broadband – delivered to consumers, businesses and government. Creating a standardised methodology for the evaluation of whole life carbon footprints of both ICT products and services would provide better information to businesses and customers. In turn, this would help create customer pull for clean technology which would drive further innovation.

Although ICT offers many ways of reducing emissions in other sectors, the sheer scale of the challenge involved in stabilising the climate means that the sector also needs to step up its efforts in reducing its direct footprint. Whilst much has been done and some ambitious targets have already been set by a number of companies, (Appendix 4) the urgency of the situation calls for the ICT industry to use all of its high-technology creativity to reduce the energy consumption of its products and services as much as it can.

There are a number of barriers preventing the ICT sector from making further efficiency gains.

One of the biggest challenges is overcoming the lack of information about the emissions impacts of products and services, especially in the context of complex configurations and integration. In the case of telecoms networks, telecoms providers often don't know the energy consumption of specific services. There are also agency issues to overcome. For example, the person buying the company's servers may not be responsible for their operating costs and therefore may

not include maximum efficiency as part of their buying specification.

Once more is known about the performance of products and services, the next step is to improve them. There may be technological or market reasons why this remains a challenge. For example, constant radical innovation is required to keep making processors more efficient. Some efficiency gains could be made outside companies' direct control – in supply chains for instance – but there is a lack of understanding about how to achieve these.

Companies may be able to increase the energy efficiency of devices at little or moderate additional cost, but there is little point if consumers can't assess which products are the most efficient. Work in this area is ongoing – PC labelling schemes such as *Energy Star* and Electronic Product Environmental Assessment Tool (EPEAT)⁴⁴ in the US help. This report cannot detail all the activities currently underway, but the surge in interest in "Green IT" over recent months is likely to bring many more options for businesses and consumers.

But while efficiency of the ICT sector's own products must be actively pursued, the impact on the overall economy – in energy efficiency and dematerialisation – could yield emissions savings that are five times larger than its own footprint, close to 8 GtCO₂e, if all enabling opportunities are adopted. Communications technologies and services would provide an enabling platform that systematically delivers efficiency and replaces high-carbon activities with alternatives wherever possible. Realising this opportunity is a different sort of challenge, as it involves cross-sectoral partnerships and new business models, but will be a crucial component of the transition to a low carbon economy. ●



03: The enabling effect

⁴⁵ A number of studies in the past decade have looked at the role of ICT (particularly, broadband, IT services and mobile communications) in energy efficiency and climate change solutions including: their effects on the productivity of the economy; their ability to replace high carbon products and activities with alternatives; and their role in monitoring and environmental management. Though far from an exhaustive list, see for example: Laitner, S (2008), *Information and Communication Technologies: The Power of Productivity*, American Council for an Energy Efficient Economy (ACEEE); Romm, J (1999) *The Internet Economy and Global Warming*, The Global Environment and Technology Foundation (GETF); Pamlin, D. And K. Szomolanyi (2006) *Saving the Climate @ the Speed of Light*, WWF and ETNO; Mallon, K. (2007), *Towards a High-Bandwidth, Low-Carbon Future: Telecommunications-based Opportunities to Reduce Greenhouse Gas Emissions*, Climate Risk and Telstra; Fuhr, J.P. and S.B. Pociask, (2007), *Broadband Services: Economic and Environmental Benefits*, The American Consumer Institute; ITU (2008), *ICTs for e-Environment*.

⁴⁶ Additional opportunities (e.g. forestry monitoring applications) in other areas where emissions are high – such as land use – could increase the mitigation potential, but because of the much greater complexity involved they were not included in the analysis.

⁴⁷ Australian Government Department of Climate Change (2008), *National Inventory Report 2005 (Revised) – Volume 1; The Australian Government Submission to the UN Framework Convention on Climate Change*, <http://www.greenhouse.gov.au/inventory/>

The ICT sector has a powerful role to play in addressing climate change by enabling other sectors, such as transport, buildings, power and industry, to become more efficient.⁴⁵ Although the ICT sector's own emissions will rise as global demand for products and services increases, these are estimated to be five times less than the emissions that can be reduced through the “enabling effect.”

To realise this opportunity will require a radical transformation of current infrastructure: companies will need to identify and monitor energy use and employ the data obtained to become more efficient and ultimately transform the way they operate throughout value chains, cities, regions and whole countries. ICT underpins many of these mechanisms.

This report is the first to put a value on the global opportunity. It found that ICT could reduce global carbon emissions by 7.8 GtCO₂e by 2020 (from an assumed total of 51.9 GtCO₂e 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 (\$946.5 billion). **Fig. 8** shows the opportunity ICT has to reduce emissions by sector.

This chapter looks at five major opportunities for reducing emissions – dematerialisation, smart motor systems, smart logistics, smart buildings and smart grids – and in each case identifies the role for ICT and the hurdles to be overcome if the full potential is to be realised.⁴⁶ These opportunities were chosen based on the potential for ICT to drive emissions reductions in key regions around the world where the best data were available.

Aside from dematerialisation, which this report looks at in a global context, a specific region was chosen to demonstrate the other opportunities. This was done to provide further

detail regarding the regulatory and market context for realising the emissions reductions.

Dematerialisation

Dematerialisation – the substitution of high carbon products and activities with low carbon alternatives e.g. replacing face-to-face meetings with videoconferencing, or paper with e-billing – could play a substantial role in reducing emissions.

Fig. 8 shows that dematerialisation could be responsible for reducing emissions by 500MtCO₂e (detailed assumptions in Appendix 3), just less than Australia's total emissions in 2005.⁴⁷ However, as in all cases, there is some uncertainty about the exact emissions reduction figure because of the unpredictability of technology adoption and development. For instance, the “paperless” office has failed to materialise and telecommuting and first-generation videoconferencing have not been adopted as widely as expected. On the other hand, dematerialisation could have a larger than predicted impact from other future technological breakthroughs, not yet identified, that substantially change the way people live and work.

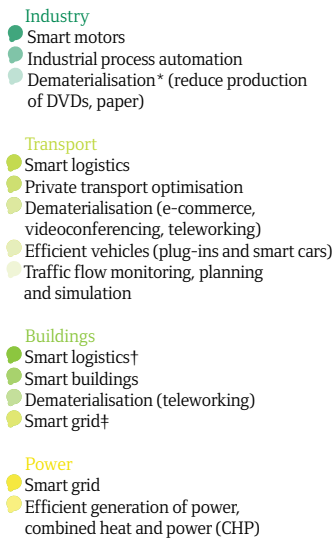
Like e-commerce, e-government could have a significant impact on reducing GHG emissions through the dematerialisation of public service delivery – particularly in countries where government constitutes a large share of the overall economy. For example, many paper-based services can be moved into the digital environment and situations where face-to-face interaction has been previously required (e.g. to prove identity) can be done virtually. There are also major energy efficiency gains to be achieved in the governmental supply chain. While many countries have already begun to implement e-government, the huge potential

Fig. 8 ICT: The enabling effect

GtCO₂e

7.8 GtCO₂e of ICT-enabled abatements are possible out of the total BAU emissions in 2020 (51.9 GtCO₂e)

The SMART opportunities including dematerialisation were analysed in depth



*Dematerialisation breaks down into all sectors except power. See detailed assumptions in Appendix 3.
†Reduces warehousing space needed through reduction in inventory. See Appendix 3.
‡Reduces energy used in the home through behaviour change. See Appendix 3.

of the low carbon public sector model remains significantly untapped.

Various dematerialisation applications where the most data were available are looked at below to identify the opportunities for mitigating emissions and the hurdles that prevent this potential from being realised.

The opportunity

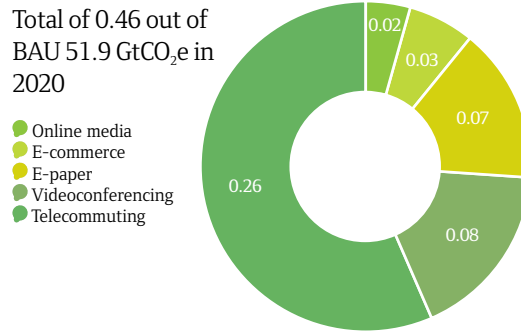
Dematerialisation can be applied to a range of current everyday practices and ultimately reduce the number of material objects that need to be produced. Online billing, media and music, replacing paper and CDs all, reduce the emissions associated with their manufacture and distribution. **Fig. 9** shows the impacts of these technologies on global emissions.

Currently the largest opportunity identified within dematerialisation is teleworking – where people work from home rather than commute into an office. Although other dematerialisation opportunities may come to prominence in the future, based on historic trends, the analysis found that teleworking would have the largest impact, up to 260 MtCO₂e savings each year (detailed assumptions in Appendix 3). For example, in the US, if up to 30 million people could work from home, emissions could be reduced 75-100 MtCO₂e in 2030, comparable to likely reductions from other measures such as fuel efficient vehicles.⁴⁸

External case studies seem to bear this out, but are not globally conclusive.⁴⁹ A UK Department of Transport study found

Fig 9. The impact of dematerialisation

GtCO₂e



Source: Expert interviews, January-March 2008

⁴⁸ Comparison based on abatement potential as outline in Enkvist P., T. Naucler and J. Rosander (2007), 'A Cost Curve for Greenhouse Gas Reduction', The McKinsey Quarterly, Number 1.

⁴⁹ TIAX (2007), 'The Energy and Greenhouse Gas Emissions of Telecommuting and e-Commerce', Consumer Electronics Association; Matthews H.S. and E.T. Williams (2005), 'Assessing Opportunities for ICT to Contribute to Sustainable Development', DG Information, Society and Media, European Commission.

⁵⁰ UK Department of Transport, 'Smarter Choices', <http://www.dft.gov.uk/pgt/sustainable/smarterchoices/>

⁵¹ Gartner; Matthews H.S. and E.T. Williams (2005), 'Assessing Opportunities for ICT to Contribute to Sustainable Development, DG Information, Society and Media, European Commission; TIAX (2007) *The Energy and Greenhouse Gas Emissions of Telecommuting and e-Commerce*, Consumer Electronics Association.

⁵² TelCoa - The Telework Coalition, *Greater Washington DC Telecommuting Online Survey Findings* May 2003, <http://www.telcoa.org/id110.htm>

that teleworking reduces the commuting car mileage travelled by teleworkers by 48-77% which, taking into account some increases in domestic travel, represents an 11-19%⁵⁰ reduction in both mileage and trips.

What the existing case studies show is that the impact of working from home varies depending on the amount of time spent at home and the efficiency of the economy in which teleworking is introduced. For example, if a significant number of people worked from home more than three days a week, this could lead to energy savings of 20-50%, even with the increase in energy used at home or non-commuter travel. Home-working allows employers to use or build smaller offices that require less energy to construct and maintain. However, the impact is much lower if take-up is lower than three days a week because it would still be necessary to maintain office space for periodic home-workers. Also, in efficient countries, such as Japan, the impact of teleworking may be reduced.

Tele- and videoconferencing – conducting meetings online or on the phone instead of face-to-face – could also reduce emissions. Previous conservative estimates have suggested that tele- and videoconferencing could replace between 5 and 20% of global business travel. Advanced videoconferencing applications in the early stage of adoption could have a very significant impact in highly distributed service industry environments in both the private and public sectors.

Dematerialisation could also reduce emissions indirectly by influencing employees' behaviour, building greater awareness of climate change and creating a low carbon culture throughout businesses, though these impacts are less quantifiable. Dematerialisation at the very least provides alternatives, allowing individuals to control their carbon footprint in a very direct way. First adopters could enable the cultural shifts necessary for ICT-enabled energy efficiency to take hold in the broader economy.

Hurdles to adoption

While dematerialisation undoubtedly has the potential to play a significant role in reducing emissions, it has had limited impact so far, mainly owing to low adoption rates. In 2005, only 1-2% of the US workforce teleworked,⁵¹ and many employers remain unsure about the technology. According to a survey by US teleworking coalition, TelCoa, 54% of companies thought that teleworking made it difficult for employees to collaborate and 46% thought it made it harder to manage employee performance.⁵²

Though technological barriers are not generally perceived as a major barrier to adoption, improvements here could contribute to a more positive attitude towards the technology. Many companies are still unwilling to adopt dematerialisation technology at higher rates because it requires adopting new ways of working with significant cultural shifts. Yet if it could be demonstrated that this new way was better and

easy to adapt to, adoption rates would improve.

There are signs that these attitudes are changing. The Economist Intelligence Unit recently launched a report based on a series of interviews with businesses that highlighted the low instance of including ICT technologies in climate change strategies. The report is optimistic that in the next few years this could change dramatically, but this will require a different approach from businesses and governments.⁵³

In terms of the broader dematerialisation opportunities outside the workplace, the challenge comes from the current global infrastructure. It does not yet support high-quality and affordable internet service to all consumers and businesses, though there are significant regional variations: most households in Europe and North America are not equipped to receive high quality digital services,⁵⁴ Asia Pacific and the rest of the emerging markets are leapfrogging old technologies and installing high-speed broadband as standard, which makes a shift towards a dematerialised way of life easier.

Overcoming the hurdles

There are a number of solutions to combat these challenges, some of which are already being implemented. They include:

- Developing company/institution blueprints for telecommuting that can be piloted and rolled out in phases
- Analysing where substitution could have the most impact and providing governments with the information they need to develop effective policy to promote these solutions
- Cities and national governments taking a leading role in promoting the delivery of broadband infrastructure, supporting advanced collaboration technologies and building remote working sites just outside city centres.

What is at stake?

The opportunity for dematerialisation to reduce carbon emissions could be substantial – 500 Mt CO₂e in 2020 – but its effectiveness depends on behavioural changes, which makes it hard to assess how quickly its true potential will be realised.

In addition, future social change facilitated by near-ubiquitous connectivity (mobile or broadband), could enable greater emissions reductions than this report suggests.

The next generation of professionals are already equipped with the tools and knowledge to take dematerialisation forward, attending to many activities and aspects of their lives online. Studies on the networking and mobile use of 10- to 16-year-olds shows that they are actively using collaborative technologies and may develop very different ways of working in the future.⁵⁵

But, as noted earlier, the carbon emission reduction opportunity that dematerialisation offers is relatively small compared with the mitigation opportunities to be found in applications that cover larger emissions bases for enabling greater efficiency in other industrial sectors. For example, emissions globally from commuters and the buildings that support them is 830 MtCO₂e, so an ambitious 31% implementation of teleworking yields 260 Mt CO₂e emissions savings. On the other hand, reducing 15% of the 4.6 GtCO₂e emitted by industrial activity would yield 680 MtCO₂e of savings globally.

The efficiency opportunities in industry, transport, power and buildings created by ICT (7.3 GtCO₂e in total) are covered in more detail below.

SMART motor systems

Motor systems – devices that convert electricity into mechanical power – lie at the heart of global industrial activity. These include transformers such as those used in compressors and pumps and variable speed drives (VSD) used in conveyor belts and elevators. Though invisible to most of us, these devices are crucial to the manufacturing sector and, as this sector expands, so does energy demand. Carbon emissions as a result of energy used by the growing manufacturing industry in regions such as China increase still further, as most of the electricity required will be generated using carbon-intensive coal-fired power stations.⁵⁶

The global context

Industrial activity is one of the largest contributors to global emissions, responsible for 23% of total emissions in 2002 (9.2 GtCO₂e). It uses nearly half of all global electrical power generated, industrial motor systems using the majority (65%) and by 2020, motor systems will be responsible for 7% of global carbon emissions (Fig. 10.1).

⁵³ Economist Intelligence Unit (2008), *Managing the Company's Carbon Footprint: The Emerging Role of ICT*, http://www.viewswire.com/report_md.asp?mode=fi&fi=1723298157.PDF&rf=0

⁵⁴ Technology may be a barrier, but was not identified as such in this analysis. However, 10 Mbit/second access is more readily available to about one third of households in Western Europe and Asia, much less so in North America or Eastern Europe.

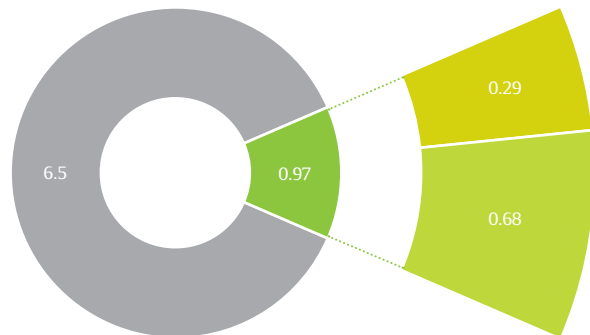
⁵⁵ Boyd, Danah. (2007) *Why Youth (Heart) Social Network Sites: The Role of Networked Publics in Teenage Social Life.* in David Buckingham (ed.), *MacArthur Foundation Series on Digital Learning – Youth, Identity and DigitalMedia Volume*, (Cambridge, MA: MIT Press).

Fig 10.1. SMART motor systems: The global impact in 2020

GtCO₂e

Total emissions BAU in 2020 = 51.9 GtCO₂e

- Total emissions from power used by industrial systems
- Total ICT smart motor system abatements
- ICT-driven automation in key industrial processes
- Optimisation of variable speed motor systems



⁵⁶ About 70% of power consumed in China is generated by coal – China Statistical Yearbook, 2006.

⁵⁷ Government of New South Wales, *Energy Smart Business Program*, <http://www.energysmart.com.au/wes/default.asp?&t=200852216>

⁵⁸ BC Hydro, *Power Smart for Business*, <http://www.bchydro.com/business/pspartner/pspartner51113.html>

⁵⁹ Consortium for Energy Efficiency, Inc., *Motor Decisions Matter*, <http://www.motorsmatter.org/index.html>

⁶⁰ Government of New South Wales, *Energy Smart Business Program: Unlocking Energy Efficiency Opportunities in the Industrial Sector*, http://www.energysmart.com.au/wes/images/pdf/technical_paper_heavy_industrial_final.pdf

⁶¹ IEA (2007), *Tracking Industrial Energy Efficiency and CO₂ Emissions*, <http://www.iea.org/Textbase/npsum/tracking2007SUM.pdf>

ICT could play a significant role in mitigating global carbon emissions from motor systems and industrial process optimisation, up to 970 MtCO₂e in 2020. These opportunities are not going unnoticed – initiatives such as *Energy Smart*⁵⁷ in Australia, BC Hydro’s *Power Smart*⁵⁸ in Canada and *Motor Decisions Matter*⁵⁹ in the US are all working with businesses to identify optimal use of smart motors in their processes and the carbon and economic savings are substantial. Indeed, the *Energy Smart Business Program* states that properly sized, energy efficient motors with electronic VSD and improved gears, belts, bearings and lubricants use only 40% as much energy as standard systems and, in financial terms, with a four-year payback project, VSD installations for the control of conveyors and combustion and ventilation fans can deliver energy savings upwards of AUS\$120 million (€73 million/\$115 million) a year.⁶⁰

The opportunity: How ICT can help

Motors can be inefficient as they operate at full capacity, regardless of load. A motor is ‘smart’ when it can be controlled to adjust its power usage to a required output, usually through a VSD and intelligent motor controller (IMC), a piece of hardware controlling the VSD.

There is a lack of information about energy consumption in motor systems and where savings can be made within a factory. ICT’s main role in the short term, therefore, will be to monitor energy use and provide data to businesses so they can make energy and cost savings by changing manufacturing systems. These data may also be useful for organisations setting standards for

motor system efficiency. The ICT sector has additional roles to play. Simulation software is required to help improve plant and manufacturing process design. Wireless networks that allow inter-machine and system communication, would improve efficiency across an entire factory. **Fig. 10.2** summarises the role ICT could play in improving motor and industrial system efficiency.

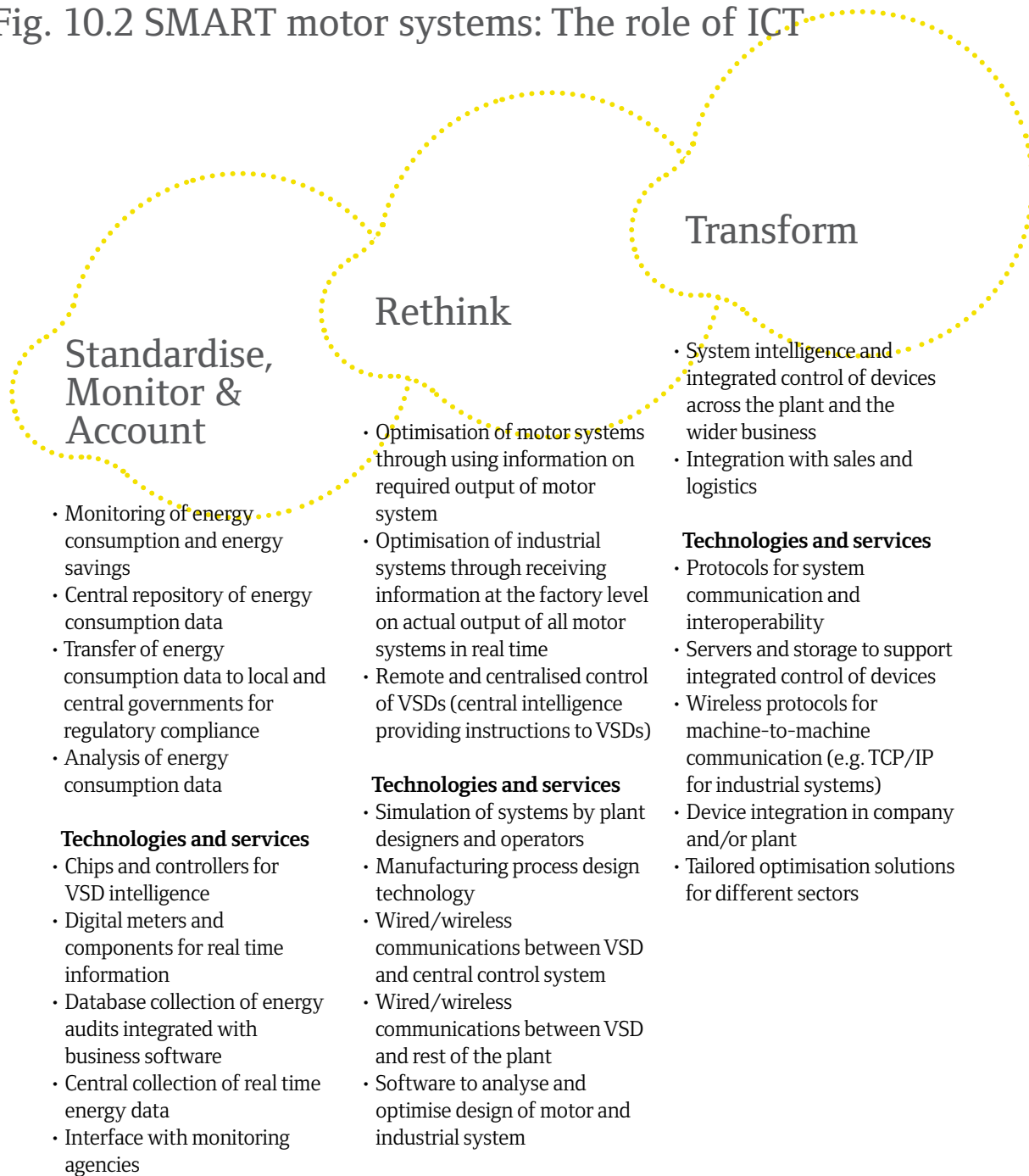
The opportunities for industry in adopting ICT-driven improvements to reduce their climate impact are clear – perhaps nowhere more so than in countries where business is booming. Given that much of the growth in industrial energy demand has been in emerging economies, with China alone accounting for about 80% of the growth in the last 25 years,⁶¹ the potential for large-scale utilisation of smart motor systems will be greatest there.

Smart motor systems in China

Manufacturing is the engine of China’s economic growth and will continue to be so until 2020, but even now it is struggling to cope with the heavy demand on its energy resources. Between 2004 and 2006 there were serious power shortages and two years ago, 26 out of 31 mainland provinces cut power for industrial and residential customers.

Motor systems are part of the reason for this: they currently use 70% of total industry electricity consumption and are 20% less energy efficient than those in Western countries. By 2020, industrial motor systems in China will be responsible for 34% of power consumption and 10% of carbon emissions, or 1-2% of global emissions.⁶²

Fig. 10.2 SMART motor systems: The role of ICT



“We cannot underestimate the potential influence that wireless communications can bring to the manufacturing process and control.” **Electronic Engineering Professor, Chinese University**

⁶² Analysis includes data from IEA (2007), ‘World Energy Outlook: China and India Insights’; Enkvist P., T. Naucner and J. Rosander (2007), ‘A Cost Curve for Greenhouse Gas Reduction’, The McKinsey Quarterly, Number 1.

* €18,298/\$28,885 - based on exchange rate figures obtained at <http://www.xe.com> on 9th June 2008 at €1=10.9300 RMB and \$1=6.92400 RMB respectively.

⁶³ This assumes a replacement rate on historic trends of 10% per year. IEA Industrial Motor Systems Efficiency workshop (May 2006); Nadel S., W. Wanxing, P. Liu, A. McKane (2001), ‘The China Motor Systems Energy Conservation Program’, LBNL.

ICT has an important role to play in making Chinese industry more efficient and with government regulation aiming for a 20% increase in energy efficiency by 2010 relative to 2005, saving energy is high on the agenda for industry.

“We have spent RMB 200,000* on simulation software. It helps us calculate the optimal value for multiple variables in our steam network.” **Manufacturing Planning Manager, Multinational Auto Manufacturer**

Industrial energy use in China could be reduced by 10% by improving the efficiency of motor systems. VSDs, which control the frequency of electrical power supplied to the motor, thereby adjusting the rotation speed to the required output, are the most effective means of saving energy - up to 25-30%. IMCs, which monitor the load condition of the motor and adjust the voltage input accordingly, offer minor efficiency gains (3-5%), but have the benefit of extending the motor lifespan, which reduces the number of new motors required and therefore the manufacturing emissions associated with this.

The impact of these measures on emissions reduction would be substantial. Motor system optimisation alone could reduce China’s emissions by 200 MtCO₂e by 2020.⁶³ This is comparable to the total 2006 level emissions from the Netherlands.

“Our research is focusing on tailored and integrated solutions for entire plants in different sectors.” **Marketing Director, Leading Chinese Automation Manufacturer**

“End users don’t directly buy small and medium-sized motors. They buy machines. Energy efficiency is not a major decision factor for these end users. Therefore, machine manufacturers

have no incentives to install VSD.” **Director of Information, Beijing Office, Electric Motor industry Body**

Hurdles to adoption

There are a number of hurdles preventing companies from adopting smart motor technology. These are:

- Lack of capital for investment in the integrated automation and ICT technologies required
- Poor awareness of the business case for reducing energy use through optimisation
- Reluctance to install technology for fear of disrupting production processes and losing revenue
- A lack of capacity and skills to operate advanced automation technologies
- A lack of nationwide standards or certification
- Out-of-date infrastructure that can’t run new systems.

“Even though there is a good business case, Chinese companies either do not trust the business case or take a short-term view. They prefer upfront cash to promised future cash flows.” **Director, Environmental NGO**

“The more you produce, the more you earn. Manufacturing disruptions mean revenue losses.” **Engineering Professor, Chinese University**

Overcoming the hurdles in China

There are a number of possible ways to overcome these hurdles. These include:

- Providing benchmarking, showcasing the most successful initiatives
- Implementing automated auditing of the most energy-intensive businesses, with aggressive energy use reduction targets and target monitoring

- Creating government subsidies for best-in-class technology adoption
- Providing low-interest loans to fund energy efficiency within industries
- Making financing mechanisms, such as energy service companies (ESCOs), available to procure energy efficiency as a service
- Developing internationally recognised ICT architectural standards for integration of efficient motor systems to enable ICT platforms
- Undertaking further research on the role of ICT and motor systems in industrial automation.

In China, a number of these solutions are already being implemented. Faced with the recent power shortages, the Chinese government has begun to tackle energy efficiency as a matter of urgency and there are now a significant number of policy measures to improve it.

The 11th five-year plan – a rolling programme for 2006-2010 – sets a national goal of a 20% improvement in energy efficiency. The Chinese government is undertaking relevant benchmarking to ensure this target is achieved, allowing Chinese companies to compare their energy efficiency performance against each other and multinational corporations (MNCs). The government has also launched the *China Motor Systems Energy Conservation Programme* and 10 key energy saving programmes, one of which focuses on motor system optimisation in energy intensive industries such as coal mining.

The *End-Use Energy Efficiency Programme* (EUEEP) run by the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) invest millions in efficiency projects. Additionally, the Chinese government is working with the top 1,008 most energy-intensive businesses, auditing their energy use, proposing aggressive energy use reduction targets and providing consulting and skill building to help companies reach these targets.

Government subsidies are now available to pay the difference between regular and high-efficiency motors and up to 20% of VSD installations, which will help deal with the lack of capital available for companies to invest in the new technologies. To increase awareness and to strengthen the business case, the Ministry of Science and Technology is financing and publishing research on areas such as motor system energy-saving technology for the mining industry

and mid-voltage, high-efficiency VSD.⁶⁴

The Energy Foundation also invests in developing policies to improve energy efficiency and overcome institutional barriers. The International Finance Corporation (World Bank) has a new *China Utility-based Energy Efficiency Finance Program* (CHUEE) with over \$50 million (€78.8 million) invested in many projects. In addition to this, further international funding mechanisms could also be made available to provide support to this process.

There is also a nascent market for ESCOs operating in China, financed by the World Bank and GEF. These companies engage in performance contracting and get paid for each kWh saved, usually based on contracts of five to six years.

The emphasis on energy efficiency in China means that both MNCs operating in the control systems market and smaller local players are growing their businesses fast. Local players are small compared with MNCs, but serve local small and medium-sized enterprises (SMEs) and therefore the Chinese automation market is expected to continue to grow rapidly, rising by 29% between 2007 and 2011.⁶⁵

What is at stake?

Assuming a carbon price of €20(\$31.5)/tCO₂e, emissions reductions of 200 MtCO₂e by 2020 would represent a saving of up to €4 billion (\$6.3 billion) pa in carbon costs. Savings in electricity use would be worth €8 billion (\$12.6 billion) pa. The total value for ICT and other high tech companies in China would therefore be €12 billion (\$18.9 billion) pa by 2020 (detailed assumptions in Appendix 3).

Whereas China offers the largest potential saving because of the size and inefficiency of its manufacturing base, ICT could reduce emissions in any industrial process throughout the world. This opportunity would be worth €68 billion (\$107.2 billion) in 2020.

SMART Logistics

Global goods transport is growing rapidly, as a result of globalisation and global economic growth. The logistics of this vast operation (including packaging, transport, storage, consumer purchasing and waste) are inherently inefficient. For instance, vehicles often carry little or nothing on return journeys. As fuel costs and

⁶⁴ Analysis includes data from expert interviews, January 2008.

⁶⁵ IDC (2007)

⁶⁶ Compared with 23% from industry (process emissions and direct emissions from primary energy use), forestry (14%) and agriculture and waste (18%). IEA (2004), *World Energy Outlook*.

taxes rise, the need to run more efficient logistics operations is increasingly important. ‘Smart logistics’ comprise a range of software and hardware tools that monitor, optimise and manage operations, which helps reduce the storage needed for inventory, fuel consumption, kilometres driven and frequency of vehicles travelling empty or partially loaded.

The global context

The transport sector is a large and growing emitter of GHGs, responsible for 14% of global emissions.⁶⁶ The majority of logistics emissions come from transport and storage. Optimising logistics using ICT could result in a 16% reduction in transport emissions and a 27% reduction in storage emissions globally.

ICT-driven applications across logistics could achieve a reduction in total global emissions of 1.52 GtCO₂e (Fig. 11.1). Although this figure is relatively modest compared to reductions offered

by other ICT-driven solutions in this report, the opportunities to make the logistics industry more efficient have important economic considerations, since it operates such a high-value market. In 2005, the value of the global logistics industry was estimated at \$3.5 trillion (€5.5 trillion).⁶⁷

The opportunity: How ICT can help

ICT can improve the efficiency of logistics operations in a number of ways. These include software to improve the design of transport networks, allow the running of centralised distribution networks and run management systems that can facilitate flexible home delivery services. Specific levers include intermodal shift, or moving to the most efficient type of transport, eco-driving, route optimisation and inventory reduction. There are a number of specific technologies that could already enable more efficient logistics,⁶⁸ as set out in Fig. 11.2.

Fig. 11.1 SMART logistics: The global impact in 2020

GtCO₂e

Total emissions
BAU in 2020 =
51.9 GtCO₂e

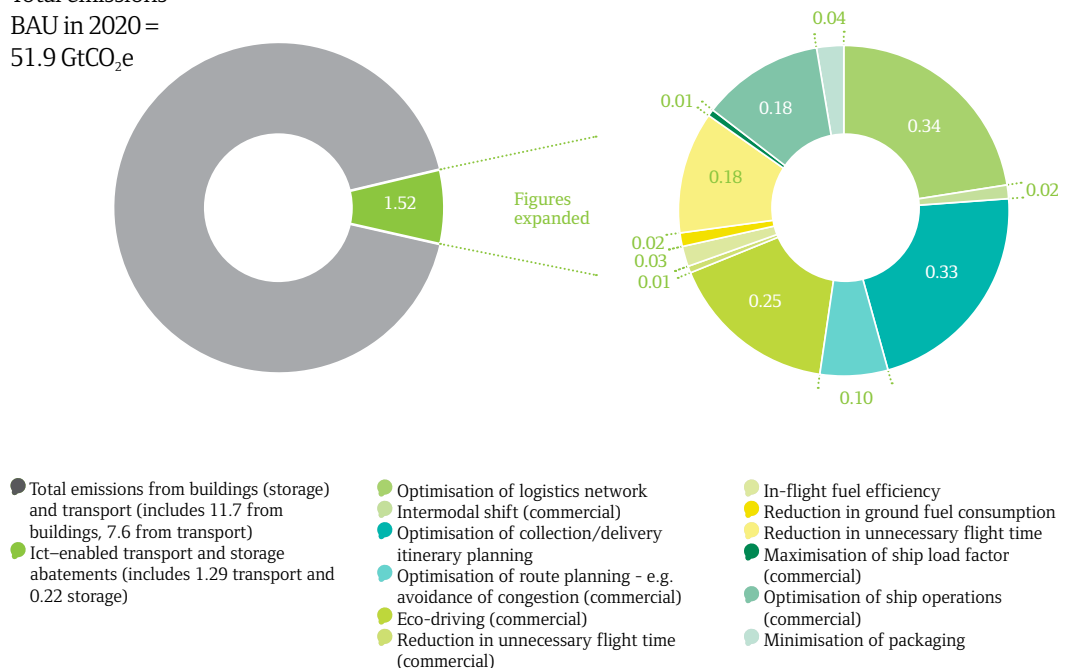
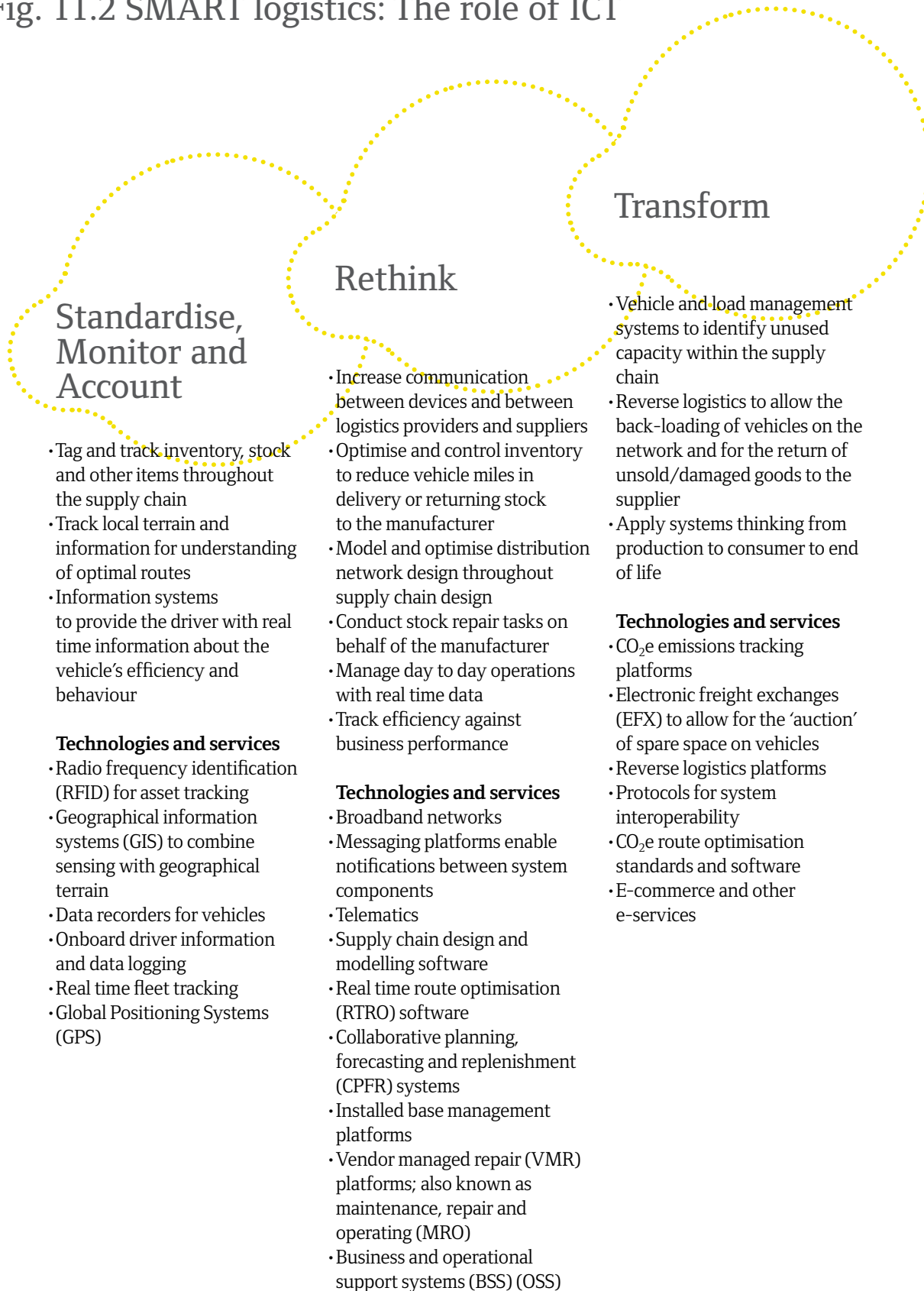


Fig. 11.2 SMART logistics: The role of ICT



“People have a tendency to look at a single element of the system rather than looking at the whole system.”
Senior Executive, Logistics Software Provider

⁶⁷ Wall Street Research, <http://www.wallstreetresearch.org/reports/wkol.pdf>

⁶⁸ Analysis included data from expert interviews, Jan – Feb 2008.

⁶⁹ BAU transport emissions are projected to rise at 1.8% pa to 2020 and beyond to 2030, mainly owing to Europe’s ongoing economic growth, aviation transport being the fastest growing in the sector. IEA (2007); Herzog T., J. Pershing and K. Baumert (2005), ‘Navigating the Numbers: Greenhouse Gas Data and International Climate Policy’, World Resources Institute; WBCSD (2000), *Sustainable Mobility Project (SMP) Transport Model*.

⁷⁰ Between 2003 and 2005, goods imported into the EU increased from 2,101 to 2,170 million tonnes, an increase of 4%. The weight of goods transported within the EU-25 rose from 1,400 to 1,500 million tonnes in the same period, also an increase of 4%. Global Insight; EU (2006), *Energy and Transport in Figures*, http://ec.europa.eu/dgs/energy_transport/figures/pocketbook/2006_en.htm

⁷¹ Expert interviews, Jan - Feb 2008.

The barrier posed by this fragmentation is vast, yet the industry is consolidating. Some of the best examples of this development can be seen in the European context.

SMART logistics in Europe

There are a number of different types of companies involved in the logistics industry, including those that help clients integrate their supply chain, provide warehousing, transport and IT services and make deliveries. It’s a rapidly expanding market: logistics activities are predicted to grow by 23% between 2002 and 2020, representing 18% of European GHG emissions in 2020. The majority of logistics emissions come from transport and storage.

These emissions have been growing and are likely to continue to do so in the long term.⁶⁹ Rising consumption, as indicated by a 2% growth in OECD Europe’s real GDP between 2000 and 2005, has increased goods transportation and cross-border trading.⁷⁰ Manufacturing often occurs far from the point of sale and products contain parts manufactured in multiple locations, which has also contributed to the increase.

Several barriers⁷¹ are preventing the widespread adoption of energy efficiency measures, the most significant of which is the high level of fragmentation in European logistics. But these also opportunities for ICT and other high-tech companies.

Hurdles to adoption

While some early adopters are taking up smart logistics technology, many are not for a number of reasons:

- European road freight market is fragmented, which creates natural inefficiencies and hampers capital investment in energy efficiency technologies

- Logistics operators and service providers tend to take a short-term approach to investment in improving efficiency
- The existing infrastructure is outdated, making it hard for wholesale changes to be implemented
- Lack of industry standards prevents interoperability between the many different systems that currently exist within the logistics industry
- Anti-competition regulations often prevent cooperation between companies: e.g. major supermarkets in the UK can’t work together to create a shared logistics chain.

“Railways give primacy to passenger travel, which means that freight can be delayed by significant amounts of time.” **Head of Research, Global Logistics Service Provider**

“80% of fleets in the UK have less than five trucks.” **Analyst, UK Government Agency**

“In order to realise the benefits of a new technology, logistics companies need to re-engineer some of their processes.” **Professor, UK University**

Overcoming the hurdles in Europe

There are a number of current technologies and strategies that could improve the efficiency of logistics. These include:

- Integrating systems across the supply chain to allow sharing of information between planning and execution to provide visibility across the system
- Calculating and monitoring the carbon footprint across the region through ICT solutions
- Developing a common protocol for freight exchange to allow small players to exchange

freight and maximise load

- Allowing exceptions to anti-cooperation laws in areas where significant efficiency gains are possible.

Some initiatives are already underway to tackle these hurdles. The French road transport industry is undergoing significant consolidation and this is starting to spread to the rest of Europe. Significant merger and acquisition activity has taken place over the past few years.⁷² Air and ocean transport players are busy consolidating, too. The top 10 container shippers had 37% of the market in 2000; by 2006 that had increased to 65%.⁷³ Further consolidation would make it easier for the industry to adopt common practices and standardise logistics efficiency improvements in the future.

Several large shipping companies have announced plans to track and reduce logistics-related emissions in the future. Six of them have formed the *Supply Chain Leadership Coalition* to press suppliers to release data on their emissions and climate change abatement strategies.⁷⁴

There are signs that rising fuel costs are starting to force operators to improve efficiency.

A survey of the top 100 freight shipping companies found that 26% of importers and 28% of exporters reported on their emissions, while 7% of importers and 10% of exporters said they had reduced emissions.⁷⁵

What is at stake?

As fuel prices rise, logistics companies will accelerate their adoption of ICT-based energy efficiency solutions, which will have a huge impact on reducing their emissions – up to 225 MtCO₂e by 2020, 27% less than BAU. The value of the potential savings through more efficient commercial road transport alone (161 MtCO₂e) is estimated to be up to €33 billion (\$52 billion) in Europe.

Improving the efficiency of logistics globally is a much larger opportunity. With emissions reductions potential of around 1.52 GtCO₂e and assuming a carbon price of €20 (\$31.5)/tCO₂e, this could be worth as much as €280 billion (\$441.7 billion), of which €251 billion (\$395.9 billion) is from energy savings and €29 billion (\$45.7 billion) from carbon costs (Appendix 3).

⁷² Analysis includes data from Eurostat; Lloyd's Register (www.lr.org/Services/Shipping+information.htm); Drewry Shipping Consultants (<http://www.drewry.co.uk/>); CI-online (www.ci-online.co.uk/); MergeGlobal (<http://www.mergeglobal.com/>); International Air Transport Association (www.iata.org/index.htm); American Shipper (www.americanshipper.com); Transport Topics (www.ttnews.com); US Census (www.census.gov/main/www/cen2000.html)

⁷³ *Ibid*

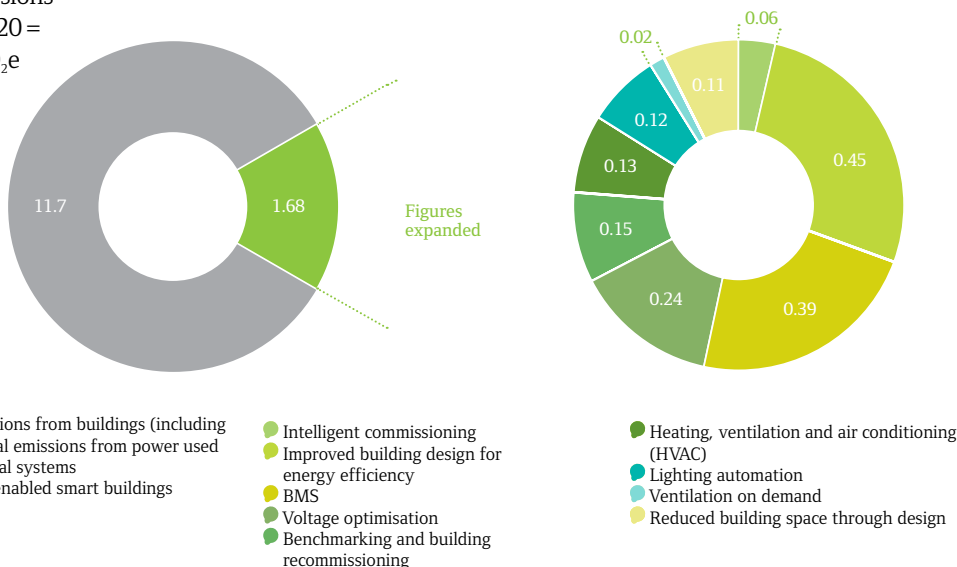
⁷⁴ CDP (2007), CDP Report 5, <http://www.cdproject.net/cdp5reports.asp>

⁷⁵ CDP (2007), CDP Report 5, <http://www.cdproject.net/cdp5reports.asp>; PIERS Journal of Commerce data (www.piers.com)

Fig. 12.1 SMART buildings: The global impact 2020

GtCO₂e

Total emissions
BAU in 2020 =
51.9 GtCO₂e



“Ideally, we could apply the principles of interoperability (‘plug and play’) to buildings. ICT plays a role, but the reality is ‘plug and pray’ rather than ‘plug and play’.” **Stephen Selkowitz, Lawrence Berkeley National Laboratory (LBNL)**

SMART Buildings

The term ‘smart buildings’ describes a suite of technologies used to make the design, construction and operation of buildings more efficient, applicable to both existing and new-build properties. These might include building management systems (BMS) that run heating and cooling systems according to occupants’ needs or software that switches off all PCs and monitors after everyone has gone home. BMS data can be used to identify additional opportunities for efficiency improvements. A host of BMS already exist and as ICT applications become more sophisticated, the range of BMS functions will expand.

The global context

Global building emissions were 8% of total emissions in 2002 (3.36 GtCO₂e). These figures exclude the energy used to run the buildings. If this is taken into account, the sector would emit 11.7 GtCO₂e in 2020. ICT offers a major opportunity to reduce emissions from this sector, by 15% in 2020, by the options set out in **Fig. 12.1**.

Emissions from buildings in emerging economies, such as India and China, are expected to grow as their populations become increasingly urbanised. In spite of increased attention to energy wasted in buildings, construction is taking place the world over with little consideration of the implementation of best practice energy efficiency measures. Several national schemes have been set up to establish and promote these best practice standards in efficiency. These include: *EnerGuide for Houses* (energy retrofits and upgrades) and *New Houses* (new construction) (Canada); *Green Building Council/House Energy Rating* (Australia); *DGNB* (Germany); *BREEAM* (UK); *CASBEE* (Japan); and, perhaps best known, *Leadership in Energy and*

Environmental Design (LEED) (USA).

Yet, while these initiatives guide proactive architects, designers and builders in their quest for ‘green’ building, until this currently niche market becomes mainstream, with mandatory standards and smart building regulations, the full positive impact of ICT on the building sector will not be felt.

In addition, because buildings are major sites for electricity consumption, there is a strong proposition to link them with ‘smart grid’ initiatives and even transport. *Project Better Place* is currently piloting plug-in vehicles, which draw electricity from the home or electric filling stations, to see whether there are negative impacts on grid stability – an initiative that relies on ICT to make it work.

The opportunity: How ICT can help

Energy consumption in buildings is driven by two factors – energy intensity and surface area. ICT-based monitoring, feedback and optimisation tools can be used to reduce both at every stage of a building’s life cycle, from design and construction to use and demolition.

Buildings are often poorly designed at the outset, with little consideration for how they will be used or how uses may change over time. Even if energy efficiency has been incorporated at the start, a building’s actual energy performance can be impaired if builders deviate from the plans or if occupants do not operate the BMS according to plans or specifications. Assuming the building has been designed and built to specification, poor commissioning (ensuring the building’s systems function as specified), constant change of use and poor maintenance can significantly reduce the effectiveness of any BMS. This means that buildings differ dramatically in the energy they consume and as a result the same technology

Fig. 12.2 SMART buildings: The role of ICT



⁷⁶ US and Canada have the highest building emissions per capita, according to Enkvist P., T. Naucier and J. Rosander (2007), 'A Cost Curve for Greenhouse Gas Reduction', The McKinsey Quarterly, Number 1; data from Global Insight.

⁷⁷ Solaire site visit; expert interviews, Jan -Feb 2008.

⁷⁸ California has decoupled energy generation from provision so that energy efficiency can be profitable.

applications can have very different impacts.

There are various smart buildings technologies available today that can help reduce emissions at each stage of a building's lifecycle. Energy modelling software can help architects determine how design influences energy use. Builders can use software to compare energy models with actual construction. Once the building is complete, ICT can measure and benchmark its performance and compare actual to predicted energy efficiency. Occupants can install a BMS to automate building functions such as lighting and heating and cooling and if a building undergoes a change of use. ICT can be used to redesign its energy model and measure the impacts of this change.

Fig. 12.2 shows how ICT can identify energy consumption, optimise for reduction in energy and emissions and transform current ways of designing and using the built environment. The US and Canada are home to some of the most exciting and ambitious innovations in smart building technology.

SMART buildings in North America

North American buildings are among the most inefficient in the world,⁷⁶ responsible for a quarter of all global building emissions. Since most of the floor space that will be in use in the US and Canada by 2020 already exists, retrofitting and better management of existing buildings will be at least as important as efficiencies in new build. Some states in the US, such as California, have already demonstrated significant potential to improve energy efficiency and reduce emissions in buildings.

Recognising the contribution that buildings make to global emissions, both the US federal government and individual states have implemented a number of policy initiatives that are starting to improve buildings' efficiency.

Case study: smart living

The Solaire building in New York was the US's first 'green' residential tower and was inspired by the Battery Park City Authority's initiatives. As well as other sustainability features, it contains a comprehensive BMS to control the entire building. This was built into the plans at the design stage, is continuously updated and undergoes an annual re-commission. The BMS provides real time monitoring and reacts to external stimuli, such as the weather. Winner of several awards and recipient of the *LEED* Gold rating, the Solaire is 35% more energy efficient than building code requirements and uses 67% less energy than other similarly sized buildings in peak hours. Since opening in 2002, energy consumption has decreased by 16% and, as a result of its green credentials, the developers have been able to charge a rental premium of 10%.⁷⁷

Among the measures are the implementation of building codes and standards, offering incentives to builders, owners and occupiers to adopt efficiency measures, strengthening the business case for investing in efficiency technology and training more people to implement and operate BMS.

But despite ICT's proven role in improving the energy efficiency of buildings, emissions are still rising. A number of barriers appear to be preventing those involved in the design, construction and use of buildings from adopting the technology and realising the full abatement opportunities.

Hurdles to adoption

There are a number of barriers the adoption of the technology and realising the full emissions savings opportunities. These include:

“Efficiency is not being built into buildings today to the extent that it could be. It will take decades to change how this is done.” **Stephen Thomas, Johnson Controls**

- Lack of incentives for architects, builders, developers and owners to invest in smart building technology from which they will not benefit
- Unclear business case for investing in energy efficiency: energy consumption is a small part of building cost structure, yet building automation costs can be high and payback periods are often long
- The buildings sector is slow to adopt new technology – a 20-25-year cycle for residential units and a 15-year cycle for commercial buildings is typical
- A lack of skilled technicians to handle complex BMS – most buildings of less than 10,000 sq ft (930 sq metres) do not have trained operating staff
- As each building is designed and built as unique, it is difficult to apply common standards for efficiency and operations
- Interoperable technologies exist but are not uniformly deployed. Many experts agree that an open standard would be the most effective way to enable further innovation
- Lack of incentives for energy companies to sell less energy and encourage efficiency among customers.⁷⁸

“Building owners and operators want simplicity. They do not want too much automation and intelligence built into the system without the ability to override it.” **Gareth Ashley, Associate, Arup**

“If airplanes were built like buildings, you wouldn’t fly in them.” **Stephen Selkowitz, LBNL**

Overcoming the hurdles in North America

A number of solutions could be implemented to overcome these barriers:

- Develop new business models to overcome the misalignment in incentives that currently exists, such as performance contracting and tax credits
- Develop new financial mechanisms for builders that support investment in energy efficiency, such as mortgages that fund energy efficiency or carbon credits
- Prioritise sectors such as retail where energy forms a large share of addressable costs
- Develop green building valuation tools
- Develop supportive long-term solutions such as government- or industry-led alliances that can accelerate industry change
- Provide better training to building operators and information to users by simple devices such as visual smart meters or interfaces to influence behavioural change
- Develop open standards to enable interoperability of BMS.

Faced with the rising energy costs of the past few years, the US government has begun to tackle energy efficiency as a matter of urgency and overcome some of these hurdles.

At the federal level, the US government is active in developing voluntary standards and tools such as the *Energy Star* programme, which is now extending to rate building energy efficiency. At state and council levels, California’s *Global Warming Solutions Act, AB 32*, which calls for GHG reductions to 1990 levels by 2020 and Wisconsin’s plan to reduce GHG emissions from public buildings by 20% by 2010 are just two of many initiatives underway.

A number of developments have taken place in the commercial sector and within industry bodies. Venture capital investment for energy efficient solutions increased by 42% in 2005-2006. Considerable promotion has gone into efficiency improvements in HVAC, smart buildings and other environmental systems.⁷⁹

⁷⁹ Cleantech Ventures, www.cleantechventures.com.au

⁸⁰ Analysis includes data from expert interviews, Jan -Feb 2008.

Tax credits, such as the *Commercial Building Tax Deduction*, have been introduced to persuade developers to invest in energy efficiency. BMS providers and ESCOs⁸⁰ now offer performance contracting, in which third parties invest in efficiency technology in exchange for a share of the money accrued from the energy savings.

Carbon credits and mortgages can now be used to fund efficiency measures and green building valuation tools, which allow an economic assessment of energy efficiency. The *Green Building Finance Consortium Initiative* is also helping to demonstrate the business case for efficiency.

Alliances and initiatives, such as the *Retail Energy Alliance* and the *Building America Consortium*, have been set up to deal with the shortage of skilled buildings managers and better training is now in place for building operators. Building users are the target of information campaigns to raise awareness of energy efficiency issues.

What is at stake?

Across North America as a whole, a 15% reduction in energy consumption from buildings could equate to emissions reductions of 420 MtCO₂e and create value of up to €39 billion (\$61.5 billion). Globally, smart buildings technology could potentially reduce emissions by 1.68 GtCO₂e and be worth €187 billion (\$295 billion) of energy savings and €29 billion (\$45.7 billion) in carbon costs (Appendix 3). This value can be captured by ICT and other high-tech companies. However, to realise this opportunity will require minimum standards of energy efficiency in existing and new buildings.

SMART Grids

Current centralised energy distribution networks are often huge, inefficient grids that lose power in transmission, require an overcapacity of generating capability to cope with unexpected surges in energy use and allow one-way communication only – from provider to customer. In most countries, selling energy back to the grid (e.g. that generated from solar panels) is impossible. This way of operating is becoming increasingly untenable: the costs of fuel are rising and a global emissions trading scheme (ETS) is likely in the next few years. Electricity producers can't afford to waste the amount of power that they currently do.

A 'smart grid' is a set of software and hardware tools that enable generators to route power more efficiently, reducing the need for excess capacity and allowing two-way, real time information exchange with their customers for real time demand side management (DSM). It improves efficiency, energy monitoring and data capture across the power generation and T&D network.

The global context

The power sector accounted for 24% of global emissions in 2002 and could be responsible for 14.26 GtCO₂e in 2020. The potential for ICT to reduce carbon emissions through smart grid technology could be substantial – some 2.03 GtCO₂e by 2020 (**Fig. 13.1**). And recent developments across the globe are working to turn that future projection into reality.

In 2005, the European Technology Platform (ETP) *SmartGrids* was set up to create a joint vision for the European networks of 2020 and beyond. The platform includes representatives from industry, T&D system operators, research bodies and regulators and the overall goal of the project is to develop a strategy

Fig. 13.2 SMART grids: The role of ICT

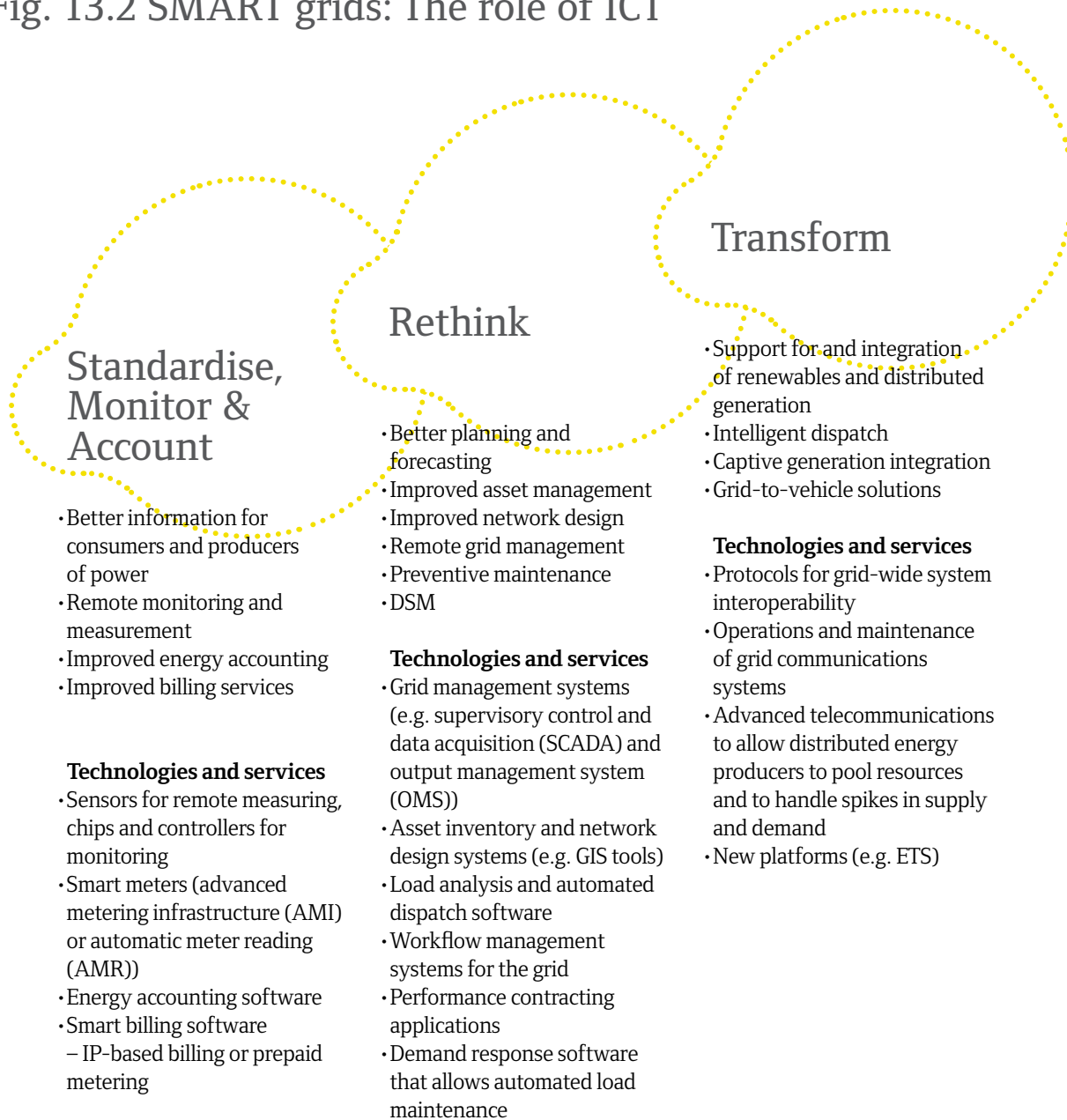
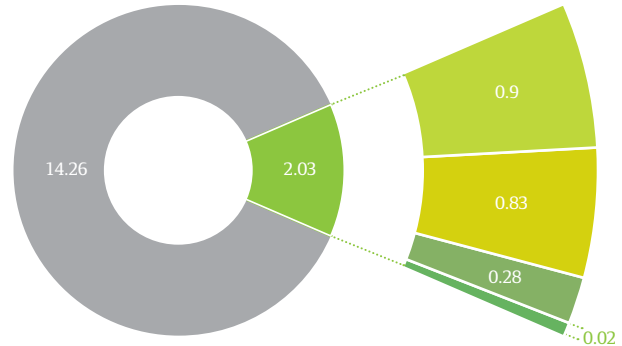


Fig. 13.1 SMART grids: The global impact in 2020

GtCO₂e

Total emissions BAU in 2020 = 51.9 GtCO₂e

- Total emissions from the power sector
- Total ICT smart grid abatement potential
- Reduce T&D losses
- Integration of renewables
- Reduce consumption through user information
- DSM



⁸¹ European Commission, *European Technology Platform SmartGrids: Vision and Strategy for Europe's Electricity Networks of the Future*, ftp://ftp.cordis.europa.eu/pub/fp7/energy/docs/smartgrids_en.pdf

⁸² Congressional Research Service, *Energy Independence and Security Act of 2007: A Summary of Major Provisions*, 21 December 2007, http://energy.senate.gov/public/_files/RL342941.pdf

⁸³ The OECD countries averaged only 14% losses. Although these are projected to fall to 22% by 2020, losses will still be substantially higher than the 13% expected in the OECD. IEA (2007), *World Energy Outlook: India's Energy Prospects – Reference Scenario*; Central Electricity Authority (2007), 'Seventeenth Electric Power Survey', Ministry of Power, Government of India.

⁸⁴ IEA (2007), *World Energy Outlook: India's Energy Prospects – Reference Scenario*.

for research, development and demonstration of smart grids in practice. The ultimate aim of the project is to work towards an interactive energy generation and distribution network across Europe in which a proportion of the electricity generated by large conventional plants can be displaced by distributed generation, renewable energy sources, demand response, DSM and energy storage.⁸¹

The US is actively pursuing smart grid solutions. In 2007, the government passed the *Energy Independence and Security Act*, Title XIII of which establishes a national policy for grid modernisation and seeks to deliver a host of measures including a research and development (R&D) programme for smart grid technologies and a regional demonstration initiative, with a view to revolutionising the country's energy system.⁸² *The Modern Grid* initiative, affiliated with a US Department of Energy research lab, is driving grid modernisation research. *Gridwise*, a public-private alliance, is also engaged in research and market development activities to support enhancement of grid reliability or plug-in vehicles.

The opportunity: How ICT can help

ICT is integral to the range of technologies that comprise a smart grid. Some of these include smart meters, which allow consumers more information about how much energy they are using or allow automated reading of energy consumption data, helping the utility to better understand where energy is being used and more advanced grid management systems. Demand

management systems (also known as "dynamic demand") automate the feedback process by allowing appliances such as refrigerators to dynamically reduce their load at peak times.

Fig. 13.2 outlines the emissions reductions opportunities for the sector.

The emergence of smart grids as an alternative to well-established, existing infrastructures is very much upon us and in the years to 2020 much change is expected. Yet in places such as India, where the network's inefficiencies are severely impeding economic growth, the imperative to transform the current system and remedy these shortcomings is immediate.

SMART grids in India

Electricity generation currently accounts for 57% of India's total emissions and will continue to do so until 2020. India's power network is highly inefficient and much of the generated electricity is wasted. The lack of transparency in the grid makes losses difficult to measure, but it is estimated that in 2007 India lost 32% of total generation.⁸³

"The power network today is blind as they do not know where the losses are." **Senior Official, Indian Ministry of Power**

At the same time, India's power sector is under pressure to grow to meet increasing demand, which could rise 13 times by 2020. Because of the country's reliance on coal-based energy (69% of total demand) and since it is not expected to

“Smart grid implementation would offer India the opportunity to leapfrog current western technologies.” **Balawant Joshi, Managing Partner, ABPS Infra**

Case study: the long path to a smart grid

Without the full implementation of a smart grid, one utility, North Delhi Power Limited (NDPL), has figured out a way to get better data about its highest-paying customers using a Global System for Mobile (GSM) communications. What is essentially a stripped-down mobile phone is programmed to call twice each month to meters where customer consumption data is stored, the way it might call to a dial-up modem. The data are downloaded and used by a local call centre to generate monthly billing. Much more real time data would be available, but for now, even this twice-monthly download gives the utility what it needs to improve billing, detect theft, get better usage and outage data and improve failure detection. It is currently automating a part of the low voltage distribution system to remotely control streetlights and inaccessible switches that will improve monitoring capability on the distribution network.⁸⁷

deploy low-emission coal technologies until 2030,⁸⁴ emissions from India's power sector are expected to grow at 4% pa, twice the global average.

Given the rapidly rising demand for energy, high carbon intensity of supply, high grid losses, rising energy costs and the fact that India is investing massively in infrastructural development in the coming years, smart grids are of particular relevance to India. Action now could prevent the country being locked-in to a high emissions situation for the next 30 years.

The most important technologies for India are ICT platforms that help reduce T&D losses. 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, whether they be theft or otherwise.

There is a further emissions reduction opportunity in smart grids' capacity to support decentralised energy production. This could allow renewable energy to be integrated into the grid, reducing coal-based generation and therefore emissions. Decentralised energy sources could also allow the grid to respond to local power surges and shortages, making it easier to manage.

Action is urgently needed to tackle the energy losses. Improving efficiency could also reduce power generation investment costs. The power sector and the Indian government are expected to invest significantly to support GDP growth, providing upcoming investments that will last 20-30 years. This represents an opportunity to put in place a 'best in class' system early and leapfrog grid technology.⁸⁶

NDPL has also implemented a supervisory control and data acquisition (SCADA) system until substation feeder level and a central SCADA control centre to manage substations and feeders, resulting in reductions of T&D losses in the region from 53% to 23%, better asset management and faster outage resolution.⁸⁸

Hurdles to adopting smart grids in India

“No investment can be tariff neutral; someone has to pay.” **COO, Distribution company**

In spite of the urgent need in India, there are barriers to smart grid implementation, which include the following:

⁸⁵ IEA (2007), 'World Energy Outlook: India's Energy Prospects – Reference Scenario'; Central Electricity Authority (2007), 'Seventeenth Electric Power Survey', Ministry of Power, Government of India.

⁸⁶ Analysis includes data from Central Electricity Authority (2007), 'Seventeenth Electric Power Survey', Ministry of Power, Government of India; CMIE database (www.cmie.com); ABS Energy Research, 'India – Utility meter market profile,' (www.absenergyresearch.com); National Council of Applied Economic Research (2005), 'The Great Indian Market'; Global Insight

⁸⁷ Wadhwa, S (2007), '5 Years of Sustained Efforts towards Business Excellence', FICCI presentation; expert interviews, Jan-Feb 2008.

⁸⁸ Ibid.

“Smart Grid technologies show great potential to (a) manage what you measure and (b) use two-way control for real time monitoring and DSM.” **Ajay Mathur, Director General, Indian Bureau of Energy Efficiency**

⁸⁹ Ministry of Power, Government of India (2007), ‘Report on Key Issues Pertaining to Indian Power Sector’; expert interviews Jan- Feb 2008.

⁹⁰ Not including the potentially large benefits of smart grids beyond the reduction of T&D losses such as DSM, integration of renewables and improved asset management.

- No proven commercial viability for large-scale smart grid rollouts
- Poor financial health of most state-owned T&D companies in India, which affects the levels of investment in new technology
- Low awareness of technological developments, with most utilities being unfamiliar with the latest options and benefits
- No coordinated national road map for smart grid implementation
- The industry is fragmented, with no standardisation between companies.

“If it is thrust on people, it is likely to be rejected.” **COO, Distribution Company**

“The political environment must support the change to a smarter grid. There are many vested interests from those who want to perpetuate this high loss regime.” **India Expert**

Overcoming the hurdles in India

There are some policies, developments and technologies that could help overcome these hurdles. These include:

- Creating a national policy roadmap for phased rollouts and pilots of smart grid technologies
- A new focus on smart grid funding policy and alternate funding mechanisms (e.g. clean development mechanism (CDM) or multilateral institutions)
- New clean tech funding mechanisms
- Staff training in new operating models and capabilities
- Accelerated privatisation of the distribution utilities
- Creation of a smart grid framework for the entire Indian electricity grid
- Establishment of common communication

- standards and protocols for the grid
- Adoption of open source standards to enable development of applications for the smart grid.

The Indian government has introduced several policy initiatives to implement some of these solutions, which are beginning to spur demand for smart grid technology.

The *Electricity Conservation Act* was introduced in 2001 and is a legal framework for promoting energy efficiency in all sectors of the economy, as it also led to the formation of the Bureau of Energy Efficiency. In 2003, the *National Electricity Act* was passed to speed up the development of efficiency within the electricity sector. The 2008 *Accelerated Power Development and Reform Programme (APDRP) v2* has been introduced to accelerate power distribution sector reforms. The programme provides 50% of the funding needed by utilities for investment as loans and offers 50% of cash loss reduction as a grant. The aim is to reduce T&D losses to below 15%, improve the commercial viability of the sector and enable the adoption of smart technology elements across the grids.⁸⁹

There is also a focus on smart grid funding in policy and on new clean technology funding mechanisms, such as the GHG tax on utilities imposed by the Rajasthan Electricity Regulatory Commission.

The Indian government is also looking to change the sector’s structure by setting a target to privatise 25-30% of electricity distribution in large urban areas by 2012, which helps in getting finance for upgrade projects.

“Under the APDRP v2, there is more emphasis on and funding available for smart technologies.” **Managing Director, State-owned Distribution Company**

Prevention of the rebound effect requires an emissions-containing framework (such as emission caps linked to a global price for carbon) to encourage the transition to a low carbon economy. Without such constraints there is no guarantee that efficiency gains will not lead to increased emissions.

What is at stake?

India needs and will continue to need, smart grids to stem losses in T&D (including theft) while reducing the carbon intensity of its power generation to help match the growing power demand and reduce emissions against a BAU growth rate. Although the market is currently dominated by non-ICT players, IT and telecom providers could extend their current capabilities to deliver solutions for smart grids. And if they can do that the opportunities are potentially huge.

Smart grids can directly address critical needs of the Indian electricity sector and could save 30% of T&D losses, equivalent to 95 MtCO_{2e} in 2020. That equates to €6.7 billion (\$10.5 billion) in energy savings and €1.9 billion (\$2.9 billion) in carbon costs. The value at stake globally is estimated to be €79 billion (\$124.6 billion) (Detailed assumption in Appendix 3).⁹⁰

Smart grid technology may also have impacts in other countries and regions. In California, for example, smart grids may meet additional needs, such as improving grid stability, improving planning and forecasting (financials) and 'grid-to-vehicle' solutions in which multiple hybrid car batteries (when not in use) could be used to provide temporary storage and supply of power. Globally, smart grids offer the opportunity to save up to 2.03 GtCO_{2e} by 2020.

The rebound effect

In all cases above, at both global and individual country level, ICT has a major role to play in driving efficiency of the economy. However, there are hurdles to be overcome, whether technological, informational, organisational, market or policy related.

But beyond these hurdles, the academic literature points to some uncertainty in the net impacts of increased efficiency. In theory, greater efficiency should lead to less energy use and fewer emissions. However, many are concerned that these gains will not be secure. Efficiency improvements in devices, machines and systems may lead to 'rebound effects', where overall consumption continues to increase.

For example, improved transport efficiency could result in lower manufacturing costs, lower prices, greater purchasing power and, as a result, increased demand for products and services.⁹¹ Using technology that saves time (e.g. teleworking which reduces the commute to work, for example) may mean more time is available for other, potentially higher-carbon activities such as holidays or shopping. In the past, pervasive, more efficient technologies such as the steam engine or the electric motor have actually increased society's energy use as economies have become more productive.⁹²

ICT technologies can improve efficiency and this will lead to reduced emissions. However, prevention of the rebound effect requires an emissions-containing framework (such as emission caps linked to a global price for carbon) to encourage the transition to a low carbon economy. Without such constraints there is no guarantee that efficiency gains will not lead to increased emissions.

⁹¹ Berkhout, Peter H. G., Jos C. Muskens, Jan W. Velthuisen (2000), 'Defining the rebound effect', *Energy Policy*, Volume 28, Issues 6-7, June, pp. 425-432; Plepsys, A. (2002), *The Grey Side of ICT*, Environmental Impact Assessment Review, Volume 22, Issue 5, October 2002, pp. 509-523.

⁹² The causal links between increases in economic output, economic output and total factor productivity remain unclear. Sorell, S (2007), *The Rebound Effect: an Assessment of the Evidence for Economy-wide Energy Savings from Improved Energy Efficiency*, UKERC, <http://www.ukerc.ac.uk/Downloads/PDF/07/0710ReboundEffect/0710ReboundEffectReport.pdf>

Conclusion

ICT can make a major contribution to the global response to climate change. It could deliver up to a 15% reduction of BAU emissions in 2020 (7.8 GtCO₂e), representing a value of €553 billion (\$872.3 billion) in energy and fuel saved and an additional €91 billion (\$143.5 billion) in carbon saved assuming a cost of carbon of €20/tonne, for a total of €644 billion (\$1,015 billion) savings. This saving in CO₂e is more than five times the size of the sector's own footprint and its size demonstrates the important role an advanced communications platform can play in the transition to a low carbon economy.

This opportunity can be broadly categorised into three roles for ICT: standardising, monitoring and therefore increasing accountability of energy consumption; rethinking how we live, play, learn and work based on those data; and transforming existing value chains and integrating infrastructure processes and systems across all sectors of the economy.

ICT could achieve additional step change savings through technological advances in the future but these are harder to quantify and have not been included in the above figures. For example, future technologies such as global freight exchanges – where hauliers and couriers can buy and sell work – could stimulate greater efficiency and behavior change that would allow further dematerialisation. Machine-to-machine communication would allow for continued optimisation of energy and industrial systems, often invisible to the consumer.

Rather than painting an futuristic picture of a low carbon society in 2020 and then looking at what would be needed to achieve it, the analysis conducted for this report relied on historic trends to derive a highly pragmatic set of impacts for the ICT sector going forward and identified the hurdles that could stand in the way.

It is becoming clear that incremental change is not going to be enough to tackle climate change to the degree and at the speed required to keep carbon at 'safe' levels in the atmosphere. Nothing less than a shift from a high to low carbon global economy is required and in many cases ICT appears to offer the best way to accelerate this. But much more needs to be done if the ICT sector is to perform this role and the final chapter suggests a framework for getting there. ●



04: The SMART 2020 Transformation

⁹³ For data centre information in particular, see the McKinsey/Uptime Institute report Uptime Institute and McKinsey & Company (2008), Revolutionizing Data Center Efficiency—Key Analyses, <http://uptimeinstitute.org/content/view/168/57>

There is no guarantee that the opportunities presented in this report will be developed at scale or deliver the emissions reductions identified.

The ICT sector must not only seek new partnerships but also act to slow the growth of the carbon footprint from its own products and services. This will require companies to develop new approaches to product and market development and move fast to grasp opportunities.

Even where technology solutions are available and there are pressing economic and efficiency reasons to adopt that new technology, there are challenges that require action from other stakeholders. However financially desirable solutions may be, they often do not happen. Although some governments are taking action, much more could be done to help the ICT sector take the lead in the transition to a low carbon economy.

Policy makers need to send clear signals that overall emissions reductions will be required. Further, they will need to harmonise policies to enable the “smart” infrastructure needed for a low carbon economy and focus on integrating ICT requirements into building codes and transport, energy, environmental and innovation policies. Setting up these appropriate policy frameworks, incentives, new business models and partnerships would facilitate knowledge transfer and implementation of the technology. Such actions would entail an unprecedented but not unachievable level of coordination and collaboration across sectors and between business and government.

SMART framework: requirements for a low carbon infrastructure

The SMART framework introduced in Chapter 3 and set out below outlines what needs to happen for this reduction in emissions to be realised.

- **Standardise:** Develop protocols to enable smart systems to interact
- **Monitor:** Make energy and carbon missions visible
- **Account:** Link monitoring to accountability and organisational decision making
- **Rethink:** Optimise for energy efficiency and find alternatives to high carbon growth
- **Transform:** Implement low carbon infrastructure solutions across all sectors at scale.

The companies within the ICT sector should first apply this framework to their own operations, products and services.

Applying the SMART framework to ICT products and services

If a SMART ICT-based infrastructure is to have the impact that the report identifies, the sector itself must comply with the highest efficiency and innovation standards for its own products and services.

More efficient ICT products and services are being developed, but take-up is low today and will need to be accelerated.⁹³ Like the shift from desktops to laptops, a structural change in the devices used to connect to the internet will be needed to achieve more than incremental reductions in emissions.

As mobile networks roll out in developing economies, they will need secure sources of power, including decentralised clean power. Development and adoption of IT architectural paradigm shifts (e.g. virtualisation across all ICT assets) has the potential to radically change current expectations of energy efficiency.

Next steps for the ICT sector to reduce its own direct footprint include the following

Standardise

Ensure that the standards organisations working in the ICT industry bring climate change considerations into their existing work. Energy consumption should be an important component of all ICT technical standards. Ensure standardisation of measurement methods across the whole life of products and services to understand emissions from raw material extraction, through manufacturing, in use and from final disposal.

Monitor

Use ICT technologies to monitor energy consumption of ICT products and networks and feed the information back into technology optimisation. Ensure that the monitoring is consistent throughout companies. Monitoring devices and tools for power management should be required as standard. Remote monitoring and control of systems should be applied wherever appropriate.

Account

Make energy and emissions transparent all along the supply chain by reporting and labelling. Use this information to optimise products and services in each innovation cycle. Incorporate the cost of carbon into current decision making processes to future proof the cost of manufacturing and operating new products and services, in preparation for having an enforced cost of carbon in the future.

Rethink

The sector needs to continue to rethink and research radical innovation across high-emission devices and services. The information above will enable the sector to optimise its own operations and product development for energy reductions.

Transform

Systematically follow best practice for rollout of new products. Transform the ICT sector to an exemplar of low carbon technology. Source low carbon power wherever possible and in particular support the use of renewable energy. ICT companies can also use their own products to demonstrate where dematerialisation is possible. As the internet becomes more integrated within developed and emerging economies, substitution of activities such as transport will become easier.

Applying SMART to other sectors - the SMART framework

Beyond its own operations and products, a major opportunity for both ICT businesses and their sectoral counterparts will be in capturing the €600 billion (\$946.5 billion) of savings at stake in optimising processes and systems in industry, power, transport and buildings to make them more efficient.

The first stage in cutting emissions is monitoring what they are, wherever they occur and ICT is crucial to this process. Once emissions levels and inefficiencies are identified, these data can be used to change operating models, supporting systems and behaviour. These monitoring tools could be used to reduce energy consumption and GHG emissions.

The most powerful opportunity (7.3 GtCO₂e) for ICT to reduce emissions in other sectors is by providing data to enable efficiency by optimising processes with a combination of behaviour change and automation. The key elements of a SMART innovation framework to realise these opportunities – and to go further – are developed below (**Fig. 14**).

Standardise: Develop protocols to enable smart systems to interact

Standards for calculating carbon emissions and

“We need standards for networking in buildings similar to those created by the Internet Engineering Task Force standards – we want lights, HVAC, etc. to operate the same in all countries.” **Bruce Nordman, LBNL**

⁹⁴ For example, in buildings, it is likely that this would initially be protocol translation, encapsulation and message broking. At a later point a dominant protocol is likely to emerge if professional societies, building component manufactures, ICT providers and energy utilities work together.

⁹⁵ See the climate change related standards on the ITU website <http://www.itu.int/themes/climate/> and their report <http://www.itu.int/ITU-D/cyb/app/e-env.html>

energy consumption are called for in every policy discussion on climate change and are critical to innovation and to bringing one-off solutions to scale. However, the major efficiency opportunities identified in this report – services and cross-sector platforms – require not only measurement but also messaging between devices.

One of the reasons for the ICT sector’s success is because it has developed layers of internationally standardised ways for machines to communicate with one another. International dialling codes, which have been around for more than a century, or the .com domain names are both obvious standards that allow rapid innovation and rollout of services. Protocols, or the rules that allow machines to send messages between each other, are hidden to the average user but underpin the internet’s rapid development. TCP/IP actually refers to a set of interconnected protocols that support email and internet connectivity. XML, one of the specifications that underpin blogging or social networking applications, also allows the development of applications that manage an organisation’s supply chains.

A stack of interoperable protocols allowing for the communications between devices, applications and the standardisation of information exchange would allow more effective monitoring, control and minimisation of energy use and carbon emissions. Applied to buildings, industry, power and transport sectors, it would enable communication between refrigerators and smart electricity meters, thermostats and generation facilities, GIS systems and delivery trucks, or motor systems and factory databases.⁹⁴ This would, for example, allow a user to turn off the home air conditioning from the office, or optimise of route planning based on the real time movement of vehicles.

Once this SMART infrastructure is in

place, applications would soon create new ways of using buildings, travelling or manufacturing. Already, the ITU is proceeding to develop standards to support scientific monitoring and networking in automobiles, among others.⁹⁵

Like the IP suite of protocols, which have grown over the lifetime of the internet, layers of standards and protocols in the wider built environment would take some time to develop. Concerns about the security implications of every device having an IP address would need to be addressed. Reliability issues would also require more research.

Monitor: Make energy and carbon emissions visible

Many companies do not know where energy is being consumed, whether in the manufacture or use of their products and services. Many utilities in the developing world are blind to the consumption and loss of energy. Individual functions and departments rarely coordinate to understand how to pool resources or reduce energy efficiently.

There are steps that can be taken today to reduce power across industry and buildings by better monitoring. Smart meters and remote measurement and monitoring allow the grid to see where the highest T&D losses exist or the greatest consumption is occurring. Already a number of companies worldwide are rolling out smart metering solutions to improve knowledge of consumption and reduce electricity outages. Homes and offices with smart meters are the first step to a smart home and a smart grid.

In industry, short-term opportunities would rely on retrofitting existing motors systems with smarter control devices and requiring new motors to be fitted with VSDs. Wireless communication will facilitate the exchange of data, placement of sensory systems

and mobility of equipment, allowing for better monitoring of consumption.

Monitoring goods and vehicles is the first step towards optimising logistics for reduction of mileage or the number of trips taken to deliver goods. Commercial travel will benefit from RFID and data exchange standardisation, which will allow goods to be tracked across borders and suppliers. Visibility of energy and fuel consumed helps reduce cost, waste and emissions.

Account: Link monitoring to accountability

In this context, “account” has two facets – one is accountability for emissions and the other is accounting for them in business decisions.

First and foremost, ICT tools enable transparency and accountability. Companies may be required to know where along their supply chains emissions are highest and report these to their stakeholders. Consumers increasingly demand energy efficiency and even carbon labelling for products.

Secondly, for individual companies, knowing where they use energy or produce emissions and allocating a price of carbon to those emissions, can help them to better understand how climate change presents a risk in their operations and value chain.⁹⁶ For local governments, a similar challenge exists to understand where in a local area or city energy consumption is highest.

A number of sectors can respond according to where energy is consumed. Energy accounting and smarter billing would follow from smart meters. The monitoring, optimising and management of energy could be integrated throughout industrial processes and logistics, where there is currently no way of accounting for the energy consumed in a good’s lifecycle.

There may be surprises – some e-commerce solutions that increase the number of trips taken to deliver a single product may no longer be viable. However, advanced videoconferencing solutions may be in further demand to reduce business travel where uncertainty in transport fuel prices or pressure to reduce emissions increases.

A range of policies and business practices would encourage accountability and accounting and will differ by region. In China, the government plans to audit the top 1,008 highest-emitting companies, encouraging skills training or subsidising technology transfer to enable energy efficiency improvements. In North America, ESCOs that finance efficiency are becoming more common and these companies will compete on their ability to account for energy accurately.

Rethink: Optimise for energy efficiency and find alternatives to high carbon growth

Standards, monitoring and accounting (SMA) achieve operational awareness at the company or government level.

However, SMA is not the whole picture. Using this information to optimise for energy efficiency in value chains and maintain profitability in spite of the rising costs of fuel – or expected price for carbon – is a first step to SMART approaches to climate change. The next step is to rethink operating and business models.

Awareness of how climate change will shape demand is also crucial to innovating for the low carbon economy. A society that delivers growth using a fraction of the fossil fuels that have driven both productivity and growth for the last 300 years will look very different from the low carbon society of tomorrow. It might even look better. For example, it would be appealing to many to avoid idling in traffic on the morning commute and instead to work from home, enabled

⁹⁶ Porter, Michael and Forest Reinhardt, *Grist: A Strategic Approach to Climate Change*, Harvard Business Review, October 2007.

“When people are ready to change behaviour, that’s when ICT’s impact could be greatest.” **Joseph Romm, Senior Fellow, Center for American Progress**

⁹⁷ Mitchell Bill (2007), ‘Transforming Workplaces’ in Kevin O’Donnell and Wolfgang Wagener (eds.) ‘Connected Real Estate’, Torworth Publishing.

by broadband and better collaboration technologies.

It is the long-term potential of ICT to completely transform existing operating systems and business models that will have the biggest impact on emissions reductions. What new technologies, products and services will customers and citizens demand that do not exist today? What new business models will be the most effective at delivering these? Strategic approaches to climate change will involve understanding not only how to do what we currently do more efficiently, but how we can do things differently.

The ICT sector will be in a position to enable new ways of learning, travelling, working and living.

In this report, dematerialisation, teleworking and videoconferencing made up a small percentage (500 MtCO₂e) of a nearly 8 GtCO₂e opportunity that consists largely of efficiency measures. However, new dematerialisation services will be crucial complements to efficiency in the transition to a low carbon society.

For example, if buildings are viewed holistically as part of the living/working built environment, a comprehensive approach encompassing the design, recommissioning and use phases could integrate efficiency and dematerialisation. Optimising space, heat, cooling and light and other requirements at the design phase reduces the materials needed for initial build as well as reducing the energy consumption later, where most of buildings emissions are concentrated. A smarter BMS can “learn” or self-adapt based on the behaviour of the occupants, recognising inefficiencies and adjusting systems such as HVAC accordingly. Complementing this change with teleworking could avoid demand for new office floor space and lead to further emissions reductions.

Efficiencies can be achieved throughout a neighbourhood or city, in a way that is not possible in a single building. More efficient inventory and distribution management systems could save 50% floor space in retail and warehouses, e-commerce could cut retail floor space and e-learning could reduce classroom requirements by 50%.

“Far greater architectural and management benefits can be realised by critically departing from [current building design] assumptions and exploiting the new design opportunities this enables than by simply networking traditionally programmed buildings and filling them with electronic devices.” **Professor of Architecture and Media Arts and Sciences, MIT**⁹⁷

Home automation technologies have the potential to bring many of the efficiencies found in larger buildings into the home. It is already possible, if not much practised, to monitor smart devices throughout the home. As homes become increasingly networked, owners will be able to control heating or lighting remotely and utilities will use the data to make better predictions about peak load.

Smart grids and their capacity for delivering decentralised energy have the potential to radically change the way electricity is generated and delivered, in India and throughout the world. Smart grids could allow renewable energy to be fed into the grid, decarbonising supply. They can allow local renewable energy generators to cover localised surges in demand and contribute to a more diversified energy mix, thereby improving energy security.

Similarly, machine-to-machine communication in factories could transform the way that products are ordered, manufactured and delivered. Intelligent systems control would allow

Fig. 14 SMART 2020: Next steps



“You need to sell the idea of smart grids, to demonstrate their effectiveness – only pilot projects will work.” **K. Ramanathan, Distinguished Fellow, Teri**

for self-diagnosis and reporting on machine performance. Standard operating platforms for robotics could facilitate software reusability and interoperability, enabling the wider use of efficiency applications and eventually allowing for self-optimisation at the factory level. The industrial process could even connect back more directly with consumers so that they understand more clearly the impact of their choices on the manufacturing process.

The opportunity for efficient logistics is spread over many activities, with small gains in each. The overall effect is larger than single opportunities like efficient motors, but takes a much more coordinated approach. The major gains will be reductions in the number of empty vehicles on return journeys, better overall network management and minimised travel and packaging throughout. Open transport management systems will allow for traffic and road configuration information to be passed to route planning platforms, resulting in mileage reductions. Open freight exchange platforms will allow for vehicle loads to be optimised thus reducing the number of empty vehicle miles travelled. Integrated supplier gateways will allow companies to share haulage and, closer to 2020, the full automation of highway systems would greatly improve the efficiency of traffic flow.

Transform: Implement smart, low carbon infrastructure at scale

Scaling up low carbon ICT solutions described above is essential. Reducing T&D losses on the Indian grid by 30% will need to involve not one utility, but many across the country. Putting BMSs in 40% of new buildings in North America is possible, but not inevitable. Reducing flight time even by 3% – if applied over 80% of flights – adds up to energy savings that aren’t possible if implemented by just one company.

Chapter 3 detailed the hurdles to be overcome. Lack of information, lack of supportive organisational structures, lack of clear market opportunities and lack of targeted policy were identified as barriers to implementation and scale. In all cases, a lack of standardised ways of measuring and reporting energy use makes it difficult to coordinate economy-wide solutions. Among the most challenging hurdles are the fragmentation in logistics and power generation markets, lack of training and skills to manage complex BMS or a smart grid and lack of technology transfer and financing mechanisms for implementing energy efficiency measures across power and other industry sectors. These and other hurdles identified will be overcome only by a combination of company leadership, disruptive innovation, government policies and behaviour change.

There is much debate about how to spur innovation and overcome hurdles to social and technological low carbon transition. Experiments, pilots and demonstrations are a necessary part of the innovation process. This currently happens as a matter of course in “clusters” such as Silicon Valley where venture capital investment allows start-ups to compete to provide solutions. In California, Silver Spring Networks is moving beyond providing smart meters to pioneering the underpinning networking technology of a smart grid.

But start-ups alone may not be able to deliver solutions at scale. Large companies have a crucial role to play in finding the small companies that are innovating and pulling their ideas into scalable products and services. Open innovation⁹⁸ is the process by which companies draw on distributed knowledge networks, by developing new models of IP-sharing and business model prototyping. Open innovation business practices by companies that build

climate change mitigation into their business strategy will be necessary to achieve the development of SMART infrastructure quickly and at scale.

Every city can be the cluster for SMART solutions, because it is where the homes, grids, industry and transport solutions intersect. Cities are home to over 50% of the world's population and are responsible for 75% of global emissions. Mass urbanisation seems set to continue. Developing the blueprints for sustainable urban infrastructures will be fundamental to whether we will be able to significantly reduce our emissions to a safe level.

Policy support is needed for innovation to occur at scale. Encouraging experimentation, as some national governments have done in the name of competitiveness, may accelerate the transformation. Countries such as South Korea have already identified the presence of high-speed internet and mobile – along with other IT services – as essential to economic development and government/industry partnerships aim to bring ubiquitous connectivity to the country. China's circular economy approach which recognises the strategic role of resource productivity is being developed into law, chiefly because environmental pollution is recognised as constraining economic growth. China is also investing in low carbon innovation zones⁹⁹ – like the free economic zones that drove economic development – to ensure China's global competitiveness in low carbon solutions. The Dutch approach is transition management which takes a long-term, systems approach to societal change. In this model, micro-level solutions can take off at the macro-level when technology, behaviour, policy and institutions are jointly engaged in learning about a specific societal transition. ICT could accelerate that process.

For each sector, the opportunities will be captured by means of partnership and providing services to all sectors. Market incentives are needed to accelerate the implementation and uptake of micro or renewable energy generation. Germany and Spain have successfully implemented feed-in tariffs that encourage renewables, for example. Public-private partnerships may also play a role. Policies need to be performance-based rather than technology-specific, in order to ensure targets are met with innovative approaches. Different policies suit each market and context. For example, smart grids in India are needed to prevent theft and losses, whereas in California they will be more crucial in facilitating efficient use of energy by consumers.

Policy action to achieve the SMART ICT opportunity will include (Fig. 14):

Standardise: Encourage standards bodies to include considerations for energy consumption in technical standards from the beginning of their development. Ensure that privacy and reliability issues that arise as data collection increases are addressed.

Monitor: Require consistent measurement of carbon emissions across sectors.

Account: Accountability to the public will be expected first from government and from the businesses it regulates. National to municipal governments can demonstrate what is possible by reporting all activities and then require businesses to do the same .

Rethink: Set stretching objectives for energy efficiency and/or targets for emissions reductions where demonstrably effective alternatives to high

⁹⁸ Chesborough, H (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business Press.

⁹⁹ Bernice Lee, Chatham House, Energy & Climate Change Programme.

The ICT industry, in partnership with other emitting sectors, has a key role to play in helping make society's impact visible and to demonstrate in aggregate the demand for new ways of reducing that impact.

carbon activities exist. Fund research into new technologies and business models and fund pilot projects in local contexts. Ensure the most energy efficient connectivity is supported.

Transform: Establish fiscal incentives to promote the mass scale-up of transformational ICT technologies. Develop coordination mechanisms to ensure consistency in reporting of energy use or emissions across policy areas that cover communications, energy and transport, environmental performance, climate change, waste, buildings, skills and innovation. Where technology is required in the built environment, require interoperable open standards between devices in homes, cars/trucks, public transport, offices, on the power grid and in factories. Set an example by procuring of low carbon products/services.

Ultimately, the learning and experimentation on drafting policies and testing technologies would need to be fed back into standards processes and allow further new substitutes to be developed and implemented at scale.

The complexity of the solutions requires companies to partner as well as compete, governments to develop innovation-led approaches for new types of development and, above all, financial institutions to redirect investment towards new solutions. The challenge cannot be underestimated, but there is little choice but to meet it, as the consequences of not doing so will be much tougher to bear.

Concluding remarks

Since Thomas Newcomen invented the steam engine in 1712, society has steamed ahead with an industrial revolution delivering both efficiency and productivity, but has also witnessed a rapid increase in energy consumption and carbon

emissions around the world. The efficiencies identified in this report could simply lead to the consumption of more high carbon products. This is not an option, which is why absolute caps in international emissions are important. Better information in real time on the optimal places to introduce caps or targets would help ease the transition for all sectors as they seek to cut their emissions dramatically.

The ICT industry, in partnership with other emitting sectors, has a key role to play in helping make society's impact visible and to demonstrate in aggregate the demand for new ways of reducing that impact. We begin to transform our infrastructure only if we can see easily where the leakage occurs and are able to use this feedback to change business and operating models, our systems and our own behaviour. The same tools could be used across all GHG emissions, not only carbon, to come closer to zero waste and zero emissions targets.

ICT can enable the transition to a low carbon economy and also begin to build the infrastructure, services and products that a low carbon society will demand.

Now is the time for the industry and government to act. 🟡



Appendix 1: Scope, process and methodology

Scope and methodology

The study set out to understand the role of the ICT sector in the transition to a low carbon economy, both by reducing its own footprint and by enabling emissions reductions across the economy.

The analysis therefore set out to answer three key questions, all measured in CO₂e:

1. What is the impact of the products and services of the ICT sector?
2. What is the potential impact if ICT were applied to reduce emissions in other sectors such as transport or power?
3. What are the market opportunities for the ICT industry and other high-tech sectors in enabling the low carbon economy?

For the purposes of this report, the ICT sector covers:

- PCs and peripherals: workstations; laptops; desktops and; peripherals such as monitors and printers
- IT services: data centres and their component servers; storage and cooling
- Telecoms networks and devices: network infrastructure components; mobile phones; chargers; broadband routers and IPTV boxes.

It does not include consumer electronics such as TVs, video equipment, gaming, audio devices and media players or other electronic equipment such as medical imaging devices.

This study was carried out in three key stages over a period of six months, from October 2007 to March 2008.

The first phase of the project aimed to quantify the direct and indirect global impact of ICT on GHG emissions until 2020. Two basic

models were developed, one to understand the direct footprint and the other to identify and quantify indirect or enabling opportunities. To ensure accuracy and credibility of the approach, the methodology and content were shared with experts and stakeholders globally.

The second phase involved in-depth case studies around five areas where the analysis suggested the greatest emissions reductions opportunities were possible using ICT solutions. In four of those cases, value opportunities were also developed.

The third phase involved an assessment of the imperatives for each stakeholder (technology providers, technology users, investors and regulators) to accelerate adoption of the illustrated case studies. Workshops were held with global experts and stakeholders to discuss potential opportunities and barriers. The outcome of this communication was a clearer understanding of the imperatives for industry and policy emerging from the case studies.

Direct ICT impact methodology

To assess the direct impact of ICT on the global carbon footprint, the contribution of each component within scope was analysed. Each of the drivers for emission growth was then assessed on a by-product basis.

The research utilised the latest estimates of the current global emissions of the sector components, penetration rates of ICT devices and infrastructure, and estimates of global population and sectoral growth to 2020. Data were gathered from: relevant publicly available studies; academic and industry literature; expertise provided by the partners; and primary research as appropriate, including consumer surveys, and expert interviews.

The analysis aimed to be as comprehensive as possible, using the ‘cradle-to-

grave' approach to carbon emissions, and as such, incorporating emissions data from manufacture, transport, use and disposal wherever possible.

The direct model was calculated based on four main components:

- **Market growth and penetration of devices to 2020** based on industry reports¹⁰⁰ and McKinsey analysis. In each section of the direct footprint in this report, the components are identified along with assumptions of growth. Growth in India and China was of particular relevance
- **Energy consumption** of the components based on publicly available or company data
- **Emissions factor.** To calculate the emissions from the energy consumption, an emissions factor was used based on McKinsey and Vattenfall's cost curve work. The conversion from energy consumption to carbon is based on the carbon intensity of electricity generation in each region on a pa basis and includes total carbon emissions generated at source. Transmission losses were also calculated for each region. Transmission figures for conversion differed in each region and year
- **Embodied carbon.** The calculation of CO₂e as part of the manufacturing process of the components is calculated based on publicly available data¹⁰¹ or company data. Energy consumed for end-of-life treatment (disposal, landfill and recycling) was included in the embodied energy estimates of ICT devices where data was available, as outlined in detail in Appendix 2.

The ICT industry is dynamic, fast-growing and subject to the emergence of disruptive technologies and paradigm shifts. It is difficult to predict the changes that are likely to take place within the industry over the period 2008-2020. For this reason, a number of assumptions have been made in this report when analysing the direct footprint of the ICT sector, which are detailed in Appendix 2.

Enabling impact methodology

The enabling model drew on McKinsey's previous work with Vattenfall on GHG reduction cost curve.¹⁰² The cost curve set out to identify on a global scale the supply of emissions abatement solutions and rank them by cost to society.

McKinsey analysed the significance and cost of each available method of reducing or 'abating' emissions relative to BAU projections. The study covered a number of areas where emissions are significant: power; manufacturing; industry; transport; residential and commercial buildings; forestry; agriculture; and waste disposal. It also covered six regions: North America; Western Europe; Eastern Europe including Russia; other developed countries; and China and other developing nations (including India), over time periods to 2010, 2020 and 2030. For the purposes of this report, a time horizon of 2020 was used.

The enabling model set out to understand how ICT applications could play a role in each of the emissions abatement solutions in the cost curve. Of the 21.9 GtCO₂e of abatement available by 2020, 7.8 GtCO₂e will involve a major role for ICT. It will also have a minor involvement with other further abatements, although not all solutions could be included in the report.

In order to inform the model and to better quantify the role of ICT in the opportunities identified through the cost curve work, four opportunities were analysed in detail, chosen because of the size of their abatement potential, the scale of the economic opportunity and the quality of data available:

- Logistics in Europe (including urban and non-urban road transport, passenger and freight transport across all vehicle modes – road, air and sea)
- Industry in China (including motor systems, process industries)
- Power in India (including generation, T&D, supply mix and demand sources)
- Buildings in North America (including residential, office, warehouses, other commercial).

In addition to these four case studies based on cost curve analysis, dematerialisation was chosen as fifth study item. Research involved extensive primary research, including expert and company interviews, regional interviews and site visits, as well as extensive literature reviews. ●

¹⁰⁰ Gartner estimates; McKinsey trend extrapolation; McManus, T (2002), 'Moore's Law and PC Power', presentation to Tulane Engineering Forum, www.sse.tulane.edu/Tef/Slides/Tulane-Moore's%20Law%20Sept02.ppt, IDC data

¹⁰¹ IVF Industrial Research and Development Corp (2007), *Preparatory Studies for Eco-Design Requirements of Energy-using Products (EuP): Lot 3 – PCs (desktops and laptops) Final Report*.

¹⁰² Enkvist P., T. Naucler T. and J. Rosander (2007), 'A Cost Curve for Greenhouse Gas Reduction', *The McKinsey Quarterly*, Number 1.

Appendix 2: The direct impact assumptions

Drivers	Market growth and penetration of devices to 2020	Constituting elements	Power consumption	Embodied carbon	Abatements (as discussed in detail in report itself)
PCs	<ul style="list-style-type: none"> • Gartner on installed base up to 2011 • Extrapolated growth trends • Capped at 2020 US penetration per capita • Assumed 20% of desktops are workstations. 	<ul style="list-style-type: none"> • Desktops v laptops • Commercial v consumer • CRT v LCD for PCs (CRT assumed to decrease to 0% in 2020). 	<ul style="list-style-type: none"> • Historic growth of power consumption per PC unit including monitors • Assume effect of efficiency gains and increased computation requirements • Workstations consume 2.5 times desktop in all modes • Commercial usage: 14 hours/day • Consumer usage: three hours/day • Desktop standby achieves 15W Energy Star rating. 	<ul style="list-style-type: none"> • Figures assessed based on European Commission DG TREN: EuP preparatory study, TREN/D1/40-2005, Lot 3. 	<ul style="list-style-type: none"> • Device change.
Telecoms devices	<ul style="list-style-type: none"> • Yankee user connections for broadband and mobile up to 2011, historic trends up to 2020 • IDC penetration on IPTV up to 2010, constant growth after that. 	<ul style="list-style-type: none"> • Mobile penetration capped for 2020 to 0.92 (US penetration) • Mobile devices, IPTV boxes, routers. 	<ul style="list-style-type: none"> • Mobile phones • Charging phone 0.5 kWh • Standby charging 13 kWh • Constant in time IPTV • IPTV rating: 25W. Active 40% of rated standby 20% of rated three hours of active TV usage, rest of the time in standby • Routers: from European code of conduct. Five active hours, rest of the time in standby. 	<ul style="list-style-type: none"> • Integrated product policy pilot project Stage 1 Final Report: "Life Cycle Environmental Issues of Mobile Phones", Nokia, 2005 • Assume router: 1/3 of laptop • IPTV: 1/2 of laptop. 	<ul style="list-style-type: none"> • Converge to 1W standby before 2020 • Reduce W in recharge over the same duration.
Telecoms networks	<ul style="list-style-type: none"> • Yankee user connection for fixed, mobile, broadband up to 2011, historic growth up to 2020. 	<ul style="list-style-type: none"> • Fixed-line • Mobile • Broadband • Cable operators (broadband only) • Satellite not included • Specific fixed network configurations such as NGN were not accounted for separately. 		<ul style="list-style-type: none"> • "Mobile Embodied Carbon from Sustainable Energy Use in Mobile Communications", Ericsson, August 2007, White Paper. 	<ul style="list-style-type: none"> • Embodied carbon stays constant as percentage of network energy consumption over time.
Data centres	<ul style="list-style-type: none"> • For each server type IDC data up to 2011 for sales. Projected global 2002 installed base according to sales • Use sales and retirements to grow up to 2011 • Straight line projection. 	<ul style="list-style-type: none"> • Three kinds of servers; and data storage units. 	<ul style="list-style-type: none"> • Three types of servers: 200, 500, 6000 W/unit • Projected growth in consumption and on historic numbers • Applied US storage consumption per server worldwide • Doubled power consumption of servers to assess cooling and power equipment. 	<ul style="list-style-type: none"> • Assumed 4% of total data centre life cycle analysis (LCA) footprint: "Life Cycle Assessment for an Internet Data Centre", NEC. 	<ul style="list-style-type: none"> • Virtualisation and cooling.

Appendix 3: The enabling effect assumptions

Assumptions behind the CO₂e calculations for the enabling effect are detailed below for the top five areas.

Dematerialisation: Global impact

0.46 GtCO₂e in 2020 – Assumptions behind the numbers in Fig. 9, Chapter 3

Lever	GtCO ₂ e	Assumptions
Online media	0.02	<ul style="list-style-type: none"> Assumes seven billion DVDs and 10 billion CDs globally sold per year 1 Kg CO₂e per CD/DVD* Eliminate all CDs and DVDs
E-commerce	0.03	<ul style="list-style-type: none"> 3% reduction in emissions from shopping transport, assumed to be 40% of non-work-related private transport, or 20% of all private transport
E-paper	0.07	<ul style="list-style-type: none"> Assumes 270Mt of paper in 2020 globally tCO₂e per tonne of paper Eliminate 25% of all paper
Videoconferencing	0.08	<ul style="list-style-type: none"> 30% of passenger air and rail travel is business travel Globally 30% of business travel can be avoided through videoconferencing
Telecommuting	0.26	<ul style="list-style-type: none"> Assumes that work-related car travel in urban and non-urban areas decreases by 80%, while non-work-related car travel increases by 20% In developed countries 10% of existing vehicles are affected, equivalent to 20% of people and 30-40% of working population, and 7% in developing countries Assumes a 15% increase in residential building emissions and a 60% reduction in office emissions, applied to 10% of residential buildings and 80% of office buildings

SMART motors: Global impact

0.97 GtCO₂e – Assumptions behind the numbers in Fig 10.1, Chapter 3

Lever	GtCO ₂ e	Assumptions
Optimisation of variable speed motor systems	0.68	<ul style="list-style-type: none"> • 30% increase in efficiency of industrial motor systems through optimisation • 60% penetration of motor system optimisation technology
ICT driven automation in key industrial processes	0.29	<ul style="list-style-type: none"> • 15% decrease in total electricity consumption • 33% penetration of process optimisation technology

SMART logistics: Global impact

1.52 GtCO₂e – Assumptions behind the numbers in Fig. 11.1, Chapter 3

Lever	GtCO ₂ e	Assumptions
Optimisation of logistics network	0.340	<ul style="list-style-type: none"> • 14% reduction in road transport • 1% reduction in other modes of transport
Intermodal shift	0.020	<ul style="list-style-type: none"> • 1% reduction in road transport owing to shift towards rail and waterborne transport
Reduction in inventory	0.180	<ul style="list-style-type: none"> • 24% reduction in inventory levels • 100% of warehouses and 25% of retail are assumed to be used for storage
Centralised distribution centres	No data available	
Optimisation of truck itinerary planning	0.330	<ul style="list-style-type: none"> • 14% reduction in road transport
Optimisation of truck route planning	0.100	<ul style="list-style-type: none"> • 5% reduction in carbon intensity of road transport owing to avoidance of congestion
Eco-driving	0.250	<ul style="list-style-type: none"> • 12% reduction in carbon intensity owing to improved driving style
Intelligent traffic management	No data available	
In-flight fuel efficiency, e.g. centre of gravity	0.002	<ul style="list-style-type: none"> • 1% reduction in fuel consumption achievable for 80% of t/km flown • Impact calculated for average European fleet

Lever	GtCO₂e	Assumptions
Reduction in ground fuel consumption	0.002	<ul style="list-style-type: none"> • 32% reduction in ground fuel consumption achievable for 80% of flights • Impact calculated for average European fleet
Reduction in unnecessary flight time	0.007	<ul style="list-style-type: none"> • 3% reduction in flight time achievable for 80% of flights
Optimisation of train operations	0	<ul style="list-style-type: none"> • 2.5% reduction in rail transport owing to better scheduling and operations of trains
Maximisation of ship load factor	0.030	<ul style="list-style-type: none"> • 4% reduction in marine transport owing to improved utilisation of ships
Optimisation of ship operations	0.020	<ul style="list-style-type: none"> • 3% increase in fuel efficiency, e.g. by adjusting ballasts and optimising speed
Minimisation of packaging	0.220	<ul style="list-style-type: none"> • 5% reduction in packaging material, leading to a 5% reduction in all transports and in storage
Recycling and remanufacturing	No data available	
Reduction of damaged goods	0.010	<ul style="list-style-type: none"> • 0.2% reduction in damaged goods achievable through better tracking (e.g. RFID) and conditions monitoring (e.g. bio-sensors)
Flexible home delivery methods	0	<ul style="list-style-type: none"> • 0.1% reduction in consumer travel to collect failed deliveries

SMART buildings: Global impact

1.68GtCO₂e – Assumptions behind the numbers in Fig 12.1, Chapter 3

Lever	GtCO₂e	Assumptions
Improved building design for energy efficiency	0.45	<ul style="list-style-type: none"> • 40% reduction in retail buildings and 30% in others • Implementation: 60% of all new builds and 15% of retrofits (except 0% for residential)
Reduced building space through design	0.11	<ul style="list-style-type: none"> • 25% reduction in retail and warehouse space • Implementation: 60% of new buildings and 20% of retrofits
BMS	0.39	<ul style="list-style-type: none"> • 12% less in residential and retail buildings, 7% in warehouse and 36% in office and other emissions • Implementation: 40% of new offices and retail and 25% retrofits; 33% of all other new and 10% of retrofits
HVAC automation	0.13	<ul style="list-style-type: none"> • 13% reduction in HVAC consumption (except warehouses) • Implementation: 40% for new retail and offices; 33% for remaining new; 25% for all retrofits
Lighting automation	0.12	<ul style="list-style-type: none"> • 16% reduction in lighting • Implementation: 40% for new retail and offices; 33% for remaining new; 50% for commercial retrofits and 25% for residential retrofits
Ventilation on demand	0.02	<ul style="list-style-type: none"> • 4% reduction in heating/cooling emissions in commercial buildings except warehouses • Implementation: 60% of new builds and 25% of retrofits
Intelligent commissioning	0.06	<ul style="list-style-type: none"> • 15% reduction in commercial building (except warehouses) heating/cooling emissions • Implementation: 60% of new builds
Benchmarking and building recommissioning	0.15	<ul style="list-style-type: none"> • 35% reduction in current commercial building (except warehouses) heating/cooling emissions • Implementation: 25% of new builds and 50% of retrofits
Voltage optimisation	0.24	<ul style="list-style-type: none"> • 10% reduction in heating/cooling and appliance consumption • Implementation: 80% of new builds, 30% of commercial retrofits and 20% of residential retrofits

SMART grids: Global impact

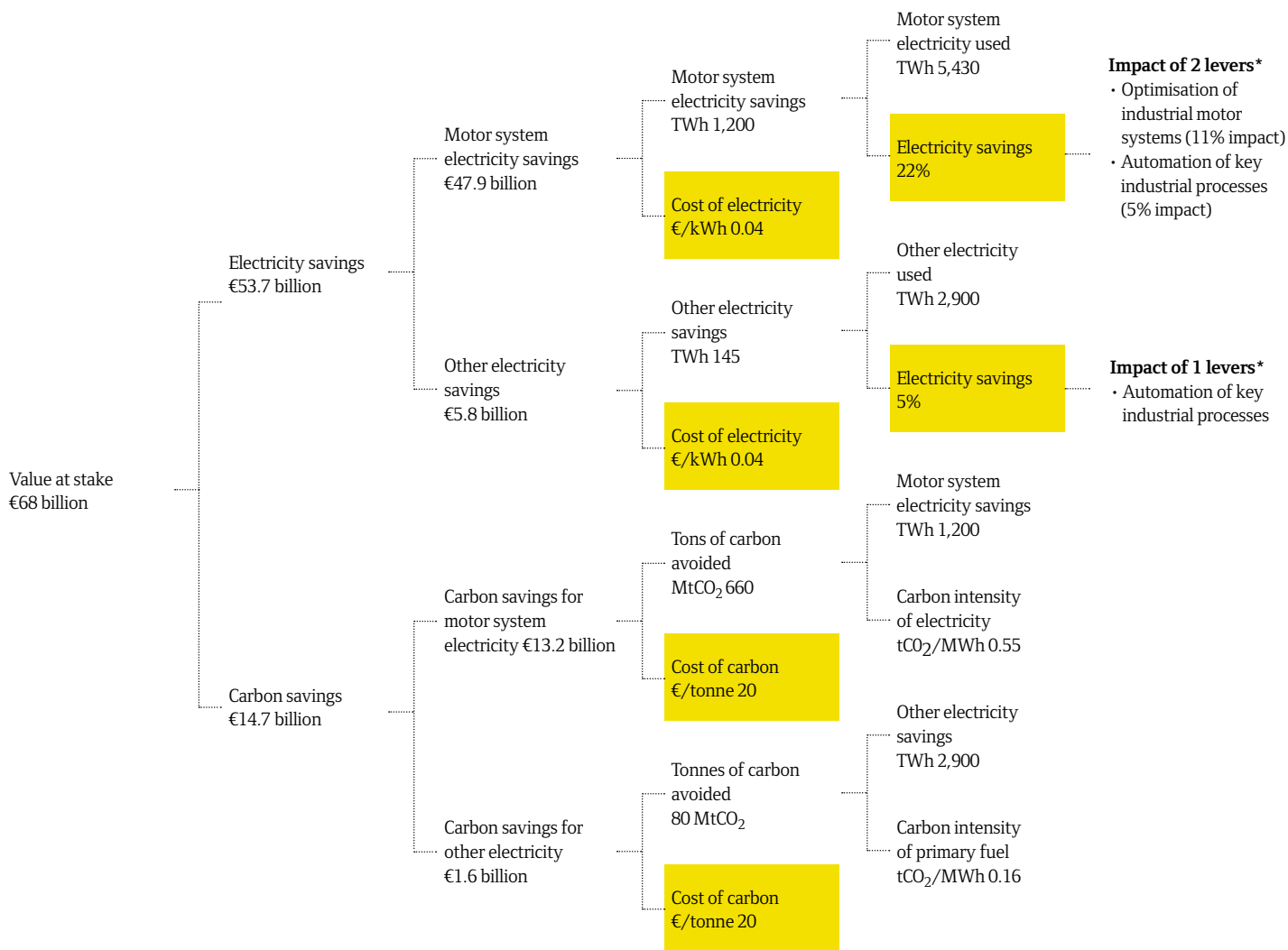
2.03 GtCO₂e – Assumptions behind the numbers in Fig 13.1. Chapter 3

Lever	GtCO ₂ e	Assumptions
Reduce T&D losses	0.90	<ul style="list-style-type: none"> • 30% reduction (14% to 10%) of T&D losses for developed countries and 38% (24% to 15%) reduction for developing countries
Demand management	0.02	<ul style="list-style-type: none"> • 3% (10 days a year) reduction in spinning reserve
Reduce consumption through user information	0.28	<ul style="list-style-type: none"> • 5% reduction in energy consumption • Effective in 75% of residential new builds and 50% of residential retrofits • Effective in 60% of commercial new builds and 50% of commercial retrofits
Integration of renewables	0.83	<ul style="list-style-type: none"> • 10% reduction in the carbon intensity of generation of developed countries • 5% reduction in the carbon intensity of generation of developing countries
Intelligent load dispatch	No data available	

Global value of the opportunity for smart motors, smart logistics, smart buildings and smart grids was developed using the detailed information available for each case study and scaled according to the assumptions outlined in each value tree:

SMART motors
Industrial automation could save up to €68 billion pa worldwide (\$107.2 billion)
 Worldwide impact, 2020

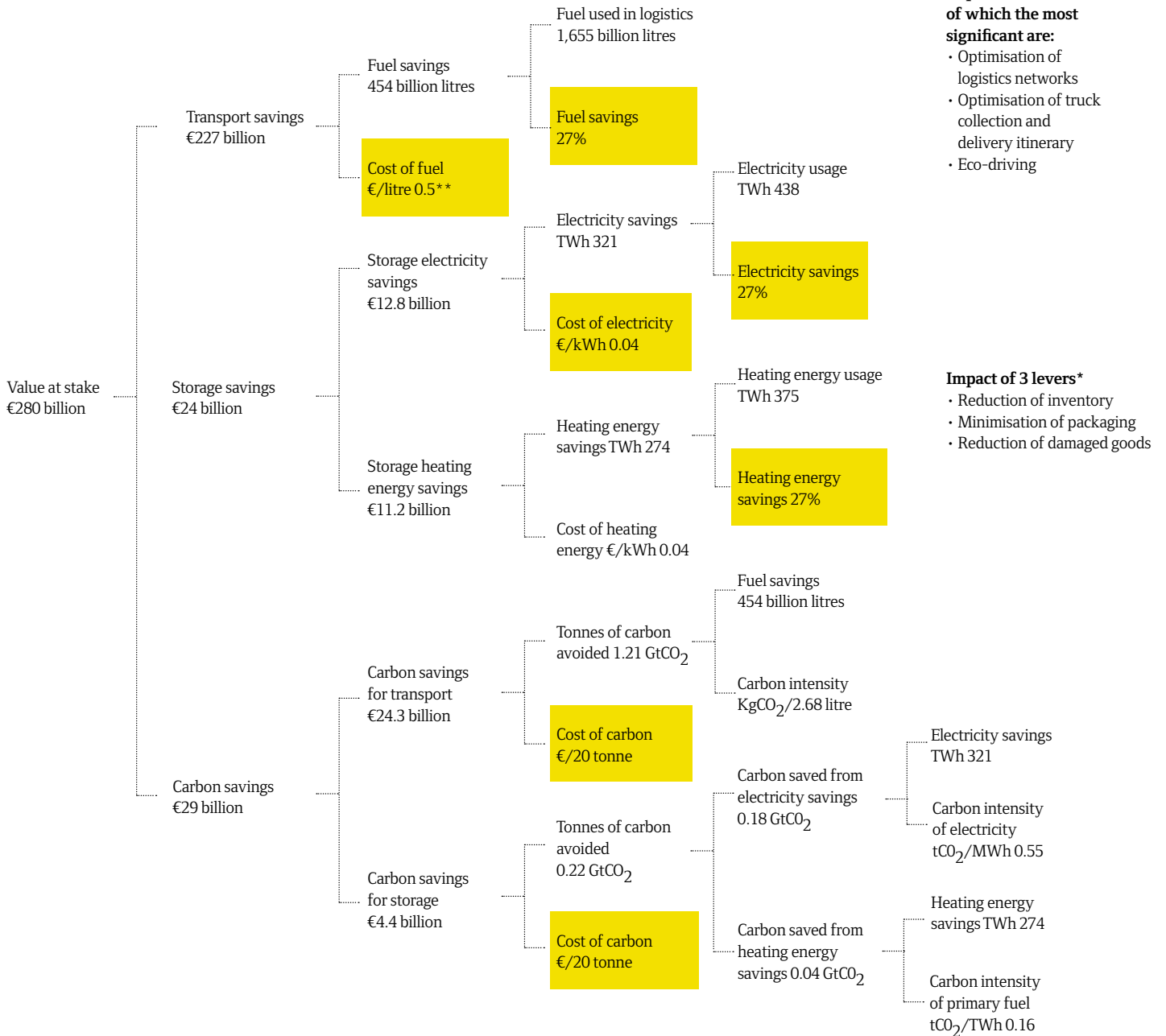
● Key drivers of business model



* Impact of individual levers determined through expert interviews.

SMART logistics:
Efficient logistics could save up to €280 billion pa worldwide (\$441.6 billion)
 Worldwide impact, 2020

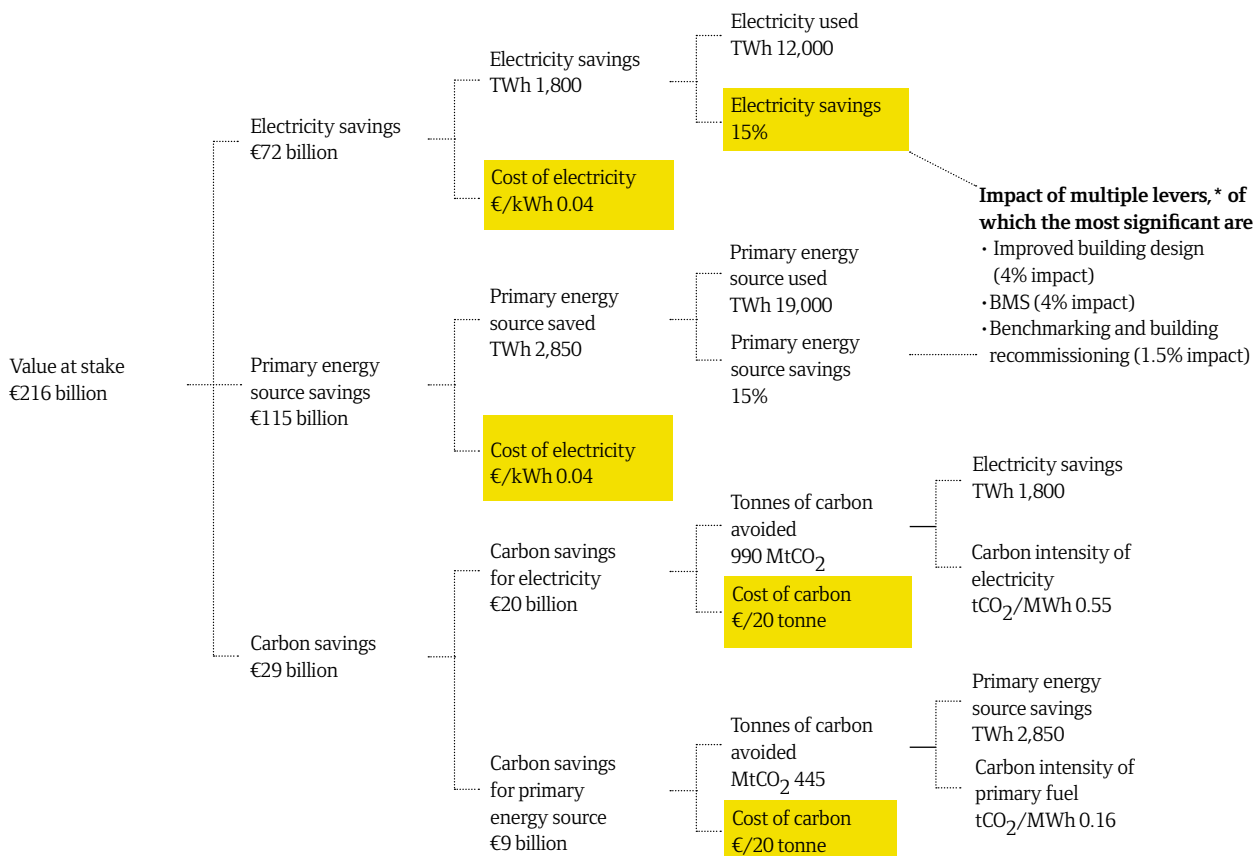
● Key drivers of business model



* Impact of individual levers determined through expert interviews
 ** Average spot trading price of gasoline excluding tax, IEA data, December 2007.

SMART buildings:
The global value at stake from building efficiency is estimated at €216 billion (\$340.7 billion)
 Worldwide impact, 2020

● Key drivers of business model



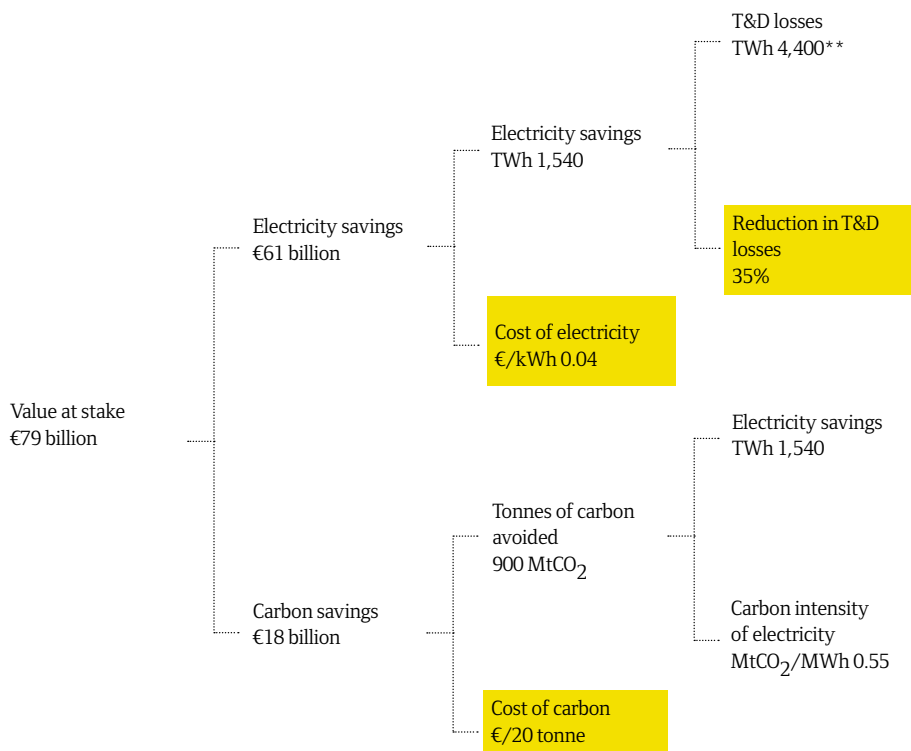
* Impact of individual levers determined through expert interviews

SMART grids:

The global value at stake from smart grid is estimated at €79 billion (\$124.6 billion)

Global Impact, 2020

● Key drivers of business model



Estimate does not include benefits of smart grids beyond reduction of T&D losses such as:

- DSM
- Integration of renewables
- Improved asset management

* Impact of individual levers determined through expert interviews
** Based on 18% average losses worldwide and 25,000 TWh produced.

Appendix 4: Company commitments

Companies	Public commitments
Alcatel–Lucent	<ul style="list-style-type: none"> • Reach a 10% reduction in total CO₂ emissions from facilities from the 2007 CSR reported baseline by the end of 2010 • Determine and report Alcatel–Lucent’s direct carbon footprint by the end of 2008
Bell Canada	<ul style="list-style-type: none"> • Reduce intensity of GHG emissions by 15%, by 2012
British Tele-communications plc	<ul style="list-style-type: none"> • Reduce the worldwide CO₂ emissions per unit of BT’s contribution to GDP by 80% from 1996 levels, by 2020 • Reduce UK CO₂ emissions in absolute terms by 80% below 1996 levels, by December 2016 • 20% of BTs employees will be actively engaged in reducing carbon footprint at work and at home by December 2012 • 25% of BT’s UK electricity to be sourced from on-site wind power by 2016
Cisco Systems	<ul style="list-style-type: none"> • Complete verified, annual EPA Climate Leaders and CDP global GHG inventories • As part of EPA Climate Leaders, develop a global, corporate GHG emissions goal to be implemented over a five to 10 year horizon. Cisco’s goal will be posted under partner goals on the EPA Climate Leaders Partnership website • As part of Clinton Global Initiative (CGI) commitment, invest at least \$20 million in remote collaboration technology to reduce carbon emissions from air travel by 10% (2006 baseline) • As part of CGI commitment, invest \$15 million in the Connected Urban Development initiative to create replicable templates for sustainable urban infrastructure development considering urban planning, built environment, transport and energy solutions to reduce carbon emissions from cities
Dell	<ul style="list-style-type: none"> • Reduce operational carbon intensity by an additional 15% by 2012 • Starting with FY08, achieve net carbon neutrality for all Dell-owned and -leased manufacturing and facilities operations worldwide, including business air travel • Double our average facilities LEED score by 2012 • Strive for 100% use of renewable power in Dell operations • Educate and empower customers to conserve energy and offset carbon related to operation of IT products • Set expectations for all primary suppliers to manage, reduce and publicly disclose GHG impacts
Deutsche Telekom AG	<ul style="list-style-type: none"> • 100% of German electricity demand obtained from renewable sources (water/wind/biomass) as from 2008 • Reduce CO₂ emissions for Deutsche Telekom Group by 20% below 2006 levels by 2020 • Achieve the target of eight million private customers using online billing by the end of 2008 (started to promote the use of online billing in 2006) • Conduct <ul style="list-style-type: none"> – a complete review of Deutsche Telekom’s energy supply including exploring further potential of all sources of renewable energies, including fuel cells and natural heat of the earth (geothermic) – a complete audit of the energy consumption of Deutsche Telekom’s data centres

Companies	Public commitments
Deutsche Telekom AG	<ul style="list-style-type: none"> • Further investigate and assess <ul style="list-style-type: none"> – the use of high efficiency geothermal heat exchangers for cooling and heating – the use of block-type thermal power stations – the optimisation of data centres and switching stations through cooling water • Investigate, assess and ensure the reduction of car fleet emissions by <ul style="list-style-type: none"> – increasing the number of cars powered by alternative engines (i.e. hybrid etc.) – using alternative fuels in the vehicle fleet
Ericsson	<ul style="list-style-type: none"> • Complete full peer-reviewed LCA study on mobile communications in accordance with ISO 14040 standards • 20% energy efficiency improvement targeted from 2006 to end 2008 for WCDMA RBS • 15% improvement in energy efficiency of GSM RBS products sold from beginning 2006 to end 2008 • Introduce power-saving standby feature for GSM RBS during low load • Have intermediate, publishable results from two or three ongoing projects for LCA, video communications and mobile applications
France Telecom	<ul style="list-style-type: none"> • Reduce CO₂ emissions for FT Group by 20% below 2006 levels by 2020 • Involve 100% of FT Group employees in reducing the company's footprint • Reduce energy consumption for FT Group by 15% below 2006 level to 2020 • 25% of FT Group electricity in Africa (EMEA) to be sourced from solar by 2015
Hewlett-Packard	<ul style="list-style-type: none"> • Reduce energy consumption and the resulting GHG emissions from HP-owned and leased facilities worldwide 16% below 2005 levels, by 2010 • Reduce the combined energy consumption and associated GHG emissions of HP operations and products to 25% below 2005 levels, by 2010 • Reduce the energy consumption of volume desktop and notebook PC families by 25% by 2010 relative to 2005 • Improve the overall energy efficiency of HP ink and laser printing products by 40% by 2011 • Quadruple the number of high-end video conferencing units at company sites worldwide by 2009, resulting in an expected reduction of more than 20,000 trips • Report energy use and associated GHG emissions in HP's first-tier suppliers, representing more than 70% of the company's materials, components and manufacturing supplier spend
Intel	<ul style="list-style-type: none"> • Reduce absolute carbon footprint by 20% by 2012 against the 2007 baseline • Reduce use of perfluorocarbons (PFCs) by 10% by 2010 against the 1995 baseline • Reduce normalised energy use in operations by 4% pa by 2010 against 2002 baseline, increasing to 5% pa by 2012 against the 2007 baseline • Reduce IT-related CO₂ emissions by 50% by 2010 by ensuring commitments to produce, sell, buy and use the most energy efficient IT equipment, via the Climate Savers Computing Initiative • Starting in 2008, purchase 1.3 billion kWh a year of renewable energy certificates
Microsoft	<ul style="list-style-type: none"> • All new owned buildings will be constructed to LEED Silver or Gold performance levels • Increase multiple occupancy and alternative transport rate for Puget Sound, Washington employees from 32% to 40% by 2015 • 100% of data centres will feature real time tracking of CO₂ emissions • Every two years through 2012, halve the measure between annual average data centre PUE and the ideal PUE (1.0) by increasing Microsoft data centre productivity

Companies	Public commitments
Motorola	<ul style="list-style-type: none"> • Reduce operational CO₂ emissions (includes direct GHG emissions and indirect emissions from electricity use) by 15% compared with 2005 • In keeping with the company's commitment as a founding member of the Chicago Climate Exchange (CCX), reduce global absolute CO₂ emissions by 6% by 2010 compared with 2000 • Assess supply chain climate impacts • Measure the impact of business travel • Understand the carbon footprint through the life cycle of Motorola products • Continuously improve the energy efficiency of Motorola products
Nokia	<ul style="list-style-type: none"> • Products: <ul style="list-style-type: none"> – Reduce the average no-load power consumption by another 50% by the end of 2010 – Roll out reminders for consumers to unplug the charger from the electricity outlet once the phone has been fully charged across its product range by the end of 2008 • Offices and sites: <ul style="list-style-type: none"> – Further energy savings 2007-2012 of 6% compared to 2006 levels • Green energy: <ul style="list-style-type: none"> – Increase the use of green electricity to 50% in 2010 • Operations: <ul style="list-style-type: none"> – Set energy efficiency and CO₂ reduction targets for global suppliers of printed wiring boards, integrated circuits, LCD's and chargers that are in line with Nokia internal target setting • Require target setting for the reduction of energy consumption and CO₂ emissions from its logistics service providers
Nokia Siemens Networks	<p>Products energy consumption targets:</p> <ul style="list-style-type: none"> • Reduce the energy consumption of typical GSM (2G) RBS by 20% by 2010 from the 2007 level of 800W • Reduce the energy consumption of typical WCDMA (3G) RBS by 40% by 2010 from end-2007 level of 500W • Reduce the energy consumption by 29% per ADSL line by 2009 from the 2007 level to meet the Broadband Code of Conduct. With ADSL low power mode, additional 30% savings are possible • Reduce the energy consumption by 49% per VDSL line by 2009 from the 2007 level and target to meet the Broadband Code of Conduct • Continue deployment and further development of energy-saving features during low traffic periods
Nokia Siemens Networks	<p>Production and office facilities energy use targets:</p> <ul style="list-style-type: none"> • Reduce energy use by 6% by 2012, exceeding the official EU target of 5% • Use 25% renewable energy in company operations by 2009, increasing up to 50% by the end of 2010
Sun Microsystems	<ul style="list-style-type: none"> • Reduce US CO₂e emissions 20% from 2002 levels by 2012 • Maintain over 50% of employees in a flexible work programme, which includes partial and full time work from home • Publish energy consumption data for all products • Drive increased energy efficiency in microprocessors, systems and storage through Sun's Eco Innovation programme • Provide tools for data centre customers to monitor ongoing power consumption of Sun products • Exceed industry targets for energy efficiency of power supplies used in Sun products.

Companies	Public commitments
Telecom Italia	<ul style="list-style-type: none">• 30% increase (with respect to 2007) of the eco-efficiency indicator for 2008: the objective for 2008 is 1,130 Bit/Joule (the value for 2007 is 873 B/J)• In 2008, 3 million kWh reduction through use of low-consumption lighting systems• In 2008, 200 tonnes CO₂ reduction by substituting new methane generators for oil boilers• In 2008, 2,700 tonnes CO₂ reduction by replacing Euro3 vehicles with Euro4 vehicles
Telefónica S.A.	<ul style="list-style-type: none">• Collect and standardise carbon emission data in all of Telefónica's operating markets and companies• Identify risks associated with future emission limits as well as the opportunities to cut them and improve the company's environmental record• Draw up an energy efficiency plan• Calculate to what extent the products and services marketed by Telefónica reduce carbon emissions• Raise awareness of the need to fight climate change among social and economic agents• Establish a company-wide culture of awareness around climate change and energy savings
Verizon	<ul style="list-style-type: none">• Verizon is committed to enhancing its green profile. Current initiatives have improved the company's carbon intensity 2006-2007 by 1%. The company is expanding its efforts by a wide range of green initiatives, some of which will incorporate customer participation and/or adoption. These will be monitored by a council of senior executives. They include:<ul style="list-style-type: none">– Promotion of paperless billing– Investigation and/or expansion of alternate energy sources such as solar, wind and geothermal– Broadband alternatives to travel– Hybrid vehicles– Supporting HopeLine cell phone recycling programme– Benchmarking best practices of leaders in energy conservation and alternate power sources
Vodafone plc	<ul style="list-style-type: none">• Reduce absolute CO₂ emissions by 50% against the 2006/07 footprint baseline, by 2020• Develop a separate climate change strategy for India and set a target by March 2009• Research and reduce the environmental impact of Vodafone's products and services• Design and deploy products and services that will help Vodafone's customers mitigate climate change

Appendix 5: Experts consulted and/or interviewed for the analysis and reporting

Name	Role	Organisation
General experts/policy		
Skip Laitner	Economic Analysis Director	American Council for an Energy Efficient Economy
James Lovegrove	Managing Director	American Electronics Association Europe
Paul Dickinson	Chief Executive	CDP
Barry Fogarty	Consultant	CDP
Joseph Romm	Senior Fellow	Center for American Progress
Michel Catinat	Head of Unit B4	DG Enterprise
John Doyle	Monitoring and Evaluation Unit	DG Info Society
Peter Johnston	Head, Monitoring and Evaluation Unit	DG Info Society
Matthew Baldwin	Energy Advisor	EU Commission President Barroso
Pierre Schellekens	Deputy Head of Cabinet	EU Commissioner for Environment Dimas
Jim Stack	Analyst	Freeman and Sullivan
Chris Bone	Head of Enterprise	Fujitsu Siemens Computers
Simon Mingay	Analyst	Gartner
Chris Large	Business Programme Manager	Global Action Plan
Faisal Qayium	Project Manager, ICT	Global Action Plan
Lawrence Harrison	Delivery Director	Intellect
Emma Fryer	Energy Director	Intellect
Jon Koomey	Staff Scientist	LBNL
Rebecca Henderson	Professor of Management	Sloan School of Management, Massachusetts Institute of Technology (MIT)
Rodrigo Prudencio	Investor	Nth Power
Bruno Giussani	European Director	TED Conferences
Nigel Zaldúa-Taylor	Head of ICT	Transport for London
Andrew Fanara	Director of Energy Star	US Environmental Protection Agency
James Tee	Project Manager, ICT	World Economic Forum
Tim Herzog	Director of Online Communications	World Resources Institute
Dennis Pamlin	Policy Director	WWF

Name	Role	Organisation
SMART motors, China		
Fan, Yaode	Senior Engineer	Bao Steel
Zhang, Hui	Engineer	Bao Steel
Jia, Ke	Information Officer	Beijing Office, National Electrical Manufacturers Association (NEMA)
Li, Yuqi	Chief Technical Advisor	CHUEE
Alex Wyatt	Director	Climate Bridge
Xu, Shuigen	Marketing and Business Development Director, China	Honeywell Process Solution
Valerie Karplus	Postgraduate Student	MIT
Qin, Hongbo	Motor Department	Shanghai Energy Conservation Service Centre
Wang, Guoxing	Motor Department	Shanghai Energy Conservation Service Centre
Song, Yu	Manufacturing Planning Manager	Shanghai Volkswagen
Five members of Marketing Department	Marketing	Shanghai Volkswagen
Yu, Haibin	Marketing Director	Supcon
Li, Yongdong	Professor	Tsinghua University
Zhao, Rongxiang	Professor	Zhejiang University

SMART logistics, EU

Darren Briggs	Logistics Consultant	Arup
Ewan French	COO	Barloworld Optimus
Nelly Andrieu	Masters Student	Carbon-Efficient Supply Chains, MIT
Lee Weiss		Carbon-Efficient Supply Chains, MIT
Edgar Blanco	Executive Director	Centre for Transportation and Logistics, MIT
Adrian Dickinson	Innovation Director, The Neutral Group	DHL
Grace Lowe	Head of Environmental Management System Initiative	Fujitsu
Darran Watkins	Senior Supply Chain Analyst	IGD
James Walton	Chief Economist	IGD
Don Carli	Director	Institute of Sustainable Communication
Professor Mohammed Naim	Professor	Logistics and Operations Management, Cardiff Business School
Alan McKinnon	Director, Professor of Logistics	Logistics Research Centre, Herriot-Watt University
Harold Krikke	Professor	Tilburg University
John Hix	Programme Manager, Freight Best Practice Group	UK Department for Transport

Name	Role	Organisation
SMART buildings, North America		
Gareth Ashley	Associate	Arup
Amit Khanna	Consultant – Mechanical/ Sustainability	Arup
Al Lyons	Information Technology and Telecommunications Team Lead	Arup
Susan Kaplan	Director, Sustainable Development	Battery Park City Authority – Tour of Solitaire
Mike Scheible	Deputy Director	California Air Resources Board (CARB)
Chuck Schlock	Programme Manager	CARB
Bill Welty	CIO	CARB
Leena Pische Thomas	City Director, Delhi	Clinton Climate Initiative
Donald Winston	Director Technical Services	Durst
Stuart Brodsky	(Former) National Program Manager, Commercial Properties	Energy Star
Stephen Thomas	Manager, Global Energy and Sustainability Communications	Johnson Controls
Bruce Nordman	Staff Scientist	LBNL
Stephen Selkowitz	Programme Head, Building Technologies Department	LBNL
Nidia Blake-Reeder		
Leon Glicksman	Head, Building Technology Programme, Department of Architecture	MIT
Bill Mitchell	Director	MIT Design Laboratory
Les Norford	Professor	MIT
Bernhard Berner	Chief Engineer	National Resource Management Inc.
Michael Brambley	Staff Scientist	Pacific Northwest Labs and ASHRAE
Carlo Ratti	Director	SENSEable City Laboratory
Jerry Dion	Head of Smart Building Technology Programme	US Department of Energy
Michelle Moore	Senior Vice President	USGBC
SMART grids, India		
Balawant Joshi	Managing Partner	ABPS Infra
Bharat Lal Mena	Director General	Bangalore Electricity Supply Company (BESCOM) and Karnataka Power Transmission Corporation Limited (KPTCL)
Ted Geilen	Senior Utilities Engineer, Electricity Pricing and Programs	California Public Utilities Commission (CPUC)
Dr. Hari Sharan	Director	DESI Power
Lee Cooper	Team Leader and Consultant to Customer Energy Efficiency	Emerging Technologies, PG&E

Name	Role	Organisation
Hal La Flash	Director of Emerging Clean Technology Policy	Emerging Technologies, PG&E
Steve Pullins	President (HE) and Leader of Modern Grid Initiative (MGI)	Horizon Energy – MGI
Alex Zheng	Author and Consultant	Horizon Energy – MGI
Ashok Emani	Management and Social Development Group, Senior Specialist – Environment	Infrastructure Development Finance Company
Sanjay Grewal	Executive Vice President	Infrastructure Development Finance Company
Veena Vadini	Senior Specialist – Environment	Infrastructure Development Finance Company
Ajay Mathur	Director General	Indian Bureau of Energy Efficiency
Jayant Kawale	Joint Secretary	Indian Ministry of Power
Giresh B Pradhan	Additional Secretary	Indian Ministry of Power
Vivek Kumar	Head of Utilities	Infosys
Dipayan Mitra	Climate Change Solutions	Infosys
Mitul Thapliyal	Associate	Infosys
Sanjay Kumar Banga	HOG (Automation and Network Analysis)	NDPL
Mithun Chakraborty	Business Development and Knowledge Management	NDPL
Praveen Chorghade	Head (Operations)	NDPL
BN Prasanna		NDPL
Robert Pratt	GridWise Programme Manager	Pacific Northwest National Laboratory
Shantanu Dixit	Director	Prayas Energy Group
Eric Dresselhuys	CEO	SilverSpring Networks
John O'Farrell	Executive Vice President Business Development	SilverSpring Networks
Raj Vaswani	CTO	SilverSpring Networks
Gaurav Chakraverty	Associate Fellow	Teri
Sangeeta Gupta	Director	Teri
K Ramanathan	Distinguished Fellow	Teri

Appendix 6: Glossary

AB 32 – Assembly Bill 32: Legislation that puts a cap on California's GHG emissions and creates a path for a market-based system and other mechanisms to bring the state's emissions back down to 1990 levels by 2020.

ADSL: Asymmetric digital subscriber line.

AMI: Advanced metering infrastructure.

AMR: Automatic meter reading.

AMS: Advanced metering system (also known as advanced metering).

APDRP v2 – Accelerated Power Development and Reform Programme v2: Programme introduced in 2008 to accelerate power distribution sector reforms in India.

API: Adaptive processor intensity.

AT&C losses – Aggregated technical and commercial losses: As well as accounting for losses of electricity T&D across the grid (technical losses), this term incorporates additional losses from theft of electricity from the grid (commercial losses).

AWBCS: Automated whole building control systems.

AWBDS: Automated whole building diagnostic systems.

BACnet: Data communication protocol for building automation and control networks, developed by ASHRAE.

Bandwidth: Rate of data transfer, measured in bits per second.

Base station (also known as radio base station or RBS):

(a) Telecoms: wireless communications station installed at a fixed location and used to communicate as part of either a push-to-talk two-way radio system or a wireless telephone system. (b) Computing: Radio receiver/transmitter serving as the hub of the local wireless network; may also be the gateway between wired and wireless networks.

BAU: Business as usual.

BMS - Building management system: Used in smart buildings to automatically control and adjust heating, cooling, lighting and energy use.

BREEAM: Building Research Establishment Environmental Assessment Method.

Broadband: Wide band of frequencies used to transmit telecommunications information.

Broad operating temperature envelope and fresh air cooling: Combined use of computing components with operating temperature range of 5-40°C with low power cooling by fresh air.

CAGR: Compound annual growth rate.

Captive power generation (also known as captive generation): Power generation from a unit set up by industry/households for exclusive consumption as a means to ensure a constant power supply.

Carbon footprint: Impact of human activities on the environment measured in terms GHG produced, measured in CO₂e.

Carbon intensity: Quantity of CO₂e emitted per unit of energy produced by the burning of a fuel.

CASBEE: Comprehensive Assessment System for Building Environmental Efficiency.

CDM: Clean development mechanism.

CDMA: Code division multiple access.

CDP: Carbon Disclosure Project.

Cholesteric LCD screen (see also LCD screen): Cholesteric liquid crystal displays are brighter and higher contrast than conventional LCDs in ambient lighting.

CHP: Combined heat and power.

CHUEE: China Utility-based Energy Efficiency Finance Program.

Cloud computing: System of computing in which the computing resources being accessed are typically owned and operated by third-party providers on a consolidated basis in data centre locations.

CMIE: Centre for Monitoring Indian Economy Pvt. Ltd.

CO₂: Carbon dioxide.

CO₂e: Carbon dioxide equivalent.

Computer number control (CNC): Programme to provide individual robots with instructions to perform manufacturing tasks.

Control system: Facilitates automated control of a manufacturing plant. Often based on DCS architecture.

Cost curve: GHG abatement cost curve developed in 2007 by McKinsey, which estimated the significance (in terms of emissions reductions) and cost of each possible method of reducing emissions globally, and by region and by sector.

CPFR: Collaborative planning, forecasting, and replenishment.

Cradle-to-grave approach: Analysis that incorporates all stages of a process from first to last (e.g. product development and manufacture to disposal).

CRT – cathode ray tube: Used in computer or television monitors, but increasingly being replaced by LCD or plasma screen technology.

Data centre: Facility used to house computer systems and associated components.

DCS architecture – Distributed control system architecture: System through which intelligence is distributed across components of the system and requires network connectivity for communication and monitoring.

Decentralised energy: Electricity production at or near the point of use, irrespective of size, technology or fuel used, both off-grid and on-grid.

Demand response: Reduction of customer energy usage at times of peak usage in order to help improve system reliability, reflect market conditions and pricing and support infrastructure optimisation or deferral.

Dematerialisation: The substitution of high carbon activities or products with low carbon alternatives.

DGNB: Deutsches Gesellschaft für nachhaltiges Bauen e.V.

Direct footprint: In this report refers to the CO₂e impact of the ICT sector.

Direct load control: System or programme that allows utilities, other load serving entities or demand response service providers to control user load.

Direct methanol fuel cell: Electrochemical alternative energy device that converts high-energy density fuel (liquid methanol) directly to electricity.

Distributed generation: Generation of electricity from small energy sources.

DSM: Demand side management.

Dynamic demand: Semi-passive technology for adjusting load demands on an electrical power grid.

Dynamic smart cooling: Dynamic detection and target cooling of areas of high temperature within data centres.

E-commerce (also known as electronic commerce): Buying and selling of products and services over the internet and other computer networks.

EDGE: Enhanced data rates for GSM revolution.

EFX: Electronic freight exchanges.

EICC: Electronic Industry Code of Conduct.

EIT: Economies in transition.

Embodied carbon: Total CO₂e required to get a product to its position and state. Includes product manufacture, transport and disposal.

EMCS – Energy management control system: Electronic devices with microprocessors and communication capabilities that utilise powerful, low-cost microprocessors and standard cabling communication protocols.

EMEA: Europe, Middle East and Africa.

Emerging markets: Business and market activity in industrialising or

emerging regions of the world.

Emissions factor: Carbon footprint of any energy source, expressed for example as kgCO₂/kWh. This report used emissions factors based on McKinsey and Vattenfall cost curve.

Enabling effect: Term coined in this report to describe the ability of ICT solutions to facilitate emissions reductions by means of: improved visibility; management and optimisation of processes; and behavioural change as a result of better information provision.

Energy Conservation Act: Legal framework introduced in India in 2001 to promote economy-wide energy efficiency. Led to the formation of the Indian Bureau of Energy Efficiency.

Energy intensity: Ratio of energy use to economic or physical output.

EPEAT: Electronic Product Environmental Assessment Tool.

ESCO: Energy services company.

EuP: Energy-using products.

EuP Directive: The EU Directive 2005/32/EC on the eco-design of Energy-using Products (EuP).

GDP: Gross domestic product.

GHG: Greenhouse gas.

GIS – Geographic[al] information system (also known as geospatial information system): System for capturing, storing, analysing, managing and presenting data and associated attributes that are spatially referenced to Earth.

Gj - Gigajoule: One billion joules.

GPS – Global positioning system: The only fully functional global navigation satellite system. Utilising a satellite constellation of at least 24 medium earth orbit satellites that transmit precise microwave signals, the system enables a GPS receiver to determine its location, speed, direction and time.

Green Building Finance Consortium: Group of corporations, real estate companies and trade groups addressing the need for independent research and analysis of investment in energy efficient buildings.

Green Grid: International not-for-profit organisation whose mandate is to increase energy efficiency in the IT sector.

GSM: Global system for mobile communications.

Gt – Gigatonne: One billion tonnes.

HVAC: Heating, ventilation and air conditioning.

ICT – Information and communications technology: Combination of devices and services that capture, transmit and display data and information electronically.

ICT company: GeSI constitution definition – “Any company or organisation which, as a principal part of its business, provides a service for the point-to-point transmission of voice, data or moving images over a fixed, internet, mobile or personal communication network, or is a supplier of equipment which is an integral component of the communication network infrastructure, or provides equipment or software associated with the electronic storage processing or transmission of data.”

IEA: International Energy Agency.

Indirect impact: Also referred to in this report as the enabling effect, the impact of ICT in reducing the GHG emissions attributed to other sectors such as transport, industry or power.

IMC – Intelligent motor controller: Monitors the load condition of motors and adjusts voltage input accordingly.

IP or internet protocol: Data-oriented protocol used for communicating data across a packet-switched internetwork.

IPCC – Intergovernmental Panel on Climate Change: Scientific intergovernmental body set up to assess the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation.

IPTV: System where a digital television service is delivered using internet protocol over a network infrastructure, which may include delivery by a broadband connection.

IPTV box: Internet protocol set-top box.

ISO 14040: International 2006 standard, which describes the principles and framework for LCA.

IT: Information technology.

ITU: International Telecommunications Union

kWh: Kilowatt hour.

Kyoto Protocol: Legally binding agreement of the UNFCCC in which industrialised country signatories will reduce their collective GHG emissions by 5.2% on 1990 levels. Negotiated in December 1997 in Kyoto, Japan, and came into force in February 2005.

LBNL: Lawrence Berkeley National Laboratory.

LCA: Life-cycle analysis (also known as life-cycle assessment).

LCD – Liquid crystal displays (see also Cholesteric LCD screen):

Screen composed of LCDs, one per pixel, which darken or change colour when activated.

Leapfrogging: Theory of development in which developing countries may accelerate development by skipping inferior, inefficient, expensive or polluting technologies and industries, moving directly to more advanced ones.

LED: Light-emitting diode.

LEED – Leadership in Energy and Environmental Design: Green building rating system established by the US Green Business Council.

Lever: In this report refers to a device, application or mechanism whose use or implementation brings about a reduction in GHG emissions.

Load control: Practices undertaken by electrical utilities to ensure that electrical load is less than what can be generated.

Load dispatch: Refers to the scheduling of power generation.

Load management: Refers to interruptible rates, curtailment programmes and direct load control programmes.

Mainframes: Computers used mainly by large organisations for critical applications, typically bulk data processing such as census, industry and consumer statistics and financial transaction processing.

Mbit: Megabit.

MCX – Multi-commodity exchange: Indian multi-commodity exchange with recognition from the Indian government for facilitating online trading, clearing and settlement operations for the national commodities futures market.

Mesh network: Means of routing data, voice and instructions between nodes.

MNC: Multinational corporation.

Mobile switching centre: System that connects calls by switching the digital voice packets from one network path to another (also known as routing).

Motor controllers: Devices that regulate motor speeds based on required output. Use information received from other system parts to adjust motor speed.

MRO: Maintenance, repair and operating.

Mt: Megatonne (1 million tonnes).

Multicore processor: Processor that has multiple processing cores that can perform several tasks in parallel with each other instead of in sequence.

National Electricity Act: Legislation passed by the Indian government in 2003 to speed up the development of efficiency within the electricity sector.

NDPL: North Delhi Power Ltd.

Network optimisation package: Software, network design and planning-based solution.

Network sharing: System that allows a device or piece of information on a computer to be remotely accessed from another computer, typically via a local area network or an enterprise intranet.

NGA: Next generation access.

NGN: Next generation network.

NGO: Non-governmental organisation.

OECD: Organisation for Economic Co-operation and Development.

OMS: Output management system.

Optical computing: Uses light instead of electricity to manipulate, store and transmit data.

pa: per annum.

PC: Personal computer.

Peak load or peak generation: Maximum power requirement of a system at a given time, or the amount of power required to supply customers at times when need is greatest.

Peripherals: Include monitors and printers associated with PCs.

Phantom power: Undesired electricity discharged by appliances and battery chargers when not in use.

PLT – Power line telecom: System for using electric power lines to carry information over the power line.

Power management: Systems that monitor and control activity levels of individual PC hardware components such as processors, batteries, AC adapters, fans, monitors and hard disk.

ppm: parts per million.

PUE: Power usage effectiveness.

Quantum computing: Quantum computers are hypothetical devices that make direct use of distinctively quantum mechanical phenomena to perform operations on data. The basic principle of quantum computation is that the quantum properties can be used to represent and structure data, and that quantum mechanisms can be devised and built to perform operations with this data.

Radio base station (see Base station).

Rebound effect: Increases in demand caused by the introduction of more energy efficient technologies. This increase in demand reduces the energy conservation effect of the improved technology on total resource use.

Replacement rate: Rate at which a particular device or application is replaced by another.

Results-only work environment (also known as ROWE):

Staff management principle in which employees are free to work wherever and whenever they want, as long as work is completed.

RFID – Radio-frequency identification: Automatic identification and data capture method, relying on storing and remotely retrieving data using devices called RFID tags.

Router: Computer whose software and hardware are tailored to route and forward information.

RoW: Rest of world. Sarbanes–Oxley accounting data legislation (see Sarbanes–Oxley Act) Sarbanes–Oxley Act (also known as the Public Company Accounting Reform and Investor Protection Act): 2002 US federal law that establishes or enhances standards for all US public company boards, management and public accounting firms.

SCADA - Supervisory control and data acquisition: Software package designed to perform data collection and control at the supervisory level.

Server: Application or device that performs services for connected clients as part of a client-server architecture.

Sinaut spectrum: Provides a control centre which gives an up-to-date summary on the distribution network at all times.

Smart building: Group of embodied ICT systems that maximise energy efficiency in buildings.

Smart charger: Device (primarily mobile phone) battery charger that turns off when the device is fully charged or if plugged in without device attached.

Smart grid: Integration of ICT applications throughout the grid, from generator to user, to enable efficiency and optimisation solutions.

Smart logistics: Variety of ICT applications that enable reductions in fuel and energy use by enabling better journey and load planning.

Smart meters: Advanced meters that identify consumption in more detail than conventional meters and communicate via a network back to the utility for monitoring and billing purposes.

Smart motors: ICT technologies that reduce energy consumption at the level of the motor, the factory or across the business.

SME: Small or medium enterprise.

SMS – Short message service: Communications protocol allowing the interchange of short text messages between mobile telephone devices.

SOAP: Simple object access protocol.

Solid state hard drives (also known as solid state drives): Data storage device that uses solid state memory to store persistent data and emulates a hard drive, thus easily replacing it in any application.

SPV – solar photovoltaics: Technology that uses energy from the sun to create electricity. Consists of layers of semiconducting material, usually silicon. Light shining on the cell creates an electric field across the layers, causing electricity to flow..

Substitution: In this study, taken to mean the replacement of one behavioural pattern by another.

T&D: Transmission and distribution.

TCP/IP – Internet protocol suite: Set of communications protocols that implement the protocol stack on which the internet and most commercial networks run.

Technology platform: Describes a bundle of related software programmes and hardware that deliver intelligent capabilities.

Technology transfer: The exchange of knowledge, hardware, software, money and goods among stakeholders that leads to the spreading of technology for adaptation or mitigation.

Telecommuting: Replacing commuting by rail, car or other transport with working from home.

Telecoms (also known as telecommunications): Systems used in transmitting messages over a distance electronically.

Telecoms network: Network of links and nodes arranged so that messages may be passed from one part of the network to another over multiple links and through various nodes.

Teleconferencing: Service that allows multiple participants in one phone call, replacing or complementing face-to-face meetings.

Teleworking: Working remotely via the use of ICT solutions. Includes telecommuting and tele- and videoconferencing.

Transformers: Devices that transfer electrical energy from one electrical network to another through inductively coupled electrical conductors.

TWh: TeraWatt hour.

UNFCCC – United Nations Framework Convention on Climate Change: Adopted in May 1992, signed by more than 150 countries at

the Earth Summit in Rio de Janeiro. Its ultimate objective is the “stabilisation of GHG concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” Came into force March 1994 and is ratified by 192 countries.

USGBC: US Green Building Council.

Utility computing (also known as on-demand computing):

The packaging of computational resource, such as computation and storage, as a metered service similar to a physical public utility such as electricity and water.

Value tree analysis: The method used for this report to calculate the value at stake in each case study from the associated savings in electricity, fuel combustion and carbon emissions.

VDSL – Very high-speed digital subscriber line: DSL technology providing faster data transmission over a single twisted pair of copper wires.

Videoconferencing: The audio and video transmission of meeting activities.

Virtualisation: Software allows computation users to reduce hardware assets, or use them more efficiently, by running multiple virtual machines side by side on the same hardware, emulating different components of their IT systems.

VMR: Vendor-managed repair.

Volume server: Fastest-growing category of server (includes blade servers) and is defined by IDC as servers that cost under \$25,000 (£39,439).

VSD – Variable speed drive: Controls the frequency of electrical power supplied to a motor.

W: Watt.

WCDMA - Wideband code division multiple access: Type of third generation cellular network.

Workstation: High-end microcomputer designed for technical or scientific applications.

XML: Extensible Markup Language

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