GeSI SMARTer 2020:
The Role of ICT in Driving a Sustainable Future

GeSI
GLOBAL e-SUSTAINABILITY INITIATIVE

BCG
THE BOSTON CONSULTING GROUP

Independent review by

- John A. "Skip" Laitner, *Senior Fellow, American Council for an Energy-Efficient Economy*
- Mike Berners-Lee, *Director & Principal Consultant, Small World Consulting*

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Contact information

Luis Neves, *GeSI Chairman* • Luis.Neves@telekom.de
Joan Krajewski, *SMARTer 2020 Steering Committee Chair* • JoanKr@microsoft.com
Philipp Jung, *Partner and Managing Director at BCG* • Jung.Philipp@bcg.com
Dr. M. Bockemuehl, *Partner and Managing Director at BCG* • Bockemuehl.Melanie@bcg.com

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Luis Neves
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Foreword

Luis Neves & Joan Krajewski

When we began our careers many years ago, it was the industry's role to enhance our communications and productivity, bringing people together and enabling business to be more efficient.

Fast forward, past astounding developments in information and communication technology (ICT), we see an even more critical role for the industry–one we didn't imagine and yet, every year becomes even more imperative.

Why is ICT so critical? It provides intelligence to manage, even lessen the impact of the most imminent threat to our existence: climate change. Rising temperatures are recognized as a national security issue, destructive force, and threat to national economies. The window of opportunity to address the predicted devastation associated with our warming planet continues to close. Accepted is that ICT is key to achieving a low carbon economy.

We need the speed that only ICT can offer. After each climate change related natural disaster, we reflect and ask ourselves tough questions. Without change to mitigate these issues, the questions and pressures will certainly intensify. But more importantly, the dimension of the impacts and disasters will increase and destroy the quality of lives around us.

When GeSI was founded in 2001 as a United Nations Initiative, it was to contribute towards a better world and referred to the United Nations MDGs as a starting point. Bringing together key players in the ICT sector with international organizations, GeSI embarked on a mission to demonstrate the positive potential of ICT to address societal challenges. By 2008, GeSI became an independent legal entity, a strategic partnership dedicated to provide thought leadership and practical tools that demonstrate the sector's potential for ICT-enabled low-carbon societies. Also in 2008, GeSI published the SMART 2020 report. ICT companies and policy makers alike were inspired by the ground-breaking role of ICT to respond to the challenge of climate change. To build on the momentum, we launched an assessment methodology report on how to quantify ICT's enabling capacities. At the same time, policy makers sought clarification of our findings.

Here, in this 2012 SMARTer 2020 report, we provide enhanced data, analysis and breadth on end-use sectors as well as change levers. This report demonstrates how ICT is a must have solution on an even wider scale than previously known. This report is not only a resource, but an essential toolkit.

For policy makers, the report is a lens for how ICT can be a key determinant of low-carbon economies, which in turn empowers regional political, market, human and social capital. We have shown the efficiencies ICT can provide at selected regional levels as well as within end-use sectors. The benefits are known – but have yet to be fully realized.

Global economic conditions require policy frameworks that leverage ICT to achieve sustained growth and long-term societal benefits. An enabling policy environment is the foundation upon which we can achieve an ICT-enabled low carbon environment. The ICT industry has demonstrated its commitment through operational and other changes and provided multiple innovative solutions to abate GHG emissions. Without support from governments to ensure adoption of these solutions and support behavioural change, it may not be possible to realize ICT's ability to decrease the projected growth of GHG emissions.

To our readers who are genuinely concerned about climate change, we believe you will be enlightened. We encourage all key stakeholders, especially policy-makers, to use the report's findings, which quantify ICT's potential, and work towards the greater deployment of ICT solutions.

We would like to express our gratitude to the direct contributions of working group representatives of the companies sponsoring the report, GeSI, and industry experts. This multi-disciplinary and collaborative team dedicated many hours of expertise to ensure that the report contains the most accurate data and credible assumptions in the most objective manner possible.

The SMARTer 2020 report presents a vision for a sustainable world through responsible, ICT–enabled transformation. Be innovative and inspired with us; only through working together can we build a sustainable economy while overcoming the greatest threat to our present and future.

Luis Neves
GeSI Chairman

Joan Krajewski
SMARTer 2020 Steering Committee Chair

SMARTer 2020 team

Alcatel-Lucent Thomas A. Okrasinski & Katrina Destrée Cochran
AT&T Roman Smith & John Schulz
Bell Ian Turpin, Daniel Gagne & Benoit Sicotte
BT Gabrielle Ginér, Mark Shackleton & Glyn Stacey
Deutsche Telekom Andreas Kröhling
Ericsson Pernilla Bergmark, Jens Malmodin, Dinesh Chand Sharma, Manka Mishra & Matilda Gennvi Gustafsson
GeSI Alice Valvodova
HP Christopher Wellise
Microsoft Joan Krajewski
Nokia Markus Terho, Petteri Alinikula, David Conrad, Kulsoom Ally, Chen Min, Helena Castren & Pranshu Singhal
Sprint Amy Hargroves & Darren Beck
Telenor Group Jan Kristensen
Verizon Larry Plumb, Alan Scott & Christopher Lloyd
BCG Philipp Jung, Dr. Melanie Bockemuehl, Heikki Henttu, Dr. Manuj Garg, Dr. Thomas Baker, Colton Staab & Dong Cui

About GeSI
(Global e-Sustainability Initiative)

The Global e-Sustainability Initiative (GeSI) is a strategic partnership of the Information and Communication Technology (ICT) sector and organisations committed to creating and promoting technologies and practices that foster economic, environmental and social sustainability. Formed in 2001, GeSI's vision is a sustainable world through responsible, ICT-enabled transformation. 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. GeSI has 32 members representing leading companies and associations from the ICT sector. GeSI also partners with two UN organizations - the United Nations Environment Program (UNEP) and the International Telecommunications Union (ITU) - as well as a range of international stakeholders committed to ICT sustainability objectives. These partnerships help shape GeSI's global vision regarding the evolution of the ICT sector, and how it can best meet the challenges of sustainable development.

For more information, see www.gesi.org.

Contents

1

1 Executive summary

Climate change is one of the most significant challenges, if not the most important challenge, facing our world today.[1] With the beginning of the Industrial Revolution, anthropogenic climate change has been driven by large increases in the atmospheric concentration of greenhouse gases.[2] Rising sea levels, extremes in temperature and precipitation, species extinction, acidification of natural water bodies, and other byproducts of climate change stand to threaten the world's prosperity and safety. In recent decades, greenhouse gas (GHG) emissions have accelerated as developing economies, particularly Brazil, China and India have begun the process of modernization while developed nations, such as the Australia, Canada and the United States, have struggled to curb their own emissions. If nothing is done to stem the rise of emissions, these trends are likely to continue: in 2011, annual GHG emissions were 49 $GtCO_2e$ and are projected to increase 12 percent to 55 $GtCO_2e$ by 2020 and by 63 percent over current levels to 80 $GtCO_2e$ by 2050.[3]

ICT-enabled solutions offer the potential to reduce GHG emissions by 16.5%, create 29.5 million jobs and yield USD 1.9 trillion in savings

As was explored in the SMART 2020 report, the rise of information and communications technology (ICT) has been one of the most transformative developments of the last several decades. But the world has changed since the publication of that report, and SMARTer 2020 seeks to take a fresh look at the role ICT can play in GHG abatement by considering recent trends, incorporating updated data, and looking a broader use of ICT in other industries. From tablets and increased use of broadband networks to cloud computing and smartphones, ICT has become an increasingly integral part of the global economy. It has continuously contributed to economic growth, resulting in an improved quality of life for people around the world. ICT has the possibility to address many of the problems in our society, including the threat of climate change.

For instance, consider the use of ICT-enabled GHG abatement solutions in transportation. Through the use of eco-driving, real-time traffic alerts, and the proliferation of ICT-enabled logistics systems, ICT stands to reduce total mileage and the amount of fuel required to transport people and goods. Online maps are excellent examples: by synthesizing maps with real-time traffic data and making this available on mobile devices these tools enable users to optimize routing decisions, reduce fuel consumption, and lower emissions. Furthermore, with the adoption of telecommuting and video conferencing, in certain circumstances ICT can eliminate transportation needs altogether. All of these contribute to reductions in energy use and, accordingly, reductions in GHG emissions.

These reductions in emissions are not limited to the transportation sector, but can be applied across the economy. In addition to transportation, this report considers five other end-use sectors: agriculture and land use, buildings, manufacturing, power, and consumer and service. ICT-enabled solutions offer the potential to reduce annual emissions by an estimated **9.1 $GtCO_2e$** by 2020, representing 16.5 percent of the projected total in that year, an abatement potential more than 16% higher than previously calculated in the SMART 2020 report.

1. "America's Climate Choices", National Academy of Sciences

2. "Anthropogenic climate change: Revisiting the facts," Stefan Rahmstorf

3. EDGAR Database; OECD, "Environmental Outlook to 2050"

Power

ICT adoption in the power sector could yield **2.0 GtCO$_2$e** in abatement (or 22% of total estimated abatement total) by playing a critical role in the creation of a more dynamic power market with supply and pricing responding to changes in demand. This more dynamic market is vital for effectively integrating renewable energy into the power supply.

Transportation

Emissions reductions in transportation could reach **1.9 GtCO$_2$e** (21% of total). Increased efficiency in cargo transit through improved logistics networks and fleet management represents a significant abatement opportunity. Telecommuting and increased use of video conferencing can reduce transportation needs and emissions.

Agriculture and land use

Emissions reductions from this sector could reach **1.6 GtCO$_2$e** (18% of total). As the inputs required to grow crops emit large quantities of emissions, ICT that allows farmers to accurately assess how much to irrigate and fertilize their crops will lead to emissions abatement. Systems that reduce the amount of land required to raise livestock and reduce their methane emissions also have significant abatement potential. Also, monitoring equipment can help governments prevent the destruction of rainforests that act as carbon sinks.

Buildings

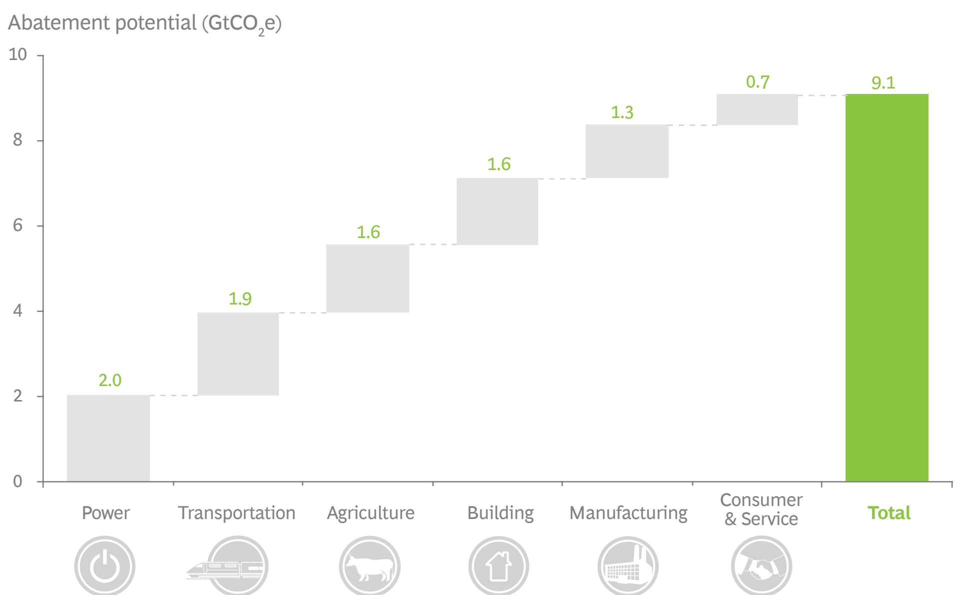
ICT can abate **1.6 GtCO$_2$e** (18% of total) in this sector by providing occupants with the systems required to support the generation of renewable energy and incorporate it into the building's power supply. Smart design can reduce lighting and heating, ventilation, and air conditioning needs while building management systems ensure that those systems are used efficiently.

Manufacturing

ICT-enabled efficiency in factories and other manufacturing applications could allow for **1.2 GtCO$_2$e** (13% of total) in abatement from the manufacturing sector. Through solutions that, for example, better control a motor system to better match its power usage to a required output, there are many opportunities for ICT to make manufacturing more efficient.

Consumer and service

Emissions reductions through ICT in the consumer and service sector could reach 0.7 **GtCO$_2$e** (8% of total). ICT connects consumers to merchants via the Internet and enables them to purchase goods online rather than physically traveling to the store. ICT-enabled software can also develop packaging that generates less waste and conserves resources.



Summary of estimated abatement potential by sector

Source: BCG analysis

Not only will ICT-enabled abatement solutions address climate change, but also present an opportunity to drive sustainable economic growth. This is of particular importance given the emphasis placed on raising incomes and living standards by policy makers, particularly those in the developing world. It is estimated that full utilization of the sublevers we have identified **could yield USD 1.9 trillion in savings** for consumers and businesses and that 29.5 million jobs would be created worldwide as a result.

It is important to note that the projections and estimates of the abatement potential of the above sublevers and the economic impact are subject to data and methodological limitations, which have been identified and expounded on in the report.

While an international framework for climate change continues to be important, effective policies at the national and local level are needed at the same time

For many of the ICT-enabled abatement solutions, the market will drive further uptake. To use Canada as an example, leveraging ICT to design and to manage new buildings to be more energy efficient will occur without policy intervention. Given current energy prices and the low upfront cost associated with altering building design and management, developers will find it economically favorable to incorporate efficient design into their buildings. The incorporation of renewable energy, however, has a weaker business case because of the availability of inexpensive electricity generated by hydro and fossil fuel sources. Driving higher uptake of renewable energy integration will require the intervention of policy makers to make renewable energy generation economically competitive with other sources.

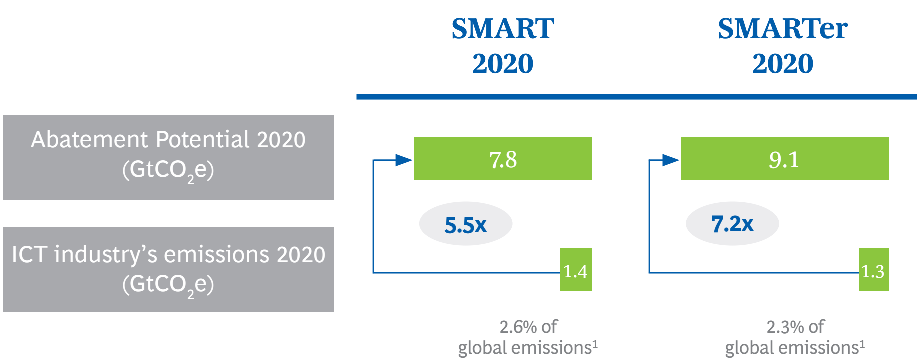
The most significant challenge facing many ICT-enabled abatement solutions is the lack of robust policies to address climate change. International policy makers have been unable to reach consensus on a global GHG emission program. Thus, while an international framework for climate change continues to be important, it is clear that effective policies at the national and local level, for example cities and states, are needed at the same time. National governments are best positioned to drive GHG reductions, and enacting policies that accelerate the use of ICT-enabled solutions is an effective way to facilitate the transition to a low-carbon economy. National policies will have even greater impact if they are supported by a global framework to limit emissions, for instance by creation of a market that establishes a price on CO_2 to improve the economics of many of the ICT solutions.

And while ICT will continue to play an important role in GHG abatement, it is important to recognize that the sector contributes to climate change as well. Widespread adoption of ICT devices has led to a rise in their associated GHG emissions; from 2002 to 2011 emissions rose from 0.53 $GtCO_2e$ to 0.91 $GtCO_2e$ and are projected to rise to 1.27 $GtCO_2e$ by 2020. This represents an increase in ICT's share of total global emissions, increasing from 1.3 percent of global emissions in 2002 to 2.3 percent in 2020. Though these emissions cannot be ignored, ICT provides significant leverage in addressing climate change; the estimated ICT-enabled abatement potential of 9.1 $GtCO_2e$ for the sectors and sublevers identified by this report is seven times the size of the sector's direct emissions. Considering only the sector's direct emissions fails to reflect its importance as a GHG-abatement tool. Moreover, the industry continues to work toward increasing the energy efficiency of its own devices to stem the rise in emissions as ICT proliferates. Even since the publication of the previous SMART 2020 report, we have seen significant adoption of energy-saving solutions within the ICT industry and increases in the role of ICT in other industries, leading to more than a 16% increase in the estimated abatement potential.

When we compare the estimates in this study with the results from the SMART 2020 report, we see an encouraging trend, as the abatement potential has increased while the direct emissions figure is lower. The increase in abatement potential is due to the innovation of new sublevers, as unforeseen technology has been introduced and has been shown to play an important role in abatement. The decrease in the ICT industry's own emissions is driven by several factors; we have seen the innovation and adoption of smart mobile devices like phones and tablets, which have started to cannibalize or reduce the use of more energy-intensive computing equipment like PCs. Additionally, the increased use of virtualization and more efficient use of cloud computing reduces estimates. Finally, the economic slowdown, especially the impact on developing markets, has decreased estimates on the use of devices in these countries.

To highlight opportunities and illustrate the differences across countries through a standardized framework, the report provides guidance to policy makers on actions that can accelerate the abatement benefits of ICT-enabled solutions in the following seven countries: Brazil, Canada, China, Germany, India, the United Kingdom, and the United States. In Brazil, the government has expressed a desire to decrease emissions and has passed some policies to fight deforestation, but a lack of resources and high demand for Brazilian agricultural products and population increase has driven emissions higher. Canadian emissions have remained relatively flat since 2000 due to increases in energy efficiency, but the extraction of tar sands and economic expansion threaten to push emissions higher. China has become the world's largest GHG emitter and ICT-enabled solutions, if implemented and scaled up, can decelerate current emissions growth trends. In Germany, emissions have fallen since reunification, but reductions have slowed over the last decade. Given the proposed phase out of nuclear energy, Germany may find it challenging to meet its emissions targets. In

While ICT's own footprint is projected to rise to 1.27 $GtCO_2e$ by 2020, its abatement potential is 7 times higher



Total estimated abatement potential compared with estimate of direct emissions from the industry. Results compared also with original SMART 2020 report

1. On a base of 55 Gt CO_2e GHG emissions (IEA)

Source: SMART 2020, IEA, BCG analysis

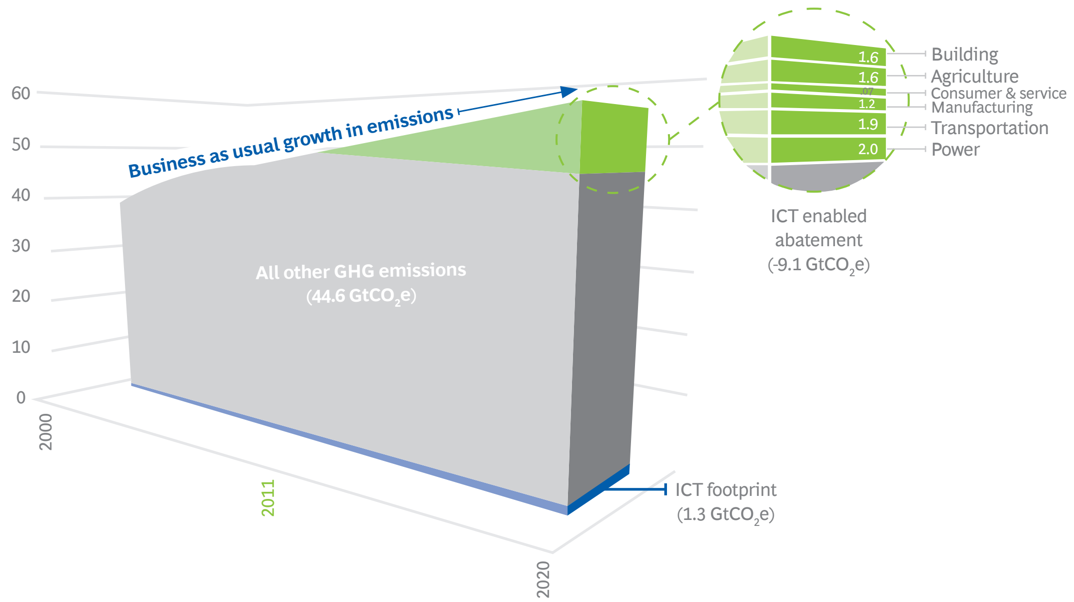
India, rapid economic growth caused emissions to more than double between 1994 and 2007 and emissions growth is exacerbated by poor power and transportation infrastructure and high reliance on fossil fuels. The U.K. has managed to decouple economic growth from emissions growth, but the adoption of new levers is essential to ensure the trend continues. And in the U.S., emissions have grew slowly but steadily until 2008 and the onset of the global financial crisis. While emissions declined 1.7% in 2011 from 2010 levels in part due to the increased use of natural gas in power generation and efficiency gains, the unfavorable political environment surrounding GHG abatement must change if U.S. emissions are to decline significantly.[4]

Reducing emissions while maintaining economic growth and improving quality of life is one of the fundamental challenges of the twenty-first century; ICT offers the opportunity to address the threat of climate change while sustainably growing the world's economies.

4. EIA

Abatement potential in 2020 plotted with the direct emissions from the ICT industry and total global GHG emissions

Source: IEA, BCG analysis



2 Introduction

2.1 Global context

Global warming is one of the most pressing problems facing society in the twenty-first century. Since the previous SMART 2020 report in 2008, the growth of greenhouse gas (GHG) emissions as a result of human activity has increased along with the potential damage that could occur due to global warming.

Global warming is the consequence of the release of carbon dioxide and other GHGs into the atmosphere as a result of human activity, namely the burning of fossil fuels. These GHGs create a warming effect by absorbing radiation reflected from the Earth that would otherwise escape back into space. While CO_2 is the main gas responsible for global warming, other GHGs include methane, nitrous oxide, and fluorocarbons, among others. These gases, while often emitted in lower concentrations than CO_2, have a much higher warming effect per molecule and can also be a major contributor to warming. In this report, we refer to both CO_2 emissions and GHG emissions. GHG emissions include CO_2 and all other GHGs and are referred to as its CO_2-equivalent (CO_2e). For more information on the difference between CO_2 and CO_2e and the reporting methodology used, please see section 14.1 of the appendix.

Little has changed since the previous SMART 2020 report in terms of the science related to global warming or the scale of the potential impact from global warming. If anything, estimates of the cost have increased and the scientific evidence regarding the role of human activity on global warming has strengthened. This statement from the previous report remains very true today: "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."[5]

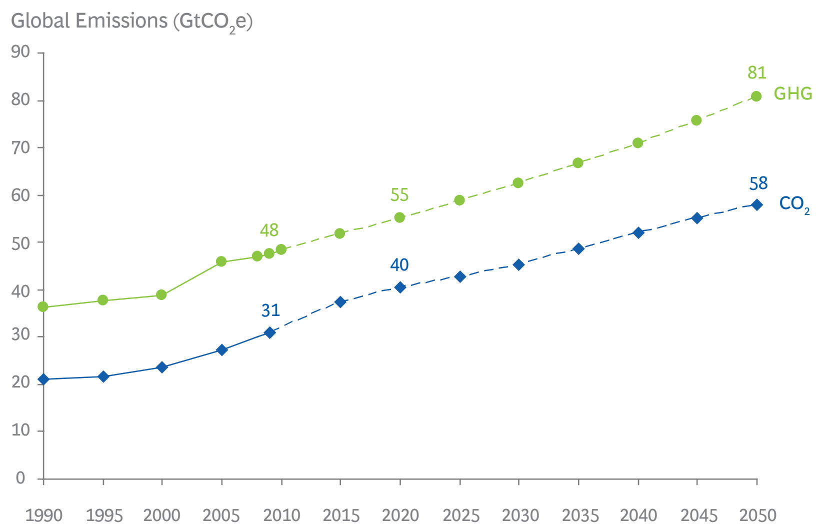
While the global recession decreased the growth of GHG emissions in 2008 and 2009, especially in developed economies, growth from developing countries has exceeded expectations and is becoming an increasingly larger share of the global total. Figure 1 illustrates the historic and projected growth of GHG emissions. Without any changes to current trends or major efforts to reduce emissions, the total annual GHG emissions could rise to over 55 $GtCO_2e$ in 2020 and exceed 80 $GtCO_2e$ in 2050.[6]

5. IPCC 2007 Synthesis Report; 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, IPCC, Geneva, Switzerland

6. Please note that Gt equals a billion (109) metric tons; OECD, http://www.oecd-ilibrary.org/environment/oecd-environmental-outlook-to-2050_9789264122246-en

Figure 1
Global annual CO_2 and GHG emissions, historic and projected business as usual assuming no significant efforts to reduce emissions

Source: EDGAR Database; OECD, "Environmental Outlook to 2050"



Impact of global warming[7]

It is difficult to fully model the exact effect that increases in GHG emissions will have on global temperatures and correspondingly the effect on our society. But it is understood that there are many significant problems that could occur. Many of these have a positive feedback effect, i.e., they get worse or release additional GHGs as warming occurs:

Cutoff of thermohaline circulation (THC)
THC is large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes. Potential changes to the thermohaline circulation are thought to have significant impact on the Earth's radiation budget and also play an important role in determining the concentration of carbon dioxide in the atmosphere. Warming increases freshwater inflow in the North Atlantic thus weakening THC and further increasing warming in the North Atlantic Ocean region.

Amazon rainforest dieback
A large fraction of rainforest precipitation is recycled, but global warming disrupts this recycling, causing rainforest dieback, which then leads to further dieback.

Permafrost melting
Atmospheric warming leads to permafrost melting, releasing large amounts of methane and further increasing warming.

Disintegration of West Antarctic ice sheet
Melting leads to ground-line retreat, potentially leading to ocean water undercutting the ice sheet and more rapid disintegration.

Disruption of Indian monsoon
Warming disrupts complex self-sustained moisture circulation of the Indian monsoon.

Melting of Greenland ice sheet
Warming leads to melt water residues left on the ice sheet surface or exposure of land, which increases surface temperature and leads to further melting.

Estimates on the economic impact vary widely as models are refined and improved, but it is clear that there is potentially a catastrophic cost to our society. According to the Stern Review, written by former World Bank Chief Economist Lord Stern, without action the overall costs and risks of climate change could be the equivalent to losing at least 5 percent of the global gross domestic product (GDP) each year.[8] Other estimates from the Intergovernmental Panel on Climate Change (IPCC) are in line with the Stern report and have been revised as more sophisticated and accurate models have been built.[9]

Global warming could potentially have a catastrophic cost on our society

The costs of reducing GHG emissions to an acceptable level can be manageable. The Stern report estimated a cost of approximately 1 percent of global GDP each year, resulting in a sufficient payback if implemented. In its most recent report, *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*, the International Energy Agency (IEA) estimated that investment in clean energy needs to double by 2020 to avoid the worst effects of global warming. This would be a total cost of USD 36 trillion between today and 2050.

However, it is important to point out that the total investment is not the same as net spending and that there are significant savings from investing in renewables and energy efficiency. By 2025, the fuel savings realized by reducing GHG emissions would outweigh investment and by 2050, the fuel savings would amount to more than USD 100 trillion. Even if these potential future savings are discounted at 10 percent, there would be a USD 5 trillion net saving between now and 2050. Regardless of the exact numbers, it is clear that the economic costs of global warming are significant and that there is a major savings potential from early intervention.

7. Timothy M. Lenton and Hans Joachim Schellnhuber, "Tipping the scales," Nature Reports Climate Change, 2007
8. Stern, N. (2008) Key Elements of a Global Deal on Climate Change, London School of Economics and Political Science
9. Jeffrey D. Sachs and Shiv Someshwar, Green Growth and Equity in the Context of Climate Change: Some Considerations, ADBI, (2012) http://www.adbi.org/files/2012.07.13.wp371.green.growth.climate.change.pdf

Scale of abatement reduction

It is difficult to determine the exact amount of CO_2 abatement needed. The scenario set forth by the IEA report discussed above would require reducing CO_2 emissions in 2050 to under 20 $GtCO_2$. Compared to the "business-as-usual" case outlined in Figure 1, this would require an abatement of around 40 $GtCO_2$, which is approximately two-thirds of total expected CO_2 emissions in that year. The Stern report identified the need to reduce GHG emissions to equivalent levels. This implies significant changes in the use of energy around the world.

To give some perspective of what this would entail, Table 1 illustrates the 2008 GHG emissions by the top 10 countries:

These top 10 countries contribute a total of approximately 29 $GtCO_2e$ of emissions and collectively emit approximately 62 percent of the world's total emissions. Though climate change will need to be addressed across the international community, these 10 countries stand to have the largest impact on reaching emissions abatement targets. The information and communication technologies sector has a significant role to play in achieving the desired abatement, as will be seen in the following chapters.

2.2 The role of ICT

The ICT industry plays a vital role in the global economy and is a major driver of growth and development. It has an important role to play in supporting growth in the slowing economies of developed nations, while serving to leap-frog and modernize developing nations. Several of the most transformative economic trends (e.g., social media, big data, multi-channel retail, etc.) involve the use of ICT. The indispensible role that ICT plays in the world economy is only projected to grow for the foreseeable future.

Table 1
List of the top 10 countries by GHG emissions in 2008

Note: Emissions from land change make up a large part of emissions in Indonesia, Brazil and Democratic Republic of Congo

Country	2008 GHG emissions ($GtCO_2e$)	Per capita emissions (tCO_2e/person)
China	9.9	7.6
United States	6.6	21.7
Russia	2.6	18.2
India	2.4	2.0
Indonesia	2.0	8.8
Brazil	1.4	7.5
Japan	1.3	10.4
Democratic Republic of Congo	1.0	16.0
Germany	1.0	12.3
Canada	0.7	22.0
Total	**29** (~62% of global total)	

As we consider the overall implications of GHG emissions, we see that they are strongly correlated with economic growth. The growth of emissions temporarily slowed in 2008 and 2009 as a result of the global recession, but has quickly rebounded and continued to grow in the last three years. Ideally, countries would seek solutions that decouple emission growth from economic growth to create wealth and improve standards of living without the corresponding increase in emissions.

ICT has an important role to play in the development of environmentally sustainable economic growth. Previous analysis shows that the ICT industry contributed 16 percent to overall GDP growth from 2002 to 2007, with the sector growing from 5.8 to 7.3 percent of the total economy. The sector's contribution to worldwide growth is expected to remain high at 8.7 percent of worldwide GDP growth by 2020.[10] ICT's contribution to economic growth is not a recent development; historically, the sector has played an indispensible role in growth. As much as one-third of all economic growth in the Organization for Economic Cooperation and Development (OECD) countries between 1970 and 1990 was due to access to fixed-line telecom networks alone.[11] Assuming full utilization of the sublevers we have assessed, the economic impact of ICT-enabled GHG abatement will be significant. If 9.1 $GtCO_2e$ of abatement is realized, the sublevers have the potential to save USD 1.86 trillion and could create as many as 29.5 million jobs by 2020.

In addition to its positive implications for economic growth, ICT's GHG abatement potential must also be considered. The ICT industry accounted for 1.9 percent of total global GHG emissions in 2011, which is significantly less than its overall contribution to GDP. Nonetheless, this is a significant amount of emissions that the industry must address, especially as we expect even faster adoption of ICT in the future. However, in the last several years there have been promising strides toward decreasing the growth rate of ICT emissions. The total embodied emissions of many end-use devices have significantly decreased, networks have become more energy efficient, and trends within the sector, such as virtualization and dematerialization, will continue to make it more efficient.

As for the environmental impact of the ICT sector, not only should we consider the direct impact of the ICT industry but also its indirect impact, which is when its products and network services are used by other sectors, especially for solutions that reduce emissions. The previous SMART 2020 report and this update seek to address four key questions around the role of the industry and climate change:

1. What is the direct GHG footprint of the ICT sector?
2. What are the quantifiable emission 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 realizing these reductions?
4. What policy measures are required to realize the full GHG abatement potential of ICT?

In the following sections of the report, we will first explore ICT's impact on GHG emissions. We will investigate the impact of the trends identified above and discuss the areas in which the industry can seek to reduce emissions. We will present a detailed model that estimates the industry's total emissions this year and projected emissions through 2020. In the second section, we will explore the broader impact of ICT on industries and quantify the abatement potential by the role of ICT (called change levers) and by the end-use sector.

10. Global insight, SMART 2020 report

11. 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

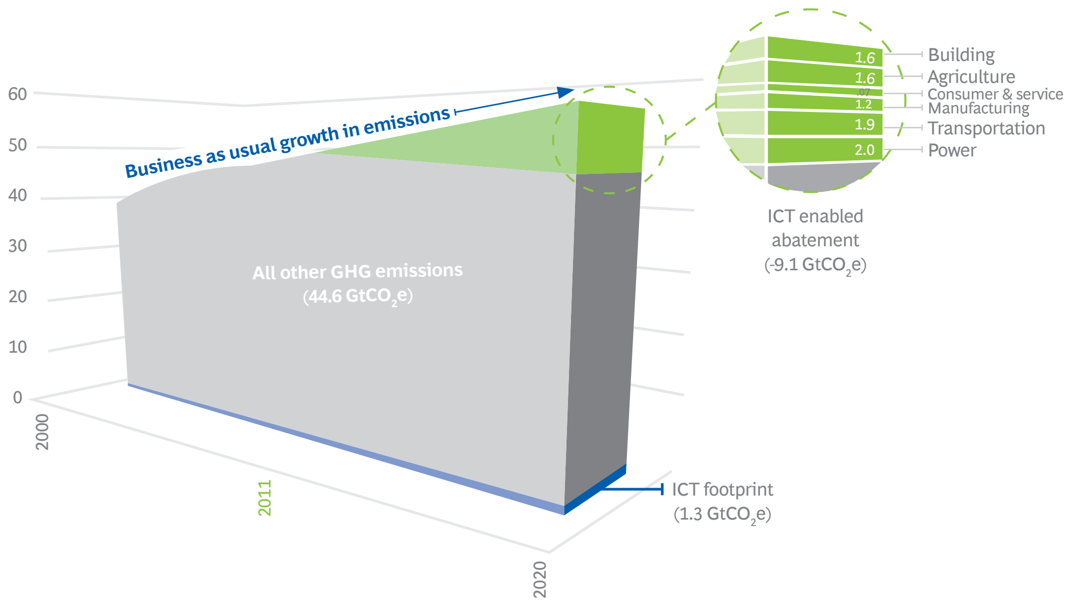
2.3 ICT abatement potential: 9.1 $GtCO_2e$ or seven times ICT direct emissions

Current estimates from the IEA and others for their "business-as-usual" case (BAU) have the total annual GHG emissions growing to around 55 $GtCO_2e$ by 2020. In this report we estimate that ICT can have a significant impact on reducing this amount, as Figure 2 below illustrates. We estimate the total abatement potential from ICT solutions to be **9.1** $GtCO_2e$, or 16.5 percent of the total BAU amount.

As indicated by Figure 2, the total emissions from the ICT industry have been estimated in this report. The industry makes up a small percentage of the worldwide emissions total and its emissions are substantially lowerthan the ICT-enabled abatement potential for the sublevers htat have been identified. We estimate that the total emissions in 2011 were 0.9 $GtCO_2e$ (1.9 percent of all global GHG emissions) and that by 2020, total emissions will be 1.3 $GtCO_2e$, or 2.3 percent of global emissions. Though this number was based on conservative estimates for efficiency upgrades, it illustrates the need for additional efforts to become more efficient within the industry. Nonetheless, it is clear that the ICT sector can make a significant impact on emissions abatement, contributing emissions abatement of seven times the industry's direct emissions. This makes a strong case for the role of ICT in our society and illustrates how ICT can aid economic growth and increasing the quality of life while at the same time reducing the impact of GHG in climate change.

Figure 2
Abatement potential in 2020 plotted with the direct emissions from the ICT industry and total global GHG emissions

Future projections and estimates on the total emissions and abatement come with inherent inaccuracies because of the difficulty of such estimations. In fact, both the BAU case and the abatement potential scenarios serve as only one scenario of many that could occur in the future. The calculated abatement potential as drawn in the figure is subtracted from the 2020 BAU case. The BAU case contains some intrinsic improvement in technology based on historic trends. This may overlap with some of the abatement potential identified in this report. Combined with the uncertainty in the BAU estimate, we caution against trying to interpret the absolute GHG emissions from the analysis, but instead encourage the reader to focus on the scale of impact that ICT can make regardless of what GHG scenario we expect in the future.



3
The ICT industry's GHG emissions

3.1 Overview of key emissions trends

The growth in GHG emissions from the ICT industry[12]—end-user devices,[13] telecommunication networks, and data centers—is expected to decrease in the next decade. While the growth rate from 2002 to 2011 was 6.1 percent per year, the growth rate for 2011 to 2020 is expected to slow to 3.8 percent per year (see Figure 3). This section discusses the factors driving this decrease in growth.

The decrease in ICT emissions growth will be due to a significantly reduced rate of growth in emissions by end-user devices. From a growth rate of 6.1 percent per year in GHG emissions between 2002 and 2011, end-user device emissions are expected to decrease to 2.3 percent per year between 2011 and 2020. Since this category accounts for 60 percent of all ICT emissions, a deceleration will have a big impact on the growth rate of total ICT emissions. The primary driver for this decline is the expected efficiency gains and a shift from PCs to laptops and tablets.

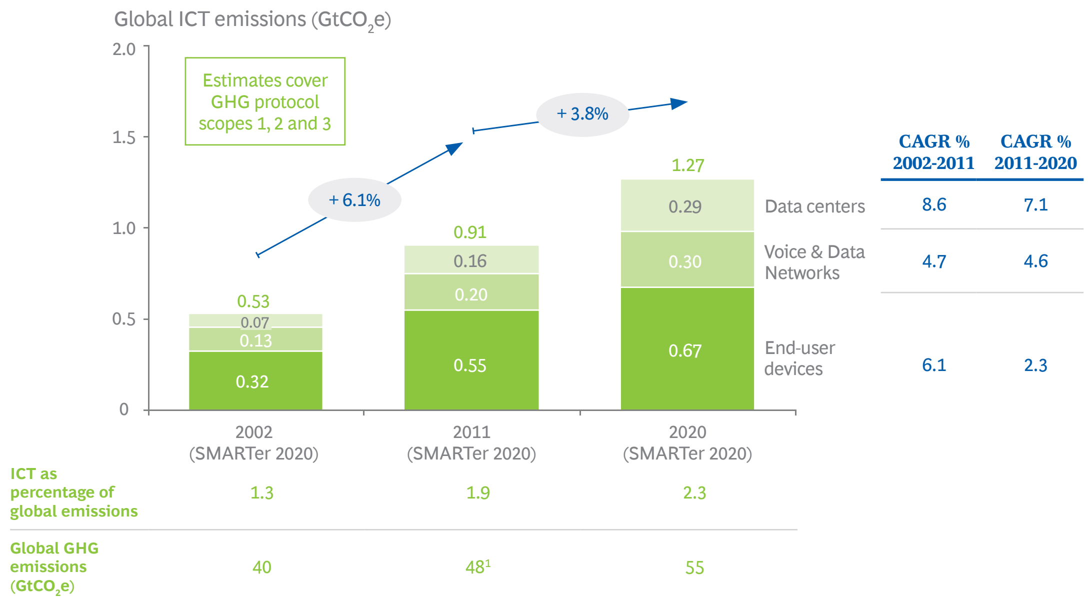
Despite the lower growth rate, the ICT industry's footprint is projected to increase at a faster rate than the total global footprint between 2011 and 2020. According to data from the International Energy Agency, global GHG emissions are expected to rise at 1.5 percent per year between 2011 and 2020. This is lower than the 3.8 percent projected growth in ICT emissions. It is, however, important to recognize that the total global GHG abatement potential enabled by these technologies is several times larger than ICT's own footprint. The next chapter delves into this subject in detail.

In 2011, the ICT industry's total footprint amounted to 0.9 $GtCO_2e$, or 1.9 percent of the global emissions. The technologies from the industry form the fabric of the

12. The scope defined here differs from that used by OECD (see appendix for details) by taking a more equipment based approach: this study considers only the main ICT equipment categories

13. PCs (desktops and laptops), monitors, tablets, smartphones, other mobile phones, printers, and peripherals (IPTV boxes, modems, routers, etc.)

Figure 3
ICT emissions growth expected to decrease from 6.1 percent to 3.8 percent



1. Data for 2010,

Source: Gartner; Forrester; U.S. Census Bureau; IEA; Greentouch; CEET; CDP; Ovum; GSMA; CERN; Cisco; CEET; SMART 2020: Enabling the low carbon economy in the information age; academic publications; industry experts; academic experts; manufacturer websites; BCG analysis modern global economy, and will see a continued increase in penetration over the next 10 years. The growth in usage, however, comes at the cost of higher emissions. Despite expected efficiency gains, the ICT industry's footprint is projected to rise to 1.3 $GtCO_2e$ or 2.3 percent of global emissions by 2020.

The emissions from all three ICT categories—end-user devices, telecommunication networks, and data centers—are expected to increase. However, the data center footprint is expected to increase most rapidly, at 7.1 percent per year, followed by networks at 4.6 percent and end-user devices at 2.3 percent.

It is important to note that these estimates are based on several projections and assumptions, all of which are stated in the appendix. It is likely that actual realization of ICT emissions in 2020 may be quite different. Several trends—slower or faster global economic growth, sourcing of rare-earth minerals from countries other than China,[14] recycling of ICT devices in western Africa in an environmentally detrimental fashion, and others—could impact ICT emissions in a significant way. Since it is hard to forecast these trends, this study does not include their impact in the estimates.

Furthermore, as noted earlier, this study uses a specific definition of ICT. Different scope and definitions of ICT would yield different estimates. All of the estimates of ICT emissions in this chapter are based on lifecycle emissions, and include scopes 1, 2, and 3 of the GHG protocol, subject to data limitations.[15]

3.2 End-user devices

End-user devices' footprint was the largest of the three categories in 2011. These devices accounted for 0.55 $GtCO_2e$, or 59 percent of total ICT emissions. Within the end-user devices, PCs had the biggest share, at 60 percent. The large PC footprint is driven by the substantially bigger embodied and usage emissions compared with other devices. Printers and peripherals make up most of the remainder of end-user devices' emissions, at 18 percent and 13 percent respectively. Low global penetration of smartphones (approximately 10 percent) and tablets (approximately 1 percent) in 2011, and lower per device footprint compared with other devices resulted in their small total footprint.

14. Japan and India have begun exploring the potential of sea-bed mining for rare-earth minerals (www.scidev.net/en/agriculture-and-environment/earth-science/features/india-backs-exploration-of-rare-earths-in-deep-sea-1.html)

15. Greenhouse Gas Protocol: www.ghgprotocol.org/calculation-tools/faq

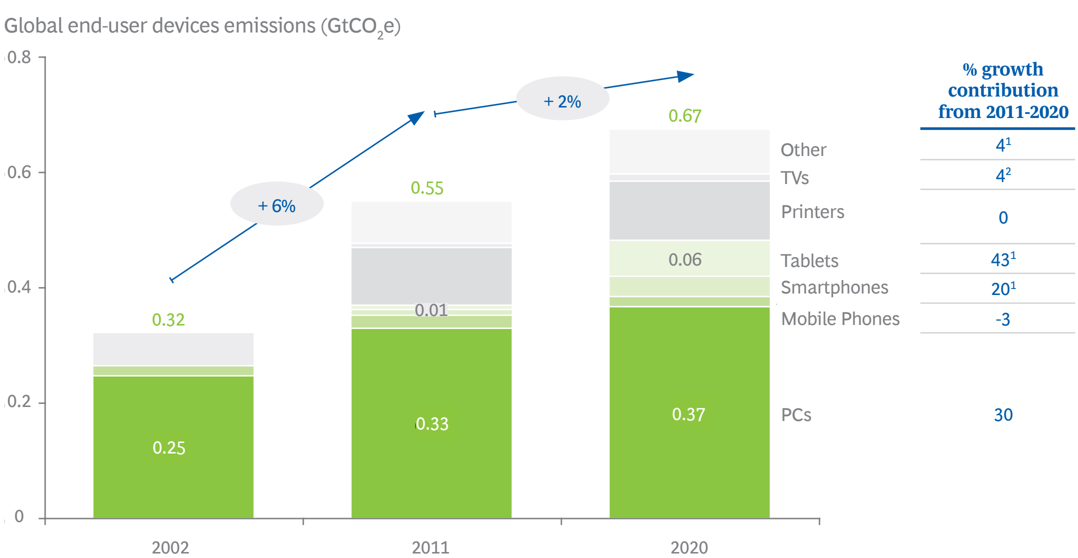


Figure 4
Growth in end-user devices emissions expected to slow down from 6 percent to 2 percent

1. Only TV usage emissions related to IPTV included

Note: Industry trend used to extrapolate 2020 installed base and shipments

Source: Gartner; Forrester; U.S. Census Bureau; IEA; Greentouch; CEET; CDP; Ovum; GSMA; CERN; Cisco; CEET; Jonathan Koomey; SMART 2020; BCG analysis

It is estimated that the footprint of end-user devices will grow at 2.3 percent per year to reach 0.67 $GtCO_2e$ in 2020. This growth rate, however, is significantly lower than the growth rate of 6.1 percent per year between 2002 and 2011. Due to this slower growth rate, the share of end-user devices in total ICT emissions will drop to approximately 50 percent in 2020.

Robust sales growth of end-user devices over the next decade will drive the higher level of absolute emissions. The installed base of PCs is expected to double to approximately 3 billion by 2020.[16] Much of this will be driven by growing markets such as China and India. Tablet penetration is expected to increase rapidly as many different vendors enter the market, thus increasing competition in the tablet market and lowering prices. Smartphone penetration will also increase, although it is likely to cannibalize some of the current regular mobile phone market. Overall, though, mobile penetration will increase substantially by 2020.

Three important technology trends will, however, reduce the emissions growth in this category (see Figure 4). First, laptops will capture an increasingly larger share of the PC market. According to data from Gartner, the current share of laptops in the PC market is around 45 percent and is expected to increase to more than 70 percent by 2020. Since laptops have a lower GHG footprint than desktops, this will lower the overall PC footprint. Second, there will be a growing tablet device base. Since a tablet's GHG footprint is less than 25 percent of that of an average PC, [17] this will also help with GHG abatement. And last, continued energy efficiency improvements in devices, especially PCs, will also be important. Standby energy use reduction in devices will likely be the biggest contributor to increased energy efficiency. A complete phase out of cathode ray tube monitors with liquid crystal display monitors will also be an important contributor.

3.3 Telecommunication networks

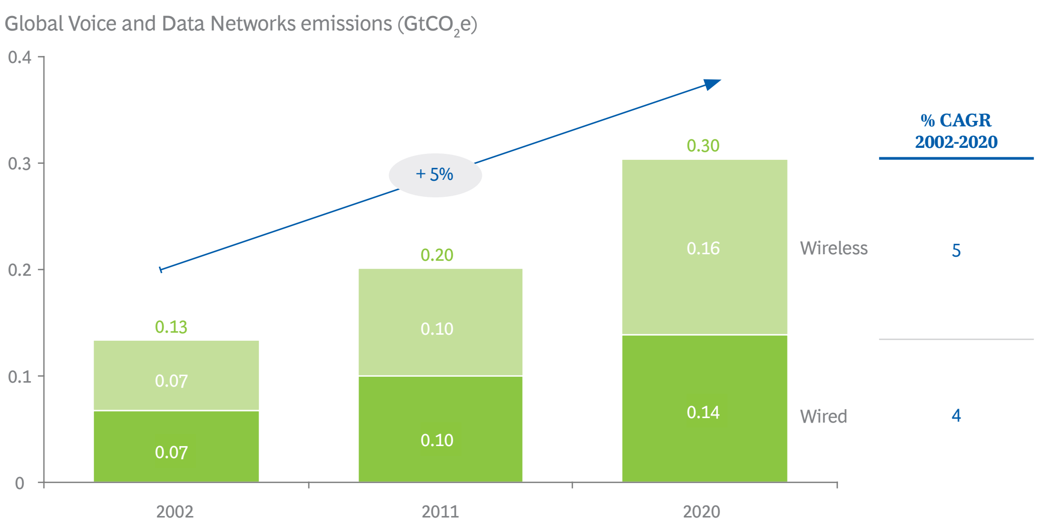
Telecommunication networks' GHG emission footprint was 0.20 $GtCO_2e$ in 2011. This amounted to 22 percent of the total ICT footprint in 2011. Wireless networks and wireline networks accounted for an equal share of the footprint at 0.10 $GtCO_2e$ (see Figure 5).

16. Given the recent economic slowdown, and the consequent downward revision of economic growth forecasts, this study uses a more conservative estimate of the 2020 installed base than the 4 billion used in "SMART 2020: Enabling the low carbon global economy in the information age."

17. Average of desktop and laptop

Figure 5
Mobile network emissions expected to grow faster than fixed networks emissions

Source: Gartner; Forrester; U.S. Census Bureau; IEA; Greentouch; CEET; CDP; Ovum; GSMA; CERN; Cisco; CEET; Jonathan Koomey; SMART 2020; BCG analysis



Wireless networks

Mobile network operators will face an explosion in the mobile data and voice traffic: the estimates for the total traffic growth vary from a 33 times increase[18] to a 70-times increase.[19] This is a major technical, operational, and financial challenge for mobile telecom operators all over the world.

Several factors contribute to the explosion of wireless data traffic. In 2011, there were 6 billion mobile subscriptions; this number is expected to double by 2020.[20] In addition to more users, data usage per user is also expected to increase as data-intensive services and applications—such as streaming video and music—are adopted by a larger share of smartphone and tablet users. The rapid increase in traffic volume will necessitate wireless network capacity upgrades and adoption of fourth-generation (4G) LTE networks.

This will increase usage emissions and the embodied emissions associated with these infrastructure upgrades. Efficiency improvements, however, are expected to lower the energy consumed per unit of mobile traffic. The expected phase-out of older networks and network equipment in favor of more modern technology; improvements in the network spectrum efficiency and in base station power amplifiers and antennas; optimization of network cell size; and the available unused capacity of the existing networks will all compensate for data traffic growth and help moderate wireless network emissions growth.[21]

Furthermore, the adoption of greener sources of energy for cell towers and base stations is also expected. For instance, well over half of the cell towers in India run on diesel, leading to an estimated 10 Mt of CO_2 emissions each year.[22] Currently, pilot programs are under way to use renewable energy, especially solar, to power these towers. If successful, scaling up these solutions to cover the maximum number of cell towers could have a huge impact on reducing emissions in India's mobile network infrastructure.

Nevertheless, these kinds of emissions reductions are unlikely to keep pace with the growth in emissions due to the remarkably large traffic volume increases. To quantify the impact of these trends, this study models the evolution of wireless network emissions as a function of traffic growth. Taking into account the expected efficiency improvements, the wireless network emissions are expected to be 164 $MtCO_2e$ with the assumed data growth of 50 times the level in 2011. [23]

While the industry continues to make significant strides in improving the energy efficiency of its communication and data networks, network equipment and management of these networks, more dramatic and faster improvements are necessary. Therefore, the industry has begun to expand upon fundamental as well as disruptive research to handle the traffic growth in a sustainable way. The **GreenTouch™** consortium, for example, was formed to increase network energy efficiency by a factor of 1,000 compared to 2010 levels. As a global research consortium with leading industry, academia and research institutes, it currently has over 25 research projects and activities, including the Large Scale Antenna System (LSAS) and the Bit-Interleaved Passive Optical Network (Bi-PON) projects, which are already beginning to demonstrate how innovative technologies can continue to increase data network efficiency. The consortium's mission is to deliver architectures, solutions, and specifications by 2015, and to demonstrate key technologies necessary to improve network energy efficiency by a factor of 1,000 compared to 2010 levels, which represents several orders of magnitude compared to the efficiency of networks in use today.

The work done by **GreenTouch™** is representative of the initiatives that need to be pursued by the industry to ensure that the emissions of future wireless, wireline, and optical networks can meet the estimated projections used in this study.

Wireline networks

Wireline networks will also face an increase in the amount of data they will carry. According to GreenTouch™ estimates, fixed Internet IP traffic in 2020 will be eight times the level in 2011. However, an increase in IP traffic is less likely to impact wireline networks than the anticipated impact on wireless networks.[23] Additionally, a move to fiber optic networks from copper networks will significantly lower the energy use of these networks. The total

18. UMTS Forum
19. GreentouchTM
20. GreentouchTM, Ovum, ITU
21. Source: Expert interviews
22. TRAI: http://trai1.gov.in/WriteReadData/ConsultationPaper/Document/TEMA.pdf
23. This holds true as long as data growth stays within the capacity limits. However, once capacity limits are exceeded, additional equipment will be needed. If data growth exceeds installed capacity, it would weaken this conclusion

number of users is also expected to stay fairly stable until 2020 as the increase in broadband subscribers will be compensated by a decline in Plain Old Telephone Service (POTS) subscribers.

Overall, wireline emissions are estimated to grow at a CAGR of 4 percent from 2011 to 2020 to reach 0.14 $GtCO_2e$. However, as identified by the previous research, abatement potential enabled by broadband technologies is significant.[24]

3.4 Data centers

Data centers' footprint was the smallest of the three categories in 2011. Data centers accounted for 0.16 $GtCO_2e$ or 17 percent of total ICT emissions (see Figure 6). Data center emissions are expected to increase most rapidly. A growth rate of 7.1 percent until 2020 will lead to the footprint reaching 0.29 $GtCO_2e$ in 2020. Significant growth in demand for data storage will be the primary driver of emissions growth. However, several technological developments —such as virtualization of servers, efficiency improvement in servers; and improvement in cooling technologies, which will lower the Power Usage Effectiveness (PUE) of data centers—will help lower the impact of the growth in data. The appendix lays out the assumptions made in this study regarding the impact of each of these levers.

Other technologies are being tested today that have the potential to substantially reduce the energy use of data centers, and in turn their GHG emissions.[25] However, it is difficult to assess which, if any, of these technologies will be proven and reach a large enough scale by 2020 to have a material impact on data centers' GHG emissions. Therefore, these technologies are not considered in the analysis in this study. As a result, this study likely underestimates the impact of technological innovation over the next 10 years.

3.5 Benefits from data centers and cloud computing

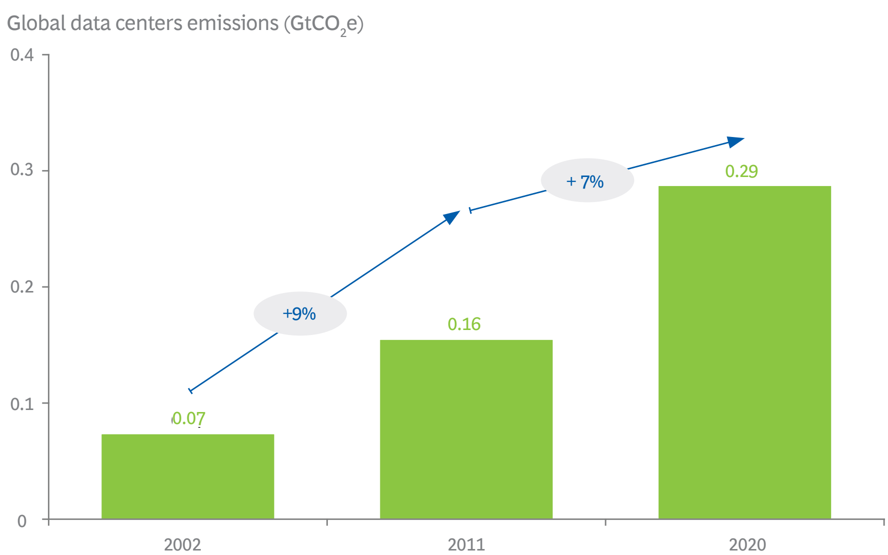
Energy use of data centers is expected to rise, but it is crucial to remember that they, along with other ICTs, are a crucial enabling technology: they create economic value and enable GHG abatement. Data centers have the potential to lower barriers to entry for small businesses, allow businesses to increase operational efficiency, and reduce time to market.

24. "Measuring the Energy Reduction Impact of Selected Broadband-Enabled Activities Within Households" – ACEE-Yankee-GeSI

25. E.g. running data centers at higher temperatures, using natural cooling, stripping equipment from servers to lower energy requirements, submerging servers in mineral oils to reduce heat generated (being tested by Intel)

Figure 6
Data center emissions growth expected to decrease to 7 percent per year

Source: Gartner; Forrester; U.S. Census Bureau; IEA; Greentouch; CEET; CDP; Ovum; GSMA; CERN; Cisco; CEET; Koomey 2011; SMART 2020; BCG analysis



While technological innovation will improve the energy efficiency of data centers, these facilities will continue to consume a substantial amount of electricity. However, this energy use pales in significance when compared with the benefits that the global economy derives from them. Web search, email, social networking, and online access to documents, music, and video are only some of the services business and consumers use daily and rely on.

Further, data centers and cloud computing enable the use of "big data." Gartner defines big data as the "high-volume, -velocity and –variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision-making". Big data technologies underlie many of the commonly used services today such as real-time traffic maps, social networking, real-time business analytics and decision-making tools, and smart metering,to name a few. Big data technologies are increasingly important tools in generating economic value.

Much of the energy use comes from small and medium-sized data centers. As the move toward cloud computing gains momentum, the increase in overall energy use will slow down as more efficient large data centers become the norm. A recent study by the Carbon Disclosure Project shows that by 2020, U.S. businesses with revenues over USD1 billion could realize energy cost savings of up to USD12.3 billion and annual CO2 emissions reduction of 85.7 Mt by spending 69 percent of infrastructure, platform, and software budgets on cloud services.[25]

It is important to realize that data centers are an essential part of the necessary technological infrastructure that enables many of the abatement sublevers cutting across all sectors and geographies. Without the enabling effect of data centers, many of these sublevers would not be implementable nor their GHG abatement potential realizable.

3.6 Comparison between estimates in SMART 2020 and this report

The first SMART 2020 study estimated that the ICT industry contributed 2.0 percent of the global GHG emissions in 2007, and 2.6 percent in 2020. Given the implied trend, the ICT footprint should have well-exceeded 2 percent by 2011. However, the present study estimates that the ICT footprint in 2011 was slightly lower at 1.9 percent of the global GHG emissions.[27]

Data centers are the fastest growing category of ICT emissions

The difference between the results of this and the previous study is primarily driven by a more precise estimate of the telecommunications networks footprint. Availability of more accurate data and new developments in the sector has led to a lower emissions estimate. Recent studies, provide a more accurate view of the emissions from mobile networks,[28] which are now considered to be substantially lower than had been previously estimated. This study uses these more precise data as inputs for estimating the emissions of mobile networks.

The 2020 estimate in the current study (2.3 percent of global emissions) is also lower than in the previous SMART 2020 study (2.8 percent of global emissions).[29] There are three primary drivers of the lower 2020 estimate in this study. First, there is the emergence and rapid adoption of smart devices such as tablets and smartphones. These devices are expected to replace desktop based computing and have significantly lower emissions. Second, there is expected to be a faster realization of efficiency gains across the industry than had been previously thought possible. Trends such as virtualization of servers, stand-by mode efficiency gains in devices and expected proliferation of energy efficient network infrastructure are some examples. Last, the global economic slowdown in 2008 and 2009 has led to lower projections of ICT adoption worldwide than had been previously expected.

26. "Cloud Computing: The IT Solution for the 21st Century" – Carbon Disclosure Project (2011)

27. Both the current and previous study estimated full lifecycle device GHG emissions, not just in-use phase emissions

28. "Mobile's Green Manifesto" – GSMA 2011

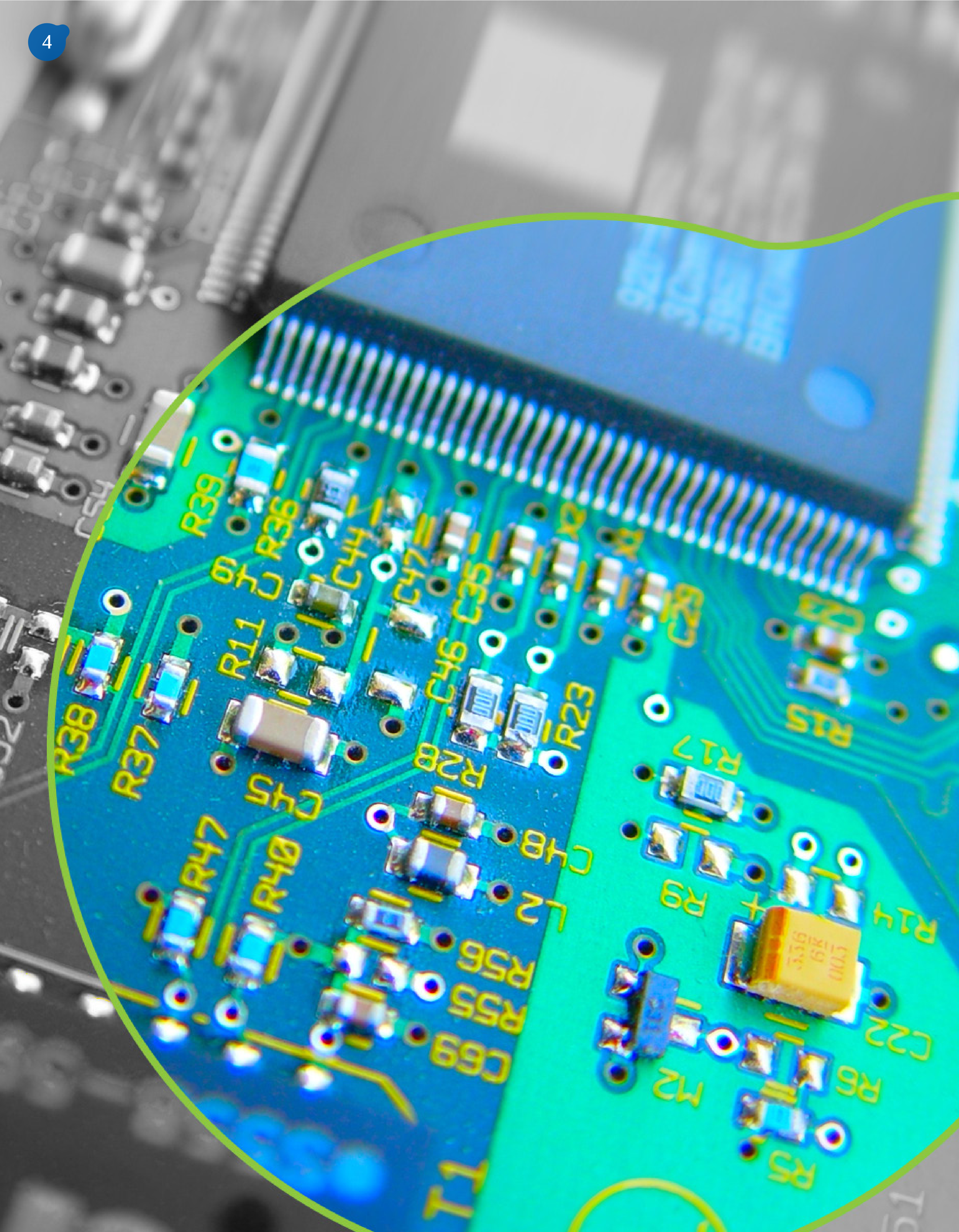
29. Using global GHG emissions of 55 $GtCO_2e$ in 2020

Case Study
Abatement potential of moving CRM, email, and groupware to the cloud

Source: "The Greenhouse Gas Abatement Potential of Enterprise Cloud Computing" -- Daniel R Williams, Peter Thomond, Ian Mackenzie

A recent study conducted by researchers at the Harvard Business School, University of Reading, and the Think Play Do Group sought to quantify the GHG emissions reductions potential from businesses in 11 countries if they were to move certain functions from local to cloud servers. The study assumes an adoption rate of 80 percent across small, medium and large businesses of cloud computing for Customer Relationship Management (CRM), email and groupware functions. Businesses were chosen for consideration because they are the most likely to switch from using localized servers and terminals to using cloud servers. Email, CRM and groupware were chosen as the applications for consideration because they are already readily available cloud computing applications and are believed to be a first step toward broader utilization of cloud computing applications. Finally, the 11 countries (China, Germany, the UK, Poland, Brazil, Indonesia, the Czech Republic, France, Portugal, Canada, and Sweden) were selected because they are roughly representative of the mix of economies globally as well as carbon intensity of electricity production.

Given these parameters, the study finds that the shift toward cloud computing by businesses in those countries today would yield a 4.5 $MtCO_2e$ reduction in emissions annually. When these findings are extended to encompass the rest of the world, as well as to include public sector and personal adoption, the emissions reduction potential is amplified. Though the emissions reductions figure is sensitive to changes in the assumptions, it is nonetheless clear that cloud computing leads to emissions reductions compared to using traditional local servers. To achieve these energy savings and emissions reductions, the study recommends close cooperation among academics, policy makers, and industry to ensure that the right infrastructure and economic incentives are in place to drive high uptake of cloud computing.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R9
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C22
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4 Emissions abatement potential of ICT -enabled solutions

4.1 Abatement levers and end-use sectors

In the following sections we will discuss the broader role of ICT in reducing GHG emissions in other industries. In this report we estimate that ICT's total abatement potential by 2020 is 9.1 $GtCO_2e$, or 16.5 percent of total emissions, which is approximately **seven times** the expected direct emissions from the ICT industry.

To help illustrate the role of ICT, it is important to first understand the fundamental ways in which ICT can reduce emissions. To do that we have developed what we call change levers, that categorize the different ways in which ICT can reduce emissions. The four change levers we have identified are:

1. **Digitalization and dematerialization**
   Substituting or eliminating the need for an emissions-intensive product or process
2. **Data collection and communication**
   Real-time data analysis and communication, feedback, and learning to enable better decision-making
3. **System integration**
   Managing the use of resources
4. **Process, activity, and functional optimization**
   Improving efficiency through simulation, automation, redesign or control

These change levers are described in more detail in the table below.

Table 2
Description of change-levers

Change-lever	Description	Examples
Digitalization and dematerialization	**Substituting or eliminating** the need for an emissions-intensive product, material, process, or service. Also the reuse/multiple use of information sources, media, etc. via ICT.	**Videoconferencing, telecommuting, e-commerce** • See global telepresence case study (page 39)
Data collection and communication	Providing **real-time** data and analysis that allows for **better decision making**, identifies a **need for change**, or encourages more efficient **behaviors.**	**Demand management, eco-driving, weather forecasting, building audit and benchmarking** • See eco-driving case study (page 38)
System integraion	**Managing** the use of resources and **integrating** lower-emissions intensive processes.	**Virtual power plant, building management system, renewables integration** • See fleet management case study (page 41)
Process, activity, and functional optimization	Intelligent **simulation, automation, redesign, or control** to optimize a process, activity, function, or service.	**Reduction of transmission and distribution losses, centralized distribution centers, building design** • See minimization of packaging case study (page 81)

Within each change lever we have identified a set of sublevers, which are specific technologies or a group of technologies that depend on the use of ICT and reduce GHG emissions during their use. An entire list of sublevers and their description is supplied in the appendix.

To further categorize our sublevers and help us understand the role of policy, we have split them by end-use sector. End-use sectors describe the general industry to which the sublever applies. We have selected a total of six sectors: **Power, Transportation, Manufacturing, Service and Consumer, Agriculture and Land Use, and Building.** The following table describes in more detail each of the end-use sectors.

Table 3
Description of end-use sectors

Change-lever	Description	Examples
Power	GHG emissions from **energy sourcing** activities (e.g. generation, distribution, and storage), including fuel combustion and fugitive emissions	• Coal-fired power plant • Natural gas-fired power plant
Transportation	GHG emissions from **transportation** activities, including fuel combustion	• Fossil-fuel emissions from jet fuel and gasoline
Manufacturing	GHG emissions (e.g., from by-products and fugitive sources) from **industrial processes**	• Cement production • Chemical production
Service and Consumer	GHG emissions from commercial and residential services and consumer activities	• Retail space lighting • Data center use • Residential cooking
Agriculture and land Use	Anthropogenic GHG emissions from **agricultural activities, forest management, land use activities, or land use** change	• Forest clearing for palm oil production
Buildings	GHG emissions from the **use and management** of buildings	• HVAC • Lighting

Table 4
Current and future emissions by end-use sector

End-use sector	2008 ($GtCO_2e$)	2020 BAU[c] ($GtCO_2e$)
Power	10.0	11.8
Transportation	6.6	7.9
Manufacturing	14.8	17.4
Service and Consumer	4.8	5.7
Agriculture and Land Use	10.6	12.4
Buildings	N/A[b]	N/A[b]
Total	**46.8**	55.2

Source: EDGAR

a. includes waste disposal and fossil fuel processing

b. EDGAR data includes building emissions in manufacturing and service and consumer sector

c. Based on total GHG forecast from OECD; with the same sector breakdown as 2008

To provide better context around the importance of each of these sectors and the role of ICT, the table provides the total and future global GHG emissions by each of our end-use sectors. The appendix provides additional details behind the assumptions used in this table.

To summarize, the role of ICT in GHG abatement has been organized by change levers and end-use sectors. The figure below gives a full break down of sublevers by the change levers (vertical axis) and end-use sectors (horizontal axis). [30]

30. There are other technologies that may in the future offer some abatement potential, such as 3-D printing, which have not been included in this report since it is difficult to estimate their feasibility and impact in the future.

Figure 7
Sublevers arranged by change lever and end-use sector

Sources of emissions by economic end-use sectors

Change levers

	Power	Transportation	Manufacturing	Service & consumer	Agriculture & land use	Buildings
Digitalization & dematerialization		• Videoconferencing • Telecommuting		• E-commerce • E-paper • Online media		
Data collection & communication	• Demand management • Time-of-day pricing	• Eco-driving • Real-time traffic alerts • Apps for intermodal transportation • Asset sharing/crowd sourcing		• Public safety/disaster management • Smart water	• Soil monitoring/Weather forecasting • Smart water • Livestock management	
System integration	• Integration of renewables • Virtual power plant • Integration of off-grid renewables & storage	• Integration of EVs • Intelligent traffic management • Fleet management & telematics				• Integration of renewables • Building management system
Process, activity & functional optimization	• Power-load balancing • Power grid optimization	• Optimization of truck route planning • Optimization of logistics network	• Optimization of variable-speed motor systems • Automation of industrial processes	• Minimization of packaging • Reduction in inventory	• Smart farming	• Building design • Voltage optimization

4.2 Abatement calculation by change lever and end-use sector

We estimate that the total abatement potential of ICT across all of the listed sublevers is **9.1** $GtCO_2e$. The two figures below split out the potential by change lever and end-use sector.

Figure 8
ICT abatement potential by change lever

Source: EDGAR, BCG analysis

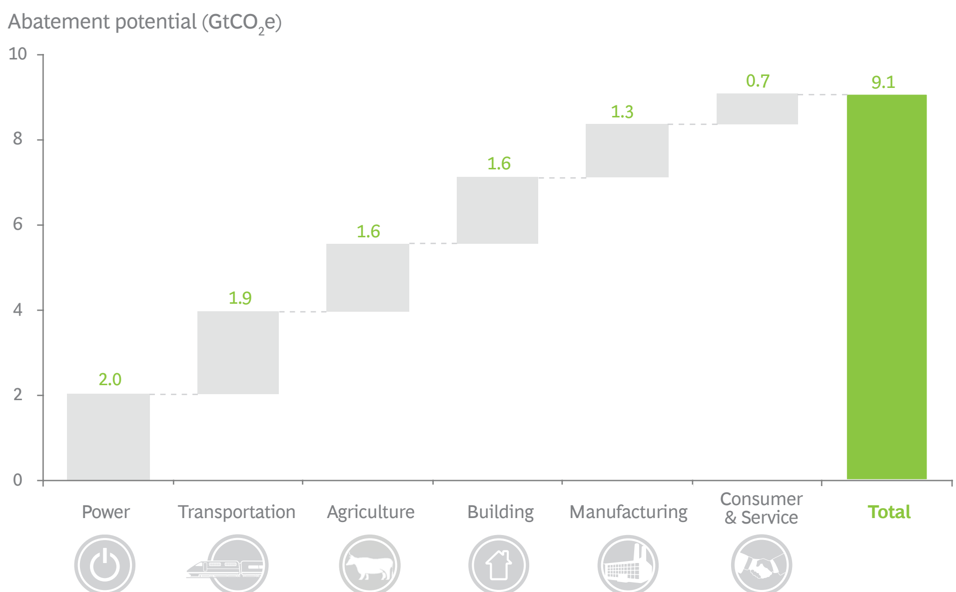


Figure 9
ICT abatement potential by end-use sector

Source: EDGAR, BCG analysis

4.2.1 Abatement in the power sector

The power sector represents one of the largest end-use sectors and totals over 21 percent of all global GHG emissions. Emissions in this sector are driven by the combustion of fossil fuels that result in the release of CO_2 and other GHG gases. Coal, the fuel that produces the most GHG emissions per unit of energy created, is the largest of all fuel sources used, accounting for up to 41 percent of the global electricity generation in 2009.[30] Fossil fuels account for 67 percent (16,218 TWh) of all electricity generated.

The power sector emits over 21 percent of the world's GHG emissions

Capturing the chemical energy trapped in fossil fuels and converting it first to mechanical energy in a turbine and then electricity energy is inherently inefficient, with only approximately 35 to 40 percent of the chemical energy actually converting into useable electricity.[31] Even once converted into electricity, there are additional transmission and distribution losses ranging from 5 to 10 percent that occur in the delivery of power to the end-user. While efforts are being made to improve the efficiency of electricity generation and replace the use of fossil fuels with clean energy sources, such as renewables or nuclear, much progress is needed.

ICT can reduce the inefficiencies of the power sector and the dependence on fossil fuels. We estimate that the abatement potential by 2020 is 2.0 $GtCO_2e$. The separate sublevers in the power sector and calculated abatement potential are shown in the table.

The sublevers in the power sector can generally be grouped into two major categories:

1. those that help facilitate the integration of renewables, and
2. those that enable the smart grid

The renewables-related sublevers include **integration of renewables in power generation, virtual power plant, and integration of off-grid renewables and storage**. These combine for a total of 1.09 $GtCO_2e$. ICT can be instrumental in integrating electricity into the grid, managing intermittent electricity production, monitoring and optimizing the performance of the generation, and helping to predict the impact of the weather on generation, as well as in many other applications.

ICT is essential in the area of virtual power plants (VPP). VPP is an emerging technology that combines a cluster of distributed generation installations (such as rooftop solar, microCHP, micro-wind, small scale storage, etc.), typically at the neighborhood/local level, and runs them collectively. Doing so allows for the integration of renewables and provides higher efficiency and more flexibility with peak load and fluctuations. VPPs are highly complex and ICT helps manage complex optimization, control, and communication.

ICT is also vital for off-grid renewables and storage. These applications are important in areas in which there is no possibility of grid

Table 6
Abatement potential by sublever within power end-use sector

Sublever	Abatement potential ($GtCO_2e$)
Demand management	0.01
Time-of-day pricing	0.21
Power-load balancing	0.38
Power grid optimization	0.33
Integration of renewables in power generation	0.85
Virtual power plant	0.04
Integration of off-grid renewables and storage	0.20
Total	2.02

31. IEA
32. International Energy Agency, "2008 Energy Balance for World", 2011

connection or the grid connection is difficult and expensive. Off-grid applications target a population of 2.5 billion people without access to a reliable electricity supply.[32] Those without reliable power often use dirty diesel generators as a substitute. ICT can be used to manage the complex connection of both the renewables and the storage needed to ensure that the system is dependable and running at all times.

ICT is the technology on which a smart grid is based. A smart grid is an electrical grid that uses information and communications technology to gather and act on information, such as data on the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.[33] Reducing inefficiencies in the grid is a particularly important element of smart grid utilization, especially in countries such as India, where a large portion of power generated is lost during transmission. Overall, the abatement potential in the power sector is quite significant at 0.9 $GtCO_2e$.

Major barriers to the adoption of ICT technologies in the power sector do exist. This list is not exhaustive, and exact barriers will depend on the country or local area, but the following are some barriers that impede the adoption of ICT and reduce emissions in this sector:

Economics
Certain technologies and sublevers do not have a positive net present value. For example, depending on the availability of natural resources and the price of electricity in the region, renewables can have difficulties competing with traditional sources of energy. Other technologies may be NPV positive but have too long of a payback period for adoption or the capital requirements may be too large. Policy could be enacted to promote technological innovation through R&D funding and programs.

Full deployment
System integration is vital and technology must be fully deployed or the entire system cannot fully capture the benefits (e.g., smart meters). It may be possible to create deterrents for those that fail to adopt. This could be similar to the alternative compliance payments used by U.S. states for those utilities that fail to adopt their renewable portfolio standards. It is also important to build a complete policy support that covers an entire range of technologies.

Aligned incentives
It can be very difficult to align incentives within the power industry. There are several factors that cause this: there is at least some government intervention in nearly every power industry, the grid is an incredibly large piece of infrastructure that is owned and managed by many different stakeholders, there is inefficient regulation/decoupling, etc. Aligned incentives also affect consumers who are unwilling to change ingrained behaviors. In major regions where electricity has such a low price, it is hard to encourage consumers to care about their energy use.

4.2.2 Abatement in the transportation sector

Personal transportation and shipment of goods has become a major component of our modern society. The need for transportation happens at nearly all scales, from the local (most of us commute to work) to the international (an increasingly more global world means people travel and goods are produced and shipped from all over the world). The significant energy needed to power our current infrastructure comes in the form of fossil fuels, and thus releases significant GHG. Even transportation using electricity can emit a significant amount of emissions, when the source of electricity is fossil fuels.

33. IEA "2010 Electricity Access Database" and "World Energy Outlook 2010", UN Secretary General Advisory Group on Energy and Climate Change – "Energy for a sustainable future – Report and Recommendations" New York, 28 April 2010

34. U.S. Department of Energy. "Smart Grid / Department of Energy"

Case study

Griffin, GA Empowers Residents with Smart Grid Electric Meters (AT&T)

Source: AT&T Case-study: "City of Griffin Empowers Residents with Smart Grid Electric Meters

The city of Griffin's Electric Department wanted to give its customers the power to monitor their electric usage to help them manage utility costs. It also sought a more precise way to measure residents' power usage to ensure accurate billing and a way to simplify routine processes. Griffin Electric officials began researching smart grid systems that give customers the ability to closely monitor energy use and cut back when the demand for electricity is highest.

Griffin replaced aging mechanical meters with smart meters that use the AT&T wireless network to transmit customers' power use to the city electric department. The Griffin City Commission authorized an installation of 16,000 smart meters, making Griffin one of the first municipal utilities to deploy a comprehensive smart metering system utilizing a public wireless network as its communications backbone.

Griffin also has the ability to connect and disconnect electric service remotely, so customers who move no longer have to wait around for the utility company—the electric department can now turn service on or off from any Internet-connected computer. When the digital meters were first installed and crews were testing them, Griffin's city manager came home one night to find his power out. "He called me while I was at a restaurant," Bosch said, "but I was able to use my smartphone to restore his service immediately."

The city has already boosted its revenues because the digital meters capture electric usage more accurately than the 40-year-old mechanical meters. Griffin also saves money since it no longer has to pay contractors to read its meters.

The smart grid solution gives customers better control over how much electricity they use and makes it easy for the city to read meters and connect or disconnect service remotely. As a result, customers are better served and the city can more accurately predict its power needs to lower the cost of its electric purchases.

There is a steady expected growth in transportation emissions: by 2020, the total sector is estimated to emit over 7.9 $GtCO_2e$ of GHG, or approximately 14 percent of all emissions under the BAU scenario. While some transportation is unavoidable, there is much inherent inefficiency in our current transportation system: automobiles idle in traffic, delivery trucks carry little to nothing on return journeys in their routes, or people choose to use inefficient travel when faster and more environmentally friendly public transit exists. For this reason, we estimate a large opportunity for ICT to reduce emissions, with a total abatement potential of 1.9 $GtCO_2e$ by 2020.

In recent years there has been strong adoption of ICT technologies in transportation, which has been driven by many factors:

- Reducing price
- Reducing size and weight of equipment
- Rapid emergence of smartphones
- Cloud and other services for data analysis

Technology is becoming more common in several ways:

Consumer-based telematics
Honda's Fit electric vehicle (EV) used ICT to enhance the EV experience. Telematics may not be as useful for the average passenger car, but for electric vehicles, apps and other telematics take on a new importance to help drivers manage their range anxiety and charging schedule. [35]

Wireless fleet management
BigBelly limits the need for unnecessary pickup of waste by monitoring the amount of trash in each waste container and sending a wireless signal when a container is getting full. Software can then optimize the pick-up route and significantly reduce transportation emissions.[36]

Location-based fleet management
Networkfleet - Provides a wide range of GPS and other monitoring-related services that can provide the location, speed, and fuel efficiency of an entire fleet of vehicles. Information can be used to optimize routing and lower carbon emissions.[37]

In addition to the examples above, there are several ways that ICT can improve the efficiency of logistics. The table below lists the sublevers identified in the transportation end-use sector and the corresponding abatement potential. ICT is key to enabling the sending, receiving, and storing of information, with the ability to affect the control on remote objects.

Sublever	Abatement potential ($GtCO_2e$)
Eco-driving	0.25
Real-time traffic alerts	0.07
Apps for intermodal travel/ public transportation	0.07
Asset sharing	0.14
Videoconferencing	0.08
Telecommuting	0.26
Optimization of truck route planning	0.19
Optimization of logistics network	0.57
Integration of EVs	0.20
Intelligent traffic management	0.03
Fleet management and telematics	0.08
Total	1.94

Table 7
Abatement potential by sublever within transportation end-use sector

35. Greentechmedia.com "Can the Right Telematics Win EV Drivers?"

36. BSR "Wireless and the Environment" ; http://bigbellysolar.com/overview

37. www.networkfleet.com

This enables, for example, the fleet management, telematics, and optimization of logistics network sublevers, which combine for a total 0.65 $GtCO_2e$ abatement potential. This allows the constant monitoring of trucks while other ICT also enables the analysis of geospatial data through GPS technology.

Communication also plays an important role in enabling gains in efficiency in transportation. Sublevers like real-time traffic alerts, intelligent traffic management, video-conferencing, and telecommuting all require sophisticated real-time transfer of data, sound, or video that are not possible without ICT.

Finally, we see some of the recent ICT mega-trends of social media and mobile apps make an important impact. “Apps for intermodal travel/public transportation” and “asset sharing” combine for a total of 0.21 $GtCO_2e$ of abatement potential.

It is important to consider the general hurdles to adoption and the role of policy on the sublevers listed above. This list is not exhaustive, and exact barriers will depend on the country or local area, but it does provide some guidelines for improving the rate of ICT adoption and reducing emissions:

Infrastructure

It is difficult for ICT to play a role in intermodal travel if proper public transit infrastructure is not in place. This can be difficult for areas in which there is a low population density, but cities are prime locations for increased investment.

Behavior and habits

People typically have strong habits when it comes to transportation. For example, public transportation can be perceived as inconvenient, slow, or dirty. Some countries, like the U.S., have a culture around car ownership and use. Work is needed to incentivize behavior change. This can often be achieved through education and making sure the consumer experience is of high quality.

Economics

Many of the sublevers in the transportation end-use sector are NPV-positive and have a short payback period; however, there are several categories, such as “asset sharing” and “integration of EVs,” in which there are still some situations with room for improvements in the business case.

Regulatory environment

To support telecommuting many countries need to update the insurance and working regulatory environment. Furthermore, the government needs to lead by example and use collaborative tools to show the potential and help change local and national culture.

Case study
Eco-driving: Customers' willingness to pay for eco-driving (Nokia)

Source: Green Street Survey, Navteq, September 2010

Eco-driving provides opportunities for ICT to reduce emissions by encouraging a driving style, through the use of alerts and other technology, which will improve the overall efficiency of the vehicle. Specific examples of solutions in the eco-driving sublever include:

1 When selecting a route to travel between two places on a GPS, offering a optimized route for low emissions combined with the fastest and shortest route (see figure 10)
2 Creating an alert when driving in a non-environmentally friendly way (e.g., excessive acceleration and breaking)
3 Adapting cruise control to hills, speed limits, traffic jams, etc.

Navteq recently performed a study in France, Germany, and the U.K. on whether consumers would be willing to pay extra for eco-driving features on their automobile and found that a fuel savings between 6 and 10 percent would convince more than half of the drivers to use the service. The anticipated frequency of usage of the features is relatively high, with a majority of users reporting that they would use eco-driving features on a weekly basis. There were some differences in what people preferred; for example, in Germany, respondents would prefer to receive fuel consumption savings at the end of the route; in France, fuel consumption and fuel efficiency savings; in the U.K., fuel efficiency and monetary savings. ICT also has a role in providing communication, as it was found that in order to better understand the benefits associated with the features, respondents would prefer to receive average savings per trip. In general, these are very promising results that show that, with the proper ICT technology in place, there is real opportunity for adoption.

Figure 10
Navigator software illustrating the choice for selecting the most efficient route

Case study
Global Telepresence (BT)

Source: BT case study; SMART 2020; Greenhouse Gas Protocol Product Standard; Cisco http://www.cisco.com/en/US/products/ps7060/index.html ; Draft Recommendation ITU-T Methodology

Business travel is a major source of transportation emissions. Air travel (versus train or other public transportation) results in a large amount of emissions andinternational business travel has grown as a result of greater global interconnectedness.

BT carried out work to calculate both the carbon footprint and the carbon benefits resulting from a Global Telepresence solution. Telepresence is a type of high-definition videoconferencing system that is often deployed in custom-fitted rooms, with multiple monitors and tuned acoustics. The technology depends on advanced network equipment and other ICT technologies. This system was deployed by one of BT's large multinational customers.

The videoconferencing system was launched internationally, comprising 36 systems/locations across 17 countries at a large multinational customer. BT used a Life Cycle Assessment (LCA) approach to guide the assessment of changes to the business-as-usual system resulting from the adoption of the videoconferencing system. The framework methodology consists of three major steps:

1 defining the goal and scope of the study,
2 limiting the life-cycle processes of relevant components identified in Step 1, and
3 assessing and interpreting the net enabling effect

The final result of the study was a total of 9,850 tons CO_2e of GHG abatement, which is the equivalent to an 83 percent reduction to the business-as-usual scenario (i.e., flying to meetings).

This case study illustrated that when deployed on a global basis within a large multinational company, ICT-enabled videoconferencing can have a significant impact on carbon emissions.


T 86

Case Study

Networkfleet and increasing truck fleet efficiency (Verizon)

Source: Verizon case study

As its consumers began to use less water, the Eastern Municipal Water District (EMWD) in Riverside, CA needed to reduce its operating costs while maintaining the same level of service. To achieve these cost reductions, the EMWD focused on increasing the efficiency of its 350-vehicle fleet. After reviewing a host of fleet management products, EMWD selected Networkfleet, a Verizon company, because of its plug-and-play installation capabilities and 24/7 roadside assistance.

Networkfleet provides a wireless fleet management solution that connects directly to a vehicle engine's onboard diagnostic unit, enabling fleet managers to remotely monitor engine diagnostics, fault codes, and emission control status. Networkfleet's systems provide the opportunity to reduce GHG emissions while simultaneously cutting energy and operating costs.

EMWD focused initially on reducing idling time and driving speed, which ultimately had a significant impact on emissions reductions and fuel usage. Any time drivers exceeded a particular speed limit or idled for too long, their supervisor would receive a notification from Networkfleet. The supervisor would then communicate with the driver to alter inefficient behaviors. EMWD was also able to leverage the GPS capabilities of the trucks to reduce the number of miles driven. When unexpected problems arose, the fleet manager used GPS tracking to reroute the trucks closest to the problem rather than guessing which was closest. Within the first six months of operation, Networkfleet helped EMWD reduce its miles driven by 165,000 miles. The combination of higher fuel efficiency and driving fewer miles reduced the fleet's overall GHG emissions and cut fuel costs by $79,000 in the first six months of installation.

Aside from fuel cost reductions, Networkfleet helped EMWD cut costs in several other ways. Higher productivity of resources helped EMWD cut labor costs by USD354,000, as its drivers spent fewer hours on the road. The vehicle diagnostics capabilities also ensured that trucks received required maintenance and spent less time being repaired for more serious problems. Enforcing adherence to speed limits reduced the number of accidents and led to reduced insurance premiums.

Networkfleet had a positive environmental impact while improving EMWD's bottom line. The Networkfleet system cut driving-related emissions from EMWD's trucks by 90.7t of CO_2 in its first six months of operation and will continue to yield GHG abatement over the vehicle's lifetime. Additionally, Networkfleet will help extend the lifespan of EMWD's vehicle fleet, which will lead to further emissions reductions in the form of fewer embodied emissions.

4.2.3 Abatement in the manufacturing sector

Manufacturing is the most significant contributor to climate change of any of the end-use sectors, with worldwide manufacturing emissions at 14.8 $GtCO_2e$ in 2008, 31.4 percent of the global emissions total. These emissions are projected to remain constant as a percentage of the world total as manufacturing emissions climb to 17.4 $GtCO_2e$ by 2020.

High rates of manufacturing growth in the developing world, where emissions targets are often lax or nonexistent, are pushing emissions rates higher. Increased demand for manufactured goods is overcoming any process efficiency gains. Moreover, the increasing competitiveness of the manufacturing sector globally and a lack of economic incentives to abate GHG emissions have made emissions reductions challenging for many manufacturers.[38] As countries fight to keep their manufacturing rates competitive, investing in emissions savings technologies has in many instances not occurred.

ICT can play a significant role in helping the manufacturing sector reduce its contribution to climate change by reducing the amount of electricity wasted through inefficient processes. ICT can also be an important part of a circular economy: an industrial system that is restorative or regenerative by intention and design by replacing "end-of-life" concept with restoration. It facilitates the shift toward the use of renewable energy; eliminates the use of toxic chemicals, which impair reuse; and aims for the elimination of waste through the superior design of materials, products, and systems.[39]

Through the adoption of ICT-enabled emissions reduction solutions, the manufacturing sector can reduce its emissions by 1.3 $GtCO_2e$, a total reduction of 8.4 percent.

Sublever	Abatement potential ($GtCO_2e$)
Automation of industrial processes	0.72
Optimization of variable speed motor systems	0.53
Total	1.25

Table 8
Abatement potential by sublever within manufacturing end-use sector

There are two sublevers in the manufacturing sector:

1 the automation of industrial processes, and
2 the optimization of variable speed motor systems

Automating industrial processes involves modernizing plants and has a worldwide abatement potential of 0.72 $GtCO_2e$. Plants would be marked by a decreased utilization of personnel resources and greater use of machines controlled by ICT devices. Higher levels of monitoring and control of equipment will help to reduce and optimize energy use for particular manufacturing processes. ICT is required to control and monitor the automated processes and ICT companies would also be involved in the maintenance and upkeep of the manufacturing equipment.

The optimization of variable speed motor systems has an abatement potential of 0.53 $GtCO_2e$ worldwide, with abatement potential highest in developing economies such as China. Motor systems are at the heart of the industrial activity and consume the majority of electricity used by manufacturers worldwide. Traditional motor systems are designed to operate at a continuous rate and do not account for the strain placed on them by varying loads. As load capacity affects the ability of the machine to perform a constant rate of work, having motors operate at a constant speed is inefficient and wastes electricity. The introduction of variable speed

38. "The Future of Manufacturing: Opportunities to drive economic growth" World Economic Forum
39. "Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition", Ellen Macarthur Foundation

Case study

China Motor Systems Energy Conservation Program and Variable Motor System Optimization

Source: "Energy efficiency in electric motor systems: Technical potentials and policy approaches for developing countries", UN Industrial Development Organization, 13-14

The China Motor Systems Energy Conservation Program, a collaboration among the U.S. Department of Energy, the Energy Foundation, UNIDO, and the Chinese government, conducted a series of energy audits in Chinese firms to improve the efficiency of their energy systems. The program evaluated 41 plants and, in most cases, investments in system optimization were made. The energy savings were between 7 and 50 percent of the systems' electricity consumption and the payback period was 1.4 years on average (although some projects revealed a payback period as long as 5 years).

One of the plants audited was a Chinese pharmaceutical company and it was quickly discovered that the plant's water cooling system consumed over 2 million kWh/year, 13 percent of the plant's total electricity consumption. Cleaning the ductwork and installing two new pumps that incorporated variable speed control was an investment of $145,000, but the investment was quickly recouped. The payback period was 1.8 years and the electricity demand by the water cooling system was 49 percent. The results were even more dramatic for a Chinese petrochemical company. The installation of 34 variable speed drives led to the reduction of electricity from 8,016 to 5,766 kWh/t crude oil refined, with a payback time of only 0.5 years.

Optimization of variable motor speed systems have been proven cost effective in factories around the world, in advanced and developing economies alike. The strong business case for the introduction of these systems means that take-up rates should be high due to its economic attractiveness. The high-level of economic attractiveness will drive GHG abatement and energy savings in similar factories around the world.

motor systems allows machines to sense the strain under which they are working and adjust output accordingly. This ensures that they are working hard and expending electricity only when necessary. ICT can provide information to businesses about how much electricity they are saving and allow machines to communicate with one another to increase overall plant efficiency.

While not explicitly listed as a sublever, it is worth mentioning the potential role of 3D manufacturing (also called 3D printing). 3D printing is achieved using additive processes; an object is created by laying down successive layers of raw material. 3D printing is considered different from traditional machining techniques (subtractive processes) which mostly rely on the removal of material by drilling, cutting etc.[40] 3D printing has the potential to be disruptive to the entire manufacturing process and could reduce emissions by reducing the amount of raw materials to create a product and removing the need for transport of end-products.

Barriers

Though barriers to technology adoption are not the same across all countries, there are several that are the most prevalent across the globe. Understanding these barriers can help illuminate the types of policies that need to be broadly pursued to ensure high penetration of these technologies.

Monitoring and enforcement
In many countries, particularly those still developing, there is a lack of data surrounding emissions and efficiency standards are non-existent for many technologies. As a result, it is difficult for manufacturers to understand their efficiency performance relative to other companies and improve their emissions if necessary. Policy makers should create a methodology for monitoring and evaluating efficiency in manufacturing. The creation and enforcement of industry-wide best practices that ensure all manufacturers are meeting this requirement would then be possible. Procurement policies can incentivize companies to adopt these policies in order to win business. Policy makers should also highlight best practices within the manufacturing industry and encourage other companies to voluntarily adopt these practices.

Slow adoption
Because reducing GHG emissions remains a secondary concern for most governments, there is not a sense of urgency to cut emissions quickly. As a result, manufacturers do not feel compelled to invest in energy-saving devices, even if they provide a positive net present value return. Accordingly, governments should begin to emphasize investing in energy savings technology. Concrete measures they can take include providing subsidies or tax breaks for energy-saving technologies as well as mandating that energy efficiency be included as a key performance indicator for manufacturers.

4.2.4 Abatement in the agricultural sector

The emissions from agriculture are so significant that it was second only to the manufacturing sector in terms of its contribution to GHG emissions in 2008. In 2008, agriculture emitted 10.6 $GtCO_2e$, which represented over 21 percent of the world's total. Under the BAU scenario, emissions from the agriculture sector are projected to reach 12.4 $GtCO_2e$, or 22.4 percent of the world's total emissions in 2020.[41] Livestock emissions alone are so substantial that they exceed emissions from the entire global transportation industry[42] and irrigation accounts for approximately 80 percent of all fresh water use in the U.S.[43] The need to feed growing numbers of people is expected to push global food production 70 percent higher than current levels; the increased demand for food will drive both energy use and emissions from the agricultural sector higher.[44]

40. "A Third Industrial Revolution" The Economist www.economist.comnode/21552901
41. Michael Pollan, Omnivore's Dilemma: A Natural History of Four Meals, Penguin Press, 2006, p. 198
42. UN, FAO, "Livestock's Long Shadow"
43. US Dept. of Agriculture, "Irrigation and Water Use"
44. Food and Agriculture Organization of the UN (FOA), "How to feed the world in 2050"

If agriculture were made more efficient, the magnitude of emissions reductions would be significant. In the last decade we have seen an explosion of the use of ICT technologies to make farming more efficient and reduce emissions. The revolution in agriculturally focused ICT puts farmers in the developing world on a more level playing field with their counterparts in advanced economies. Unlike the costly, bulky, and energy-intensive equipment that was formerly required, ICT applications in agriculture are relatively inexpensive, adaptable, and accessible.[45] Many of farming's most essential questions, such as how to increase yields, how much input is required to produce a healthy crop, and how to adapt to weather conditions, can be answered via ICT. These investments can increase yield, increase input efficiency, and, most importantly for farmers, increase profitability.

Approximately 21 percent of all GHG emissions produced by human activity are attributable to agriculture

These increases in efficiency are not only beneficial for individual farmers but are also critical in reducing agricultural emissions. ICT allows for more careful calibration of inputs, and higher resource efficiency means lower emissions as a byproduct. Through four means of abatement, ICT can reduce emissions from agriculture by 1.6 $GtCO_2e$ worldwide.

Table 9
Abatement potential by sublever within agriculture and land use end-use sector

Sublever	Abatement potential ($GtCO_2e$)
Livestock managment	0.70
Smart farming	0.25
Smart water	0.03
Soil monitoring/Weather forcasting	0.62
Total	1.60

Livestock management, the first sublever, centers primarily on reducing enteric methane emissions through monitoring. The last three sublevers focus on reducing the amount of inputs required to grow crops.

Because livestock release large quantities of methane, which is a potent GHG, controlling livestock emissions is critical to alleviating the effects of climate change. Monitoring via ICT-enabled methane monitors is a key component to decreasing emissions. ICT can also reduce the amount of space required to raise cattle by preventing eating patterns that lead to over- or under-grazing of fields. RFID monitors can check the health of cattle and prevent sickness and premature death, which represents a significant waste of resources.

Smart farming utilizes information generated through satellite imagery to control crop inputs. Satellites have the capacity to measure the temperature and health of individual plants on the ground by analyzing the type of light they reflect and can then communicate this information to farmers through smartphones or computers. Based on this information, farmers can adjust the amount of fertilizers, pesticides, and water used.

Smart water applications allow farmers to remotely control irrigation systems and channels. Many irrigation systems have their own timing systems and begin when scheduled, regardless of whether more water is actually needed. Smart water systems give the farmer greater control over water use. If smart water technology could yield a 5 percent reduction in the amount of water used for irrigation over a year, this would yield 1.5 trillion gallons in water savings.[46] Since a significant amount of energy is needed to treat, pump, and transport water, reducing the amount of water needed can play an important role in reducing emissions.

Of the input-precision sublevers, soil monitoring and weather forecasting offer the most abatement potential. Farmers rely on educated guesswork

45. ICT in Agriculture e-Sourcebook, 3
46. BSR Wireless and the Environment 43

Case Study
Wireless Wine in Sonoma County, CA

Source: BSR Wireless and the Environment

Hoot Owl Creek/Alexander Valley Vineyards in Northern California wanted to more accurately control the water and nutrient inputs that it was providing to its plants. As a result, the grower placed soil monitors across 300 acres of land to monitor conditions such as moisture, temperature, humidity, methane and hydrogen sulfide levels. The monitors fit easily under plants and wirelessly transmit information to a data management website and can be accessed via the Internet at any time.

The monitors were a success, helping the vineyard reduce its water input by over 60 percent and cut its overall GHG emissions. By reducing water requirements, emissions are abated by cutting water processing needs and electricity needs from water pumps. These results were typical of the savings seen across Northern California. Victor Hugo Vineyards realized water savings of between 50 and 60 percent. The owner of the vineyard explains that the vineyard was able to switch from one long, intensive irrigation cycle to two lighter cycles, allowing for far lower water usage.

One study estimated that if all vineyards across the region were to use wireless soil monitoring technology, up to 16,713 acre-feet of water could be saved and energy costs could be lowered by USD1.8 million. In total, these savings would yield 7,411 $MtCO_2e$ in reductions.

Having been shown to be effective in Sonoma vineyards, this technology could be more broadly deployed to vineyards and other types of farming operations to reduce energy costs, water waste, and GHG emissions around the world.

to decide how much fertilizer and pesticides to use on a field. ICT-enabled soil monitors can give a much more accurate picture as to what level of inputs is required to maximize yield. The information provided by these monitors, combined with weather forecasting data, can tell a farmer exactly how much fertilizer, pesticides, and water should be applied.

Despite the benefits of ICT technologies in agriculture, there are several major barriers to widespread adoption. Overcoming these barriers is essential to ensuring that these emissions-reducing technologies become commonplace.

Economics
Though many ICT technologies are less expensive than traditional capital investments, such as tractors and combines, they are still more expensive than other investments, such as genetically modified (GM) seed. GM seeds that are resistant to herbicides and insecticides can sometimes yield internal rate of returns of over 350 percent, making them very attractive for investment.[47] As a result, investments in ICT may become deprioritized. Policy makers could use subsidies and tax incentives to make emissions-reducing ICT technology more economically attractive to farmers.

Education
Many farmers may simply be unaware of the benefits of using ICT technology to increase yield. In the United States, for instance, only 8 percent of farmers utilize soil monitoring and weather forecasting technology despite the increase in crop yield that technology adoption would allow.[48] Many farmers are unaware that such ICT solutions are available to them; policy makers could encourage ICT uptake by mandating that information on emissions-reducing technology be included with purchases of other farm equipment (such as seed and fertilizer) and could directly distribute educational materials to farmers.

Lack of infrastructure
The sublevers that have been identified are all highly reliant upon high-speed data networks to transmit information from sensors and data centers to farmers on the ground. Though the required infrastructure is largely in place in developed nations, the ICT infrastructure may be lacking in many developing economies, particularly in rural areas where farmers live. Data network construction in developing rural areas should be incentivized in countries where this is a concern.

4.2.5 Abatement in the buildings sector

Energy use in buildings is a major source of emissions, but there are several factors that should drive strong uptake of ICT-enabled abatement solutions in this sector. There should be significant incentives for reducing the energy costs of buildings. Commercial buildings offer particularly good opportunity to reduce energy costs because of their size, their long-term occupants, and their typically more sophisticated building managers. Furthermore, their energy costs can be high, increasing the magnitude of financial incentives to make emission reduction upgrades. In the U.S. alone, the total commercial energy costs are USD179 billion (approximately USD 1.50/ft2). We expect energy consumption in a typical commercial building in a developed economy to be approximately 40 percent HVAC (heating, ventilation, and air conditioning), 30 percent lighting, 15 percent appliances, and 15 percent water heating and cooking.[49]

Most buildings, including older buildings and new constructions, have not leveraged opportunities to increase their energy efficiency. Energy waste is high due to inefficient heating and cooling, lighting, and other power systems. ICT could be instrumental in the use of abatement technologies that address these energy consumption inefficiencies. The total abatement potential is **1.68 GtCO_2e**. The table lists the abatement potential by sublever.

47. www.seedtoday.com/info/ST_articles.html?ID=121894
48. BSR Wireless and the Environment 40
49. "Commercial Buildings Energy Consumption Survey", EIA

An important sublever to reducing emissions is building management systems (0.39 $GtCO_2e$). These ICT-dependent computer-based systems control and monitor buildings' mechanical and electrical equipment including ventilation, lighting, power systems, fire systems, and security systems. These systems were developed as a result of advances in software, sensor, and control technologies and serve as the connection point for other decentralized applications (photovoltaic, combined heat and power, etc.).

Voltage optimization (0.24 MtCO2e) is an electricity-saving system that, when used in tandem with the main electricity supply, provides a reduced supply voltage for a building's equipment. Voltage optimization can reduce energy waste by balancing phase voltages and filtering harmonics and transients from the supply.

Sublever	Abatement potential ($GtCO_2e$)
Building design	0.45
Building management system	0.39
Integration of renewables in commercial and residential buildings	0.50
Voltage optimization	0.24
Total	1.58

Table 10
Abatement potential by sublever within buildings end-use sector

The list below, though not exhaustive, presents some of the major barriers to the adoption of the building sublevers:

Financing
This is likely the most important barrier, as private and public customers often do not have the capital to cover high-up front costs. As a result, financing and contracting are likely to become an essential part of the customer offering. This barrier is especially important in developing economies as cost of capital is much higher than developed economies.

Economics
Certain technology and sublevers are not NPV-positive, e.g. building management systems for home owners. Some technologies may be NPV-positive, but the payback period is too long for private adoption. An important role of the ICT sector is to lower prices or provide higher performance at current prices. Policy makers should consider rebates for ICT-enabled upgrades and solutions and, more controversially, should institute a CO_2e tax or permit system to encourage more green technologies.

Behavior/Education
Due to the complexity of contracting, financing, and execution, customers are often ill-informed and hesitate to start projects because of a lack of familiarity. The role of policy and governments is to ensure access to information needed to make informed decisions and use case studies and examples to build credibility and make benefits more clear.

Landlord-tenant problem
Most frequently, the tenant pays for their energy costs, but cannot convince the landlord to install energy efficiency upgrades. Even if the tenant has control to make upgrades, it may not make economic sense as they cannot ensure that they will live in the building long enough cover the initial cost of the investment. The situation can be even more challenging for commercial spaces in which there may be many stakeholders involved within the same building (i.e., the tenant, the building manager, a real estate intermediary, the official building owner, etc.). Policy has a role through regulation to align incentives to encourage the purchase of energy efficiency upgrades.

Case Study

Energy Management System by Johnson Controls in the Empire State Building

Source: Press releases from Johnson Controls; BCG analysis; Neal Elliott, Maggie Molina, and Dan Trombley, “A Defining Framework for Intelligent Efficiency, June 201

A tenant energy management system developed by Johnson Controls provides tenants at the Empire State Building with an online micro-website and dashboard that enables them to track and manage their energy use. The system includes information collected from on-site electricity meters and sensors in the office space. The information is used to calculate and display key performance indicators and metrics for tenants. The system also supports benchmarking of energy performance to inform and encourage energy-saving behavior from tenants. Johnson Controls made several other improvements to the building including fitted new windows, radiator insulation, HVAC, and other high-tech controls.

Customers enter into a performance contract with Johnson Controls. These contracts often cover the upfront costs of all of the upgrades and guarantee a lower energy bill at a set price. This saves the customer money and shields them from the risk of volatile energy prices, in addition to significantly reducing emissions.

In this specific case study, Johnson Controls guaranteed annual savings of USD4.4million. The initial investment in the upgrades gave a three-year payback and there was a 38 percent reduction in energy use.

4.2.6 Abatement in the service and consumer sector

Today the ICT emissions in the service and consumer sector are **4.8 GtCO_2e**. Though it is one of the smaller sectors in terms of emissions, ICT is already used in the sector and will play an increasingly important role in reducing GHG emissions.

The adoption of ICT in the service and consumer sector is driven by increasing broadband penetration, the growing number of mobile devices, the presence of online buying platforms, and an equally enthusiastic uptake by businesses and consumers as they find it a more efficient method for shopping and doing business. Global e-commerce sales are expected to increase from approximately USD 600 billion to USD900 billion in 2013, a growth rate of 19 percent.[50] By 2020, it is estimated that 14 percent of global retail spending will have moved online, surpassing USD 3 trillion in revenue.[51]

Today, there are many innovative examples in which ICT technology is being deployed:

Virtual supermarkets
Tesco created the ability to order groceries while in public, allowing users to shop using their smartphones via QR2 codes and web transactions. Billboards display images of products and their codes, consumers scan the code and the product is delivered to their home within a day.[52]

Mobile payment solutions
Square is an electronic payment service that allows users in the United States to accept credit cards through their mobile phones, either by swiping the card on the Square device or by manually entering the details on the phone.[53] This technology is particularly important in areas in which the availability of ATMs and banks are low, especially in developing countries. Mobile payment systems allow consumers to make fewer trips to the bank and reduce the need for physical banking infrastructure.

Interactive online stores
IKEA created a fully interactive online store that is similar to the experience of flipping through a catalog, but more interactive and dynamic. The user can click on the icons next to certain products to get a closer look or view hidden features, change views to look around the room, or skip the room view and look at a simple grid of products.[54]

ICT-enabled solutions for retailers help reduce their emissions footprint. Through the sublevers identified below, we estimate the total abatement potential in this end-use sector to be 0.7 GtCO_2e. The table below describes the abatement potential by each sublever.

E-commerce, e-paper and online media represent emissions reductions through dematerialization. Rather than having to travel to a brick-and-mortar store or buy a physical product, e-commerce allows consumers to buy goods online and have them shipped to their homes and, in certain cases, can allow for the digitization of a product

Sublever	Abatement potential (GtCO_2e)
E-Commerce	0.09
E-paper	0.06
Minimization of packaging	0.22
Online media	0.02
Public safety/disaster managment	0.03
Reduction in inventory	0.18
Smart water	0.13
Total	0.73

Table 11
Abatement potential by sublever within the service and consumer end-use sector

50. Forrester: Mobile Commerce Forecast
51. Goldman Sachs: dotCommerce: Social networks
52. Guardian, August 6, 2012, www.guardian.co.uk/business/2012/aug/07/tesco-virtual-supermarket-gatwick-airport
53. https://squareup.com
54. www.ikea.com

Case study

Mobile money in Kenya (Ericsson)

Source: The World Bank. 2009. Poor People Using Mobile Financial Services: Observations on Customer Usage and Impacts from M-PESA. https://openknowledge.worldbank.org/handle/10986/9492; Greenhouse gas (GHG) Protocol initiative http://www.ghgprotocol.org/; IEA, international energy agency IEA. 2008. Key world energy statistics 2008. Paris: International Energy Agency. Http://www.iea.org; Koomey, J.G. 2007a. Estimating Total Power Consumption by Servers in the U.S. and the World. Lawrence Berkeley National laboratory and Stanford University; Koomey, J.G. 2007b. Estimating regional power consumption by servers: a technical note. Lawrence Berkeley National laboratory and Stanford University; US EPA. 2007. Report to Congress on server and data center energy efficiency, Public Law 109-431. EPA ENERGY STAR Program. www.energystar.gov. Accessed September 2009.; World Desk Reference, http://dev.prenhall.com/divisions/hss/worldreference

Banking infrastructure is very limited in rural areas in developing economies. Individuals are forced to travel from rural areas to more central villages and bank offices in cities in order to make payments and carry out other bank transactions. Large amounts of emissions are generated as a result of unnecessary travel. This includes emissions from the use of private and public transportation and, in the long run, additional road infrastructure, more public vehicles, and increased banking infrastructure requirements. ICT could provide millions with better access to banking services, which would significantly improve their standard of living and reduce banking-associated emissions.

Mobile money can eliminate travel in other ways as well. Physical travel by migrant workers to ensure the safe arrival of remittances could also be reduced. Mobile money represents a safer, quicker way to send money long distances to family members than either physical travel or through a postal system. Mobile money can also reduce travel needs within communities by allowing for direct mobile bill payment. For instance, the electric company can charge consumers directly via their mobile devices, eliminating the need for the customer to travel to the company physically to pay the bill.

ICT companies (mobile network providers, in particular) can also play an active role in fostering the adoption of mobile money. Though some developing country mobile phone users, particularly in much of Africa, are wary of using banking services through their phones, mobile network providers are in an excellent position to assuage these concerns. As network providers tend to be more accessible than banks, they can serve as locations where consumers can turn cash into mobile money. They can also address concerns surrounding financial security and lost and stolen phones.

To use Kenya as an example, there are 6.5 million subscribers who currently carry out 10 million banking transactions per day, with an average value of USD 20. The calculated environmental impact is 22 kgCO_2 per subscriber per year. The primary enabling effect of the mobile money service is lower transportation emissions; secondary enabling effects include reduction in the number of buses needed, less road construction, fewer road repairs, lower hard cash needs, and diminished bank-related infrastructure needs. If this level of mobile money penetration and emissions reductions in Kenya holds for the rest of the continent, mobile money would reach 161.3 million consumers and would yield 3.55 Mt in CO_2e emissions reductions in Africa alone. If broadened to encompass consumers in Asia, the Middle East and Latin America, the emissions reduction potential would be even more substantial.

(i.e. buying an MP3 file instead of a CD). The delivery of catalogs and brochures on computers, tablets, and phones also makes delivering paper copies unnecessary.

By leveraging ICT-enabled software, producers of consumer goods can minimize the amount of materials that are necessary to protect a good while in transport. ICT can also help producers of consumer goods design their products more efficiently and choose more eco-friendly materials. This can yield significant materials savings and prevent 0.22 $GtCO_2e$ in emissions.

Further, other ICT-enabled solutions can help optimize retailers' inventory levels, representing a 0.18 $GtCO_2e$ abatement potential. The ability to keep lower inventory levels reduces retailers' emissions associated with storage and can help decrease the logistical or transportation emissions.

Barriers in the service and consumer sector include:

Behavior
Because products and services offered in this sector are an important part of people's lives, there can be significant reluctance to adopt new technologies or change old habits. Even in situations in which the new technology offers many additional benefits, there still can be a hesitation to switch. A classic example is the preference by some for vinyl records, paper books, or other physical media, even though viable alternatives exist. Other changes, like the explosion of social media in the retail space, can create legitimate concerns (e.g., privacy concerns) and thus future use of ICT needs to be properly managed.

Awareness and information
Addressing this barrier is vital for giving individuals and companies the information to make the most efficient decisions. Often consumers and the retailers that serve them are unaware of the benefit from adopting green solutions. There is insufficient availability of information to make green choices.

4.3 Differences between this report and the SMART 2020 report

In 2008, GeSI published the SMART 2020 report. It was one of the first publications to fully explore the impact of ICT in reducing emissions. While the conclusions published in that report hold true (and, as we will argue, they have in fact become even more important), recent trends and events in the last several years have significantly changed the ICT industry and its role in society. No one could have predicted the impact of the global economic recession or the explosion in the adoption of drastically new ICT technologies and devices (e.g., 4G networks, smartphones, cloud computing, etc.). In this section, we take a closer look at how some of these events and trends have affected this current update of the previous SMART 2020 report.

It is clear from the trends published in previous chapters and many of the other materials we have reviewed that ICT has an even bigger impact in society than in the past. From disaster management to social network/crowd sourcing to smart agriculture, ICT has penetrated nearly every corner of society. To reflect these changes, we have slightly changed the organization of sublevers from the previous report. The fact that ICT can capture such a wide spectrum of abatement is the reason we decided to organize the abatement by both end-use sector and change levers. We have re-written the change levers (Digitalization and dematerialization; Data collection and communication; System integration; Process, activity, and functional optimization) to be very explicit about the actionable ways in which ICT can make an impact. We have tried to consider every possible role when attempting to create a complete list. In addition to organizing by the role of ICT, we felt it was very important to organize by the end-use sectors (Power; Transportation; Manufacturing; Service and

Consumer; Agriculture and Land Use; Buildings). This was done because of the interplay among many of the sublevers within a sector (e.g., the smart grid in the power sector is a combination of many of our sublevers). As a result, policy is most often drafted at a sector level (in addition to the targets set to cover the entire economy, i.e., GHG and CO_2 targets) and thus our policy and other analysis was designed to reflect this.

In addition to the changes in how we organized the sublevers, there have been modifications to the sublevers themselves. We have added several sublevers to reflect the increased role of ICT, but have also removed sublevers for which we felt the abatement had already been realized or there was overlap with other sublevers. Please see the appendix for a full breakdown of the changes to the sublevers.

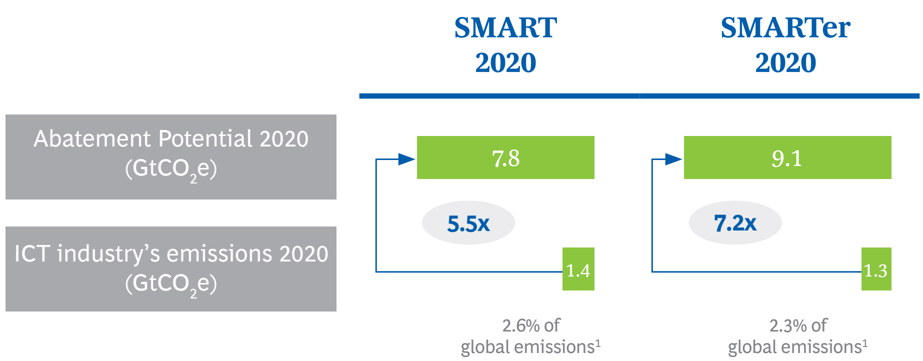
Given the current trends and updates in the data, we have also updated the analysis for estimating the abatement potential. While we leveraged the results for sublevers for which we could confirm there were few changes, in many other sublevers we updated the analysis.

A principal goal of this report is the transparency of our methodology and our assumptions; we encourage the reader to find more specific details on our assumptions and calculations in the appendix. The figure below summarizes the updated estimations.

When we compare the estimates in this study with the results from the SMART 2020 report, we see an encouraging trend, as the abatement potential has increased while direct emissions have decreased.

The increase in abatement potential is due to the innovation of new sublevers, as unforeseen technology has been introduced and has been shown to play an important role in abatement. Additionally the values used in also reflect further improvements in data quality and use of more up-to-date product information. Higher abatement projections are also simply due to a growing baseline, as estimated emissions for 2020 from the IEA and IPCC and others have been revised up since publication of the last report. In general, we have revised upward the estimates due to recent encouraging trends in uptake and penetration of ICT.

Figure 11
Emissions versus abatement potential



1. On a base of 55 Gt CO_2e GHG emissions

Source: SMART 2020, IEA, BCG analysis

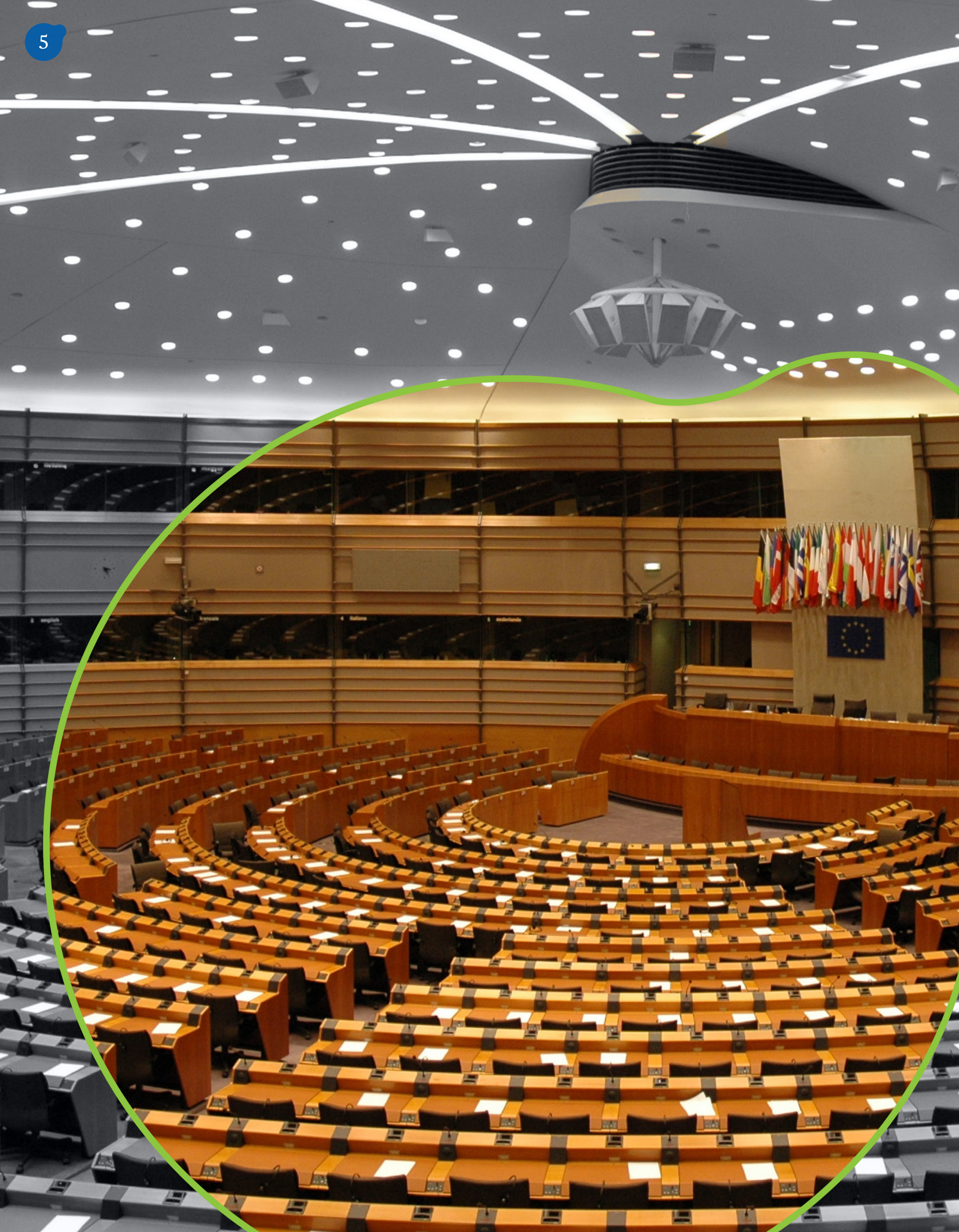
4.4 Important considerations for estimates

In this section we describe some of the important details about the estimations published in the report.

It is important to point out that all of the forward looking estimates are based on forecasts. These forecasts depend on several unknowable factors: evolution of technology and the ability of the ICT industry to deliver solutions, role of governments in supporting policy, future energy prices and impact on business cases, etc. Sensitivity analysis of the forecasts was beyond the scope of this study. We took special care to source the most up-to-date and credible estimates and analysis, but naturally any of the forecasted numbers are estimates and should be treated as such. Furthermore, the estimated abatement represents the total potential of the ICT industry in the broader economy. It assumes that policy and other tools are used to remove the barriers to adoption (as we will discuss in more detail in the next chapter). In calculating this potential, sources of discrepancy can be the result of errors in estimating the full penetration of the solution or the savings potential (expected technical reduction in emissions as a result of implementing the solution) and changes in other industries that may or may not occur but could have an impact on the abatement potential of ICT-enabled solutions. The reader is encouraged to view the appendix for all of the assumptions used in both the estimate of ICT's emissions and the abatement potential.

ICT plays a varying role, with each of the sublevers used to estimate the abatement potential. Although all proposed GHG abatement potentials are related to ICT, some of the mentioned abatement sublevers are much more strongly linked to ICT (e.g. telecommuting) while others play a more indirect role (e.g. integration of renewables). Since it is impossible to allocate a fraction or portion of the abatement from a specific sublever to that attributable to ICT, we included the entire abatement potential to provide the most accurate and clear result.

Finally, the last important consideration for abatement estimates is the consideration of rebound effects. A "rebound effect" occurs when a new technology is introduced (in our case a solution that uses less energy than the previous technology) but results in an increase in energy or resource use. Examples include the modern light bulb, which is many more times efficient in output of light per unit of emissions created, but has increased the demand in lighting, resulting in a large net increase in lighting emissions. Another example is video conferencing which can help replace flights, but may strengthen relationships to the point where there is appetite for face to face contact. A third example involves traffic optimization. If traffic times go down, the efficiency gains will induce more commuters to use private transportation, which leads to an increase in emissions. In general, there are several cases in which efficiency brings about a net increase in total consumption, because if a unit of consumption delivers more utility, it becomes more desirable. The calculated abatement results in this report do not include rebound effects. They are incredibly complicated and difficult to model, there are no agreed upon scientific approaches, and they depend on highly variable socio- and macro-economic factors. That said, rebound effects are important, and it is important for policy makers, the ICT industry, and other stakeholders to consider these effects when designing policy and discussing the environmental impact of the industry.



5 Framework for ICT-enabled emissions reduction

In the previous sections we have identified the role that ICT can play in reducing emissions (9.1 $GtCO_2e$). To realize the abatement potential, however, significant barriers to adoption need to be removed. The opportunity to remove these barriers span a wide variety of stakeholders: the ICT industry, other private industries, policy makers, private individuals, NGOs, and many more. While one should not discredit the importance of any of the stakeholders in this list, we will dedicate the rest of this section to addressing what is potentially the most important barrier to ICT adoption: public policy.

We will take a global view of policy before diving deeper into the national policy for each of the key end-use sectors. Before discussing policy, it is worth exploring overarching barriers, themes, and the role of international organizations in helping enable ICT abating technologies.

Key barriers to the adoption of ICT

It is important to start by identifying the key barriers to the adoption of ICT, as this will drive most of the design of policy. Of course, these barriers are not universal and may not apply to every country or end-use sector, but discussing these at a global level helps us understand what is limiting the adoption of ICT solutions:

1 Economics
Poor economics limits the adoption of ICT because of a lack of a strong business case in certain specific cases. This can be the result of high costs for implementing the solution or little value in return. Solutions in this category may not bring a return at all, might not have a high enough internal rate of return, or may have too long of a payback period for an investor to be comfortable with the project.

2 Financing
High up-front investment costs of solutions can be especially problematic in situations in which the cost of capital is high, common for many of the ICT solutions. While the actual risk of many of these solutions are low, the perceived risk can be high (due to unfamiliarity with these types of projects among lenders), which can increase the cost of capital or discourage traditional sources of capital (i.e., banks and other financial institutions) from providing the funds. This barrier can be especially problematic for individual consumers or households in which the access to capital is limited.

> Policy has an important role in reducing the barriers to the wide-scale adoption of ICT abatement solutions

3 Lack of technology or infrastructure
For certain industries or situations the effective technology for carbon abatement may not exist or is still in development. Furthermore, even for developed technologies, the underlying infrastructure needed to run the technology may not be in place or fully enough deployed to realize the full potential of the ICT solution.

4 Split incentives
These occur in situations in which those receiving the benefit of the ICT solution do not have full control over its implementation, or other situations in which energy or resource use is not priced. Many split incentives occur because of the principal-agent problem, which concerns the difficulties in motivating one party (agent) to act on behalf of another party (principal.) A classic example is the landlord-tenant relationship, in which the tenant is often paying for the energy costs, but does not have the control to install energy efficient upgrades.

5 Behavior
Full-scale adoption of ICT, especially at the individual level, can require or may affect the behavior of individuals. Without the right incentives or motivation to change, behavior can be a major barrier to adoption. In most cases this can come down to habits; the ICT

solution would provide better quality of life along all dimensions, yet the consumers are hesitant to change.

6 Awareness
Many consumers and businesses around the world are unaware of the ICT-enabled abatement opportunities available to them. To ensure that the abatement potential is realized, it is crucial that people are aware of the sublevers that can be utilized.

Again, these are general barriers that may not necessarily apply to every country or type of economy. In general, we observe that barriers like infrastructure, economics, and financing are not as strong in developed versus developing economies. Naturally, there is more advanced infrastructure (such as ICT networks, public transit, electric grid, etc.) in developed economies and the business case for ICT solutions are typically stronger because of higher energy prices (with the U.S. and Canada being clear exceptions) and lower costs of capital. Developing economies typically have lower energy costs and, since they are growing, the cost of capital can be quite high, making economics and financing especially important. Behavior and split incentives can be more important in developed economies because of increased regulation. Developing economies can "leap-frog" certain technologies, making behavior and habits less of an issue. We must be careful not to over generalize; we will explore more deeply the specific barriers to adoption of ICT for each country.

Role of policy

After considering the important barriers to adoption of abatement technologies, we can now start to consider the way to overcome these barriers. As a first approach, the ICT industry itself should offer attractive-enough value propositions to the customers that would allow the market to drive the adoption without any external intervention. If that is not realized, the industry can establish groups that focus on removing the implementation barriers by, for example: defining common standards, sharing R&D or by better marketing the solutions for customers. If the previous levers are ineffective, public policies should be considered. Much like we did with the barriers, we can consider general levers that policy can deploy. This list is not meant to be exhaustive, but it does provide some key ways in which policy can be implemented:

1 Targets
Setting specific limits on GHG emissions, the use of energy, or other targets at the sector-or technology-specific level (e.g., fuel efficiency standards for automobiles) help set hard limits to amounts of CO_2 and other GHG gases that are released into the atmosphere. For targets to be effective, there must be an enforcing mechanism (typically through fines) if the target is not met.

2 Investment in R&D
Helps reduce the costs of ICT or improve the effectiveness of a product; R&D is also helpful in addressing the need for new solutions.

3 Incentives
Can be implemented through tax breaks, rebates, or other direct subsidies. These help improve the business case for solutions by reducing costs.

4 Education
Sharing of information is vital for implementing the most efficient and effective ICT solutions. Policy can have an important role of promoting this through sharing best-in-class practices, IP sharing, etc. Also, the implementation of the project at the customer level can often be complicated (due to the complexity of contracting, financing, and execution). Customers need more education to increase familiarity with ICT solutions. This lever is instrumental to helping change the behaviors of individuals and create bottom-up demand for abatement technologies. Furthermore, collection and sharing of data is important for making efficient decisions. For instance, certified energy efficient buildings sell at a premium in real-estate markets. If data could be collected that demonstrated the efficiency/cost reduction gained by installing a building energy management system, this would help with finance and business case issues for many ICT solutions.

5 Regulation

Non-energy or emissions-specific regulation or laws (e.g., building codes, appliance codes, etc.) can have significant impact on emissions by affecting consumer and commercial behavior. Regulation can be redesigned to promote the adoption of ICT technologies that reduce emissions. In some situations, regulation can be very detrimental. Examples include outdated national laws that can impede the use of fuel efficient cars (e.g., automated cars or implementation of other advanced driver aids). Another example includes the regulation of renewables, e.g., restrictions on building wind turbines and constructing solar power plants.

With an understanding of the important barriers and policy levers, we can begin a discussion on the role of global policy and targets and how global targets and incentives can help drive the need for national policy.

Global policy

The figure below illustrates the role of global policy at a high-level and how it can serve as the basis for national policy.

There is a fundamental policy that can drive reduction in emissions: setting and enforcing global reduction targets. There has been good progress toward setting targets. The Kyoto protocol set standards for each country with the goal of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent significant changes to the climate.[55] Global policy can also indirectly reduce emissions through other polices like the U.N.'s Sustainable Energy For All Initiative, which seeks to give universal access to modern sources of energy, double the share of renewable energy in the global energy mix, and double the rate of improvement in energy efficiency, by 2030. [56]

55. Article 2". The United Nations Framework Convention on Climate Change
56. Source: http://www.sustainableenergyforall.org

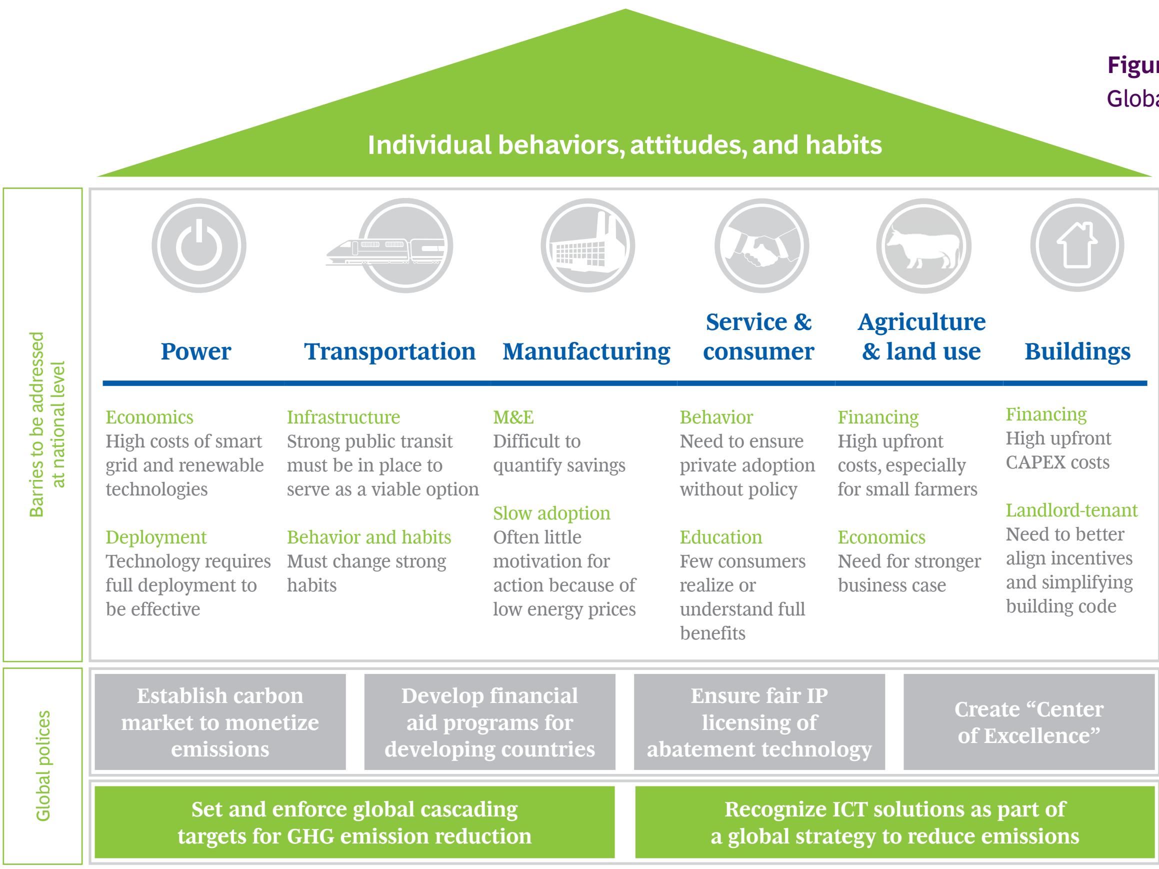


Figure 12
Global policy framework

Policy can also be set at a regional level; for example, the EU has the “20-20-20” targets that seek a 20 percent reduction in EU greenhouse gas emissions from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20 percent; and a 20 percent improvement in the EU’s energy efficiency by 2020.[56] There are also several other targets set at more local levels. Setting a target is easy; enforcing and ensuring the targets are met requires more effort. Future work is needed to create penalties and other negative consequences for those countries or regions that do not meet their targets. It is also important at the global level to recognize the role of ICT in GHG abatement.

Moving up from the bottom, at the second step, these are more specific policies that can be implemented at a global level by international organizations. These are:

1 Establishing a GHG market
Creating an efficient market that establishes a price on CO_2e could help improve the economics of many of the ICT solutions and would create market incentives to reduce emissions. A GHG market may be needed since the negative externalities of the release of GHG are not currently taken into account.

2 Providing financial aid to developing economies
Developing countries may be unable to afford the expensive up-front costs for advanced GHG abatement technologies, yet most of the extreme effects of climate change will likely be felt in these countries.

3 Ensure fair IP licensing of abatement technology
The technology required to reduce emissions through renewable energy incorporation, higher energy efficiency, ICT applications, etc., the protection of intellectual property; sharing IP could help speed the adoption and innovation of ICT technologies. However, it is important to strike a delicate balance as it is vital to reward those responsible for innovation. This is partly addressed by establishing clear and fair rules at the onset of the program.

4 Creating a global “Center of Excellence”
Best-in-class implementation of ICT solutions could potentially have a large effect, but most parties only capture part of the full abatement potential. An existing international body (e.g., IEA, ITU-T, UNFCCC, etc.) could help share best practices (e.g., sharing information and analysis) through effective communication among several parties, or a new body could be created.

In addition, at a global level, barriers to global trade in ICT should be avoided in order to encourage the uptake of ICT. Therefore, border tariffs should be avoided as stipulated in the plurilateral WTO Information Technology Agreement (ITA). WTO members not currently participating in ITA are encouraged to sign on to the Agreement, making ICT products on their national markets more affordable.

Global policy naturally feeds into and helps influence national policy, since it is at the national level that established governments can take action. The top half of Figure 12 summarizes some specific barriers within each end-use sector. We will explore in more detail in the following country deep-dives how national policy can help address some of the specific local concerns by sector while also meeting global targets.

5.1 Understanding the business case in relation to the role of policy

Understanding the business case of each of the sublevers is vital to prioritizing and designing the role of policy. At the country level, we will explore the business case for specific key sublevers. To do so, three key considerations will be used:

57. European Commission

1 Investment attractiveness
If the cost of the upfront investment is too high, people may choose other investments with a lower upfront cost. Being able to finance the upfront cost is crucial because even if the upfront cost is reasonable, many will not have the capital on hand to make the investment outright. The distribution of the cost between suppliers and consumers and how this affects subsequent consumption behavior can also influence attractiveness.

2 Return on investment
If the absolute return on investment is too low, the monetary gain may not justify the effort even if the margin percentage is high. Furthermore, if the margin percentage is too low, investors will direct their capital to other investments with a higher percentage return.

3 Risk and feasibility
If there is a high degree of variability for the return, many will look to investments that are less risky. If the effort involved in putting a product in place or providing an appropriate service is too high, the required time investment upfront may not be justified by the monetary return. Risk can be due to problems with technology, changes in policy, or any other issues that could increase the cost of capital or otherwise make the investment unattractive.

When considered together, these three elements give a sense of what is required to induce sublever adoption. If the business case for adoption is strong, little to no policy intervention is required. If the business case for a technology is weak but the potential for CO_2e abatement is high, policy makers should be engaged to help change factors that drive the unattractiveness of the business case. Business analysis based on these above criteria will be conducted for the most significant sublevers for each end-use sector in the individual country reports.

Considering Figure 13, it is evident that different technologies or solutions have varying levels of CO_2e abatement potential and business case attractiveness. Those sublevers in the right quadrants require little to no policy intervention to drive adoption. There is already a compelling business case and businesses and individuals will adopt those technologies regardless of policy incentives. Meanwhile, those in the top quadrants offer the greatest GHG abatement potential. As a result, the upper left corner shows ICT-enabled abatement solutions that require policy intervention. Though the business case is not particularly attractive for those technologies, they can reduce emissions significantly and policy makers should implement policies that make them more economically attractive. Throughout the report, concrete steps that policy makers can take to drive adoption of key abatement technologies will be highlighted.

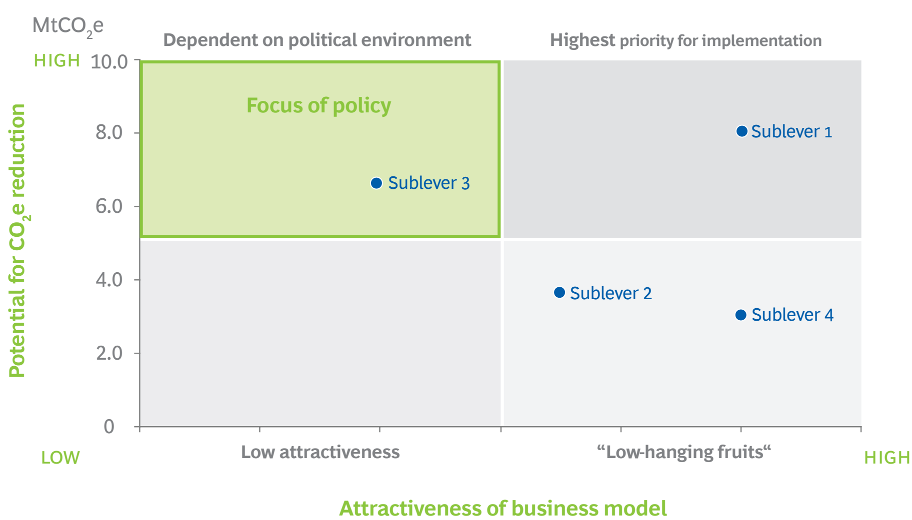


Figure 13
Framework for analyzing the role of policy in each sublever

6
Cross-country deep-dive comparison

Though the global section of this report provides an overview of how ICT can be leveraged to abate GHGs around the world on average, no "average" country exists. Each country has its own history, resources, culture, and economy that distinguish it from other countries. Though there is the temptation to separate the problems created by climate change into those relevant to developed countries and those relevant to developing countries, the reality is more complex. Because countries' abilities to use ICT to address climate change differ, the following chapters provide an in-depth analysis of seven countries (Brazil, Canada, China, Germany, India, the U.K., and the U.S.) to provide a sense of that diversity across the international community.

Below is a list of the factors that affect a country's potential to leverage ICT to address climate change:

1 **ICT penetration**
2 **Sectoral composition of the economy**
3 **Climate change awareness and education**
4 **Political willingness and ability to act**
5 **Income**

ICT penetration is relevant because unfamiliarity with the technology and a lack of infrastructure can leave a country unprepared to abate GHGs through ICT. Sectoral composition of the economy is important because it impacts which sublevers are important for a particular country. For instance, the manufacturing sublevers are of greater significance in Germany than Canada, despite similar income levels. In many countries, there is a lack of awareness of the severity of the effects of climate change, causing consumers and businesses to deprioritize GHG abatement over other concerns. Political willingness and ability to act is significant because in some countries, such as the U.S., lack of political will and legislative gridlock are serious impediments even though a majority of the country has accepted climate change as fact.[58] Finally, income is an important differentiating factor across countries, as wealthier countries are in a better position to invest in GHG abatement solutions because of greater availability of funds and a less urgent need to raise living standards.

Nonetheless, ICT can play an important role in abating GHGs in all countries while providing a positive economic impact; per capita income level is not a sufficient reason to avoid addressing GHG emissions. Though some lower income countries face financing and fund availability constraints not present in some advanced economies, ICT can provide a positive economic return while abating GHGs in countries across the world. In India, for instance, smart meters in the power system can play a significant role in identifying and correcting inefficiencies in the power grid. This will help power companies return to profitability and will reduce electricity waste and emissions. In wealthier countries with high levels of advanced ICT penetration there still remains much room for the implementation of the identified sublevers. In Canada, for instance, the use of logistics optimization systems has the potential to provide significant abatement in the transportation sector despite already high penetration of logistics networks and ICT.

However, one commonality across all countries is the need for policy intervention to ensure that the abatement potential of the identified sublevers is realized. Though many of the sublevers have a positive business case and uptake will be driven by the market, some sublevers require policy intervention to promote high levels of use. The following list, though not exhaustive, lists the four most common barriers to sublever adoption across countries:

58. " Americans' Global Warming Beliefs & Attitudes: March 2012", Yale University

1. **Economics**
2. **Financing**
3. **Awareness and education**
4. **Lack of infrastructure**

The economics of certain sublevers presents a barrier to adoption in almost all countries. In Brazil, for instance, the use of livestock management systems has enormous abatement potential by improving land use and reducing methane enteric emissions from cattle. The challenge, however, is that ranchers currently have little economic incentive to invest in such systems; unless policy makers fairly price land or introduce a GHG emissions penalties, ranchers will not utilize such technology.

Financing is another common barrier, even in wealthy countries. In the U.S., building management systems have a positive business case but can often be too expensive for building owners to purchase outright. Government-facilitated financing can be a way of overcoming this concern. Another solution would be to incorporate environmental costs in energy prices.

Awareness and education surrounding many of the sublevers is another broad concern. For example, voltage optimization systems have a positive business case in the U.K., are relatively inexpensive, and typically do not require financing, but uptake is low because people are simply unaware of the technology. By increasing awareness through government publications and increasing energy efficiency standards, the government can drive uptake.

Finally, the lack of ICT infrastructure serves as a barrier in many countries. The lack of high speed data networks in India, for instance, will make it difficult for truckers to adopt logistics optimization technology because truckers cannot communicate with logistics centers in their absence. Policy makers can intervene by reducing the red tape that delays the construction of information networks and by subsidizing construction in rural areas where there is not yet a positive business case for data network construction.

Though this section provided an overview of the factors that distinguish a country's ability to engage in ICT-driven abatement, sufficiently understanding the variety of circumstances across the international community requires more in-depth consideration. The country deep-dives that follow will provide the analysis needed to ensure that the 9.1 GtCO2e of identified abatement potential is realized across the globe by 2020.


United Kingdom

7
United Kingdom

7.1 Context

The U.K. has managed to reduce its GHG emissions over the last two decades. While the U.K.'s GHG emissions declined at the rate of 1.3 percent per year from 1990 to 2010, its GDP grew at a rate of 2.3 percent per year. This is a very encouraging trend since many countries—both developed and developing—are still struggling to break the correlation between GDP growth and GHG emissions. The U.K. clearly demonstrates that it is possible to achieve economic growth while successfully reducing GHG emissions.[59]

According to data from the UNFCCC, the U.K.'s emissions in 2010 were 590 $MtCO_2e$,[60] or 1.2 percent of the estimated 48,000 $MtCO_2e$ of global GHG emissions (see Figure 14). The energy and manufacturing sectors made up the biggest share of the emissions in 2010 at 27 percent each. The transport sector was next at 20 percent, followed by service and consumer at 18 percent and agriculture at 9 percent.

However, emissions have been declining steadily in the U.K. at the rate of 1.3 percent per year since 1990. Figure 14 shows the trend from 1990 to 2010. This decline has resulted in 23 percent lower emissions in 2010 compared with 1990. This is a significant improvement, especially since many other countries with high emissions such as China, the U.S., and India have seen an increase during the same period. It is also important to note that the U.K.'s share of global emissions has declined from 2.1 percent in 1990 to 1.73 percent in 2000. In 2010, the U.K.'s share was only 1.22 percent.

The reduction in the U.K.'s emissions has been led by the manufacturing sector. Of the total decline of 174 $MtCO_2e$ between 1990 and 2010, 67 percent came from the manufacturing sector: in 2010, the manufacturing sector's footprint was 160 $MtCO_2e$ compared with 277 $MtCO_2e$ in 1990. The primary driver of this reduction in the manufacturing sector's footprint has been a continuously smaller share of the manufacturing sector in the U.K.'s economy as much of it has shifted overseas to countries with a lower cost of production.[61] As a result, the footprint of manufacturing in the U.K. decreased from 22 percent in 1990 to 10.8 percent in 2010. Nonetheless, the U.K. remains one of the world's largest industrial nations, and further reductions in emissions in this sector are necessary.

59. This view is based on "territorial accounting" of emissions. "Consumption-based accounting" of emissions shows a different picture – emissions of the U.K. have been increasing from 1990 to 2008. See "Consumption-Based Emissions Reporting; Twelfth Report of Session 2010–12" – Energy and Climate Change Committee, House of Commons

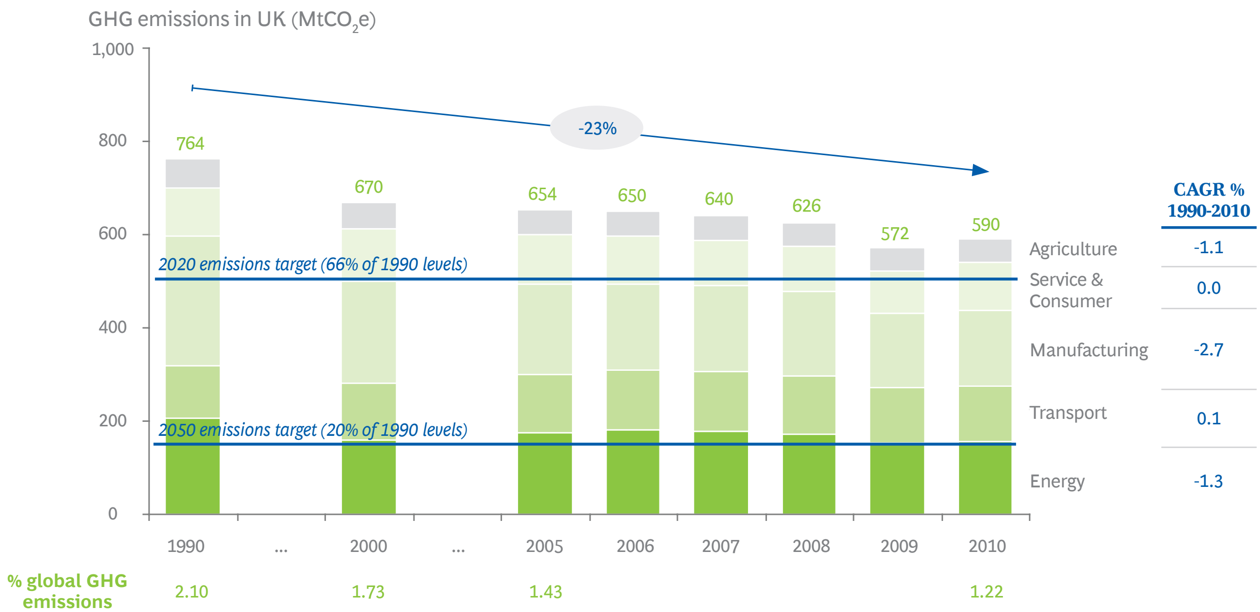
60. Excludes "land use, land use change, and forestry"

61. See earlier comment about territorial vs. consumption-based emissions accounting

Figure 14
The U.K.'s greenhouse gas emissions (1990-2010)

Note: Emissions data excludes LULUCF

Source: UNFCCC; UK's Climate Change Act 2008; BCG analysis



The energy sector has also seen a substantial reduction in GHG emissions: 27 percent of the total decline in the U.K.'s emissions is a result of the gradual de-carbonization of the energy sector. The primary driver of this trend has been a significantly higher share of gas in power generation leading to lower dependence on coal. The share of gas has gone up from 24 percent in 1990 to 45 percent in 2010 while the share of coal has come down from 37 percent in 1990 to 20 percent in 2010. Further de-carbonization of power generation is expected as coal is gradually replaced by gas and renewables.

Among the remaining sectors, agricultural emissions have decreased slightly. However, the overall impact of the improvement in the agricultural sector is small as its emissions are relatively insignificant. Other sectors—transport and service and consumer—have not fared as well. Figure 14 shows that total emissions from these sectors have stayed flat or increased slightly.

Current policy environment

State and public awareness regarding climate change is high in the U.K and accordingly, there is strong policy support for emissions abatement. The Climate Change Act 2008 sets clear targets for GHG emissions reductions in the U.K. and also provides for a carbon budgeting system that caps emissions over five-year periods, with three budgets set at a time. The first three carbon budgets were set in May 2009. The first carbon budget ran from 2008 to 2012, with the remaining budgets to run from 2013 to 2017 and 2018 to 2022. As part of the Act, the Committee on Climate Change (CCC) was created to advise the government on the level of carbon budgets and areas in which cost-effective carbon abatement can be realized.

Several targeted policies have already been implemented in the buildings and service and consumer sectors. The Energy Act (2011) aims to bring about a step change in the provision of energy efficiency measures to homes and business.[62] This Act created the Green Deal, a new framework to enable financing of energy efficiency improvements in domestic and non-domestic properties. The Act also mandated that starting in April 2016, private residential landlords may not refuse tenants' request for consent to make energy efficiency improvements where financing is available, such as through the Green Deal. The Act also provides for the creation of the Energy Company Obligation that will take over from existing obligations such as the Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP). Besides these measures, it also includes steps to enable use of low-carbon technologies. Also, Buildings Regulation 2010 lays out the standards and certification requirements.

U.K.'s GHG emissions in 2010 were 23% below 1990 levels

Besides these acts, other measures such as subsidies and tax benefits are in place to encourage energy efficiency. Energy-intensive industries are already covered by the European Union's Emissions Trading Scheme. Further, all businesses listed on the Main Market of the London Stock Exchange will have to report their levels of GHG emissions from the 2013 financial year. The U.K. is the first country to make it compulsory for companies to include emissions data in their annual reports. This move has been welcomed by the vast majority of businesses as it provides greater clarity and transparency.[63]

Achieving GHG emissions reduction targets

Under the Climate Change Act 2008, the U.K. has set ambitious GHG reductions targets, which exceed the EU-wide commitments. The GHG emissions target for 2020 is 36 percent below the level in 1990. Likewise, the 2050 target is 80 percent below the 1990 level. If emissions reductions were to continue at the current pace, the U.K. would achieve its targets. However, the U.K. cannot rely on further reduction in the size of the manufacturing sector to achieve this target and will therefore have to focus on adopting new levers for emissions abatement.[64]

62. Department of Energy and Climate Change

63. DEFRA (http://www.defra.gov.uk/news/2012/06/20/greenhouse-gas-reporting/)

64. The U.K. sets hopes on the ability to use Carbon Capture and Storage technology to help with this. However, this potential is unlikely to be realized until the late 2020s (Source: http://www.decc.gov.uk/en/content/cms/emissions/ccs/ccs.aspx)

This study focuses on levers in the buildings and service and consumer sectors. Total emissions in these sectors have been largely constant. The buildings sector accounts for 35 percent of the country's emissions[65] and, as previously mentioned, the service and consumer sector accounts for 18 percent. The following sections discuss the trends in these sectors in greater detail. Given the large share of these sectors and little-to-no reduction in total emissions, this study discusses the role that ICT-enabled solutions can play in emissions abatement. However, as mentioned in the section on global abatement potential, ICT will play an important role in enabling GHG abatement in other sectors as well.

7.2 Impact of ICT on GHG emissions

The U.K. has a strong foundation for scaling up innovative ICT-enabled GHG abatement solutions. Business and consumers alike have adopted these modern technologies in their day-to-day activities.[66] Good ICT infrastructure—access to computing and mobile devices, high-speed networks—contributes to an innovative culture in and around GHG abatement solutions in the U.K. There is already a vibrant start-up community focused on "cleantech". Venture capital funding is increasingly focused on such start-ups, similar to the trend in the U.S.

Moreover, as the next section will discuss in more detail, innovative ICT-enabled solutions are already available in the market today—for example, building management systems. While the market is expected to drive adoption of some solutions, such as online and digital media, policy can play a role in scaling up solutions for which the market is not likely to drive adoption.

The use and adoption of ICT is expected to increase by 2020. Smartphones are widely used in U.K., with a 40 percent penetration. While in its early days, the adoption of tablets has been rapid as well. As the prices of smart devices continue to fall, they will become more accessible to a larger population. Further, increased proliferation of devices and Web-enabled services will increase the amount of data traffic on networks and data stored in data centers.

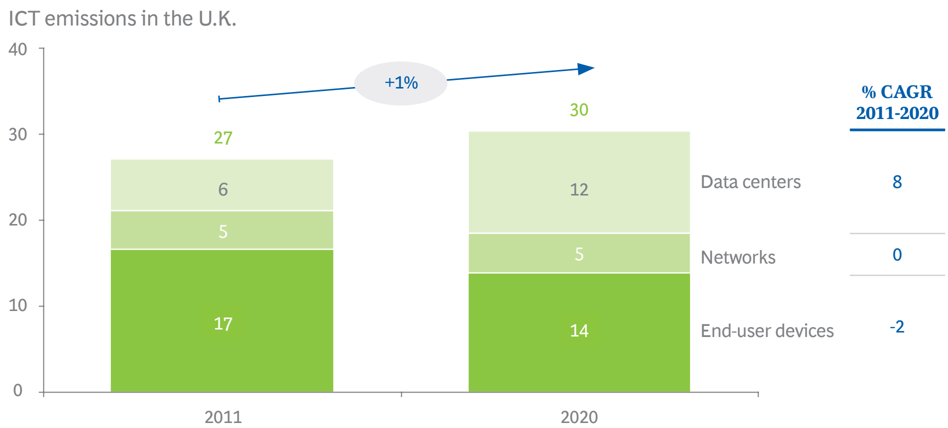
This widespread adoption of technology, however, comes at the cost of high greenhouse gas emissions. Figure 15 shows ICT emissions in the U.K., which were estimated to be 27 $MtCO_2e$ in 2011. As a result, the ICT sector contributes 4 percent to the U.K.'s overall emissions, which is twice the global average. Three-quarters of these emissions are from end-user devices, while networks and data

65. Emissions from buildings have been captured in the other sectors in Figure 14; to avoid double-counting, these emissions have not been shown explicitly

66. The U.K. ranks among the top countries in the world in terms of ICT end-user readiness. ITU's 2011 report titled "Measuring the Information Society" considered 11 sub-factors across three major categories (access, use, and skills) to assess ICT development within a country. The U.K. got a score of 7.6 out of 10, which placed it tenth highest in the world, ahead of Germany and the U.S.

Figure 15
The ICT industry's greenhouse gas emission in the U.K.

Source: Gartner; Press search; BCG analysis



centers make up the rest. The higher usage of ICT will lead to an increase in the total emissions to an estimated 31 $MtCO_2e$ in 2020.

While the number of devices in use will go up, the overall footprint of end-user devices is estimated to decrease. Two important trends will drive this reduction: significant improvements in manufacturing and usage energy, and a shift from desktop PCs to laptops and tablets that are more energy efficient. Efficiency improvements in networks will similarly compensate for the higher data traffic carried. On the other hand, data center emissions are expected to double as the amount of stored data is expected to increase drastically. Several technologies to improve data center energy usage are currently in development and being tested. For instance, switching to DC power, using natural cooling, and running data centers at higher temperatures. However, since many of these are at an early stage, it is difficult to predict if any of them, or even all of them put together, will make any material difference on a national scale.

7.3 Abatement potential in prioritized buildings and service and consumer sectors

As discussed earlier, this study focuses on the buildings and service and consumer sectors in U.K. to demonstrate the GHG abatement potential of ICT-enabled solutions.

The buildings sector accounts for a high share of the total GHG emissions in the U.K. and has seen little reduction in total emissions. ICT-enabled GHG abatement solutions, while already available, have not been widely adopted in this sector. Similarly, the services and consumer' sector accounts for a large share of emissions and has not seen a decline in the last 20 years. The next section discusses the emissions trends in these sectors, drivers of these trends, the role of ICT-enabled solutions, and the role that policy can play to encourage their adoption.

Buildings

Context

GHG emissions from buildings in the U.K. amounted to 220 $MtCO_2e$ in 2008. [67] This is equal to 35 percent of total emissions in 2008. Buildings emissions in the U.K. are primarily driven by the existing stock of energy-inefficient residential and commercial buildings. High demand for heating in the U.K. further amplifies the need for energy efficiency of buildings.

Figure 16 shows the trends in buildings emissions. Emissions from buildings were only 5 percent lower in 2008 compared with 1990, whereas the total emissions in the U.K. had come down by 18 percent in the same period. As a result, the share of buildings in the U.K.'s total emissions has increased from 30 percent in 1990 to 35 percent in 2008.

Residential buildings account for two-thirds of buildings emissions, or 23 percent of the U.K.'s total greenhouse gas emissions. Fifty-six percent of residential emissions are "direct"—that is, nonelectricity related, mostly due to heating. The remaining 44 percent are "indirect"—that is, electricity usage for running appliances, lighting, and so forth. There has been little decline in residential emissions since 1990. Compared with 1990, residential emissions in 2010 were only 6 percent lower. The primary driver is the continuously high direct emissions due to few energy-efficiency improvements in the existing stock of buildings. Also, the energy mix for heating has largely remained the same. The small decline has come mainly from a reduction in indirect emissions due to a switch from coal to gas power generation.

Non-residential buildings, which comprise private and public office buildings, factories, hospitals, schools, stores, and so forth, account for the remaining third of the building emissions. Their share amounts to 12 percent of the U.K.'s total GHG emissions. Commercial buildings account for 75 percent of non-residential-buildings emissions, while the remainder comes from public buildings.

67. Most recent available data is for 2008

Emissions from commercial buildings are largely indirect, whereas for public buildings the split between direct and indirect emissions is more even. Public buildings have fared much better than commercial buildings in terms of emissions reductions over the last 20 years. Public buildings' emissions are 30 percent lower compared with 1990, but the emissions from commercial buildings have been largely flat. The emissions intensity has come down in the buildings sector, but the increased usage has neutralized any realized gains.

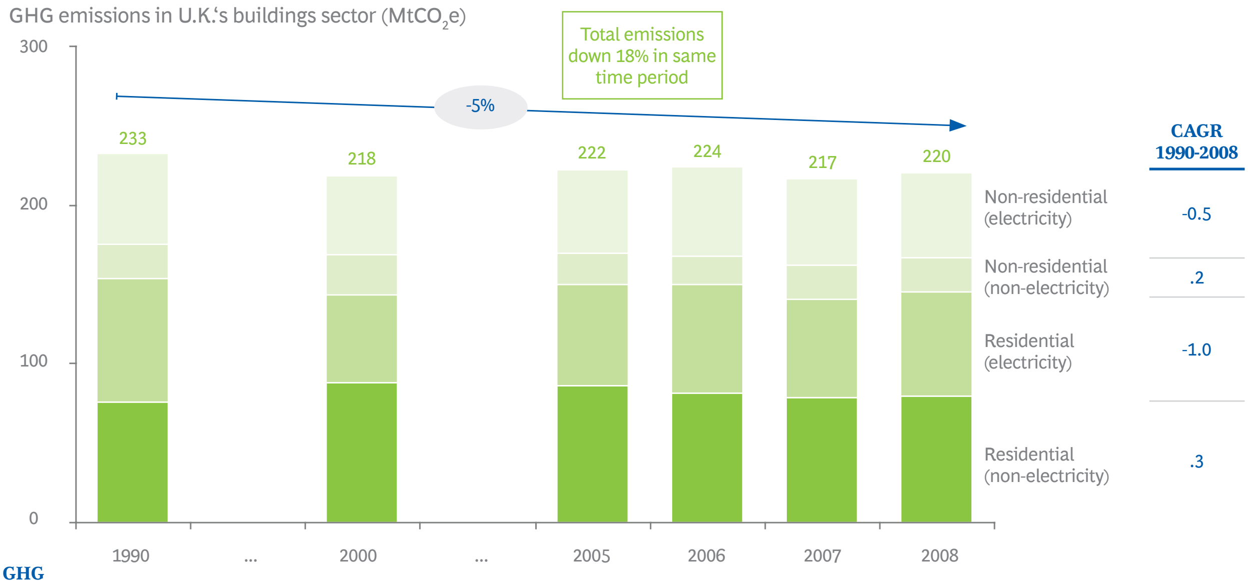
Public policy in the U.K. recognizes the buildings sector as a key area for emissions reductions and provides strong support. Several policies and measures, such as subsidies and tax relief for incorporating low GHG solutions in existing buildings, have been adopted. Insulation standards have been defined for residential and non-residential buildings in Building Regulations 2010. Additionally, new financing measures have been proposed. The Green Deal, a part of the Energy Act, seeks to provide financing options for upgrading the energy efficiency of the existing stock of residential buildings. It proposes tying low-interest loans for energy efficiency improvements to the energy bills of the properties on which the upgrades are performed. This will allow for low upfront costs of what are expected to be positive net present value (NPV) upgrades.

Aside from financing and standards, informational requirements are also in place. Starting in 2007, all residential buildings have had to display an Energy Performance Certification before they are sold or subleased. It is hoped that such energy labeling will raise awareness about energy efficiency among consumers, and ultimately encourage property owners to undertake energy efficiency upgrades.

While the biggest impact can be made by improving the energy efficiency of existing buildings, new buildings—residential and non-residential—are also being targeted for emissions reduction. By 2016, all new homes constructed will be expected to be zero carbon. Similarly, all new commercial buildings will be required to be zero carbon by 2020. These are encouraging regulations, but effective

Figure 16
Greenhouse gas emissions in the U.K.'s buildings sector

Source: "The Fourth Carbon Budget" (Committee on Climate Change); BCG analysis



UK GHG emissions	1990	2000	2005	2006	2007	2008
($GtCO_2e$)	771	674	661	656	647	634
%	30	32	34	34	34	35

implementation will be crucial. Additionally, the replacement rate of buildings in the U.K. is much too low to have a significant impact by 2020.

Clearly, the buildings sector has lagged behind the rest of the economy in reducing its own GHG emissions. The recent policies should play an important role in reversing this trend. Given the large share of emissions, buildings emissions will have to decline drastically if this sector has to play its part in achieving the U.K.'s ambitious carbon reduction targets.

Buildings abatement potential

ICT-enabled GHG abatement solutions for buildings are already available in the U.K. These include building management systems and programmable thermostats, among others. If adopted widely, these solutions can play an important role in reducing buildings emissions, especially since high energy prices in the U.K. make the economics of adopting these solutions favorable.

Figure 17 shows the total abatement potential of each of the four building sector sublevers. The total abatement potential using these sublevers is 23 $MtCO_2e$ in 2020. Building design and integration of renewables offer the highest potential. The combined potential amounts to 71 percent of the total possible abatement.

Voltage optimization offers savings from reduction in voltage received by the end-user and consequently reduces total energy use. Several firms already build and market these solutions. The economics of adopting these solutions favor the end-user and involve relatively low upfront costs. Further, these solutions apply to nearly all buildings—old and new, urban and rural. Consequently, adoption of voltage optimization solutions

38 $MtCO_2e$ Breakdown of ICT-enabled GHG reduction potential	Sublevers	Drivers of sublevers
13%	Voltage optimization	• Savings from reduction in voltage received by end-user; reduces energy use • Applies to all end-users that can be covered by smart grid infrastructure, easy to implement and cost is low
16%	Building management systems	• Savings from more efficient use of ventilation, lighting etc. • Applies mostly to large builds as scale is needed to make the economics work; not ready for residential mass market yet
29%	**Integration of renewables**	• Large building electricity use creates opportunity to replace electricity from grid with a carbon-free energy free of transmission and distribution losses • Applies to rural areas, large industrial parks and warehouses in urban settings • But limited potential in the UK due to small overall resource of distributed solar and wind
42%	Building design	• Zero Carbon or Near Zero Carbon new buildings due to better design • Applies to nearly all new buildings due to low design cost, but will be less impactful due to low replacement rate

Figure 17
ICT-enabled GHG reduction potential in buildings sector

Source: BCG analysis

should be easy to scale up in the U.K. and is likely to be driven by the market, provided there is sufficient awareness about their availability.

Building management systems enable efficient use of ventilation, lighting, and so on. Several such solutions are already available in the market today, such as those offered by Siemens and BMSi. While effective at reducing energy use, given their cost, these solutions are currently best suited to large buildings. They are not yet ready for the mass market. However, companies such as AlertMe are bringing these solutions to the residential market. It remains to be seen if the price and performance of these solutions will improve to make them more appealing to a broader set of residential customers.

High electricity use in the buildings sector creates an opportunity to replace electricity from the grid with low-emissions energy. Additionally, local generation averts any transmission and distribution losses. Integration of renewables should offer a valuable avenue to reduce energy demand on the grid, and thus to lower emissions. In the U.K., this sublever is relevant for rural areas in which space is not a constraint. In urban areas, large industrial parks and warehouses offer potential for distributed generation, although the potential in the U.K. is limited because of the small overall resource of distributed solar and wind energy at an individual building or household level. [68]

68. However, the U.K. had 7 GW of installed wind capacity in 2011, making it the eighth largest in the world. This is substantially smaller than some of the leading countries though – China (63 GW), the U.S. (47 GW), and Germany (29 GW). (Source: Global Wind Energy Council)

Better building design is a good opportunity to start accumulating a stock of energy efficient buildings. ICT is leveraged in designing more efficient buildings by allowing for architects to use advanced drafting technology that enables them to minimize future building energy use by considering site-specific conditions (for example, sunlight and wind patterns). The U.K. has legislated targets for all new building construction to be zero or near-zero carbon by 2020. This impact per building is the highest among all sublevers discussed. However, given the low replacement rate of buildings, it will take time for the full benefit of this sublever to be realized.

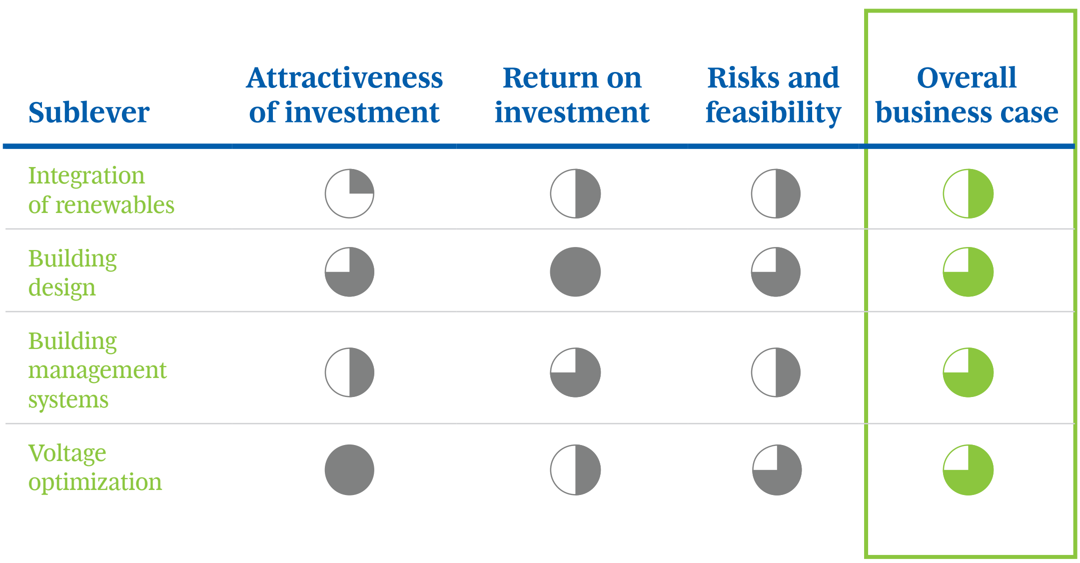
Barriers and recommended policy steps to overcome them

ICT-enabled sublevers offer substantial potential to reduce GHG emissions in the buildings sector if scaled up. However, several barriers to their adoption exist. This study discusses these barriers and proposes policy steps to ensure successful adoption of these solutions. In general, the business case for sublevers in

Figure 18
Business case assessment of buildings sector sublevers

Source: BCG analysis

Low attractiveness
High attractiveness



Case Study
BT plans to implement a remote smart energy management and control system across its centers

BT is close to completing a remote smart energy management and control system across its estate, with the aim of reducing its carbon footprint by 5% and knocking £13M off its energy bills.

The initiative, in conjunction with Matrix Energy Control Solutions Ltd will connect smart energy meter consumption data, Building Energy Management Systems and invoice data into one central system called IEMS, the Integrated Energy Management System.

This is expected to reduce BT's carbon footprint by 60,000 tonnes a year - equivalent to the annual emissions of electricity supplied to 23,000 houses.

IEMS is a significant and ambitious project. It links half hourly consumption data from more than 72,000 smart energy meters, controls and alarm information from circa 1,950 Building Energy Management Systems with data from some 92,000 invoices a year. IEMS will cover all of BT's UK offices, data and call centres with a drive to go global.

The System provides a central data repository for energy management projects and will allow energy consumption to be turned into useful business insights. It will be used for all aspects of energy management, including data validation, billing, actual and comparative forecasting, monitoring and verification, benchmarking, analysis and reporting.

The system is a flexible, scalable solution that provides the ability to select and filter data in order to deliver customised reports, graphs and charts. The power of the system will allow BT to have 'energy intelligence in action' by allowing the Energy Control Centre in BT to develop and implement initiatives to avoid energy waste whilst optimising control strategies.

"Having real-time energy usage information for thousands of buildings will really help us drive down BT's carbon footprint and energy bills," said director of energy and carbon Richard Tarboton.

"Thousands of smart meters placed at BT offices, telephone exchanges and data centres will help us monitor energy usage levels and identify areas where we can deliver savings."

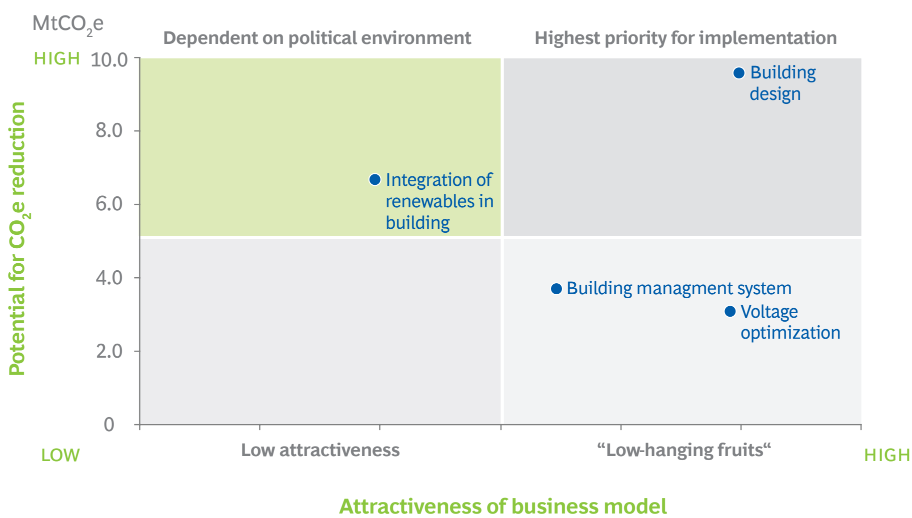
the buildings sector is strong. High upfront costs and the longer payback periods, particularly at the small-scale, weaken the business case for the sublevers in this sector. The strongest business case among the sublevers exists for building design and voltage optimization. Both of these sublevers have relatively low up-front cost and little implementation-risk associated with the solution. The return on investment, however, is better for building design than for voltage optimization. The business case for building management systems (BMS) is also quite strong when the implementation is at a large scale (see BT case study). However, the upfront cost can be high, which increases the risk since a decline in the price of energy over the lifetime of the BMS could make the economics less favorable. Finally, the weakest business case is for the integration of renewables because of the limited potential of wind and solar in the U.K. and the high up-front investment required. However, in general, compared with other countries such as the U.S. where energy prices are substantially lower, the business case is much stronger for the buildings sublevers in the U.K..

Figure 19 combines the business case analysis with the abatement potential analysis in the previous section. Combining the two, it becomes clear that the role of policy is likely the strongest in facilitating the integration of renewables since the abatement potential is high and the business case is weak. Adoption of BMS, better building design and voltage optimization will likely be driven by the market given the strong business case. Thus, policy intervention will likely not be required be required to facilitate the adoption of these sublevers.

Financing is a barrier in adopting multiple GHG abatement solutions, especially at a smaller scale. High up-front investment, such as that for distributed generation, often prevents adoption of these solutions. State-sponsored financing is more readily available for large industrial-scale energy efficiency projects, such as that via the Green Investment Bank (GIB). The GIB, capitalized with GBP 3 billion, has a mission to provide financial solutions to accelerate private sector investment in the green economy. However, similar funding for smaller-scale projects is also vital to fully realize the potential offered by these solutions.

Figure 19
Buildings sector sublever prioritization by potential for CO_2e reduction and business potential

Source: BCG analysis



Easy access to capital will be essential to drive adoption of these solutions. Government funded, but privately controlled, financing avenues should be made available to lower the burden of upfront costs at the small-scale level. One way to do this could be to provide access to small-scale projects to the GIB's balance sheet via an intermediary. The intermediary would be a single "large" investment for the GIB. In turn, the GIB could make multiple small scale loans, something that would not be feasible for the GIB.

Even if financing were available, the unfavorable economics of certain solutions are a barrier in their adoption. For instance, building management systems require a large scale to be NPV-positive. As discussed earlier, these systems are not yet economically attractive for residential buildings. Policy could help improve the economics of these solutions by promoting investment in technological innovation that drives down the price, improves their performance to increase returns from these solutions, or both. It is important to note that in general, though, the economics are particularly favorable in the U.K. because of high energy prices.

For the commercial sector, there is currently no incentive to purchase electricity from renewable sources. Since much of the emissions of commercial buildings are indirect (that is, from electricity usage), an incentive to purchase green electricity could help reduce emissions related to commercial buildings. For instance, purchasing electricity from renewable sources could be made a part of the CRC Energy Efficiency Scheme. This would let owners of these buildings offset some of their carbon requirement and, in the process, provide a demand-side boost to renewable energy.

Lack of awareness and education regarding the availability of solutions can be a barrier in some cases, even if the financing and economics are not a problem. For instance, voltage optimization solutions, though readily available, are not widely used. Programs that inform and instruct consumers about these solutions could help bridge the gap to large-scale adoption. Further, while buildings regulations already mandate that buildings must prominently display a Display Energy Certificate (DEC), more underlying information could be provided to consumers. This would enable consumers to make more informed choices when looking to rent or purchase real estate. The long-term strategy for mobilizing investment in the renovation of residential and commercial buildings, as required by the forthcoming EU Energy Efficiency Directive, offers an opportunity for considerable improvement in the energy performance of buildings in the U.K.

Lastly, even if none of the previously discussed barriers exist, the split incentive between landlords and tenants is another formidable barrier. Owners, who make the investment for upgrades, do not reap the benefits of lower energy bills. Tenants are direct beneficiaries of these upgrades. Therefore, unless some of these financial benefits accrue to the owners, return on their investment cannot be guaranteed. Further, a complex ownership structure for large commercial buildings prevents implementation of solutions as far as may be economically feasible. A regulatory framework that addresses this problem is needed.

The U.K. government could also be the "efficiency leader" in this sector. As discussed earlier, the public sector has seen a significant improvement in its building emissions. The best practices and learnings from the government's own experience can be shared with other building owners or operators. The forthcoming EU Energy Efficiency Directive's requirement for renovation of public buildings can provide exemplary solutions and good experiences in this respect.

Service and consumer

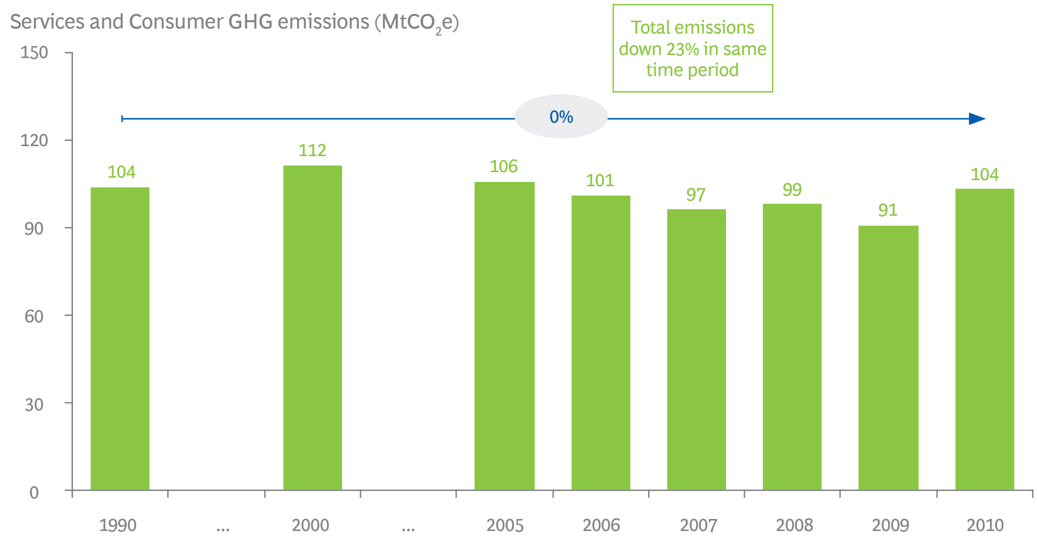
Context

The service and consumer sector has an important role in the U.K.'s economy. The sector's share of the domestic economy is the largest among various countries in the world. As the share of manufacturing has decreased over the years, the services and consumer sector has grown. However, a large economic footprint comes with subsequently large emissions. Greenhouse gas emissions from the service and consumer sector amounted to 104 $MtCO_2e$ in 2010. This is equal to 18 percent of total emissions in 2010. According to UNFCCC data, this share is substantially larger than that in other developed countries studied in this report—the U.S. (8.4 percent), Canada (10.1 percent), and Germany (15 percent).

Table 12
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome these barriers

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Financing	• High up-front costs of some solutions, e.g., distributed generation via renewables, prevents mainstream adoption • Some funding available for large-scale projects, e.g., via Green Investment Bank, but few financing avenues for small-scale projects	Provide easy access to capital	• Create government funded but privately controlled funds for financing upgrades facility and adopting other solutions at small-scale, e.g., Green Investment Bank finances a program responsible for making loans to small-scale projects
Economics	• Certain technologies and sublevers are not NPV-positive at small scale, e.g., building maganagement systems	Change economics through:	• Promote technological innovation that drives down costs at small-scale or improves performance • Offer Tax rebates for EE upgrades
	• No incentives for companies to source energy generated from renewable sources	Provide incentitves to purchase renewable energy	• Provide carbon offset benefits to compnaies for purchasing renewablw energy by e.g., including it as part of CRC Energy Efficiency Scheme
Awareness & education	• Lack of awareness can be abarrier in some cases even if the solutions do not involve high cost and the economics work, e.g., Voltage Optimization	Initiate programs targeted at educationg consumers	• Provide consumers with more information, e.g., data underlying DECs[1], to make them better informed and allow them to make "greener'"choices
Split incentives	• Tenants or others that are renting capture benefits of effieciency upgrades but the owener will not make the investment unless ROI is guarnteed • Complex ownership structure for large buildings prevents pushing abatement solutions as far as is economically resonable/ possible	Create regulatory structures that align incentives	• Encourage building owners to implement carbon abatement solutions by transferring some of the energy cost savings from tenants to owners • Alternatively, could implement property taxation based on energy efficiency

1. Display Energy Certificates
Source: BCG analysis



% UK's GHG emissions	1990	2000	2005	2006	2007	2008	2009	2010
	14	17	16	16	15	16	16	18

Figure 20
Greenhouse gas emissions of U.K.'s service and consumer sector

Source: UNFCCC; BCG analysis

Figure 20 shows the trends in service and consumer emissions. Emissions in this sector have remained largely flat since 1990, whereas the total emissions in the U.K. have decreased by 23 percent in the same period. As a result, the sector's share of the U.K.'s emissions has increased from 14 percent in 1990 to 18 percent in 2010.

ICT-based goods and services in this sector are readily available in the U.K. High ICT penetration and end-user readiness has enabled piloting and testing of solutions such as smart water meters. Others, such as e-commerce, have been available for a while and are now on a path to robust growth.[69]

Digital and online technologies have already seen significant uptake in the U.K. A recent BCG study estimated that e-commerce contributed over GBP100 billion to the British economy in 2010 and is expected to grow.[70] Consumers increasingly shop online. According to data from the Office of National Statistics, 32 million people (66 percent of all adults in the U.K.) purchased goods or services over the Internet in 2011, up from 62 percent in 2010.

Smart devices, especially e-readers and tablets, have also been adopted quickly. In 2011, the penetration of tablets and e-readers was 5 percent and 9 percent, respectively. Their penetration is expected to grow rapidly and accelerate the move from physical media to online and digital media. This trend is borne out in the declining sales of physical CDs. Annual sales of CD albums fell by 13 percent to 86 million discs in 2011 while sales of digital albums rose 27 percent to 27 million.

Additional smart technologies are being adopted or tested in other facets of business and daily life. For instance, Thames Water is piloting a smart water meter in London. The pilot program is part of the company's goal of installing 85,000 meters in their area by 2015. The objective is to lower the water use for residential use and for yards, gardens, pools, and so forth, thus reducing emissions from water use. Further, smart inventory management tools are available in the market today. These tools help optimize the amount of inventory a retailer has to keep, thus lowering costs and emissions.

> The service and consumer sector's share of emissions has increased from 14 percent in 1990 to 18 percent in 2010

All of these solutions are being driven by the market today and further growth is expected to follow without government mandate or intervention. The government does, however, have an important role to play in providing

69. Other solutions such as field force automation, mobile working, home or flexible working and workstyle management solutions are also seeing fast adoption. These are covered in other sectors in this report.

70. "The Internet Economy in the G-20," BCG Perspectives.

information and raising awareness to enable consumers to make green choices. Further, the government can lead by example by adopting these green technologies in its own functioning.

Service and consumer abatement potential

ICT-enabled solutions for the service and consumer sector are widely used in the U.K. This is driven by an enthusiastic uptake by businesses and consumers alike. However, these solutions will truly have significant GHG abatement impact if they are scaled up further to cover a larger population of the country.

Figure 21 shows the total abatement potential of each of the SMARTer 2020 service and consumer sublevers. The total abatement potential by 2020 is 22 $MtCO_2e$. Solutions that help lower retailer footprint offer the highest potential. The combined abatement potential of minimization of packaging and inventory reduction amounts to 69 percent of the total abatement potential. Online and digital technologies—e-commerce, online media, e-paper—together provide 24 percent of the total abatement potential.

Figure 21
ICT-enabled GHG reduction potential in service and consumer sector

22 $MtCO_2e$ Breakdown of ICT-enabled GHG reduction potential	Sublevers	Drivers of sublevers
1%	Public safety	• Lower footprint from human activities e.g., security cameras replace need for constant patrolling • London amongst earliest adopters; similar solutions already exist in other cities, thus limiting total unrealized potential
17%	Online media and e-paper	• Elimination of emissions from production and distribution of physical media • Sales of physical media in U.K. among the highest in the world, e.g., fourth highest CD sales in U.K. in the world[1] • Applies to all people using physical media, e.g., CDs, DVDs, physical books
5%	Smart water	• Reduced production and distribution emissions due to lower end-use consumption of water • More applicable in the southeast, less so in the rain abundant northwest
7%	E-commerce	• Lower physical footprint of retail sector and reduced logistical/ transportation emissions • Consumers already used to e-commerce, so possible to scale up further
31%	Reduction in inventory	• Less storage space required • Lower logistical/ transportation emissions due to optimized levels of inventory
38%	Minimization of packaging	• Reduction in total materials required • Lower emissions from eco-friendly materials

1. IFPI annual report 2010
Source: BCG analysis

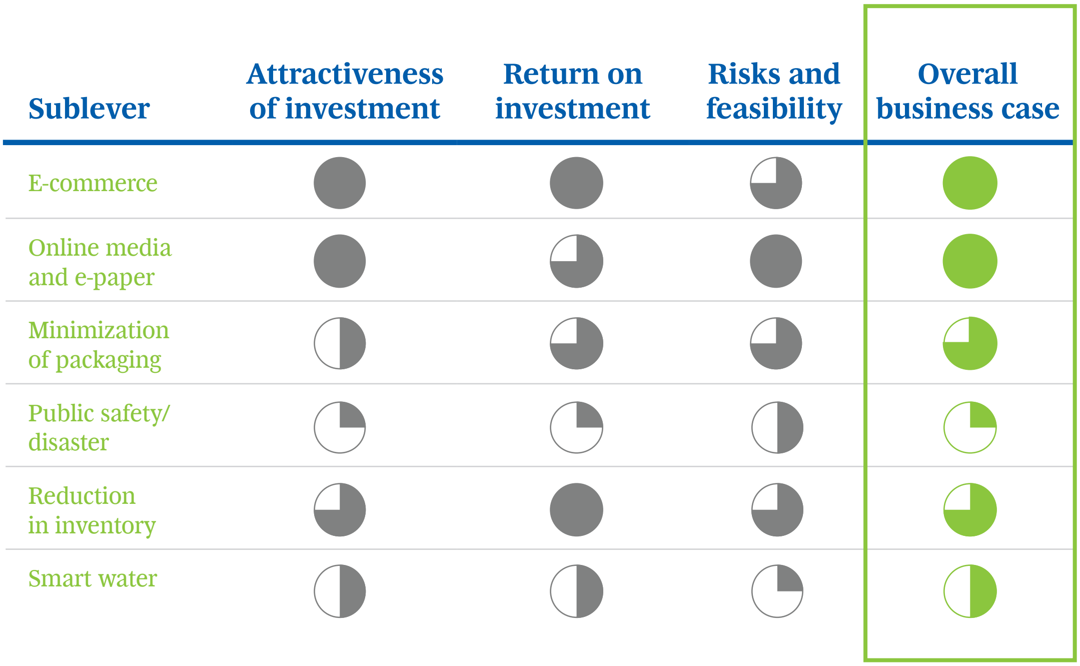


Figure 22
Business case assessment of service and consumer sector sublevers

Low attractiveness
High attractiveness

ICT-enabled solutions for retailers help reduce their GHG footprint. Better product design along with the use of eco-friendly materials and a reduction in total materials required offer significant potential for decreasing emissions in the retail sector. Further, other ICT-enabled solutions can help optimize the inventory requirements of retailers. Ability to keep lower inventory levels will reduce retailers' emissions associated with storage. Also, lower inventory levels can help reduce the logistical or transportation emissions. Given the large economic footprint of the service and consumer sector, a reduction in retailer emissions can make a significant contribution to GHG abatement in this sector.

A shift to online media reduces production and distribution emissions of physical media. Since the U.K. has high sales of physical media (for example, the fourth highest CD sales in the world), there is still scope to lower the associated emissions. Similarly, growth in e-paper can help reduce emissions from production and distribution of paper-based media. Approximately 5 percent of the world's printing paper was consumed in the U.K. in 2011. This makes the U.K. one of the biggest users of paper after the U.S., Japan, China, and Germany. Because of this large use of paper, scaling up e-paper could have a meaningful impact on GHG emissions.

E-commerce reduces GHG emissions associated with brick-and-mortar retail provided delivery of goods to customers is efficient. An estimated 20 percent of all private transportation is dedicated to shopping at physical stores.[71] E-commerce helps reduce emissions associated with this significant amount of traveling. Further, on the retailer side, e-commerce helps lower logistical emissions. Since a large number of consumers are already used to shopping online in the U.K., further scaling up will be feasible as behavioral barriers are largely coming down on their own.

71. SMART 2020

Barriers and policy

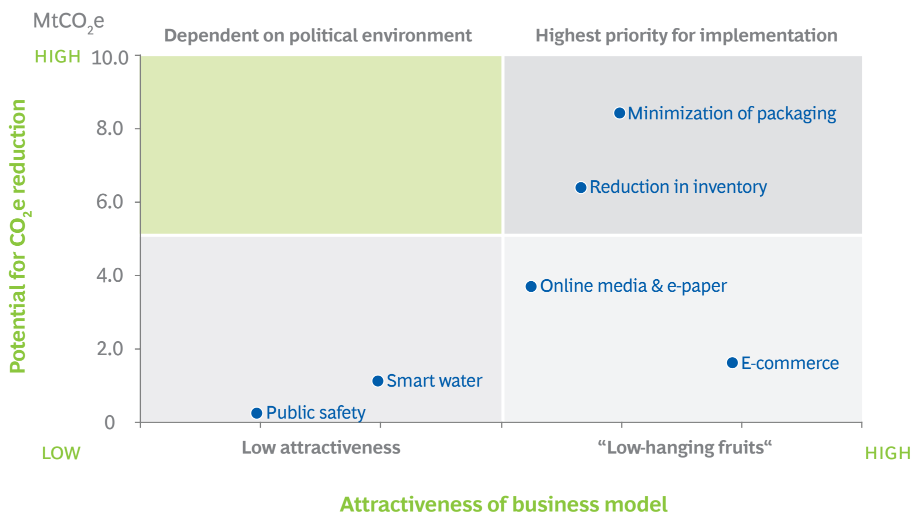
Adoption of most of the ICT-based solutions in this sector is currently being driven by the market, for example, e-commerce, online media, and so forth. Only behavioral barriers to higher adoption remain. For instance, many people, especially older generations, still prefer physical media. Also, "late adopters" of relatively new technologies such as tablets will take up these devices in time. Tablet and e-reader penetration is expected to increase rapidly as more competing products enter the market and the prices become lower. We see little role for policy to play in driving adoption of these technologies as the market is primarily expected to fulfill this role. The business case for most sublevers in the service and consumer sector is strong. E-commerce, online media, and e-paper offer the strongest business case. This is evident from the rapid penetration of these solutions in the U.K. today. Solutions targeted toward reducing retailers' footprint—that is, minimization of packaging and reduction in inventory—also offer a strong business case. As a result, the uptake of these is also expected to be market driven.

Figure 23 combines the business case analysis with the abatement potential analysis in the previous section. Combining the two, it becomes clear that the role of policy in driving the penetration of the sublevers in this sector is limited since the business case is very strong for most of the sublevers. For the others (public safety and smart water), since the abatement potential is relatively low, this is unlikely to be the focus of policy.

Figure 23

Service and consumer sector sublever prioritization by potential for CO_2e reduction and business potential

Source: BCG analysis



Case Study
Green Packaging at Tesco

Tesco is one of the largest retailers in the world. Given the large volume of products Tesco sells, the environmental impact of the packaging of its products is substantial. Tesco recognizes this and has made a commitment to using greener packaging options. The self-imposed target is to reduce all product packaging by a quarter on food and non-food goods, such as electrical items and housewares, and on branded products as well.

While it is important that packaging of all products is reduced and made more environmentally friendly, Tesco is currently focusing on key products in which they see the biggest impact. These include wines, sauces, preserves, and canned foods

Some early successes include the following:

- Tray-less bags are used for chickens, reducing packaging by 68 percent (equivalent to 540 fewer vehicles on the road).
- Tomato puree tubes no longer come in cartons, reducing packaging by 45 percent.
- Size of the caps on bottles of carbonated drinks have been reduced, saving 603 tons of plastic per year.
- Tesco's lightweight wine bottles are 30 percent lighter, which will reduce glass usage by 560 tons per year.

Overall Tesco has worked with more than 300 suppliers and is on track to save over 100,000 tons of packaging this year. As Tesco expands its efforts beyond the set of products currently in focus, the reduction in packaging and realization of the GHG abatement potential will increase.

Cost-effective choices to reduce GHG emissions could be encouraged if emissions pricing were underpinned with a globally replicable labeling system—offsetting price premiums with a revenue -neutral levy would act as an incentive for consumers to purchase cleaner energy. This would encourage competitors to enter the market and improve their service offering. Emissions intensity labeling of electricity would have the added benefit of increasing confidence in the transparency of emissions energy accounting. An "A-G scheme" could be considered (see Figure 24).

Further, the government should lead by example. For instance, the government could adopt a policy of "green procurement." This would lower the government's own emissions, as it is itself a large purchaser of goods and services. Additionally, it will set an example for businesses to emulate.

Figure 24
A A-G carbon intensity labeling scheme

	Electricity CO_2 label	CO2 /kWh	£/MWh
A	Renewable/zero carbon	0g	£4
B	Low carbon/CCS	<200g	£6
C	Gas CHP	<300g	£8
D	CCGT gas	<400g	£9
E	UK average/gas	<600g	£10
F	Good coal/oil	<800g	£12
G	Coal	<800g	£14
Average levy			£9

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Behavioral	• Sublevers impacted: E-commerce, online mediea, E-paper • Reluctance to adopt new technologies • Many people, especially older generations, prefer physical media	Little role for policy to play	• Market will drive furth uptake of these solutions
Financing	• Smart Water: high cost of smart water meters	Allocate government funding to drive adoption	• Provide subsidies to drive intial adoption; work with manufactureres to rduce cost • Try alternative pricing schemes for meters
Awareness & education	• Little incentive for retailers to lower carbon footprint • Insufficient availability of information to make “green” choices • Public opposition to ICT-based safety technology due to, e.g. privacy concerns	Lead by example Mandate provision of energy intensity information	• Make “green” a criteria in government procurement • Energy intensity labeling of appliances to help change consumers’ habits and attitudes towards energy use

Table 13
Barriers to adoption of ICT-enabled carbon abatement solutions and policy steps to overcome these barriers

Source: BCG analysis


Brazil

8 Brazil

8.1 Context

Despite its relatively modest income levels, Brazil is one of the world's largest emitters of greenhouse gases. Any serious attempt at addressing climate change will require Brazil's engagement given its large contribution to the world's emissions totals. Moreover, deciding what techniques to use when moderating Brazilian emissions requires an understanding of its unique emissions profile.

Considering only CO_2 emissions, Brazil is the world's fourteenth largest source. In 2008, Brazil emitted 450 Mt CO_2, representing a 1.4 percent contribution to worldwide emissions in that year.[72] Considering only CO_2, however, understates Brazil's contribution to climate change. In other countries, roughly 77 percent of total emissions result from CO_2, but in Brazil that figure is only 34 percent.[73] Sixty-six percent of Brazil's contribution to climate change results from deforestation, other land use changes, and methane from livestock. When non-CO_2 sources are incorporated into the total, Brazil emitted 1,288 tons of CO_2e in 2008, placing it as the world's sixth-largest GHG emitter.[74]

Though CO_2 and other GHGs come from different sources, both have been growing roughly at the same rate since 1990 as the economy has expanded rapidly. As is the case in the majority of developing nations, emissions growth is correlated with GDP growth, more so in countries where manufacturing is a big component of the economy. CO_2 emissions have been growing at a rate of 3.6 percent CAGR since 1990, resulting in CO_2 emissions 88 percent higher in 2008 than in 1990.[75] Similarly, CO_2e emissions have been growing at 3.1 percent CAGR since 1990, exceeding the global growth rate of 2.0 percent over the same period.[76]

72. EIA
73. "Brazil Low Carbon Case Study", World Bank
74. EDGAR Joint Research Centre
75. World Bank
76. Ibid

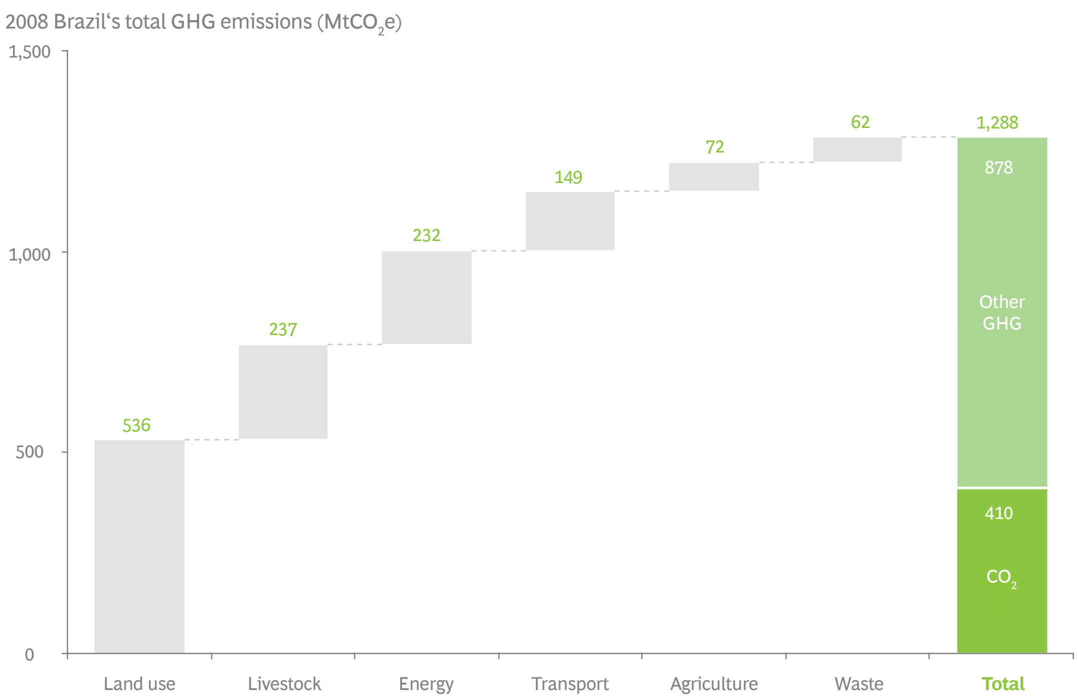
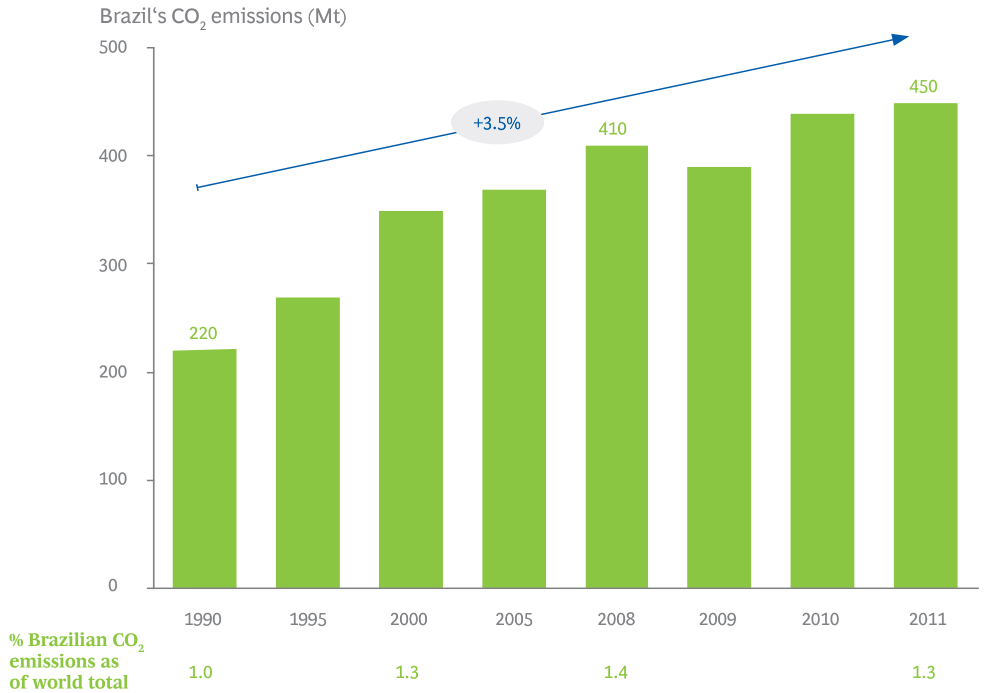


Figure 25
Brazil's 2008 total GHG emissions breakdown

Source: Brazil Low Carbon Case Study, Energy Sector Management Assistance Program

Figure 26
Brazil's CO_2 emissions 1990-2010

Source: EDGAR



Land use changes, agriculture, and livestock emissions, all intimately connected, play a particularly important role in understanding Brazil's climate change contribution. Deforestation, particularly in the state of Amazonas, contributes to 42 percent of Brazil's emissions and is driven by demand for Brazilian agricultural products. Livestock, which contributes 18 percent to the total, consumes 70 percent of the land that is deforested and is a particularly GHG-intensive industry.[77] Agriculture contributes an additional 6 percent to total emissions and consumes the remaining 20 percent of deforested land.[78] The remaining 34 percent of Brazil's emissions come from energy (18 percent), transport (12 percent), and waste (5 percent).[79]

> Land use changes comprise a significant amount of all GHG emissions

Land requirements for livestock and agriculture are the principal drivers of deforestation. As demand for Brazilian agricultural products, and livestock in particular, has grown, ranchers and farmers have increased their operations and have consumed a large area of what was formerly rainforest. While the agricultural and livestock sector itself is a large contributor to climate change, the destruction of forests is an even more egregious concern, contributing almost twice as much to Brazil's total emissions.

Transportation, which constitutes 12 percent of Brazil's total emissions, is particularly inefficient and is projected to contribute 17 percent to Brazil's total emissions by 2030.[80] While over half of Brazil's fuel used in transit is eco-friendly biodiesel derived from sugar cane, Brazil is highly reliant upon private

77. "Livestock Report", Carbon War Room
78. Brazil Low Carbon Case Study
79. Ibid
80. Brazil Low Carbon Case Study 21

transit to move both passengers and cargo. In urban areas, public transit is so inefficient that its share of total rides is declining. Brazilians have been turning to cars despite increased congestion and transit times, particularly in urban areas. With cargo shipping, there is little rail and water infrastructure for cargo transport, so heavy trucking is essential to the transit system. Increasing reliance on these modes of transportation is projected to raise the transportation sector's share of total emissions.

Brazil has attempted to address climate change concerns, but the policies put in place have been ineffective because of difficulties with implementation. Brazil's National Policy on Climate Change, signed into law by then-President Luiz Inácio Lula da Silva in 2010, seeks to reduce Brazil's GHG emissions between 36.1 to 38.9 percent by 2020 from 1990 levels. To reach this goal, the government's aims include reducing deforestation in the Amazon by 80 percent, recovering 15 million hectares of land that has been degraded by cattle grazing, and creating 4 million hectares of integrated farming and livestock land.[81] However, these efforts have so far been hampered by the inability to detect and punish illegal actions that cause deforestation. The use of satellite imagery to detect deforestation and punish violators in some states is a promising development that has helped the country work toward meeting its deforestation reduction targets.

Particularly pressing is the need of economic incentives for GHG abatement. As Brazil is abundant in land and renewable energy sources, energy and land costs are low. As a result of low prices, it is challenging to incentivize the conservation of energy and protection of the rainforests. Rather than use more concentrated farming techniques, it is currently more economical for farmers to use more land when existing land becomes exhausted. Because of pervasive apathy and lack of understanding of the effects of climate change, the economics behind many of the sublevers need to become more attractive to drive widespread uptake.

8.2 Impact of ICT on GHG emissions

The ICT market has grown rapidly since the opening of the Brazilian economy in 1990. Between 2000 and 2007, the value of the Brazilian ICT market grew 108 percent, with most of the growth being driven by the communications and IT hardware segments.[82] High growth levels are projected to be sustained through 2020.[83]

Despite high levels of ICT growth, private ICT R&D expenditures are perceived to be lagging.[84] Though the sector is more innovative than the average industrial sector, it is inherently dependent on large multinational firms: 70 percent of Brazilian ICT revenues come from 16 percent of ICT firms, all of which are large multinational corporations. [85] These companies import the majority of the components they use and set the electronics standards that dominate the industry, erecting barriers for homegrown innovation. Combined with a lack of interest from multinational corporations in investing in R&D in Brazil, there are relatively few high value-added opportunities within the Brazilian ICT sector.

Furthermore, the level of advanced ICT penetration is relatively low. Only 45.0 percent of Brazilians regularly use the Internet (in Hungary, where per capita income levels are similar, that figure is 59.0 percent). [86] Lack of universal access depresses this figure, as the infrastructure is not in place to accommodate all those who desire Internet access. Consider the number of broadband terminals in Brazil: currently, there are only 60 million high-speed data terminals for a population of 196 million. This is largely due to the concentration of infrastructure in urban areas while large

81. "New Decree Details: National Policy on Climate Change", www.brasil.gov.br
82. The ICT Landscape in BRICS Countries: Brazil, India, China, 20
83. Ibid
84. The ICT Landscape in BRICS Countries: Brazil, India, China, 23
85. The ICT Landscape in BRICS Countries: Brazil, India, China, 21
86. World Bank

geographic regions are neglected. The lack of universality of high-speed Internet access may hinder ICT's ability to offer GHG abatement solutions in Brazil. Most of the levers identified to reduce emissions depend largely on high speed mobile Internet access.

Nevertheless, Brazil's high speed networks are in the midst of expansion. The number of high speed Internet terminals is slated to rise to 160 million by 2017, an increase of 167 percent over five years.[87] This expansion of the high speed data network is occurring at a rapid rate, but remains lower than many countries at a comparable stage of development.

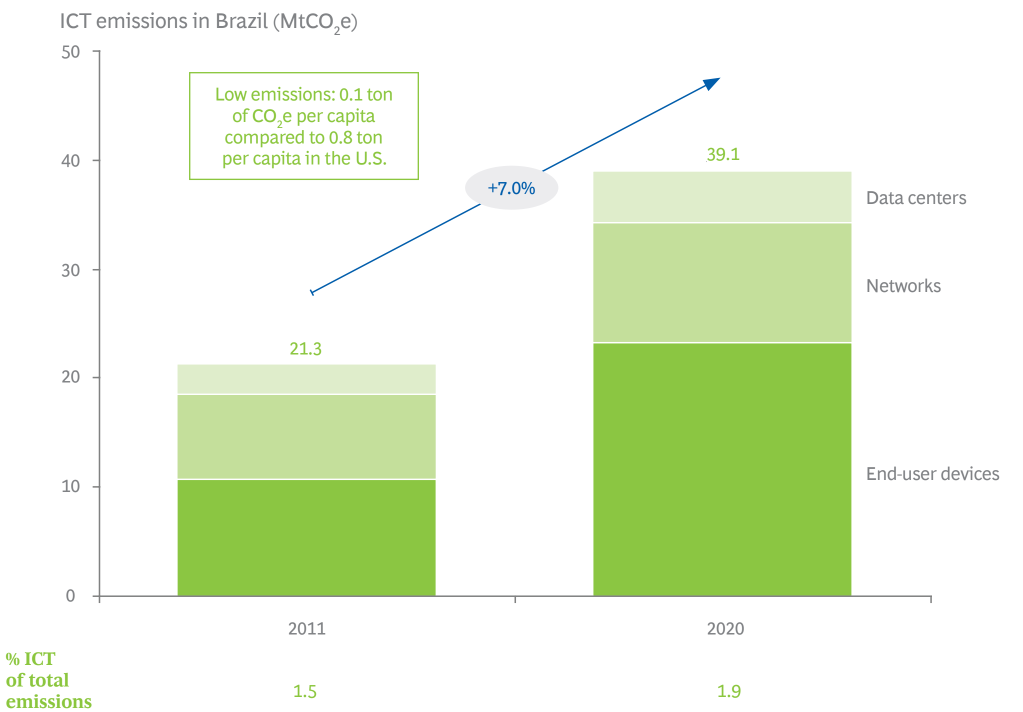
As a result of the ICT industry's rapid growth, direct emissions are slated to rise from 21.3 $MtCO_2e$ in 2011 to 39.1 $MtCO_2e$ by 2020, a 7.0 percent CAGR over that period. While growth in emissions is attributable to growth from all three segments (data centers, networks, and end-user devices), 70.0 percent of the growth in emissions results from a higher number of and more energy intensive end-user devices. These emissions, though growing, are still low by developed economy standards. In Brazil, the per capita ICT emissions are 0.1t while in the U.S. the emissions are 0.8t per capita. The lower emissions in Brazil are attributable to both lower penetration of ICT devices and the fact that a high percentage (82 percent) of Brazil's power comes from renewable sources, primarily as hydroelectric generation.[88]

87. The ICT Landscape in BRICS Countries: Brazil, India, China, 27

88. Brazilian Ministry of Energy and Mines, 2007

Figure 27
ICT sector's direct emissions in Brazil

Source: Gartner, BCG analysis



8.3 Abatement potential in agriculture and land use and transportation end-use sectors

Sector prioritization

When considering which end-use sectors to address using ICT, two sectors stand out as particularly important: agriculture and land use and transportation.

The agriculture and land use sector is particularly important in Brazil because it comprises 66 percent of Brazil's overall emissions. High demand for Brazilian agricultural products, livestock, and cattle causes deforestation. To prevent further loss of forest cover, the economic factors driving agriculture must be addressed. ICT can be leveraged to make agriculture and livestock more efficient so as to require less land and to slow deforestation.

Transportation is another excellent opportunity for ICT-enabled GHG reductions. Brazil is highly reliant upon private transportation within urban areas and on heavy trucking to move cargo, and this dependency is projected to grow. As there is currently a lack of rail and water infrastructure to move both passengers and cargo in a more energy efficient manner, improving the efficiency of trucking and public transportation through ICT has the potential to yield large GHG reductions.

Agriculture and land use

Overview

Deforestation is the single largest component of Brazilian GHG emissions, comprising 42 percent of Brazil's emissions total. In 2008, 536 Mt CO_2e was released primarily as a result of clearing land that was formerly occupied by rainforests. Many farmers and livestock herders are engaged in what is known as slash and burn farming, in which they cut down the foliage and burn the remaining waste to clear the land. Not only does this destroy carbon sinks in the form of trees, but it also releases the carbon that was held in the foliage.

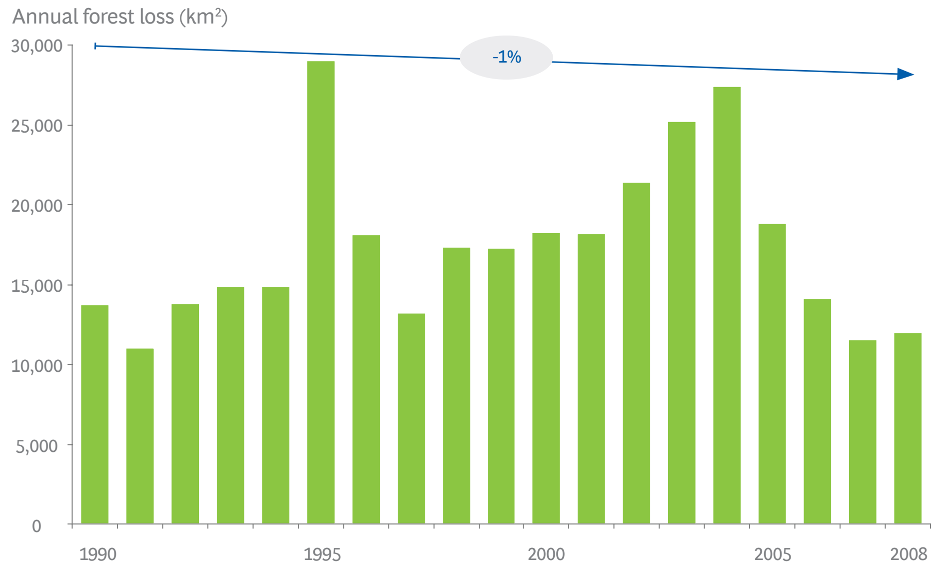
In the Amazonas region, the destruction has been particularly devastating. Since 1970, 745,289 km_2 of rainforest coverage in the Amazons has been lost; this loss is equivalent to twice the size of Germany.[89] Though deforestation policies are in place, the Brazilian government has struggled to slow deforestation. Annual forest loss has a high degree of variance, but since 1990 the deforestation rate has declined by only 1 percent CAGR.[90] Nevertheless, satellite surveillance used in conjunction with ICT has provided Brazilian state governments with a powerful tool to catch and punish actors that cause deforestation. The use of PRODES and DETER detection software, for instance, has helped push deforestation rates from 27,000 km_2 to less than 6,500 km_2 from 2004 to 2010 in the Amazonas region.[91] It remains to be seen, however, if satellite-based deforestation prevention techniques alone are powerful enough tools to keep deforestation rates low.

A large majority of the deforested land is used for livestock, more specifically cattle ranching. Because tropical soil tends to be resource poor, agricultural workers realized that raising livestock was a more productive use of the land than attempting to cultivate crops. Additionally, strong international demand for Brazilian beef drove exports higher. Between 2000 and 2007, beef exports grew 397 percent as Brazil became the world's largest exporter of beef.[92] Seventy percent of all deforested land and 91 percent of deforested land since 1970 is used for livestock.[93] Using deforested land only exacerbates the emissions total because of the high emissions intensity of livestock production. Through digestive emissions, an individual cow can annually produce between 80 and 110 kilograms of methane, which is 21 times more potent per molecule than CO_2.[94] As a result, Brazilian livestock collectively released 237 MtCO_2e in 2008, which was equivalent to 18 percent of Brazil's total emissions.

89. Projeto PRODES: Monitoramento da Floresta Amazonica Brasileira por Satelite", Brazilian Ministry of Science and Technology
90. National Institute for Space Research
91. ICT-Based Monitoring of Climate Change Related Deforestation: The Case of INPE in the Brazilian Amazon
92. USDA-FAS attaché report
93. "Causes of Deforestation of the Brazilian Amazon." World Bank Working Paper No. 22
94. "Ruminant Livestock", U.S. EPA

Figure 28
Brazilian deforestation rate 1990-2008

Source: National Institute of Space Research



Constituting 6 percent of total emissions, Brazil's agricultural production is largely defined by a farmer's geography. The southern half of the country is characterized by better growing conditions, sufficient infrastructure, and more advanced technology. The northern half is populated largely by subsistence farmers and has poorer growing conditions and inadequate infrastructure. Aside from the risk of deforestation, the emissions intensity from sustenance farming is relatively low. Wealthier farmers in the southern regions of Brazil tend to utilize more fossil fuel-intensive equipment, engage in higher levels of tillage, and use more fertilizer, and have higher emissions as a result. Therefore, the use of ICT technology to reduce agricultural emissions will be most effective in the wealthier, more technologically advanced southern region.

Land use and agricultural abatement potential

ICT offers tremendous opportunities for GHG abatement within the agricultural and livestock sector. The ICT-enabled abatement potential across the end-use sector is 90 $MtCO_2e$, which is 7.1 percent of Brazil's total emissions, representing huge abatement potential. The largest opportunities for abatement potential come from deforestation prevention (52 percent), livestock management (20 percent), and soil monitoring and weather forecasting (19 percent).

Deforestation prevention is such a significant abatement opportunity because of the frequency with which it occurs and its importance as a carbon sink. The use of satellite detection systems to determine where deforestation is occurring and then providing that information to law enforcement officials so they can punish individuals acting illegally will serve as a major deterrent against deforestation. GPS systems and GIS mapping can also be used to more accurately determine how much land was cleared by a particular individual. This system is currently being utilized to a degree, but could prevent even more deforestation if penetration were higher and if more Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) environmental protection agents were hired to protect forests.

90 $MtCO_2e$
Breakdown of ICT-enabled GHG reduction potential

	Sublevers	Drivers of sublevers
20%	Livestock management	• Changing cattle diet and monitoring methane will dramatically reduce methane emissions • Using GPS collars will allow for integration of livestock pasture and cropland • Former pasture land can be reforested
8%	Smart farming	• Apps inform farmers as to appropriate crop rotation to reduce the amount of fertilizer required for crop cultivation • Crucial for Brazil because land is so resource depleted
1%	Smart water	• Sensors measuring moisture in the soil can prevent unnecessary irrigation and soil erosion
19%	Soil monitoring/ Weather forecasting	• Reduces the amount of fertilizer required for crop cultivation • Monitors the weather conditions immediately around the plants and data can be collected remotely or on site
52%	Deforestation prevention	• The use of satellite-based detection systems will allow for IBAMA agents to prosecute deforestation policy violations, serving as a deterrent to destroying forest coverage • Sublever specific to Brazil

Figure 29
ICT-enabled greenhouse gas reduction potential in agriculture and land use sector

Source: BCG analysis

Livestock management is a profound opportunity for abatement because Brazilian livestock production is inefficient by developed country standards and consumes a growing portion of formerly forested land. While most cattle are held in concentrated animal feeding operations in developed nations, in Brazil, the majority of cattle graze freely outside in inefficient feeding patterns that lead to over-grazing and under-grazing. The concern with over-grazing is that it keeps the grass too short and prevents it from sinking its roots into the soil, eventually leading to desertification and soil erosion. [95] Under-grazing can also be detrimental, as it allows for healthy grass to become overgrown by other plant species. Both require that new land with fresh grass be made available, often leading to more deforestation. ICT can be utilized to reduce the amount of land required to raise cattle by using smart fences and GPS tracking of livestock. Smart fences keep animals in a specific area by producing a slight electric shock to warn the animal that it is crossing the boundary, keeping it in the appropriate pasture.[96] Given that 70 percent of all deforested land is used to raise cattle, reducing the amount of land required per animal is an essential component of combating deforestation.

Two other applications of ICT in livestock management include radio frequency identification (RFID) health monitoring and methane emissions monitoring.[96] RFID animal health monitors can alert ranchers as to when their animals are becoming sick, helping prevent the death of an animal. The premature death of an animal that cannot be used as meat means that emissions created in its lifetime were to no end. Methane emissions can be

95. “Wireless and the Environment”, BSR, 40
96. “Wireless and the Environment”, BSR, 48

reduced through the deployment of monitors. Researchers have discovered that cattle produce different levels of emissions at different periods of the day, depending on feeding schedules. Wireless monitors placed in the rumen (the second stomach of the cow) can reduce methane emissions through better control of cattle's feeding schedule.

Soil monitoring and weather forecasting have the potential to abate 18.5 $MtCO_2e$, largely because of how difficult it is for farmers to determine exactly how much to water crops. Farmers currently base their watering schedule on intuition, attempting to take into account factors as diverse as soil characteristics, the type of crop, and weather projections, yielding an educated guess as to how much water their crops require. Because it is difficult to coherently analyze such disparate variables, there is much excessive and wasteful irrigation.

ICT-enabled monitors in the soil can provide information as to exactly how moist the soil is and, combined with accurate weather forecasting information and knowledge of the crop, a crop insight website can inform the farmer exactly how much irrigation is required.[97] This prevents crop loss due to overwatering and water waste, both of which lead to higher CO_2 emissions. This sublever is of particular importance in Brazil because rainfall can be challenging to predict.

Smart farming also yields significant abatement potential at 7.6 $MtCO_2e$. Because of the resource depletion and inconsistencies of Brazilian soil, it is challenging for many farmers to determine how much fertilizer to use on their crops and how frequently to till the soil. Satellites can monitor the health and temperature of individual fields and transmit this information to a farmer's computer or smartphone. This information can then be utilized to adjust tilling schedules and fertilizer application. Ensuring that tilling does not occur too frequently prevents unnecessary CO_2 release, and moderating fertilizer usage prevents its waste.

Business case

The business case for each of the sublevers varies quite widely. Soil monitoring and weather forecasting is the most attractive business opportunity because of the moderate upfront costs, low risks and high rate of return. Soil monitoring systems will almost always yield a positive return because, as described earlier, determining the correct soil inputs is highly dependent on guesswork. Ensuring the correct ratio of water and fertilizer has the potential to increase yield substantially. Smart farming, though attractive, is not quite as attractive as soil monitoring and weather forecasting; smart farming returns information similar to that of soil monitoring and weather forecasting systems but has a higher upfront cost. Deforestation prevention, though easy to implement on a small scale, would require large increases in the number of environmental protection officers to be fully effective. Though satellite-based deforestation monitoring provides the information law enforcement needs, the law cannot be enforced if there are too few officials; lack of funding for large personnel increases makes full implementation of ICT-based deforestation prevention less likely. Smart water is not particularly attractive because of the low return on investment in both absolute and percentage terms. Livestock management is the least attractive from a business perspective.

Livestock management, despite its high abatement potential, is particularly unattractive because CO_2e externalities are not incorporated into the price of a good and land in Brazil is inexpensive. Because farmers do not pay for the methane their cows emit, there is no monetary incentive for farmers to invest in methane monitoring equipment as it will not improve the productivity of their cattle. In the absence of a penalty for emitting GHG emissions, the business case behind methane monitoring will not be persuasive. The business case for virtual fences to prevent overgrazing of land is also poor; if cattle ruin pasture it is

97. "Wireless and the Environment", BSR, 42

inexpensive and easy for ranchers to deforest more land to use for grazing. The case for health monitoring of cattle is slightly stronger, in that ensuring that cattle do not fall to illness prematurely has the potential to yield a positive return. For RFID health monitoring to be effective, however, it requires outfitting each animal with a health sensor and purchasing equipment to check each animal; as a result, the breakeven point may take a long time to reach, if it indeed ever comes.

Barriers and policy recommendations to overcome them

ICT-enabled sublevers have the potential to reduce GHG emissions in Brazil's agriculture and land use sector, but several barriers exist that prevent their widespread adoption. Prudent policymaking and, most importantly, effective implementation can ensure that these solutions are adopted.

The current economics of GHG abatement in Brazil is particularly challenging for ICT-enabled abatement adoption. As is the case in many countries, there has been virtually no attempt to incorporate the externalities associated with GHG emissions into the prices of goods. For instance, there is no economic penalty for producing large amounts of methane from cattle and accordingly ranchers have little incentive to use methane emissions monitoring technology. Ideally, a CO_2e permit market or a CO_2e tax would be instituted to ensure that all economic sectors have an interest in abatement, but such a system would be very unpopular politically and, because of high levels of corruption, difficult to implement. Though such a system could theoretically be set up through an international agreement, it is highly unlikely that Brazil will unilaterally take action to institute a CO_2e trading regime.

Therefore, policy-makers should consider other alternatives. The most significant lever the government could use is its ability to more fairly price land. Particularly with regards to deforestation and livestock, many ranchers choose to clear land to raise more cattle because it is cheaper than using the land they currently own more efficiently. Raising the price of land would make some livestock management systems more competitive economically. To price land more fairly, the government could pursue a number of alternatives, including increasing the percentage of private land that must be left forested, buying land for conservation purposes, and

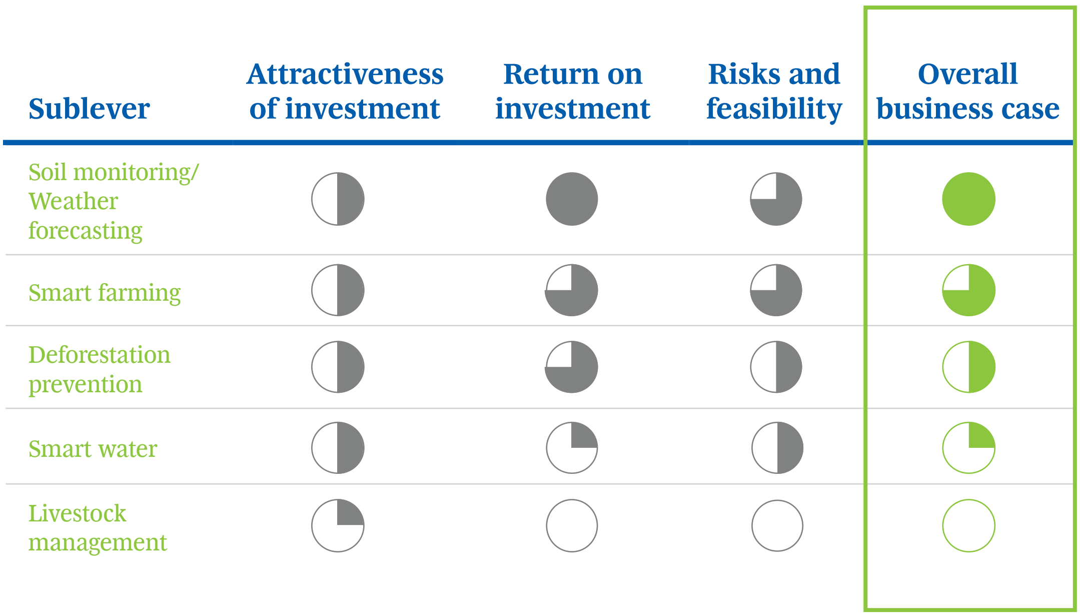


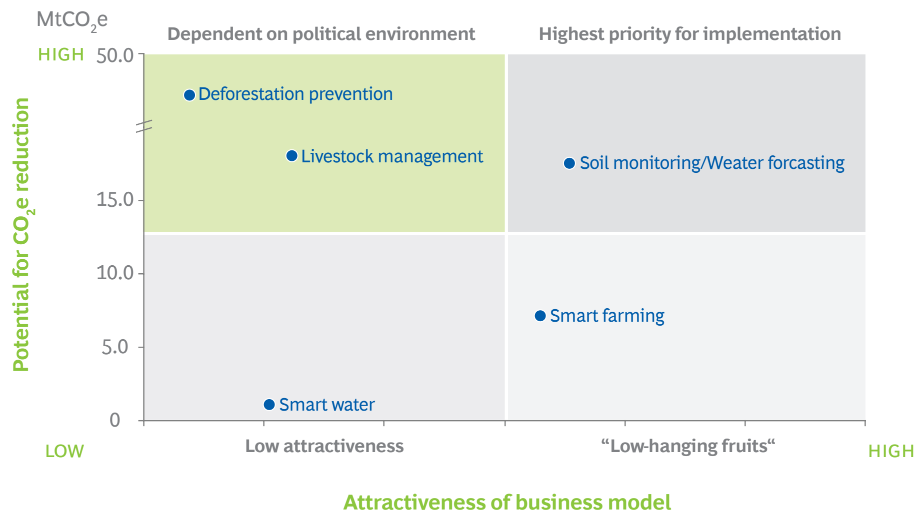
Figure 30
Business case assessment of agriculture and land use sector sublevers

Source: BCG analysis

Low attractiveness
High attractiveness

Figure 31
Prioritization of policy by potential for CO_2e reduction and business potential

Source: World Bank, BCG analysis



using ICT to ensure that encroachment onto protected lands by ranchers does not occur. These policies surrounding increasing land prices are relatively inexpensive to implement and would yield large amounts of abatement. As a result, they should be a priority for Brazilian policy makers, but care should be taken that small farmers are not penalized unfairly because of these policies.

A second challenge from an economics standpoint is that other technologies yield a higher IRR than ICT-enabled technologies. For instance, the adoption of genetically modified corn seeds in Brazil could yield up to $3.59 for each dollar invested, higher than the IRR for soil monitoring and weather forecasting.[98] These other solutions, however, do not directly address climate change concerns. Because the government has a vested interest in meeting its emissions targets, it should lower the price of ICT-enabled solutions by subsidizing agricultural systems that also reduce GHG emissions. Lowering the price to the point where ICT-enabled solutions are competitive economically with other agricultural investments will induce farmers to more readily adopt ICT.

Financing presents another barrier to adoption. Though many larger ranchers and farming operations may have the capital on hand to purchase profitable net present value ICT technology outright, many smaller-scale farmers and individual ranchers are not in the same financial position. Furthermore, even if farmers are able to buy the technology without financing, many may choose not to because of the high upfront cost and long payback periods.

The Brazilian government has already set up a fund through the Ministry of Agriculture, Livestock and Food Supply called the Low Carbon Agriculture Program, which is a good start toward helping farmers adopt NPV positive emissions reduction technology. The program provides USD3.150 billion for green technology adoption with a maximum borrowing limit of USD1 million, interest rates of 5.5 percent per year, and a payback period of five to 15 years.[99] Given the size of the Brazilian agricultural sector, however, this program is too small and many farmers may not be aware of the program. The government should increase funding for the program and should mandate that information about the program be included with purchases that farmers make regularly, such as seeds or fertilizer, to increase awareness. ICT-enabled mobile banking can allow for better connectivity between lenders and borrowers.

98. "Transgenics Seed Produces Healthy ROI For Brazil's Farmers", Seed Today Journal
99. "Livestock and Food Supply", Brazilian Ministry of Agriculture

Table 14
Barriers to adoption of ICT-enabled GHG abatement solutions in Brazilian agriculture and policy recommendations

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Economics	• GHGs are externalities for farmers • Maintaining land quality more costly than using new land • Efficient techniques not necessarily NPV+ • Other investments yield higher IRR	Price farm land fairly Develop carbon markets to yield higher IRR for GHG saving investments	• Encroachment onto public lands must be prosecuted • Government could buy land to reduce overall supply available for farming
Financing	• Farmers cannot afford to purchase the equipment outright • Difficult to enforce loan contracts due to high mobility	Government support of agricultural ICT purchases	• Ready provision of low interest loans • Mobile banking can be used to connect borrowers and lenders
Education	• Farmers do not understand the benefits of smart farming techniques	ICT educational initiative	• Distribute educational materials • Dispatch representatives from ICT providers to explain equipment
Infrastructure	• Data networks do not exist in remote farming areas	Promote construction of high-speed data networks in remote areas	• Loosen regulations pertaining to data network provision • Sale of radio spectrum portion at low price • Required personnel and materials may not be available domestically

Lack of information surrounding both ICT and climate change seriously hamper ICT uptake. Even in developed nations in which information regarding NPV-positive ICT is readily available, uptake is low. In the U.S., for instance, only 8 percent of farmers utilize soil monitoring and weather forecasting technology; the rate is even lower in Brazil.[100] The Brazilian Ministry of Agriculture should include information regarding NPV-positive applications of ICT in agriculture with information on the Low Carbon Agriculture Program to clearly explain how emissions-reducing technology can help them become more profitable.

Finally, there is a significant lack of communications infrastructure in many parts of Brazil. Particularly in rural areas of the Amazon where deforestation is the most serious, it would be nearly impossible for ranchers and farmers to utilize the ICT discussed; even if they possessed the hardware they would not be able to connect to the networks that make such devices work. As a result, the federal and state governments must ensure that high-speed data and mobile networks continue to develop. Government can foster this growth by lowering tariffs on ICT hardware from abroad, removing red tape that hinders data network construction, and selling portions of the radio spectrum at low

100. “Wireless and the Environment”, BSR, 40

prices to make private development more attractive. These steps are easy to implement and could actually generate revenue through spectrum auctions and cut costs by eliminating unnecessary bureaucracy. Increasing the attractiveness of communications infrastructure development should be a priority for policy makers because of its ease of implementation.

Transportation

In 2008, the Brazilian transport sector emitted 149 $MtCO_2e$, which was equivalent to 12 percent of total emissions in that year. Brazil is highly reliant upon road transportation to move both cargo and passengers; over 90 percent of transportation emissions came from road transportation, with the remaining portion coming from rail, water, and air transport. Fifty-six percent of the road transportation emissions resulted from private transportation in urban areas, with the remaining 44 percent coming from private transit in rural areas and trucking.

Emissions from transportation have been growing at a moderate rate since 1995. In 1995, emissions from transit were 103 $MtCO_2e$ and had reached 149 $MtCO_2e$ by 2008, a CAGR of 3 percent. The percentage of emissions from transportation as a percentage of the total was 12.7 percent in 1995 and 11.6 percent in 2008, a small relative decline. Despite the observed decline, emissions are expected to climb to 245 $MtCO_2e$, which would comprise 17 percent of total emissions, assuming that business proceeds as usual.

Emissions growth in recent years has been driven by increased reliance on private transit and trucking. In urban centers, commuters are pushed to use cars because of inefficient and unreliable mass transit systems. Only São Paulo is considered to have an adequate metro system; all other Brazilian cities rely heavily on buses for public transit.[101] Inherently slower than metro systems, Brazil's bus system is further beleaguered by poor management. Over 5,000 localities and organizations oversee Brazilian mass transit systems, making coordination among different agencies difficult.[102] The inability to coordinate leads to slow resource mobilization and high levels of unpredictability. Slow and unpredictable service, combined with fares rising faster than inflation, has led to plunging public transit usage. The share of rides that were taken using public transportation has declined from 75 percent to 50 percent in 2010.[103] The share of

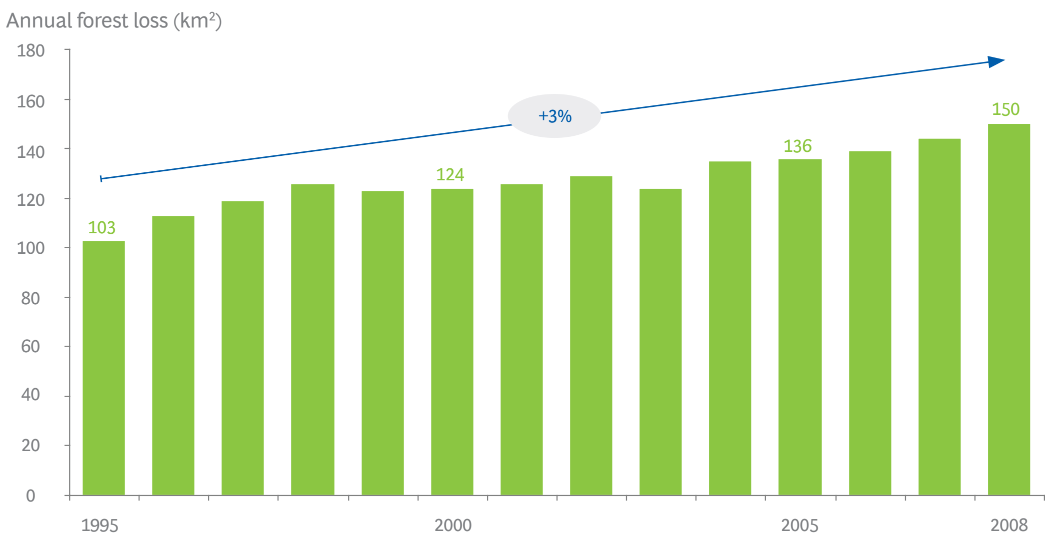
101. "Making up for lost time: Public transit in Brazil's metropolitan areas", Economist Intelligence Unit

102. Brazil Low Carbon Case Study

103. "Making up for lost time: Public transit in Brazil's metropolitan areas", Economist Intelligence Unit

Figure 32
CO_2 emissions from Brazilian transportation sector, 1995-2008

Source: World Bank



DRAFT

Case study
Deforestation and PRODES and DETER satellite imaging software

Enforcing anti-deforestation policies has long been a challenge for the Brazilian government. Despite its zero deforestation policy, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) has had trouble pinpointing exactly where deforestation is occurring and determining its extent. Beginning in the 1990s, however, IBAMA began to use satellite imagery produced by the United States' Landsat service in conjunction with deforestation detection software called PRODES to determine where the most egregious instances of deforestation were occurring. Using the information from PRODES, policy makers realized the troubling extent of deforestation in Brazil and subsequently enacted tougher legislation to prevent the rainforest's destruction. In 2004, the law enforcement tool DETER was developed to help IBAMA agents track deforestation and fine people who were cutting down forests.

Though it is difficult to quantify exactly how much PRODES and DETER have contributed to slowing deforestation, they are likely to have had a major impact in the slowing of deforestation rates since 2006. Since 2006, deforestation has declined from 27,000 km2 to 6,500 km2, yielding tremendous CO_2e savings over that period. Though penetration of the technology is likely to be high because of the relatively low cost, for this sublever to be effectively utilized the government must add more IBAMA officers to pursue violations. Currently there are only 580 officers for the entire Amazonas region, which is an equivalent to one officer per 800,000 hectares, double the size of Rhode Island. For PRODES and DETER to be used more effectively, there must be more agents to pursue the illegal deforestation the software discovers. Nonetheless, these tools represent an enormous opportunity to help Brazil reach its zero deforestation target if IBAMA is given appropriate resources for the program.

rides on public transit is projected to plunge further by 2025. A mere 19 to 38 percent of rides will be taken via public transit if trends hold.

Because Brazilians are reluctant to rely on public transit, they have come to embrace the car and motorcycle. Between 2000 and 2010, the number of car registrations grew 120 percent as the population grew 11 percent. This increasing reliance on cars is occurring despite more congestion in population centers. The average speed on São Paulo's arterial roads during evening rush hour declined from 40 km/h in 2003 to 26 km/h in 2010.

Brazil's cargo transit system is similarly dependent on road transportation. Because of a lack of other modes of transport, namely rail and water, Brazil is highly dependent on trucking via the national highway system to move cargo. Sixty percent of Brazilian cargo is moved using heavy trucking because of a lack of economically viable rail and water alternatives. [104] The rail network is nowhere near the density or quality of American or European networks and is concentrated in the economically powerful southern regions. A lack of standardization across states also plagues interregional rail. Port fees in Brazil are higher than in places like Hamburg and Singapore and many lack sufficient connections to highways and rail lines. Moreover, inefficient intermodal transfers raise the cost of transferring loads from trucking to alternative forms of transportation.

Despite heavy reliance on trucking, logistics systems penetration is low. Logistics costs are twice as high as the OECD average, which threatens the competitiveness of Brazilian exports. The transportation sector has become dramatically more consolidated in the wake of Brazil's economic opening in 1990, but many of the larger consolidated firms have delayed logistics systems implementation. Low logistics systems penetration means that ICT can be leveraged to make trucking much more efficient and reduce GHG emissions.

High levels of use of eco-friendly biofuels derived from sugar cane is a bright spot for the Brazilian transportation sector. Though the initial Brazilian biofuel legislation dates back to the 1970s and stems from concerns surrounding Brazilian energy independence, sugar cane biofuel has helped reduce the emissions intensity of the Brazilian transportation sector. Unlike corn-based ethanol, which has dubious environmental benefits, sugar-cane-based ethanol reduces GHG emissions by 61 percent over combusting gasoline. All Brazilian fuel used in cars is a blend that contains a minimum of 20 percent ethanol, and flex-fuel vehicles have become incredibly popular. By 2009, 92.3 percent of new cars and trucks sold in Brazil could run off either a gasoline-ethanol blend or pure ethanol, and by March 2012 there were over 15 million flex-fuel vehicles on Brazilian roads. Since February 2008, well over half the fuel consumed in the Brazilian gasoline-powered fleet has been sugar cane ethanol.

Transportation abatement potential

Because of the numerous inefficiencies in the Brazilian transportation sector, ICT-enabled GHG reductions solutions are poised to make a significant impact in reducing Brazilian emissions. The abatement potential for the identified ICT solutions in transportation is 43 $MtCO_2e$, a mere 5 $MtCO_2e$ lower than the abatement potential for agriculture and land use despite making up a significantly smaller portion of total emissions.

Of the 11 sublevers, logistics network optimization, telecommuting, eco-driving, and truck route planning offer the greatest opportunities for GHG abatement and will be described in greater detail. A list of all the transportation abatement sublevers and their abatement potentials can be found in figure 33.

Logistics network optimization is a powerful sublever, with 11.4 $MtCO_2e$ in potential emissions reductions due to poor current state

104. "Logistics in Brazil", DHL

38 $MtCO_2e$
Breakdown of ICT-enabled GHG reduction potential

Breakdown	Sublevers	Drivers of sublevers
8%	Eco-driving	• Mobile applications provide drivers with feedback on fuel usage and driving style
3%	Real-time traffic alerts	• Provides drivers with traffic updates to help them avoid congested traffic areas, particularly in large cities like Sao Paolo and Rio de Janeiro
3%	Apps for public transit	• Would increase ridership by making public transit systems that fall under the 5,000 different transit authorities more predictable
6%	Crowd sourcing	• Gives urban Brazilians the ability to share transit resources through car and ride sharing
6%	Video-conferencing	• Allows for meetings to be conducted over the Internet through A/V equipment even if participants are in the same city
20%	Telecommuting	• Would prevent a large amount of emissions by preventing the need to use private transportation to get to work, particularly in congested urban areas
9%	Truck route optimization	• Utilizing real-time traffic reports can help trucks avoid congestion and closed routes
30%	Logistics network optimization	• Prevents trailers from going empty by ensuring coordination amongst truckers in a given area, which is particularly important because of Brazil's heavy reliance on trucking over other modes of transport
9%	Integration of EVs	• When used in conjunction with ICT, EVs can provide power back to the grid, reducing the need for peaking power plants during periods of high power demand
2%	Intelligent traffic management	• Reduces the amount of time that drivers burn fuel on congested roadways
4%	Fleet management	• Allows a centralized fleet manager to ensure that drivers are driving at the appropriate speed, are braking correctly and have the right tire pressure

Figure 33
ICT-enabled greenhouse gas reduction potential in transportation sector

Source: BCG analysis

of logistical planning. Despite a wave of consolidation within the trucking industry that increased efficiency, Brazilian logistics costs remain twice the OECD average, diminishing the competitiveness of Brazilian goods. Logistics networks optimization has the ability to reduce emissions in a number of ways, including reducing the number of trucking loads by ensuring that loads head to the same destination are on the same truck. Frequently, trailers will go as much as 80 percent empty and multiple trucks headed in the same direction, carrying cargo that could be carried by a single truck. Connecting the trucks to a logistics center can coordinate communication among different parties and reduce the number of trucks on the road by ensuring fuller loads, thereby reducing emissions.

Logistics optimization also allows for just-in-time delivery that greatly reduces the need for inventory. Housing inventory is an energy-intensive process, as it requires the construction of warehouses to hold the merchandise and electricity to ensure that goods are held in the appropriate environment. Just-in-time delivery is particularly important in Brazil, given its high production and transport of agricultural goods. Logistics network optimization can also prevent manufacturers from producing more of their product than the market desires because as supply wanes they can rely on the logistics network to move new product to shelves quickly rather than producing preemptively.

Also aimed at increasing trucking efficiency, truck route planning offers 3.4 $MtCO_2e$ of abatement potential. Truck-route-efficiency software will not only find the shortest route available, but will also monitor changes in traffic and will take tolls and other barriers into account to determine which route will require the lowest amount of fuel for a particular trip and even how much profit that trip would generate. These fuel savings translate into lower GHG emissions.

Telecommuting also yields significant GHG emissions savings, at 4.3 $MtCO_2e$. Telecommuting allows certain Brazilian service workers to work from home using their computers and phones rather than going into the office physically. Telecommuting does not work for Brazilians that are employed within many sectors, but this sublever offers significant abatement opportunities because of the high reliance on private transit.

Finally, eco-driving can help reduce GHG emissions by 3.0 $MtCO_2e$ by informing drivers how they can alter driving behavior so as to reduce fuel consumption. ICT built into a car or used through a smartphone reduces fuel consumption by informing drivers when they drive too fast, accelerate too quickly, take turns too sharply, and have tire pressure that is suboptimal. Again, this sublever has a relatively high abatement potential because of the high rates of private transit use in Brazil.

Business case

Sublevers that involve increasing the efficiency of the Brazilian trucking system are the most attractive from an investment standpoint; as Brazilian logistics costs are twice the relative OECD average, investments in logistics stand to make a large return on investment despite potential high up-front costs. Eco-driving is attractive to many, and low adoption costs may drive high uptake, but the absolute return on investment may be too low to induce people to change their behaviors. Telecommuting and videoconferencing, though technically feasible, may not be practical because of the need to meet face-to-face, and the split incentives problem may make it challenging to convince employers to invest in such systems. Potential videoconferencing partners need to have also invested in A/V equipment, which stands as a barrier in Brazil. Traffic management and alerts systems are feasible and reasonably attractive investments, but the return on investment for local governments is unclear. Integration of EVs in Brazil has a very poor business case because of the large infrastructure upgrades required, and Brazil's sustainable biofuels make electrification of the vehicle fleet a low priority..

Truck route optimization in Brazil has an exceptionally strong business case. In other parts of the world, companies have been able to reduce their overall fleet costs by as much as 16 percent through daily utilization of route optimization software; in Brazil, the current high level of inefficiencies could yield even higher savings.[105] Even without investing in large capital upgrades, truckers can take advantage of route optimization technology. There are Web-based services that can help a driver plan his route at the outset to take the most fuel efficient route. These Web apps have a minimal upfront cost and yield

105. "Optimizing Fixed Truck Routes and Delivery Schedules", Paragon Routing

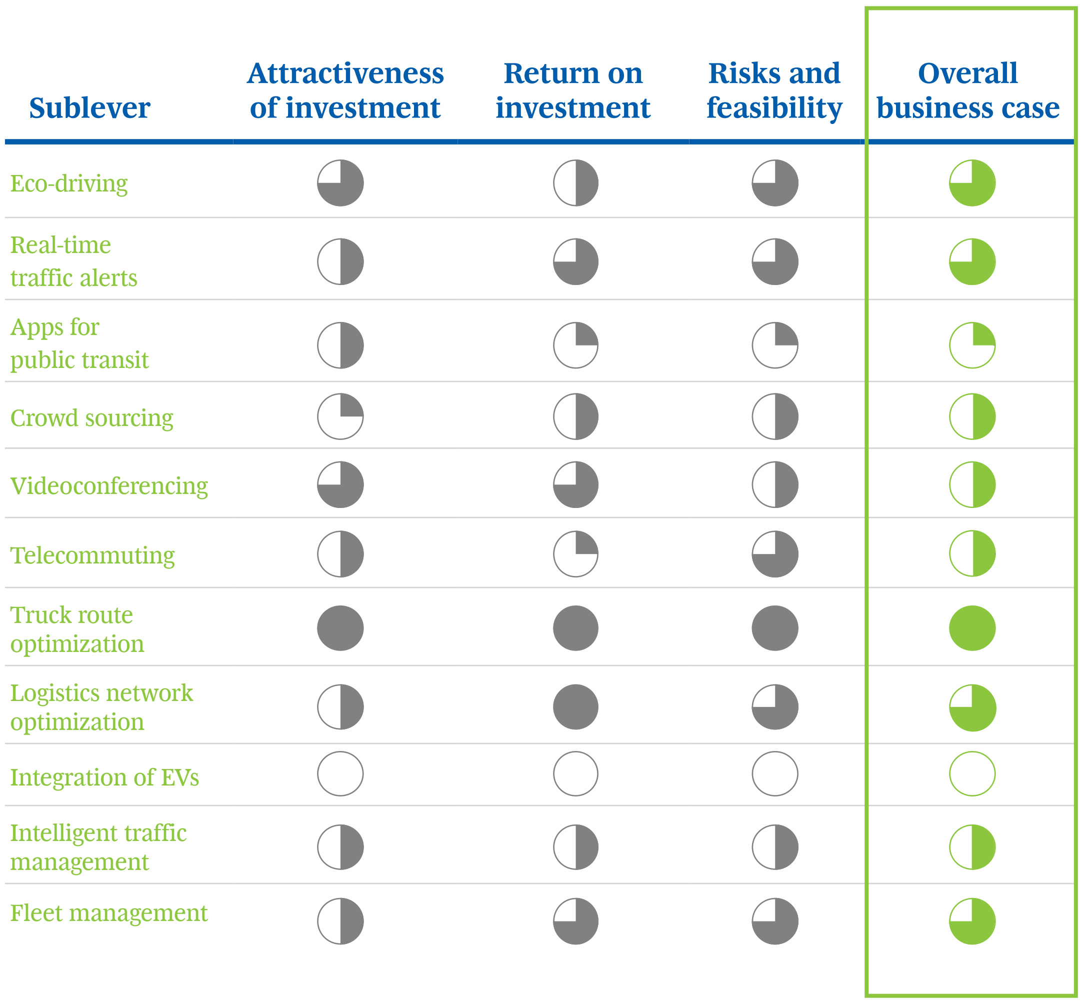


Figure 34
Business case assessment of transportation sector sublevers

Source: BCG analysis

Low attractiveness
High attractiveness

immediate mileage and fuel savings. Given more limited access to capital for logistics upgrades, low-cost, Web-based solutions will be attractive in Brazil. Aside from reducing fuel cost and mileage, truck route optimization can also make scheduling more predictable and can cut down on inefficiencies caused by multiple trucks arriving at the same destinations and warehouses at the same time. Moreover, when route optimization is combined with fleet management systems, real-time data can be incorporated and savings can be increased even further.

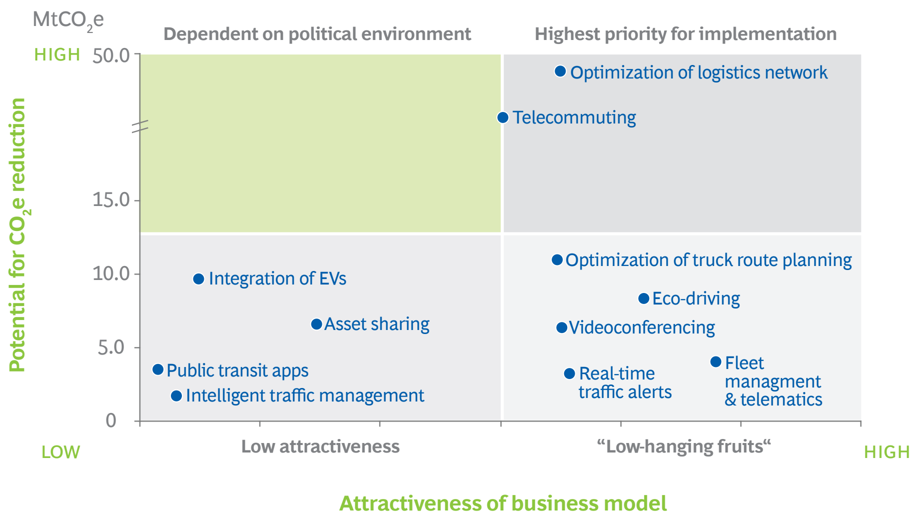
Barriers to ICT-adoption and policies to overcome them

There are a number of barriers that could prevent companies from adopting ICT as a means of reducing GHG emissions. Effective policy making, however, can help overcome these barriers.

A significant concern surrounds inducing behavioral changes. With regard to eco-driving, it is challenging to convince drivers to alter their driving behavior if they have driven a particular way for an extended period. Aside from more aggressively enforcing speed limits,

Figure 35
Prioritization of policy by potential for CO_2e reduction by business potential

Source: World Bank, BCG analysis



it is challenging for governments to mandate that drivers drive in an eco-friendly manner. Given this, the government should inform drivers about the potential energy and money savings that eco-driving and other green techniques yield. Such information could be displayed on highways and main thoroughfares and could be distributed when people go in to renew their driver's licenses. Furthermore, the government could mandate that all government vehicles utilize eco-driving applications and principles. By leading by example, the government may be able to convince a greater percentage of people to adopt eco-driving technology and techniques. Policy makers could also consider raising gasoline and biofuel taxes, but such a policy is likely to be very unpopular. Finally, the government could consider mandating that all vehicle manufacturers integrate eco-driving technologies into vehicles for sale in Brazil. Such legislation would also be unpopular in Brazil as it would drive up the sticker price of vehicles, despite the long-term savings.

> Financing is the biggest barrier to ICT-enabled abatement in the transportation sector

Financing is another potential barrier. Even if an ICT-enabled solution is NPV-positive, many companies will be deterred because of high upfront costs. NPV-positive investments with a payback period that is too long are not as attractive as other uses for capital. This present bias could be a concern when expensive investments in ICT solutions are required, such as in the establishing of logistics networks. A solution to this bias is to provide financing for logistics systems and other ICT solutions that abate GHGs in transportation. This program could be modeled after the Low Carbon in Agriculture program and administered by the Ministry of Transport. Providing financing spreads out the upfront costs to make investments more attractive to potential buyers that already have capital on hand and also makes technology available for those who otherwise would not be able to pay for it.

Split-incentives concern can be a barrier to telecommuting. Depending on the nature of job, managers and workers may have misaligned incentives with regards to telecommuting; it saves workers time, money, and energy when they are able to avoid their daily commutes but companies are often

Table 15
Barriers to adoption of ICT-enabled GHG abatement solutions in Brazilian transportation and policy recommendations

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Split incentives	• Financial incentives for workers to telecommute but employers must pay for telecommuting capabilities and are worried about workplace culture deterioration	Financial reward if a percentage of workdays are done via telecommuting	• Ensuring the reward is sufficient enough to compensate for both tangible and intangible costs
Financing	• High upfront costs for cites to adopt ICT for transit • High upfront costs for private companies to build logistics systems	Assist local governments with transit ICT purchases Provide financing for logistics systems purchases	• Government appetite for using public funds • Expected IRR and pay-back period • Government appetite for using public funds • Expected IRR and pay-back period
Economics	• Return on investment for investing in logistics systems unclear	Allow for tax write offs	• Fiscal implications of allowing for equipment tax write offs
Infrastructure	• High speed data networks may not cover the entire route	Promote high speed network development	• Construction of new networks is expensive • May require expertise and equipment not found in Brazil
Coordination with state	• Multitude of fractured state institutions overseeing transit may not be willing to use same ICT systems	Mandate transit information system standardization	• Certain localities may not be able to use the standardized system effectively

concerned about lost productivity, workplace culture deterioration, and paying for the ICT systems that enable telecommuting. Aside from some reductions in office space and energy use, employers reap few economic benefits from telecommuting yet must bear the the costs. To induce employers to allow workers to commute from home, the government should provide a tax credit if a certain percentage of work days are allowed to be completed remotely. This tax credit, however, must be large enough to offset the cost of purchasing ICT systems that allow for telecommuting and to cover the intangible costs of office culture deterioration. Even though there are fiscal implications that result from allowing such a tax write off, promoting telecommuting should be a priority for policy makers because of the large abatement potential, even if funds are limited.

Coordination with the multitudinous Brazilian transit authorities presents another challenge. As commuters attempt to use ICT to make commutes and public transit more predictable, a lack of coordination among and use of different

Case Study
Bus Rapid Transit in Curitiba

The city of Curitiba, with a population of 1.7 million, developed a unique and innovative transit system in 1974 that piqued the interest of many worldwide: the Bus Rapid Transit (BRT) system. Curitiba was faced with rising congestion, poor air quality, and a lack of infrastructure and was looking to improve its public transit system despite a lack of funds. Because constructing a metro system was beyond the city's capabilities and the bus system was plagued by high travel times and too many stops, the city sought to incorporate the positive elements of both.

As a result, the unique features of BRT transit include dedicated bus-only lanes, platforms that enable level boarding, payment before entering the bus, fewer stops, communication with a central transit authority, and coordination with traffic signals to ensure that intersections are clear for BRT vehicles. These final two features are particularly important and require ICT for implementation.

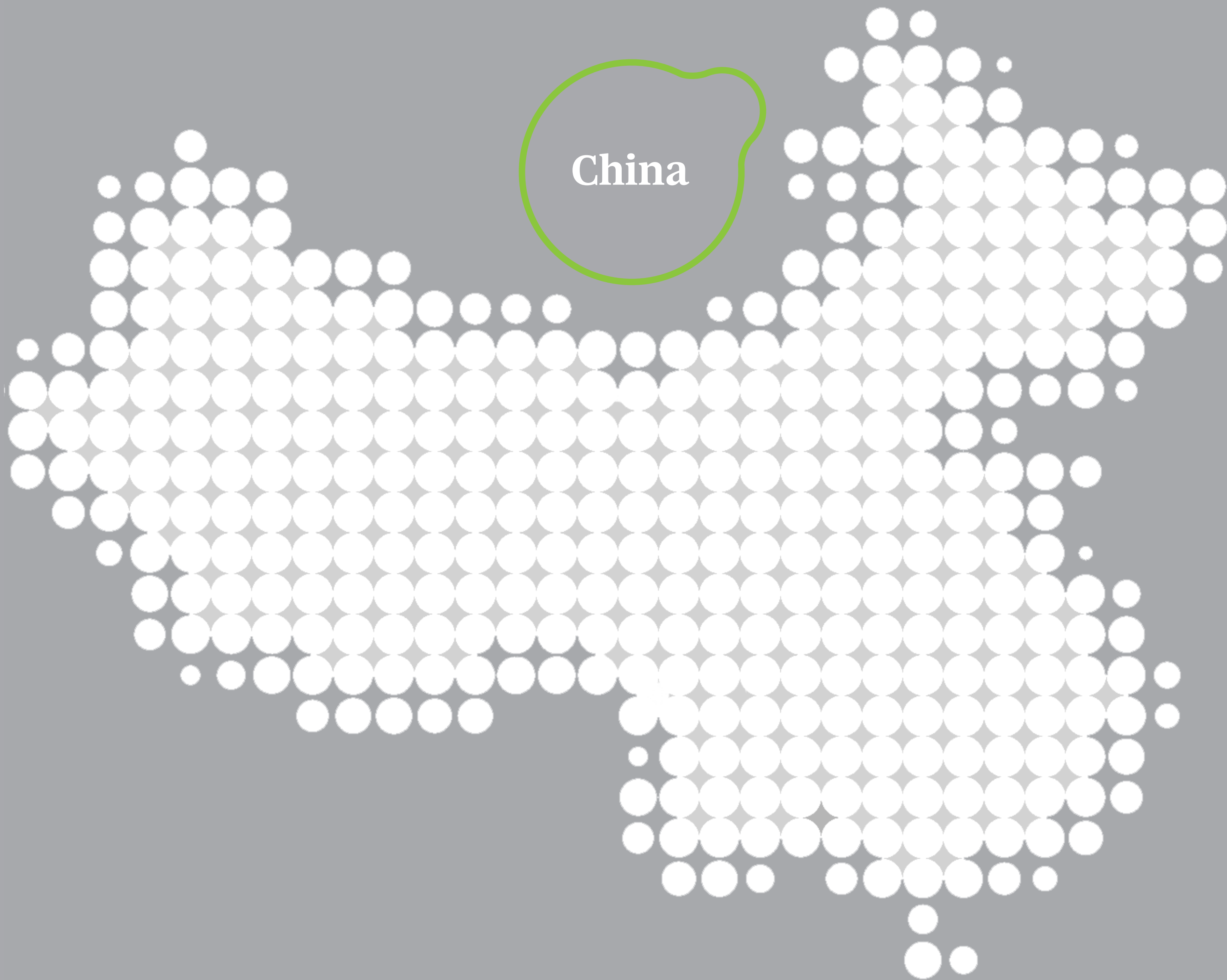
BRT vehicles are deployed to respond to increases in demand at particular stops. ICT is required to run the automated scheduling and dispatch service, which inform drivers when demand is increasing at particular stops so that they can divert resources to respond to the increase. Communication with traffic signals is also vital to prevent wasted time sitting at red lights. As a BRT vehicle approaches an intersection, the stoplight receives a signal from the bus and changes to allow the bus to pass unimpeded. The fleet is also connected to a fleet management system that conveys real-time schedule updates to riders so they can more accurately schedule their commutes and reduce waiting time. ICT enables the Curitiba BRT system to operate as efficiently and as reliably as it does while communicating its operating schedule with riders; without it, ridership would likely be lower.

BRT in Curitiba has been enormously popular and has had a significant environmental impact. It is estimated that the BRT system saves 27 million auto trips per year, yielding savings of 27 million liters of fuel. As a result, per capita fuel use in Curitiba is 30 percent lower than in similar Brazilian cities of its size.

BRT was developed in Curitiba because it required only the modification of existing resources and is economical compared to other alternatives, such as building a metro system. As a result, it has the potential to be scaled up in large cities across Brazil, though it is important to recognize that doing so could worsen congestion through the creation of dedicated bus lanes.

standards across various transit agencies could thwart their efforts. As a result, the federal government should consider passing legislation that would consolidate the 5,000 different agencies into larger, more coherent units. If this proves unpopular or unfeasible politically, the government should at a minimum pass legislation that would standardize the use of transit information systems at the state and local levels. Even if consolidation is not an option, this would enable the agencies to interface with one another more easily and better coordinate traffic and public transit flows between localities. A concern, however, is that a single, standardized transit management system may not be the most effective for each transit authority.

Finally, difficulties surround the lack of infrastructure. As discussed with regard to agriculture, the ability to connect to data networks is imperative for the use of the sublevers that we have identified. Although data networks are widely available in urban areas, there is a lack of suitable connections in many parts of rural Brazil, particularly areas that truckers tend to frequent. To address this barrier, policy makers should foster the development of high speed data networks in areas that have so far been overlooked. In some locations, the business case for mobile broadband may not be particularly strong, but the government can remove tariffs on ICT equipment imports, or at least lower tariffs on essential ICT equipment imports, sell electromagnetic spectrum rights at lower prices, and loosen regulations pertaining to data network development. These policies would help the ICT industry take broad strides toward achieving a more uniform distribution of data networks across Brazil.


China

9 China

9.1 Context

China's economy has made great progress since the economic reforms of 1978. The rapid GDP growth also meant that China became the largest GHG emitter in the world. As of 2008, China accounted for 7,032 Mt CO_2, which is 22 percent of CO_2 emissions worldwide.

Figure 36 shows the steadily increasing CO_2 emissions over the past 20 years in China. The average growth rate of total emissions in China was 3.3 percent in the 1990s. Between 2000 and 2008, however, total CO_2 emissions accelerated to a CAGR of over 9.5 percent and reached 7,032 Mt in 2008. During this period, almost all the sectors of the economy have seen increasing emissions. With economic growth and urbanization expected to continue, GHG emissions in China are expected to increase further.

Figure 36 shows that two sectors—power and manufacturing—contribute the largest shares of China's total emissions. The power sector has witnessed the highest growth with an annual growth rate of 9 percent between 1990 and 2008. As of 2008, the power sector contributed 48 percent of all CO_2 emissions. An important reason for this is the power generation energy resource mix: coal-fired power plants still dominate the Chinese power supply market and generate over 78 percent of electricity.[106]

Following the power sector is the manufacturing sector, which accounted for 31 percent of total CO_2 emissions in 2008. This high share is mainly due to rapid growth in manufacturing output in China over the last two decades. As the share of the manufacturing sector in China's GDP grows, it may contribute a higher share in total emissions in future.

China is the world's largest emitter of GHGs

More recent data from EDGAR shows that China's CO_2 emissions in 2011 had reached 9.7 Gt.[107] This makes China's emissions 29 percent of the 33.9 Gt global CO_2 emissions in 2011. However, breakdown by sector is not available, so it is not possible to tell how the sector-specific trends discussed below have evolved since 2008.

106. Wood Mackenzie

107. Emission Database for Global Atmospheric Research. Because of discrepancies in the emissions data from EDGAR and the World Bank, the two sources have not been merged to avoid inconsistency (e.g. according to EDGAR, China's CO_2 emissions in 2008 were 7.79 Gt or approximately, 0.79 Gt higher). The latest, most robust data available that allow for a consistent breakdow of emissions by sector have been used in this report

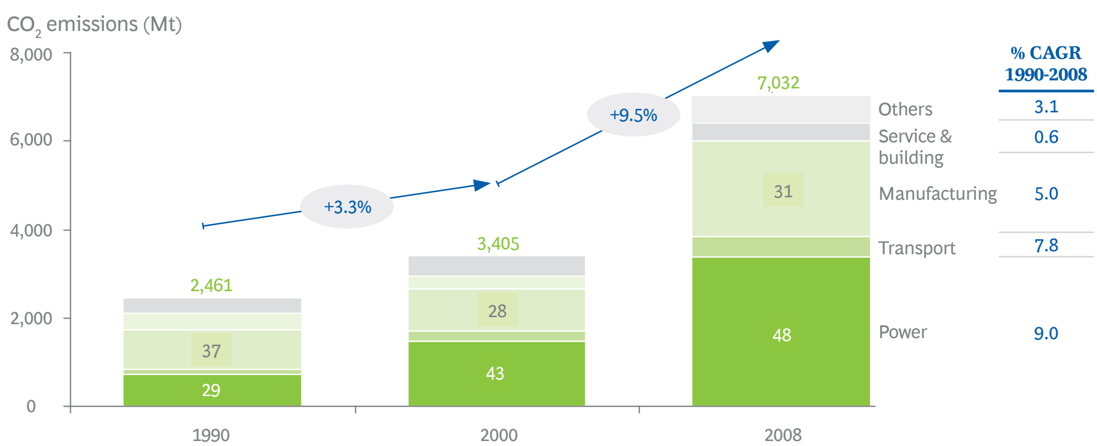


Figure 36
China's CO_2 emissions (1990-2008)

Source: World Bank; Wood Mackenzie; Xinhua Agency; China's 12th Five-Year-Plan; BCG analysis

The Chinese government realizes the importance of the environmental hazards related to high emission growth. It has increasingly devoted itself to controlling emissions. In the eleventh five-year plan (FYP) introduced in 2006, the government stated its position on energy efficiency. For the first time, it aligned the energy conservation targets with the GDP growth targets.[108] At the UN Copenhagen Summit in 2009, the Chinese government announced a plan to cut the 2005 level of "emission intensity" by 40 to 45 percent by 2020.[109] To meet the target set in the Copenhagen summit, the emission intensity of China has to drop to at least 0.65 kg CO_2 per dollar of GDP. In 2008, emissions intensity was 0.86 kg CO_2 per dollar of GDP (see Figure 37).

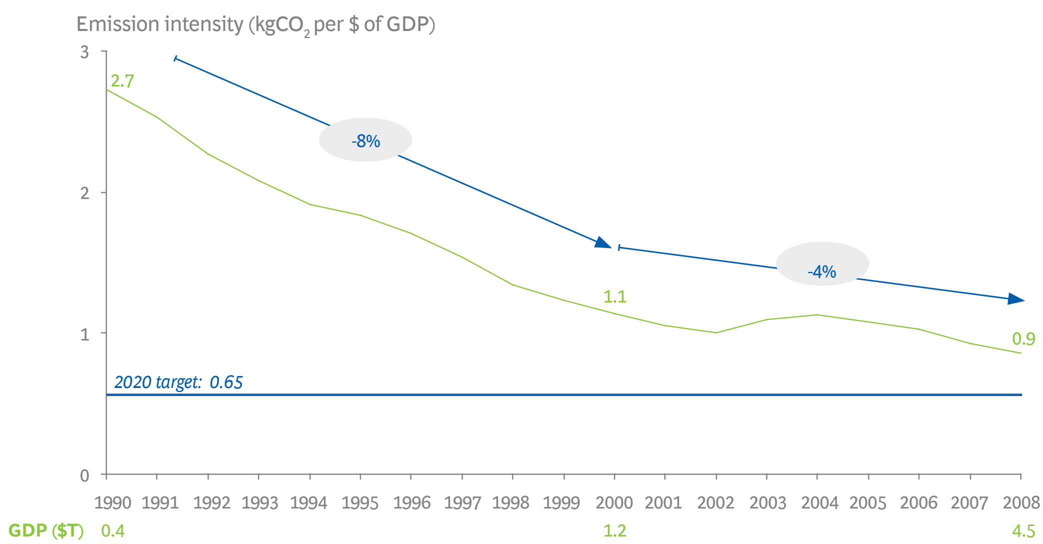
It should be noted that China's emissions target differs from those set by other countries. China does not aim to reduce overall emissions, but instead its "emission intensity," which is defined as the CO_2 produced in kilograms per U.S. dollar of GDP generated. The implication is that to reduce the emission intensity, the total CO_2 emissions do not necessarily need to decline. As long as GDP growth outpaces emission growth, emission intensity can be reduced even though total emissions rise. In fact, this is the scenario that is most likely to unfold in China in the coming years.

While emissions are expected to increase in China, we can identify at least three favorable trends in emissions that can potentially reduce the pace of growth. First, the government is making serious efforts to improve the air quality. In part, this effort is driven by increasing concerns among the Chinese public about air pollution. One of the measures is to close coal-fired power plants and manufacturing plants in urban areas, which helps reduce GHG emissions. Second, the government intends to gradually replace high-polluting coal as the primary energy source with other resources that are less emissions-intensive. The government's investment in renewable energy is a promising trend.[110] Third, China's GDP growth rate is likely to slow down, as the government targets a so-called "soft landing" to ensure healthy and sustainable growth in the long term. In the twelfth FYP, the annual growth target was set at 7 percent despite an average of 11.2 percent during the eleventh FYP. As the GDP slows down, the pressure to reduce GHG emissions will increase to meet the emissions intensity target.

108. China's 11th FYP
109. Copenhagen Accord
110. More details in section 1.1.3

Figure 37
Development of the emission intensity in China

Source: World bank; Wood Mackenzie; Xinhua Agency; China's 12th Five-Year-Plan; BCG analysis



9.2 Impact of ICT on GHG emissions

The penetration of ICT is currently low in China compared with the world's other largest economies such as the U.S., Japan, or the U.K. ITU ranked China eightieth among 150 countries in terms of ICT end-user readiness in 2011. China had reached only 20 percent penetration of computing devices in 2011. Broad-based uptake of ICT-based solutions across the economy is also lacking.

A recent survey of ICT professionals in China conducted by Alcatel Lucent and Tsinghua University shows a high level understanding of what green ICT is and why it is important. However, the understanding declines when it comes to how to implement green ICT, driving achievable targets, and how reaping the full potential of green ICT can help China achieve social and economic goals.[111]

However, cloud computing, in particular, is expected to be widely adopted in China. A forthcoming study by GeSI and Microsoft finds that the GHG abatement potential of moving three services to the cloud—cloud-based e-mail, customer relationship management, and groupware applications—is 1.9 MtCO2e annually.[112]

As China's economy grows, the penetration of ICT, especially of end-user devices, is expected to rise rapidly. For example, mobile penetration will compare with that in developed countries, and many consumers are expected to trade up to smartphones. The rising ICT penetration will lead to substantial increase in IP traffic, both mobile and fixed. As ICT penetration increases, the direct GHG emissions of the ICT industry will rise as well, with a 6 percent CAGR from 2011 to 2020. This growth rate is higher compared to some developed countries such as the U.S. and the U.K.

Figure 38 shows the estimated emissions growth of the ICT sector in China. Emissions are expected to grow from 197 Mt in 2011 to 326 Mt by 2020. End-user devices will remain the largest contributor and constitute 68 percent of the entire ICT sector's emissions by 2020. Data centers are expected to register the highest annual growth rate of 13 percent per year between 2011 and 2020.

111. "Green Information Communications Technology in China" – Alcatel Lucent and Tsinghua University

112. "The Enabling Technologies of a Low-Carbon Economy- a Focus on Cloud Computing" – GeSI and Microsoft (study conducted by ThinkPlayDo Group of Imperial College London)

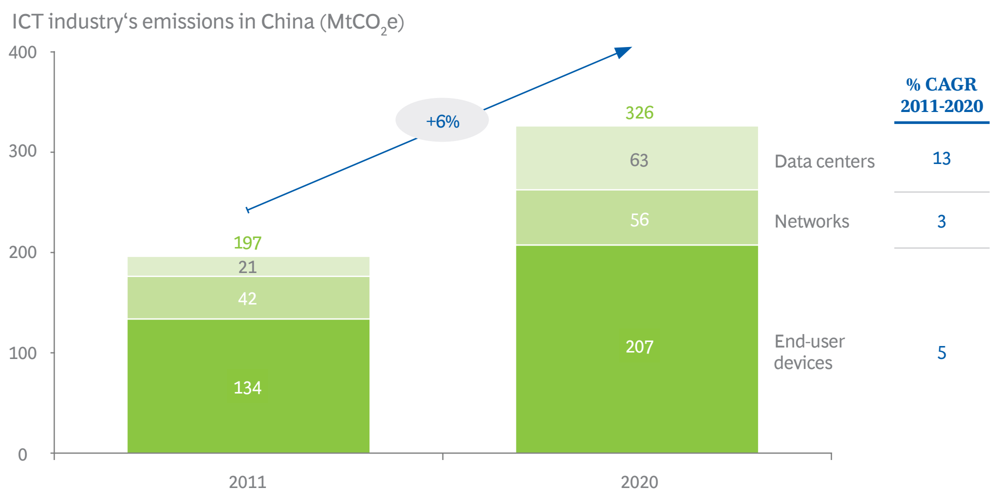


Figure 38
ICT industry's greenhouse gas emission in China

Source: Gartner; IEA; Greentouch; Ovum; GSMA; press search, BCG analysis

9.3 Abatement potential in power and manufacturing end-use sectors

As discussed earlier, the largest contributors to carbon emissions in China are the power and manufacturing sectors, with shares of 48 percent and 33 percent in 2008, respectively. The share of emissions from other sectors is relatively low. This gives us reason to focus mainly on these two sectors in the context of this study.

Power

Context

CO_2 emissions from power generation in China amounted to 3,470 Mt in 2010, making the power sector—with a share of 48 percent—the largest emitter among all sectors. Figure 4 shows the rapid growth of emissions in this sector. The annual growth rate of 11 percent between 2000 and 2010 in the power sector exceeded that of total emissions across all sectors during the same period.

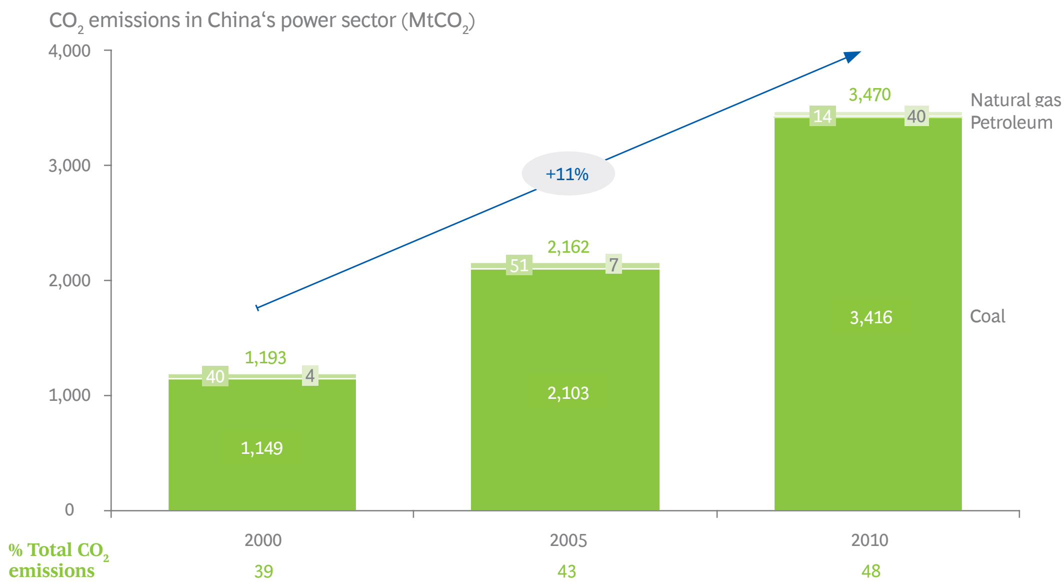
The dominant energy source for power generation in China is coal. In 2010, 78.5 percent of all power was generated from coal-fired power plants.[113] Compared to coal, the usage of other less polluting fossil fuels (for example petroleum and natural gas) for power generation is limited. Other energy sources such as nuclear and renewable energy are expected to gain share in power generation. But at least in the near term, coal-fired power will remain the backbone of China's power supply.

Currently, significant inefficiencies exist in China's power sector, resulting in both unnecessary consumption of energy resources and high GHG emissions. For instance, to

113. Wood Mackenzie

Figure 39
CO_2 emissions of China's power sector

Source: IEA, Wood Mackezie; BCG analysis



generate 1 kWh of electricity, China consumes about 50 to 60 grams more coal than the highest efficiency level in the world. Further, transmission loss is estimated to be 2.0 to 2.5 percent higher than that in advanced nations.[114] Therefore, improving energy and process efficiency will play a significant role in controlling emissions in China's power sector. Currently, the Chinese power sector is still a highly regulated market. Despite some recent liberalization attempts (for example, separation of the State Power Corporation into five national power-generation groups in 2002), the state maintains its control over the power sector, including generation, distribution, and pricing. The lack of competition and the high subsidies provided by the government (required for state-controlled electricity pricing) worsen the inefficient resource use and consumption.

China's plan to promote renewable energy is ambitious. For instance, it targets a total installed base of 200 GW on-grid wind power capacity and 50 GW solar power capacity by 2020. This would represent approximately 16 percent of the 1600 GW expected power capacity in 2020. Given that installed capacities for these two sources in 2008 were 12.2 GW and 0.14 GW, respectively, meeting the 2020 targets a challenging task.[115] The initial signs are encouraging. The Chinese government is making large investments in renewable energy, not only because of concerns about sustainability but also to secure mid- and long-term energy supply for economic growth. In 2009 alone, China added 25.8 GW of wind capacity, which was the largest in the world that year.[116] In 2011, China spent USD52 billion on renewable energy, which was almost one-fifth of total global investment.[117]

Besides efforts in power generation, China is investing heavily in the power transmission infrastructure. It plans to build several ultra-high voltage grids by 2015. These grids will mainly connect the power plants in China's western and southern parts with the economically advanced and high-power-consuming eastern part of the country. The ultra-high voltage technology is an efficient way to lower losses through long distance transmission.

Compared with the level of focus on the supply-side improvements, there has not been much action with regard to demand-side management. Some pilot projects like smart metering and dynamic pricing exist in economically developed regions. A large-scale rollout of such programs could have a strong impact on future GHG abatement in China.

Power-sector abatement potential

ICT-enabled solutions can contribute to GHG abatement in the Chinese power sector in different ways. Figure 40 shows the abatement potential of each identified sublever. In total, 390 Mt CO_2e could be avoided by 2020 if these ICT-enabled solutions are implemented and scaled up. The most promising sublever is the integration of renewable energy sources, which could cut GHG emissions by 153 Mt CO_2e by 2020. This is a result of high investments in renewable energy in China and expected rapid expansion of renewable power plants.

> Power emissions contribute to 48% of all CO_2 emissions in China

The second most effective sublever is power grid optimization. It is expected to contribute a reduction of 143 Mt CO_2e by 2020. These estimates are based on recent efforts by the Chinese government to optimize the power grid infrastructure. It is especially important to equip the new grids with the most modern ICT. Doing so will minimize distribution losses, thereby lowering GHG emissions.

A key issue in abating emissions in the power sector is matching the demand and supply of power. Innovative pricing mechanisms like time-of-day pricing could shift the peak demand to off-peak hours via variable

114. China's electrical power sector, environmental protection and sustainable trade, IISD (2009)

115. National Development and Reform Commission; Reuters, Renewable Energy World

116. "Market Analysis Report: China's Renewable Energy Industry," APCO

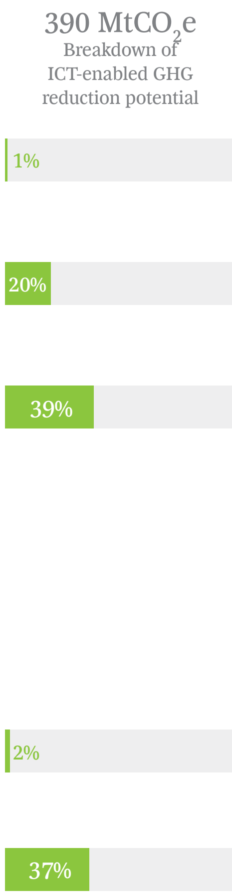
117. Forbes

electricity tariffs based on consumption time. As a result, not only can the utilities avoid supply shortages during peak time, but also the total power demand will decline. The abatement potential of time-of-day pricing could be as high as 79 Mt CO_2e.

Compared to these sublevers, other ICT-enabled sublevers are expected to have a relatively minor impact. For example, the consolidation of decentralized renewable power plants to virtual power plants has an abatement potential of 2 Mt CO_2e. This sublever requires advanced-grid-infrastructure capabilities, which are not well developed in China as yet.

Figure 40
ICT-enabled GHG reduction potential in the power sector

Source: BCG analysis, BCG interviews, BCG Perspectives, EPRI, IEA, Pike research, PNNL



Sublevers	Drivers of sublevers
Demand management (4 MtCO_2e)	• Reduction of peak load electricity • Government has stronger control of industry and could potentially mandate
Time-of-day pricing (79 MtCO_2e)	• Reduces emissions by shifting peak consumption to base-load – will require upgrade to infrastructure and a market for pricing electricity (pilots being conducted at industry level)
Integration of renewables (153 MtCO_2e)	• Increasing the use of carbon-free energy • Strong government support, but ICT (smart grid) has important role to overcome technical barriers to adoption
Virtual power plant (2 MtCO_2e)	• Not a major sublever in China – requires advanced grid infrastructure capabilities • Current grid monopoly hinders large implementation
Island Grid (1 MtCO_2e)	• Some small potential in China because of number of diesel generators and other off-grid applications
Power-load balancing (9 MtCO_2e)	• Not a major sublever in China – requires high electricity prices to make the economics favorable
Power grid optimization (143 MtCO_2e)	• Improve efficiency of distribution and minimize losses • Government has indicated they will take strides to incorporate ICT technology to optimize the grid

Case study
China's first demand response project

To achieve better demand-side management, a demonstration project launched in 2012 by Honeywell and the Tianjin Economic-Technological Development Area intends to implement China's first smart-grid demand-response project. This project aims to connect the utility and its commercial and industrial consumers in a smarter way. With the help of ICT, utilities can automatically put into action a customized energy reduction strategy. For example, during peak hours, utilities could quickly and reliably drive down the consumer's overall power consumption. This would avoid the running of peak power plants and unnecessary carbon emissions. In addition, consumers could cut their energy use and save on energy costs without compromising critical operations.

The deployment of automatic demand response is estimated to enable peak-load reduction by 15 to 30 percent. Given the huge power demand in China, the potential of this initiative for carbon abatement is considerable.

This project is currently at the planning stage. Because of high technological feasibility and realistic energy and carbon savings, an expansion of this project could contribute immensely to the country's goal of developing a smarter electrical grid to better meet the growing power demand and improve the reliability and efficiency of the power supply in China.

Barriers and recommended policy steps to overcome them

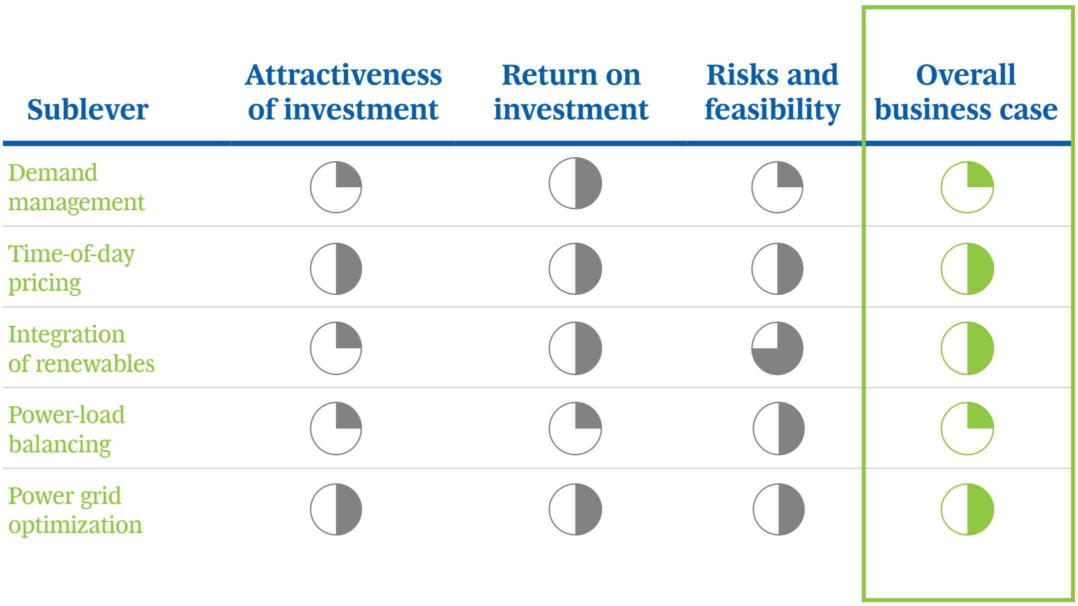
ICT-enabled solutions offer significant abatement potential in the Chinese power sector. But there are several barriers that can affect the full deployment of these solutions. In most such cases, appropriate support from the government through laws or policy is necessary.

The business case for most sublevers in the power sector is medium to weak. The primary drivers of this are the high upfront cost given the lack of modern power infrastructure and the currently low energy prices. Power grid optimization likely presents the best business case given the possibility to avert transmission and distribution losses. Power load balancing is not very attractive because of the need for the high investment required to build the necessary storage technology and capacity. Demand management also requires a high upfront investment and is risky, as it may not be implementable without a government mandate.

Figure 41
Business case assessment of power sector sublevers

Source: BCG analysis

Low attractiveness
High attractiveness



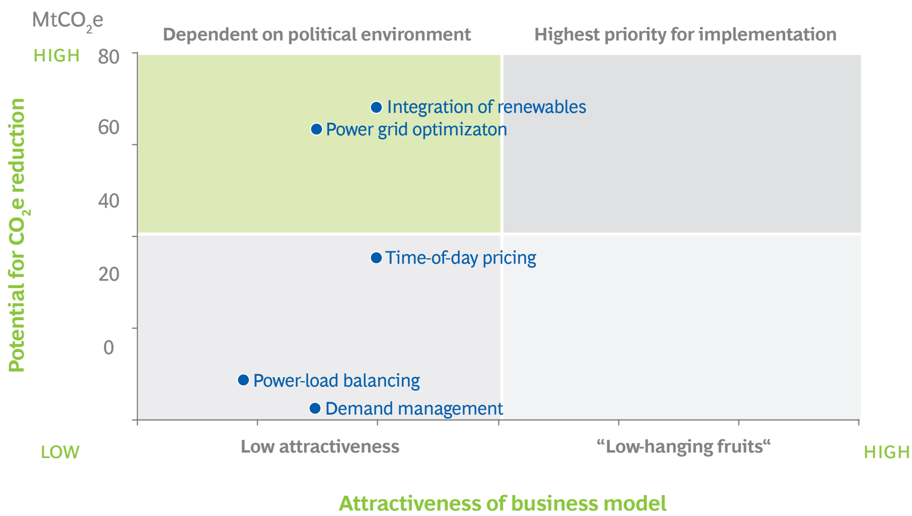


Figure 42
Power sector sublever prioritization by potential for CO_2e reduction and business potential

Source: BCG analysis

Figure 42 combines the business case analysis with the abatement potential analysis in the previous section. The key insight from the combined view is that the role of policy is likely the strongest in facilitating the integration of renewables and power grid optimization. China is already one of the biggest markets for renewable energy. Integrating renewables into the grid can yield significant benefit for China if done successfully. Similarly, power grid optimization offers significant abatement potential but needs a push from policy for implementation because of the lack of a strong business case.

Compared to their multinational counterparts, firms in the Chinese power industry still have to bridge a huge technological gap. As already discussed above, inefficient resource use and high transmission losses suggest that the Chinese power industry lacks technological excellence and efficiency. Consequently, the government could continue to promote research and development through new regulations or attract foreign investment and technology.

Currently, dominant state control over the power sector discourages industrial initiatives because of lack of competition. Therefore, deregulation of the Chinese power sector must be intensified so that the power supply will be secure while also encouraging sufficient competition to drive the technological progress. However, it is important to note that this is not a new idea and there has not been much progress on it in the past.

A big challenge within the power sector is managing peak demand. If utilities are not able to provide sufficient power required by customers during peak hours, expensive fossil-fuel-fired peak-power plants have to be run, which usually stay idle during the off-peak time. This process is economically disadvantageous and causes additional GHG emissions. Demand-side management could play a vital role in balancing the peak load and avoiding these unnecessary emissions. The government could consider mandating demand-side management for very large industrial users. However, expanding to consumers will first require building the necessary infrastructure.

From the point of view of the consumer, general awareness about green power is still low. There are also few economic incentives for consumers to change their behavior and manage their demand. Therefore, the government needs to enhance awareness through education campaigns. Besides encouraging consumers to optimize their consumption voluntarily, other innovative power pricing mechanisms (for example, time-of-day pricing) will create additional incentives to hasten this shift.

Table 16
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome these barriers

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Technology	• Advanced technologies still controlled by MNCs • Lack of domestic technological excellence and efficiency	Promote technological innovation	• R&D funding and program • Strengthen IP protection • Attract foreign investments and joint ventures
	• Dominant state control discourages innovation and competition	Proceed on deregulating the power sector to encourage market pricing and innovation	• Induce competition among power companies • Encourage market pricing and innovation
High demand for power	• Dependence on coal – high emission fossil-fuel • Government efforts focus on securing the supply rather than shifting demand	Increase emphasis on demand-side management	• Consider mandating demand-side management for very large industrial users • Expanding to consumers will first require building the necessary infrastructure
Awareness/ incentives	• Low general awareness about green power among consumers • Limited incentives for consumers to change their behavior	Enhance public education program	• Encourage consumers to voluntarily change their behavior into a more efficient way by educating the benefits of efficency
		Adopt different pricing mechanism	• Create incentives for consumers to adjust their consumption, e.g. reduce power demand during peak hours etc.

Manufacturing

Context

With a contribution of 31 percent in 2008, the manufacturing sector is the second biggest contributor to China's GHG emissions. In 2008, it reached a total CO_2 emission of 2,168 Mt (see Figure 43). While the growth in emissions was low in the 1990s, it increased rapidly after 2000. Between 2000 and 2008, the CAGR in emissions was 10.6 percent.

The main drivers for the rising CO_2 emissions in the manufacturing sector were rapid industrialization and high GDP growth. Despite the growth of the tertiary sector, the manufacturing sector enhanced its share in China's economy from 36 percent in 1990 to 40 percent in 2010.[118] Within the manufacturing sector, some industries, such as iron and steel, cement, and chemicals, contribute significantly to the sector's total emissions. For example, the steel industry contributes 6.5 percent of the global GHG emissions[119] and China is currently the world's largest steel producer, with a share of 45 percent.[120]

Taking note of these emissions, the Chinese government has been including the improvement of energy efficiency and manufacturing emission control in its five-year plans since 2006.[121] Its policy focuses mainly on reducing the energy intensity per unit of output. The policy mandates that before a company adds new production capacity, an energy efficiency assessment is required. Further, several inefficient manufacturing facilities have been closed down. These are among the first steps that the Chinese government has taken to limit GHG emissions in the manufacturing sector. But as of now, no binding sector specific emission targets have been set.

118. OECD

119. World Steel Association: Presentation by Dr. Edwin Basson in Rio de Janeiro in 2012

120. World Steel Association: World Steel in Figures 2012

121. China's Eleventh Five-Year Plan

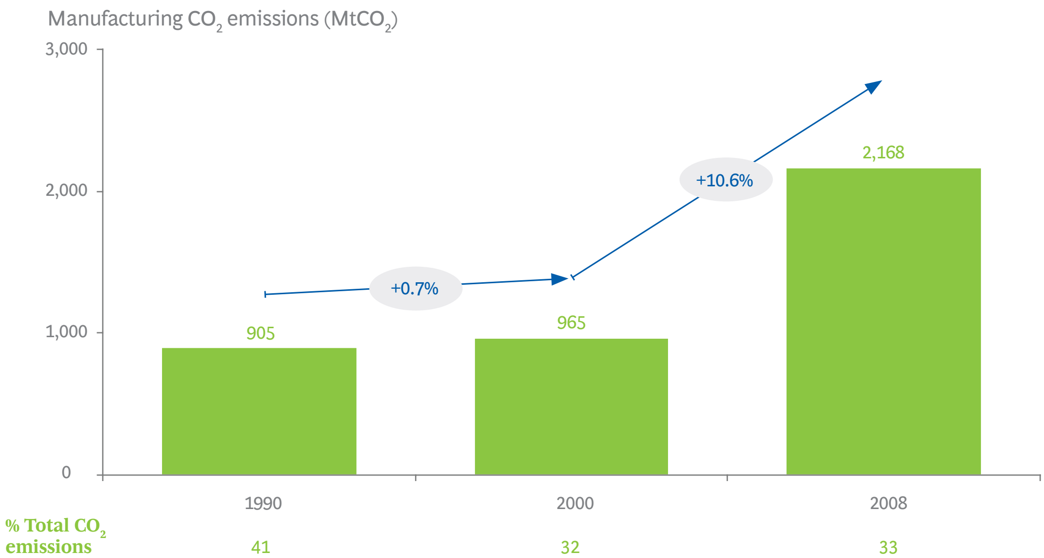


Figure 9
CO_2 emissions of China's manufacturing sector

Note: 1. Permanent growth of the tertiary sector and decline of the agriculture sector change the manufacturing share only slightly 2. Since the 11th Five-Year-Plan

Source: UNFCC; World Bank; China's 12th Five-Year-Plan; BCG analysis

Figure 4
ICT-enabled GHG reduction potential in the manufacturing sector

Note: Motor electricity consumption accounts for 60% of all electricity consumption and over 70% of these is attributed to inefficient medium and large induction motor system

Source: BCG analysis, BCG interviews, IEA, Smart 2020 Report, World bank databank

512 $MtCO_2e$
Breakdown of ICT-enabled GHG reduction potential

512 $MtCO_2e$	Sublevers	Drivers of sublevers
68%	Optimization of variable speed motor systems (347 MtCO2e)	• A frequency converter as add-on for the actual motor to vary the rotational speed and better match the energy use with required output • Huge potential in China due to poor efficiency of the current motor systems1 • Economically favorable due to short pay-back period • Can be widely used e.g. in pumps and ventilators
32%	Automation of industrial processes (165 MtCO2e)	• Monitoring and control for large industrial process to optimize and reduce the energy use of the process • Replacing older, inefficient processes with current best-practices • Closing the existing efficiency gap offers great potential for emission abatement

Manufacturing sector abatement potential

The potential of using ICT-enabled solutions to reduce carbon emissions in the Chinese manufacturing sector is promising, given the current high technological deficit. If implemented well, a total emissions abatement of 512 Mt CO_2e could be reached by 2020 (see Figure 44).

The optimization of variable-speed motor systems is the strongest sublever and could help reduce 347 Mt CO_2e. The current motor systems in China are of poor efficiency, since over 70 percent of all electricity used by motor systems is attributed to inefficient medium and large inductor motor systems.[122] Variable-speed motor systems, which are equipped with a frequency converter, can adjust the rotation automatically according to the performance required. For example, when lower performance is required, the motor rotation slows down, thereby saving energy. Such energy savings would not be possible with conventional motor systems without variable drives. In economic terms, this option could be highly attractive for manufacturing companies to implement because of the short payback period.

Another ICT-enabled sublever is the automation of industrial processes. The abatement potential of automation is estimated to reach 165 Mt CO_2e by 2020. The main purpose of this sublever is to reduce the energy use of industrial processes through automatic monitoring and control.

122. IEA

Case study
Process automation at the Sinopec Qingdao Refining and Chemical Corporation Ltd.

Sinopec is the largest producer of refined oil products in China. In light of the increasing cost of oil in the world markets and the strong growth in China's demand for refinery and petrochemical products, Sinopec planned to build a new integrated oil refinery in Qingdao capable of processing 10 million tons of crude oil per year. Becuase of growing awareness about safety and environmental protection issues in China, the government now requires any newly built facility to comply with tightening energy efficiency regulations. Therefore, applying the latest information and communication technologies to manage the production processes automatically and efficiently was central to the project.

The specifications drew up by Sinopec included a wide range of industrial activities, including instrumentation, human machine interface (HMI), safety, data archiving, inventory control, services for maintenance, and so forth. These activities could all be efficiently supported by ICT-enabled solutions. Through automation, productivity could be significantly improved, production costs lowered, and quality improved. Because of the improved efficiency, energy consumption could be reduced substantially, which would in turn reduce carbon emission.

In addition to automation, several new advanced technology processes were employed as well. For instance, the waste products from the distillation stages were processed in a coking plant to release further economically useful materials. From the coking unit, the waste products then went into a boiler, where energy was generated for use in other processes. These improvements all had a positive impact on reducing carbon emissions.

Industrial automation via ICT could definitely contribute to the national carbon abatement targets in China. Investments made in automation typically have a short payback period for the enterprises. Automation would significantly improve the productivity and efficiency of a firm's production processes. Such improvements would also be critical in sustaining the competitiveness of enterprises, given the continuously increasing energy prices.

Barriers and recommended policy steps to overcome them

To realize the abatement potential of ICT-enabled solutions in the Chinese manufacturing sector, several barriers need to be addressed. Similar to the power sector, the existing technological deficit embodies a significant barrier for emission abatement. The government should encourage rapid adoption of the most modern technologies.

The business case for both sublevers in the power sector is strong. The primary drivers of this are the relatively low-to-medium up-front cost and a short payback period. The feasibility for broad-based adoption, however, may become a barrier if sufficient skilled labor for managing advanced manufacturing systems and processes is not available.

Figure 46 combines the business case analysis with the abatement potential analysis in the previous section. The combined view reveals that indeed there is a limited role for policy. A strong business case is expected to be sufficient to drive market-based adoption.

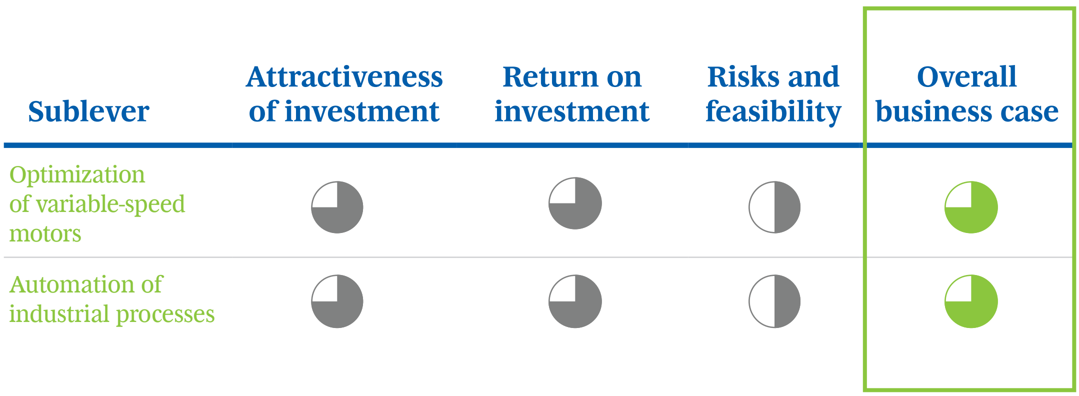


Figure 45
Business case assessment of manufacturing sector sublevers

Source: BCG analysis

Low attractiveness
High attractiveness

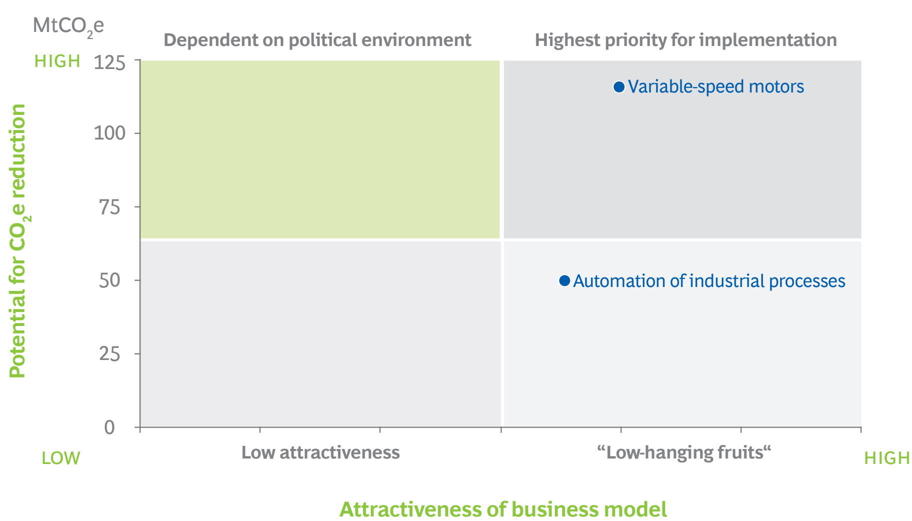


Figure 46
Manufacturing sector sublever prioritization by potential for CO_2e reduction and business potential

Source: BCG analysis

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Technology	• Local manufacturers face huge technological gap compared with MNCs • Existence of inefficient production	Promote technological innovation	• R&D funding • Attract foreign investments and joint ventures
Alignment with national goals	• Carbon emissions reductions is still not a priority for the government • Lack of government support for enterprises regarding energy efficiency	Create national industrial efficiency standards	• Close down inefficient plants • Address energy efficiency and emissions in KPIs • Create standards by device/ industry type • Supervise and offer local support for energy efficiency
Monitoring and evaluation	• Absence of data standards for emission and efficiency • Limited possibility to benchmark or assess improvement	Establish data and measurement standards	• Create industry wide standards/ methodology for monitoring and evaluation • Enforce compliance to emission measurement • Encourage "learning from the best practices"
Social perspectives	• Potential rise of unemployment due to automation and shut-down of inefficient plants (if not replaced with more efficient ones)	Provide further training opportunities	• Strengthen human capital for cross-sector re-employment

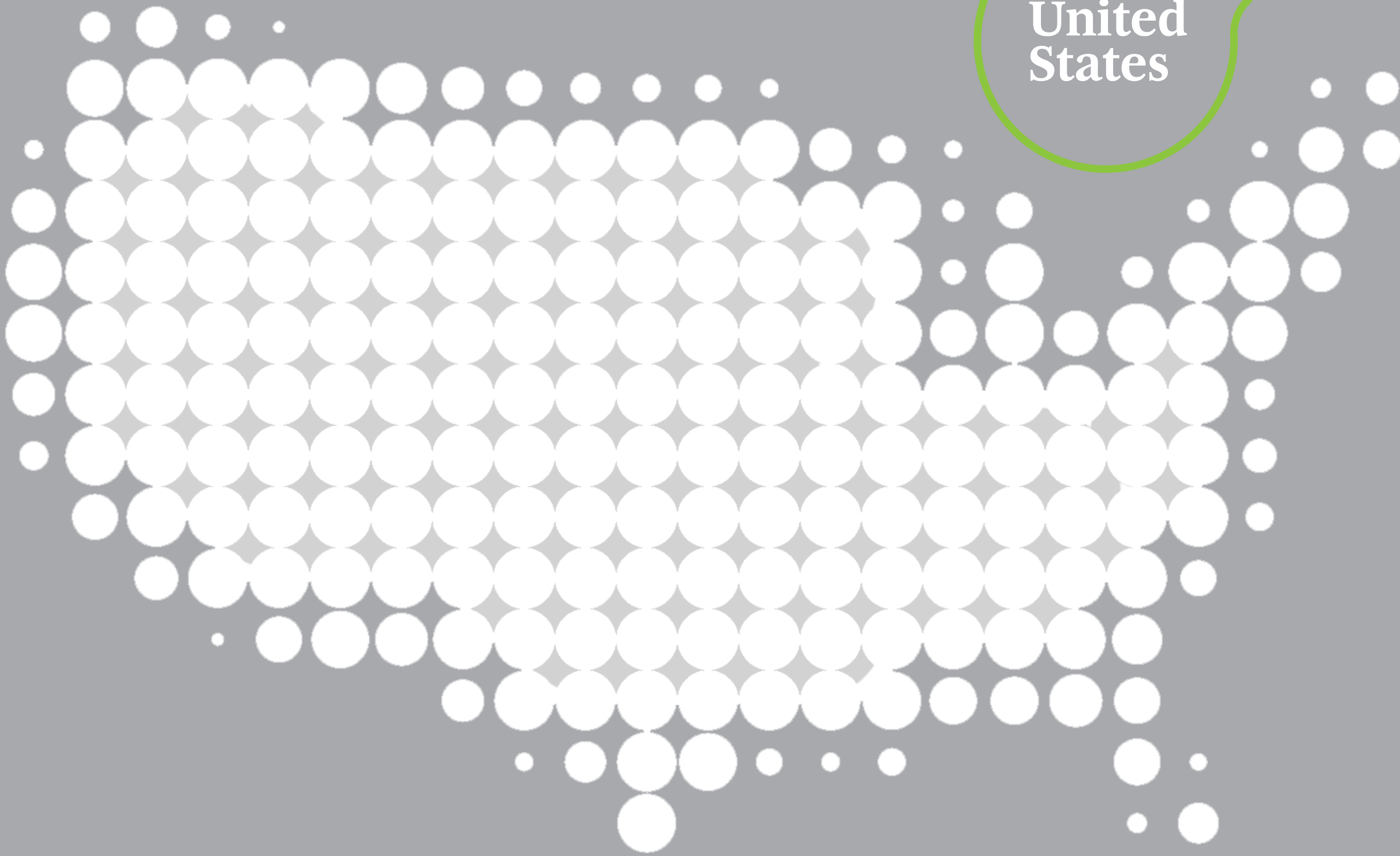
Table 17
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome these barriers

For a long time, the central and local governments in China were focused only on GDP growth while the GHG emissions have largely been ignored. This changed in 2006, when the Chinese government announced its eleventh five-year plan. For the first time, energy conservation and emission abatement were added to the five-year plan. In the future, aligning emission targets with GDP growth goals will play a significant role in China's emission control. Indicators for energy efficiency and emissions should be addressed in key performance indicators to evaluate government performance. Defining national industrial efficiency standards could help the government identify inefficient plants and take action. This could enhance the state's role as supervisor and partner to offer specific support, so that small and medium enterprises (SMEs) especially could get access to and adopt advanced technology to improve their energy efficiency.

Another important barrier is a lack of monitoring and evaluation of a manufacturer's footprint. In China, no such standards have been established. Without standards, availability of data, or benchmarking, an assessment for improvement is almost impossible. The need to create such data and measurement standards for GHG emissions is acute. Doing so will help the government monitor and evaluate industrial emissions more effectively.

Finally, the social perspective should be considered as well. The Chinese manufacturing sector has made great strides in the last several decades, but there is still a need for large-scale modernization. A pre-requisite for this will be a highly trained labor force. Therefore, availability of a well-trained labor force should be ensured. Training opportunities could be offered to strengthen human capital and facilitate further modernization of the manufacturing sector.

United States



10
United States

10.1 Context

As the world's largest economy, the U.S. is the second-largest emitter of GHGs in the world, representing 14 percent of the global total. A modern and industrialized society, the U.S. has lower emissions per economic output than those of a developing economy (for example, China is the second-largest economy yet the largest GHG emitter). But lower emissions per unit of output are not necessarily due to more efficient use of energy and resources, but rather to the mix of sectors in the U.S. Over the last several decades, the U.S. has transitioned from high-emitting industries like manufacturing, as many of those jobs have moved overseas, and toward lower-emitting sectors like service.

The ICT industry has an important role to play in emissions reductions while also achieving other important goals like creating jobs and increasing energy independence. The abatement potential from ICT in the U.S. is quite large—350 $MtCO_2e$ in the power sector and 305 $MtCO_2e$ in the buildings sector—providing significant reductions (combined to be approximately 7 percent of U.S. total emissions in 2010). These reductions will result largely from lowering the use of energy and increasing the power mix to domestic renewable-energy sources. Furthermore, the savings from implementing ICT solutions can be invested back into the American economy.

A large abatement potential for ICT exists because there is still significant room for improvement in the U.S. toward reducing GHG emissions. Figure 47 illustrates that emissions have risen 10 percent since 1990. Unlike other developed countries—such as Germany and the U.K., which have generally decoupled economic growth from growth in emissions—the U.S. has experienced increases in GHG emissions as its economy has grown. In fact, the correlation with economic growth is clearly visible in 2008 and 2009 when the U.S. GDP fell as a result of the global recession; when the economic recovery began in 2010, emissions rose once again. There are,

> The U.S. is the second-largest GHG emitter, contributing 14% to the world total

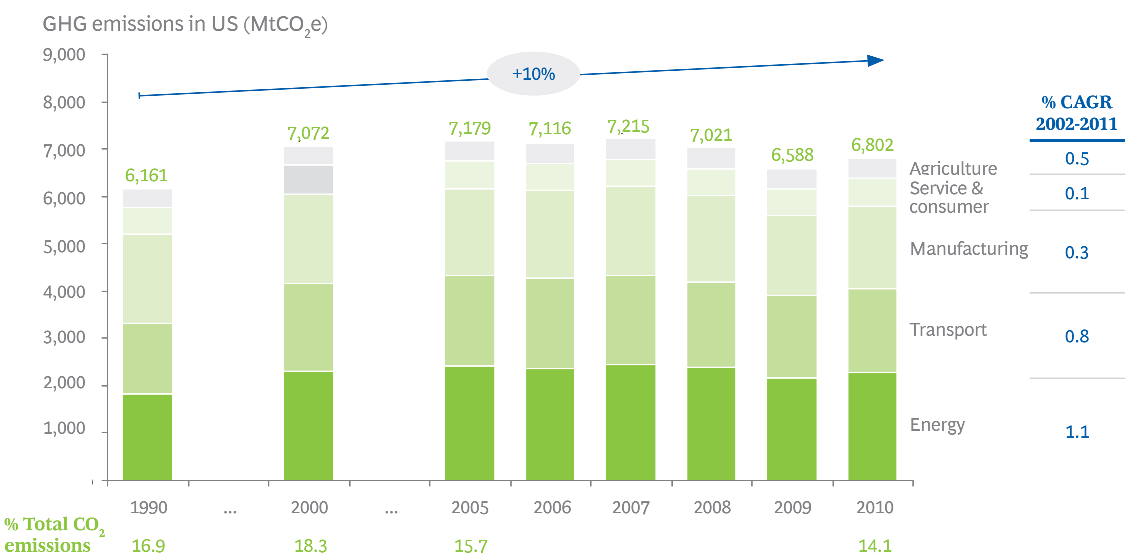


Figure 47
U.S. greenhouse gas emissions (1990-2010)

Note: Emissions data excludes LULUCF
Source: UNFCCC; BCG analysis

however, some indications that carbon emissions fell in 2011 (ignoring other GHG gases) as many U.S. power companies swapped out coal for relatively cleaner natural gas, consumers used less energy for heating because of a mild winter, and people drove less and purchased more efficient cars. [123]

The largest source of growth in U.S. GHG emissions has been in the energy sector, with total growth of 25 percent between 1990 and 2010. This was driven by increases in the need for electricity (electricity generation grew 37 percent from 1990 to 2010) with little effort taken to reduce the carbon footprint of generation.* It is likely, however, for emissions from power generation to fall in the future as more power generators switch from coal to natural gas. Transportation emissions have also significantly grown in the last two decades, at a CAGR of 0.8 percent. It is likely that emissions from the transportation sector will decline as well as a result of recently passed fuel efficiency standards: CAFÉ standards raised average fuel efficiency by 2016 to the equivalent of 35.5 mpg and 54.5 by 2025 which will cut 2M barrels of consumption of oil per day.[124]

Current policy environment in the U.S.

The policy environment in the U.S. for ICT GHG abatement solutions is mixed. While there are no major national targets set to address the increase in GHG emissions, there are some strong programs in place at the state level. These state level targets are not consistent across the U.S, and GHG reduction goals change drastically from state to state. Much of the reason that a concerted policy effort to address climate change does not exist at the national level and in many states is that many Americans remain unconvinced of the science behind climate change.[125] Moreover, the misconception that legislation to address climate change will necessarily have an adverse economic impact has become widespread, causing many American policy makers to deprioritize climate change legislation in favor of pursuing other items on their political agenda.

While targets were set for the U.S. in the Kyoto agreement (a multinational commitment to reduce GHG emissions worldwide that first entered into force in 2005) the U.S. chose not to ratify the targets, nor has it come close to achieving those targets. While there are some targets for reducing energy use in federal buildings, there is no coherent national emissions reduction plan in place at the national level. All efforts to institute a carbon tax or trading scheme have failed.

Most energy and environment policy is set at the state level, and certain states have more stringent standards. Several states have aggressive targets for acquiring energy from renewable sources, enforced through a renewable portfolio standard (RPS). As of 2012, 29 states and the District of Columbia have an RPS. [126] However, few states have explicit targets for reducing emissions; only 20 states have some form of energy efficiency resource standards (EERS). EERSs establish specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy-efficiency programs.[127] The strength of the RPS and EERS varies by state; some have strong targets with high alternative compliance payments (the penalty the utility has to pay for not meeting the targets) while others have weaker targets with little to no penalty.

There has been some development in creating regional cap and trade markets for emissions. Two programs are being developed in the U.S. The first implementation phase of the Western Climate Initiative (WCI) will start in 2012 in several U.S. states (California, Montana, New Mexico, Oregon, Utah, and Washington) and some Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec). WCI's target is to reduce 2020 emissions by 15 percent versus 2005 levels. Another regional program, the Regional Greenhouse Gas Initiative (RGGI), was implemented in 2008 and includes several northeast states. RGGI's target is to

*Note: "Electricity", EIA

123. IEA news http://iea.org/newsroomandevents/news/2012/may/name,27216,en.html

124. www.nhtsa.gov/About+NHTSA/Press+Releases/2012/Obama+Administration+Finalizes+Historic+54.5+mpg+Fuel+Efficiency+Standards

125. "Fall 2011 National Survey of American Public Opinion on Climate Change", the Brookings Institute

126. DSIRE; www.dsireusa.org/documents/summarymaps/RPS_map.pdf

127. DSIRE, www.dsireusa.org/documents/summarymaps/EERS_map.pdf

reduce 2018 emissions by 10 percent from 2009 levels. However, it is unclear how useful the support has been, and some states have threatened to leave the program (New Jersey left the initiative in late 2011). On a positive note, RGGI has amassed USD993 million in auction proceeds through March 2012; this is invested in consumer benefit programs, including energy efficiency, renewable energy, direct energy bill assistance, and other greenhouse gas reduction programs. The California Air Resources Board will also launch its own cap and trade system in 2013 that will be linked to the WCI.

Policy will play an important role in promoting ICT-enabled abatement solutions in the U.S. This is especially true because of the lack of a national target for emissions reductions and the fact that energy prices are low, which reduces the scope of economical applications. There is also likely no immediate price on carbon to discourage emissions, another reason that policy is important for removing any barriers to ICT adoption. As we will explore in the next sections, the potential for abatement in the U.S. is quite high.

10.2 Impact of ICT on GHG emissions

The U.S. has a strong foundation of innovative, ICT-enabled carbon abatement solutions. Business and consumers have always been eager to adopt modern technologies in their day-to-day activities. In fact, the U.S. is ranked seventeenth out of 152 for "ICT readiness" by the UN/ITU.[128] There is ready access to ICT, with widespread access to multiple devices and networks. There are an average of 1.16 computers per household[129] and nearly 100 percent of the population has access to some type of cell-phone service, more than 75 percent with 4G LTE.[130]

High quality and reliable ICT infrastructure, access to computing and mobile devices, high-speed networks, and the like contribute to an innovative culture surrounding carbon abatement solutions in the U.S. The U.S. is the leading country in ICT R&D spending (USD80 billion in 2008).[131] There are numerous innovative start-ups and established companies that develop many of the ICT solutions that have the opportunity for GHG abatement. But as we will explore in more detail for the power and building end-use sector, while the U.S. is innovative, it lags behind in large-scale adoption. Policy can

128. UN / ITU "Measuring the Information Society" 2011 report
129. 2008 data, Bureau of Labor Statistics
130. Verizon
131. TIA Whitepaper www.tiaonline.org/sites/default/files/pages/TIA%20U%20S%20%20ICT%20RD%20Policy%20Report.pdf

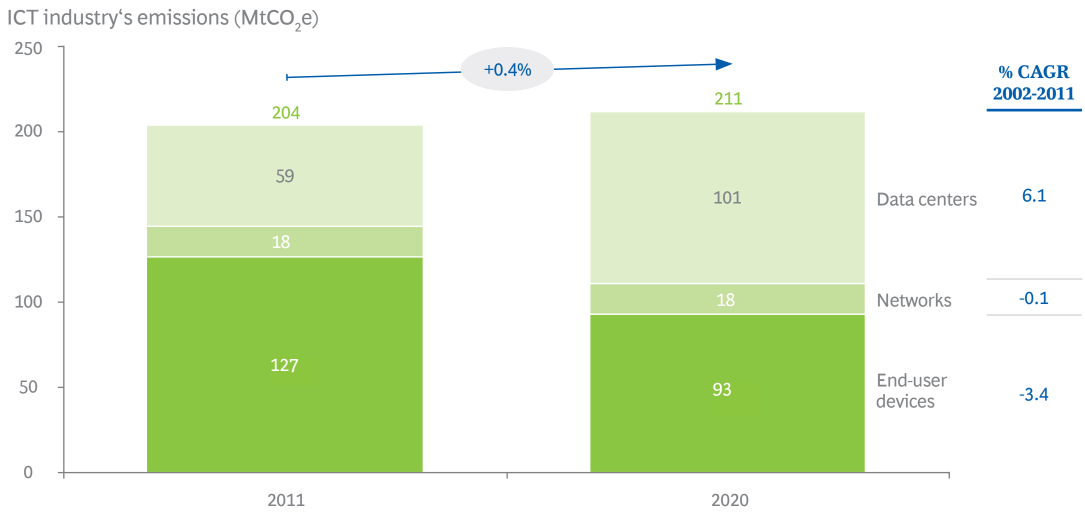


Figure 48
ICT industry's greenhouse gas emission in U.S.

Source: Gartner; Press search, BCG analysis play an important role by scaling up solutions where the market likely will not drive adoption.

Figure 2 shows ICT emissions in the U.S., which were estimated to be 204 $MtCO_2e$ in 2011 (representing approximately 3.0 percent of U.S.'s total emissions). Around 60 percent of these emissions were from end-user devices. Networks and data centers made up the rest. The higher usage of ICT in the future will lead to a slight increase in the total emissions to an estimated 211 $MtCO_2e$ in 2020 from 204 $MtCO_2e$ in 2011.

While the number of devices will significantly increase, the overall footprint of end-user devices is expected to increase only slightly, by 0.4 percent per year. Three important trends will drive this reduction: significant improvements in manufacturing, device efficiency increases, and a change in device mix from desktop PCs to laptops and tablets. Efficiency improvements in networks will nearly match the need for the higher data traffic, causing those emissions to stay constant. On the other hand, data center emissions are expected to nearly double as the amount of stored data is expected to drastically increase. Several technologies (for example, running data centers at a higher temperature, virtualization, more energy-efficient processors, natural cooling, switch to DC power, and so forth) to improve data center energy usage are currently in development and being tested. However, since many of these are at an early stage, it is hard to predict if any will lead to substantial emissions reductions.

GeSI's U.S. Addendum to the SMART 2020 report estimated ICT industry's emissions in 2007 at 150 $MtCO_2e$. The estimate for 2011 in this study is higher by 54 $MtCO_2e$ because of two drivers: inclusion of embodied emissions and a broader scope of devices covered in this study. Embodied emissions in the U.S. are approximately one-third of the total ICT emissions, and thus account for the bulk of the higher estimate. SMARTer 2020 includes smartphones, tablets, and Web-enabled TVs, all of which were not included in the U.S. addendum. All of these amount to only 14 $MtCO_2e$ in 2011.

As a matter of fact, after accounting for these two factors, the 2011 estimate in SMARTer 2020 is slightly less than what would be expected on the basis of the U.S. addendum. This is consistent with the lower global ICT emissions estimate in SMARTer 2020 for 2011 due to more accurate data, especially for networks emissions.

Further, this study estimates a slightly higher footprint of the ICT industry in 2020 than GeSI's U.S. Addendum to the SMART 2020 report. The current estimate is 31 $MtCO_2e$ higher, primarily due to the inclusion of smart devices (tablets and smartphones) and Web-enabled TV emissions. The former accounts for 17 $MtCO_2e$, while the latter for 11 $MtCO_2e$. Further, as mentioned in the chapter on global emissions, availability of more accurate data has made the current estimate more precise.

10.3 Abatement potential in power and buildings end-use sectors

In the U.S. section we will focus on the power and buildings sectors. The power sector in the U.S. makes up 42 percent of all emissions. There are several factors driving these emissions. One is simply that the U.S. has a relatively dirty power mix: the most prevalent fuel for electricity generation in the U.S. is coal (37 percent), which emits more CO_2 than any other traditional fuel source aside from oil, which is rarely used.[132] The total emissions factor is 0.67 $kgCO_2/kWh$, much higher than the EU27 average of 0.44 $kgCO_2/kWh$.[133] We focus on the power sector not only because the addressable emissions are large but also because there is a large abatement potential and a strong role for ICT. As we will explore in more detail in the next section, ICT plays a vital role in smart grid, integration of renewables, and other important sublevers in this sector.

132. EIA

133. Department of Energy & Climate Change, " 2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting"

The second sector we focus on is the buildings sector, which is responsible for approximately 37 percent of all emissions in the U.S.[134] This sector plays an especially important role in the U.S. because of the high average building size and relatively high heating and cooling needs. We believe there is substantial room for improvement in policy. The U.S. lags significantly behind in policy on energy efficiency for buildings. The business case for energy efficiency improvements is frequently strong, and these improvements are an under-utilized source of savings. There is an important role for policy to identify some of the structural barriers, like building codes and other regulations, that restrict the adoption of technology that could reduce emissions. This sector is also especially important because ICT is the principal driver behind many important sublevers, fore example, building management systems.

The next section discusses the emissions trends in these sectors, drivers of these trends, the role of ICT-enabled solutions, and the role of policy in encouraging adoption.

Power

Context

The power sector, critical to the functioning of the American economy, is marked by high energy use, a dirty generation mix, and an aging and inefficient grid. The emissions from this sector make up 42 percent of all U.S. emissions. This presents a excellent opportunity for ICT-enabled solutions to reduce emissions and make the power grid more efficient. In fact, we estimate that the total abatement potential of ICT in the power sector is 350 $MtCO_2e$ or 1.7 times the total emissions from the ICT industry in 2020.

The U.S. has a relatively dirty power-generation mix. Coal represents the largest fuel source and is used for 37 percent of the total electricity generation. The second largest fuel source is natural gas, followed by nuclear. The focus on fossil fuels for generation results in a high emissions factor (0.67 $kgCO_2e/kWh$), which is significantly above the EU27 average of 0.44 $kgCO_2/kWh$.[135] There are likely future reductions in the emissions factor; however, as coal power plants are decommissioned for economic and regulatory reasons. Natural gas will become an increasingly important fuel source, as growth in domestic production will continue to push prices lower. Because it emits fewer GHGs per unit of energy created, natural gas will help lower the U.S.'s emissions factor.

37% of the electricity in the U.S. is generated from coal

Figure 49 illustrates that emissions from the power sector have been decreasing over the last decade at a rate of 3 percent, from 4.3 $GtCO_2e$ in 2000 to 3.2 $GtCO_2e$ in 2010. This decrease in emissions is mainly driven by decreases in the emissions from coal as the generation has shifted to using other fuels.

But while emissions have been decreasing, the grid has remained outdated and inefficient, with important concerns surrounding reliability, especially as demand increases in the future. Grid operators and regulators will have to maintain sufficient reserve margins to preserve adequate supply reliability. This could become troublesome as a significant amount of generation is going off-line and there is little price support for building new capacity, especially in unregulated markets.

The U.S. generally has low energy prices. This is partly due to lower taxes on energy than in other developed economies as well as the availability of domestic oil-and-gas resources. This decreases the economic favorability of many renewables and some of the sublevers discussed in this section, increasing the importance of policy to ensure widespread adoption.

The policy landscape for ICT in the U.S. is quite mixed. There are generally no national level targets or support for the power sector, with a clear exception being the investment

134. EIA
135. Department of Energy & Climate Change, " 2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting"

Table 18
U.S. electricity generation in 2010 split by fuel

Source: EIA

Fuel	% of total generation
Coal	37
Gas	31
Nuclear	20
Renew	5
Other	7

tax credit (ITC) and production tax credit (PTC).[136] Both of these are tax-related subsides that provide support for investment in renewables. Any other support for renewables is set at the state level through RPS, which set targets for the amount of generation a utility must source from renewable sources.[137] The strength of these standards varies by state, with states like California and New Jersey leading the way.

Net metering is an policy that is currently driving much of the adoption of solar and other distributed generation. Under net metering, system owners receive retail credit from a utility for at least a portion of the electricity generated by their on-site renewables that they cannot use and which are thus fed back into the grid. This policy improves the economics of solar and other systems, since the peak for solar power generation occurs during the day, when people often are notat home to use this electricity. Over 43 states have some policy addressing net metering.[138]

There is less support for smart grid and other demand management technologies. While there have been significant improvements in the policy space, especially through recent FERC orders,the region independent service operators (ISOs) have been slow to make any significant change toward large-scale adoption, although it is worth noting there have been some important pilot demonstrations.

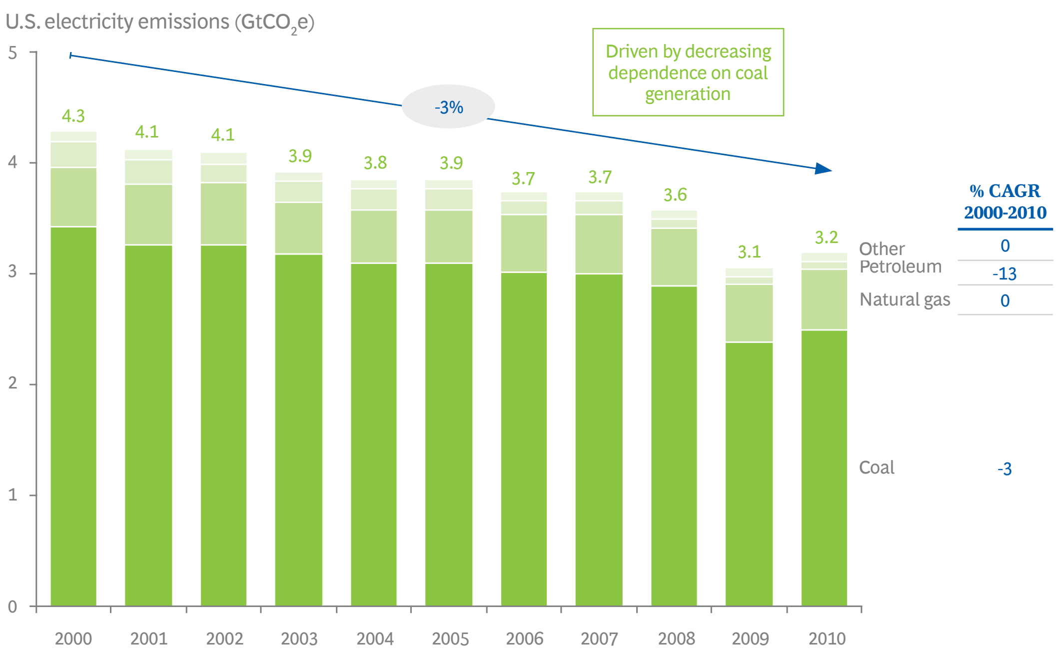
Power abatement potential

ICT has an important role to play in GHG abatement in the power sector in the U.S. We estimate that the total abatement potential is 350 $MtCO_2e$, driven by several important

136. DSIRE
137. DSIRE; www.dsireusa.org/documents/summarymaps/RPS_map.pdf
138. www.dsireusa.org/documents/summarymaps/net_metering_map.pdf

Figure 49
U.S. electricity emissions in the power sector by fuel

Source: EIA



sublevers, most notably integration of renewables (197 $MtCO_2e$) and power grid optimization (91 $MtCO_2e$). The full results are listed in Figure 50.

Integration of renewables represents nearly half of the abatement potential in the power sector. Being a nearly-carbon free source of energy, it can replace carbon intensive power generation. ICT plays an important role in integrating these renewables into the grid. Most renewables are described as being intermittent, which means their generation fluctuates depending on variables like the weather or time of the day. This can be a problem because the supply of electricity must perfectly match the load; in the U.S., an aging and efficient grid makes this balance even more difficult. ICT can assist this integration by improving communication between grid operator and the renewable power plant, analyzing weather for predicting future generation, and performing complex data analysis and optimization.

ICT also plays an essential role in power grid optimization, representing 26 percent of the abatement potential. Power grid optimization is essential for reducing transmission and distribution losses, and for reducing the reliability concerns. ICT is important both from a communication and optimization perspective, as it can monitor the grid and provide real-time optimization of its use.

350 $MtCO_2e$ Breakdown of ICT-enabled GHG reduction potential	Sublevers	Drivers of sublevers
6%	Demand management (21 $MtCO_2e$)	• Reduction of peak load electricity • Dependent on system of smart meters and other Smart Grid infrastructure and changing consumer behavior
6%	Time-of-day pricing (22 $MtCO_2e$)	• Increasing the percentage of base-load generation and reducing the demands on the grid – requires proper market to price electricity
56%	Integration of renewables (197 $MtCO_2e$)	• Creates opportunity to replace electricity from grid with a carbon-free energy – dependent on RPS at state level, grid's ability to handle intermittent generation and new transmission
2%	Virtual power plant (6 $MtCO_2e$)	• Dependent on advanced smart-gird technology and advanced regulations that cut 'red-tape'
	Island grid	• Not an important driver in US due to availability of grid-connected electricity
4%	Power-load balancing (13 $MtCO_2e$)	• Large abatement opportunity, but may be technologically limited • Dependent on ISO and other regulatory changes
26%	Power grid optimization (91 $MtCO_2e$)	• Important abatement potential in the US due to aging infrastructure

Figure 50
ICT-enabled GHG reduction potential in power sector

Source: BCG analysis

Case Study
Echelon launches apps for the smart grid

Although many utilities in the U.S. would like to effectively use smart grid technology to understand their customers' energy consumption patterns, managing the deluge of smart grid information is a challenge. Making sense of all of the data collected by smart meters, grid sensors, and other devices typically requires building large, centralized data centers to analyze the inputs. The problem, however, is that utilities do not necessarily have these "big data" capabilities to make sense of what they receive or have the resources to build them. As a result, they cannot effectively use the smart grid to improve grid efficiency and cut their GHG emissions.

Echelon, a San Jose, CA-based company, has developed innovative smart grid monitoring technology that is modular and does not require companies to invest in large back-end ICT support systems to understand and analyze smart grid outputs. Rather than analyzing large quantities of individual data points at a centralized center, Echelon's smart grid app analyzes the data itself at the transistor and condenses it into more manageable quantities of information before sending it to the utility for analysis. This more manageable level of information allows companies to more easily form load profiles to understand where, when, and how their energy is being used. By virtue of the fact that Echelon's meters are cutting down on the quantity of data sent to utilities, it can integrate even more useful data than other systems. Echelon's apps have integrated data on distribution transformers monitoring, outage and low-voltage loss detection, transformer oil temperature, and other quality-monitoring data. All of these data, if successfully understood and incorporated by utilities, offer the ability to cut down on transmission losses, unnecessary power generation, and GHG emissions.

Though innovative, Echelon's technology has yet to find a strong foothold. Despite holding a large share of the smart grid app market in Europe, Echelon has only one project in the U.S., with Duke Energy. If Echelon can demonstrate the superiority of modular data processing for smart grid technologies over more traditional big data-center approaches, it could help more utilities make sense of the smart grid data they are receiving and, in turn, cut emissions.

Barriers and recommended policy steps to overcome them

ICT-enabled sublevers offer substantial potential to reduce carbon emissions in the renewable sector. However, several barriers to adoption exist. This study discusses these barriers and, the importance of business case, and proposes policy steps to ensure successful adoption of these solutions.

In general, the business case for sublevers in the power sector is not strong; additional support is needed from policy to encourage development in this sector. The least favorable business case by sublever is time-of-day pricing and virtual power plant. Both of these sublevers depend on regulation, markets, and advanced pricing structures that simply do not exist for large-scale adoption today in the U.S. Balancing the grid through reducing demand (demand management) or storage (power-load balancing) can have a slightly better business case, but is still difficult to implement because of high up-front costs in the case of storage; or the lack of proper regulation and pricing structures in the case of demand management. Because of the dependence on regulation and sensitivity to small changes in pricing, many of these sublevers are also quite risky from a business case. On the other hand, power-grid optimization sometimes can have a stronger business case because of the significant reduction of transmission and distribution losses.

The business case for the integration of utility-scale renewables without subsides is currently weak. The revenue from utility-scale renewables depends on wholesale rates of electricity, which can vary drastically, but are often quite low in the U.S. (anywhere from \$0.04 to \$0.08/kWh).[139] These low prices can make it difficult for large utility scale renewables to compete because of high up-front costs. The standard tool for comparing the total cost for generation versus the electricity rate is the levelized cost of electricity (LCOE). It includes the initial capital, discount rate, and the costs of continuous operation,

139. EIA

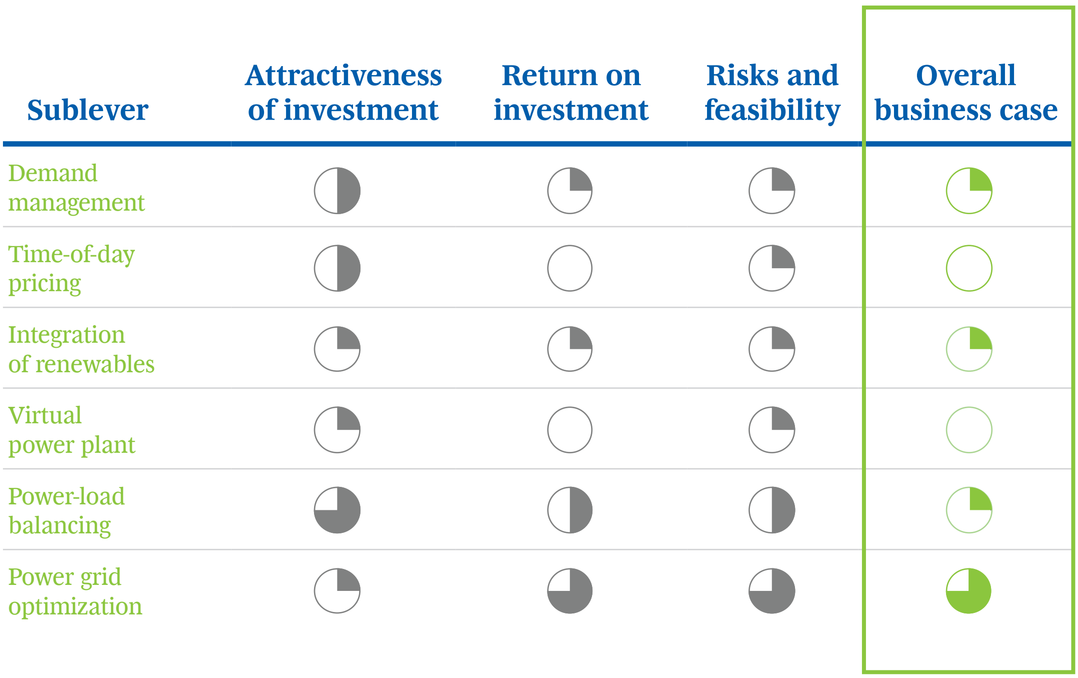


Figure 51
Analysis for business case by sublever

Source: BCG analysis

Low attractiveness
High attractiveness

fuel, and maintenance. Today, system costs can average around \$2.5/W.[140] With typical assumptions for a more sunny location in the U.S.[141] the estimated levelized cost of electricity will be around \$0.13/kWh. Including the investment tax credit (a 30 percent reduction on the upfront costs), this lowers the cost to around \$0.10/kWh, still significantly higher than the wholesale rate of electricity, meaning that additional support from RPS and other local incentives are still needed. However, system costs are likely still going to decrease in the future, meaning the LCOE could start to approach the wholesale electricity rate in the long term.

140. NREL, please note that prices are quickly decreasing

141. BCG model; model assumes WACC of 0.05, lifetime of 20 years, and total solar irradiance of 5.3 kWh/m2/day

To first understand where policy should play the biggest role, we prioritize on the basis of the business case and total abatement potential.

As you can see from Figure 51, very few of the sublevers in the power sector have a favorable, unsubsidized business case in the U.S., which means that there is an important role for policy to play to helping improve the economics. We prioritize policy on those sublevers that have the greatest potential to reduce emissions (those in the upper-right quadrant of the plot); that is, integration of renewables in power generation and power grid optimization

Figure 52

Prioritization of policy by potential for CO_2e reduction and business potential

Source: BCG analysis

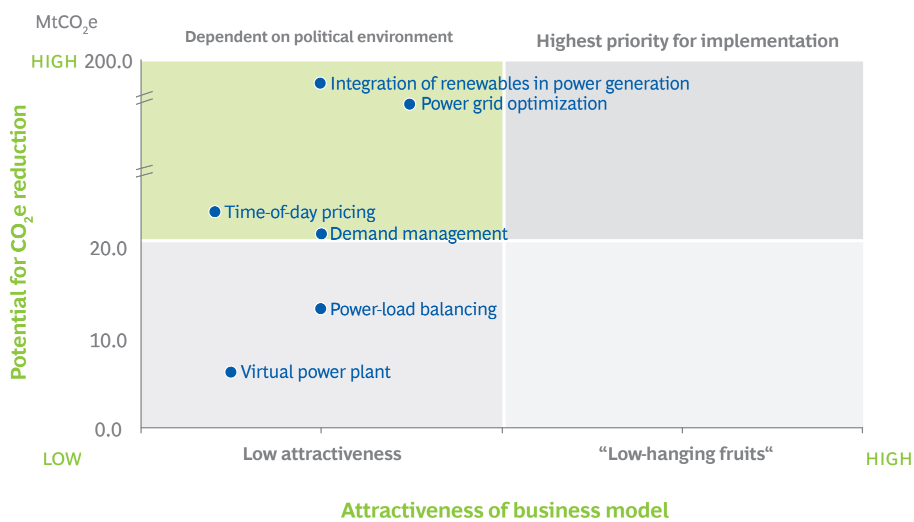


Table 19
Barriers to adoption of ICT-enabled carbon abatement solutions and policy steps to overcome these barriers

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Economics	• Certain technology and sublevers are not NPV positive • Other technology may be NPV positive but have too long of a pay-back period for adoption or the capital requirements are too large	Promote technological innovation through R&D funding and programs Change economics through:	• Important role for ICT industry to reduce costs • Advertise the potential of jobs through "green-growth" and opportunity of new industries/ start-ups through innovation • Rebates for ICT enabled upgrades and solutions • Price carbon to encourage more green technologies (but difficult to implement in US)
Full deployment & adoption	• System integration is vital, technology must be fully deployed or the entire system can't function (e.g. smart meters)	Mandate through state regulators	• Create decentives for those that fail to adopt (but not as strong as incentives) • Build a complete policy support that covers entire range of technologies
Aligned incentives/ consumer behavior	• Regulation/decoupling in the power sector • Proper set-up of pricing schemes for electricity (e.g. dynamic pricing, price for carbon, negawatts, DR, etc.) • Consumers unwilling to change ingrained behaviors	Set up regulations and markets that are favorable to carbon abatement	• Encourage market pricing of electricity and negawatts – make information and business case clear • Factor in the need for changing consumer behavior in policy • Important to promote ICT's role in providing energy security

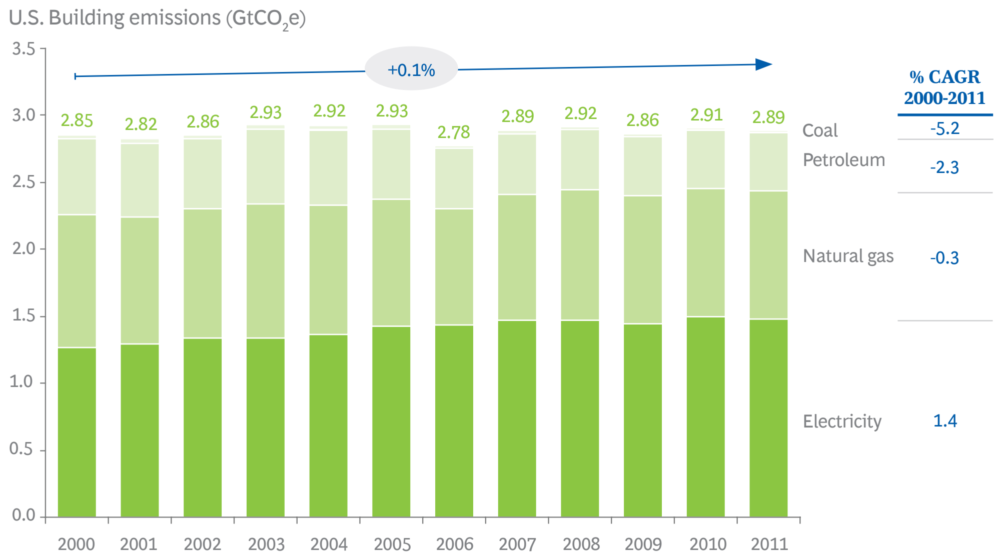
Table 19 lists specific barriers to the adoption of these sublevers (and the other in this sector) and the role of policy. There are three important barriers we have identified: economics, full deployment, and aligned incentives.

As identified above, the single most important barrier is economics. Most of the sublevers in the power sector do not currently have a strong business case. They are either too high in cost or do not provide enough return in terms of revenue of savings. While there is some policy in place today to address costs, additional measures can be taken, one of which is to promote more fundamental research (through organizations like the National Science Foundation or the Department of Energy) that is targeted at improving the performance or reducing the costs of the technologies used in these sublevers. The investment in this primary research opens the door and helps drive further innovation and the creation of new jobs—a core strength of the U.S. Addressing research helps drive long-term concerns with economics, but to address more immediate problems, direct incentives can be used, such as stronger RPS policies across more U.S. states and additional rebates for ICT technologies.

A second significant barrier is the need to have deployment and adoption. This is particularly important for the smart grid in that there are several technologies that must be deployed in order to capture the entire value. Time-of-day pricing and demand management serve as two illustrative examples. These technologies depend on the implementation of smart meters in the case of time-of-day pricing and smart appliances in homes and businesses for both of those sublevers. Without covering the entire technology suite, they are ineffective. The role of policy is to ensure adoption, ideally through

Figure 53
Historic emissions from U.S. buildings, split by fuel

Source: EIA



incentives, but could also consider penalties for those who fail to adopt. Smart policy that supports the entire value chain is also needed and takes into account the first- and second-order implications and interplay among the technologies.

The last major barrier identified is the need to align incentives, important for nearly every power sector worldwide. The U.S. is especially ripe with misaligned incentives because of the complex rules around regulation, which vary drastically from state to state. Very often in the sector the organization or individual with the authority or ability to implement an innovative solution does not reap the benefit. Here, policy has an important role of making sure current regulations align incentives. For example, by providing the proper pricing of electricity in open markets, policymakers can ensure that all parties involved reap the benefits of ICT solutions in a transparent manner.

Buildings

Context

Buildings in the U.S. use a significant amount of energy, which results in approximately 37 percent of all GHG emissions in the U.S.[142] This high energy use is partly driven by poor design and lack of insulation. In addition, there are several regions of the country where there are inherently high heating or cooling costs because of the climate. All of these factors combine to result in very high costs; for example, the total commercial energy costs in the U.S. are USD179 billion (approximately USD1.50/ft_2).[143] This provides an excellent opportunity for ICT to provide substantial financial savings in addition to reducing GHG emissions.

While buildings are responsible for a large amount of U.S. emissions, over the last decade emissions have been generally steady. Figure 53 illustrates how emissions have grown at a rate of 0.1 percent from 2000 to 2011 (emissions were approximately 2.9 $GtCO_2e$ in 2011). Electricity makes up the largest portion of emissions, followed by fuels used for heating (natural gas and petroleum).

Most buildings in the U.S., including older buildings and new builds, have not leveraged opportunities to increase their energy efficiency. The U.S. lags significantly behind other developed economies in policy for building energy efficiency. There are very few binding goals or targets at the national level. One of the few goals, reducing energy consumption by 30 percent by 2015, applies only to the federal sector. Much as in the power sector, most of the energy efficiency

142. EIA
143. Buildings, EIA

standards are set at the state level. Only 20 states have some form of EERS, which establish specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs.[144] At a local level, there are some state- and national-supported utility programs for energy efficiency and some progress toward rating buildings based on their efficiency has been made (for example, LEED certification of commercial buildings) but in general, more support is needed.

The business case for energy efficiency improvements, depending on the technology used, can be very strong and thus these improvements represent an under-utilized source of savings. Policy is needed to identify structural barriers, such as building code and other regulations, that restrict the adoption of technology that could reduce emissions.

Buildings abatement potential

We estimate the abatement potential for the identified ICT-enabled solutions is 305 $MtCO_2e$ (or 1.4 times the total emissions of the ICT industry), driven by several important sublevers like building design (130 $MtCO_2e$) and integration of renewables (87 $MtCO_2e$). The full results are listed in Figure 54.

Building design provides the largest abatement potential (130 $MtCO_2e$) among all of the building sublevers in the U.S. This potential is partly driven by current inefficient design of U.S. buildings. ICT can be used to help model and calculate the ideal design. While efficient buildings can be built without the use of ICT (by using more insulation, for example), ICT can help plan for the most efficient use of resources. The sublever has a small up-front cost but results in significant savings in energy and GHG over the lifetime of the building.

Building management systems are ICT-dependent, computer-based systems that control and monitor the building's mechanical and electrical equipment including ventilation, lighting, power systems, fire systems, and security systems. We estimate the total abatement from these systems to be 48 $MtCO_2e$. Through cases like the example implemented at the Empire State Building in the global chapter, it is clear these systems have the opportunity for GHG abatement in the U.S., especially in large commercial buildings.

144. DSIRE, www.dsireusa.org/documents/summarymaps/EERS_map.pdf

305 $MMtCO_2e$
Breakdown of ICT-enabled GHG reduction potential

	Sublevers	Drivers of sublevers
28%	Integration of renewables (87 $MtCO_2e$)	• Large building electricity use creates opportunity to replace electricity from grid with a carbon-free energy free of transmission and distribution losses
16%	Building management system (48 $MtCO_2e$)	• Would provide savings for nearly every type of building – very large addressable market but depends on quality technology and favorable economics
43%	Building design (130 $MtMtCO_2e$)	• Large addressable market because of current inefficient design and high penetration because of low costs (requires very little investment during design phase)
13%	Voltage optimization (40 $MtCO_2e$)	• Large theoretical potential driven by large electricity use in building sector, but dependent on smart grid infrastructure being in place

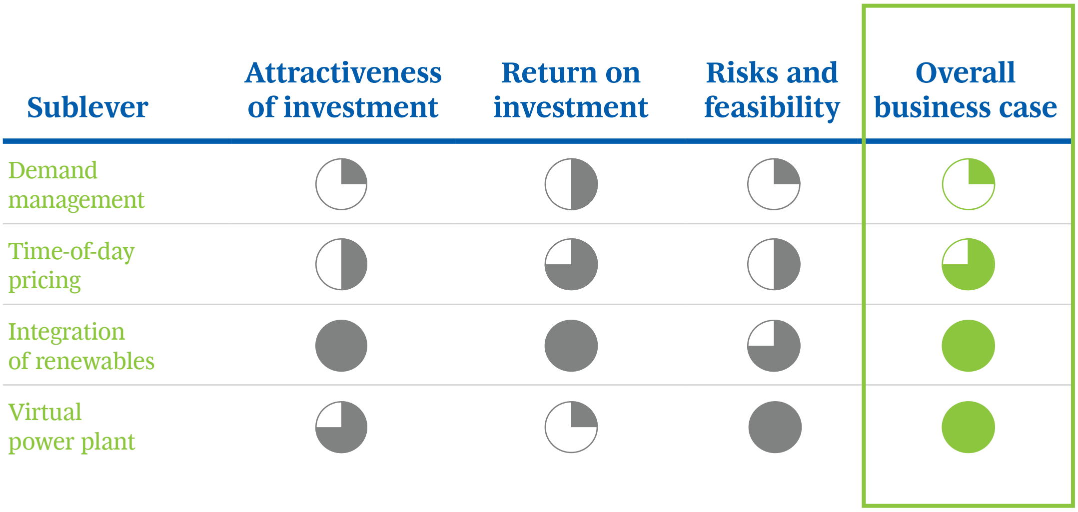
Figure 54
Analysis of business case by sublever

Source: BCG analysis

Figure 55
Analysis of business case by sublever

Source: BCG analysis

Low attractiveness
High attractiveness



Voltage optimization offers savings from reduction in voltage received by the end user, and consequently reduces total energy use and emissions (potential of 40 $MtCO_2e$ in U.S.). As with nearly all of the sublevers, the economics of adopting these solutions should be favorable in many situations.

Barriers and recommended policy steps to overcome them

The business case for adopting ICT-enabled sublevers in the buildings sector is generally positive. But even with a positive business case, the U.S. has failed to see large-scale adoption. In this section, we will explore the business case and resulting barriers restricting the adoption of ICT.

In general, the business case for sublevers in the buildings sector is strong, especially in terms of the total return. Weakening the business case are high up-front costs and the longer payback periods. The strongest business case among the sublevers exists for building design and voltage optimization. Both of these sublevers can have relatively low up-front costs, little risk associated with implementing the solution, and a strong return on investment. Of the two, building design is likely the strongest case, with a relatively low investment and a reduction in emissions (and thus resulting reduction in energy costs) as much as between 30 to 40 percent.[145] The business case for building management systems (BMS) is also quite strong; however, the upfront cost can be slightly larger and also a bigger risk since changes in the price of energy over the lifetime of the BMS could change the economics (namely, significant decreases in the cost of heating fuels and electricity could reduce the expected savings in energy costs that was expected to pay for the high up-front costs; this is especially important for systems that are funded by a third party where a performance contract promises savings in the future). Finally, the weakest business case (though it drastically depends on the local weather and retail electricity rates of the region) is the integration of renewables.

Exploring in more detail the business case for the integration of renewables, there are two important factors to consider: the total system price for installing the system and the retail rate of electricity. Compared to installing renewables in the power sector, the business case for buildings is much more favorable because the retail rates of electricity are much higher. In the US, retail rates generally vary from ~$0.08 to $0.15/kWh (and even higher in a state like Hawaii).[146] If we explore rooftop solar energy in more detail, the up-front costs have drastically decreased within the last couple years, with module prices falling by at least half. Today's system costs can average around $4.5/W.[147] With typical assumptions for a more sunny location in the U.S.[148] the LCOE for solar is

145. SMART 2020
146. EIA "State electricity profiles"
147. LBNL, NREL
148. BCG model; Model assumes WACC of 0.05, lifetime of 20 years, and total solar irradiance of 5.3 kWh/m2/day.

DRAFT

Case study
Controlling home heating using occupancy prediction

Heating buildings when occupants are not present represents a large waste of resources. Home heating uses more energy than any other residential energy expenditure, making it an important goal for reducing energy use, saving money, and cutting GHGs. Though programmable thermostats help address this problem, fewer than half of U.S. households have them installed and over 30 percent of those that do fail to use the programming feature. This unnecessary heating wastes money for consumers and releases GHGs.

To address this problem, Microsoft developed PreHeat, a system that is easier to use than a programmable thermostat and helps avoid the tradeoff between comfort and energy savings. PreHeat systems were installed in three houses in the U.S. and two in the U.K. and utilize active RFID, passive IR-based occupancy sensors, temperature sensors, and heating system controllers used in conjunction with PC-based control software. From those sensor inputs, the software learns to predict occupancy schedules on the basis of present and past occupancy patterns, and turns on the heat only when people require it.

The homes in the U.S. were heated at the level of the entire house (for example, not room by room) and PreHeat was able to ensure much better occupant comfort than when using a programmable thermostat and consumed the same amount of gas. The homes in the U.K., on the other hand, were analyzed and heated at the room level, giving PreHeat the ability to acquire additional energy savings by heating rooms adaptively at different times of day. In the U.K. homes, PreHeat halved the amount of time an occupant spent in unheated rooms while reducing gas usage by 8 to 18 percent. While these results are impressive, there is room for improvement. Microsoft is hoping to use more sophisticated algorithms to predict when occupants are about to depart or to detect when occupants are sleeping to lower the heating costs and emissions. Though PreHeat has already demonstrated its ability to save on energy costs and lower GHG emissions from heating, its abatement potential will rise as the software becomes increasingly sophisticated and becomes commonplace technology in buildings worldwide.

around \$0.25/kWh. Once the ITC incentive is included, the cost is reduced \$0.17/W, approaching the retail rate of electricity. With increasing costs of electricity, drastically decreasing system costs (due both to the fall in module prices and the remaining cost of installation), it is expected that integration of solar energy will be profitable in many of the sunnier states that have higher electricity rates within the next couple years.

To first understand where policy can play the biggest role we explore each sublever based on the attractiveness of the business case and total abatement potential (see Figure 56).

It is clear in Figure 56 that the business case for many of the solutions is quite positive. Only the integration of renewables in buildings sublever has a weak business case. This is due to relatively low retail electricity rates of electricity and the relatively high costs of distributed generation. Many of the policy recommendations discussed in the power sector (investment in R&D and financial incentives) will help improve the economics of this sublever.

Among the other sublevers, there are several important structural barriers to consider; these are listed in Table 20.

The single most important barrier for the buildings sector is financing. While ICT-enabled solutions have a substantial return, the up-front costs can be especially high, particularly in the residential sector, where it can be difficult for homeowners to cover them. This is especially true in the U.S., where large home sizes make these upgrades expensive and very few financing opportunities for these types of upgrades are available to homeowners. The role of government and policy is to provide easier access to capital for these types of upgrades. This can be done directly by giving government-backed loans at low costs of capital. Policy also has a role, through tax incentives and relaxing financial controls, to help reduce the cost of capital for building upgrades.

A second important barrier is behavior and education. In the U.S., many homeowners and commercial building owners are unaware of the existence of ICT solutions to save energy costs. Lack of familiarity with these ICT-enabled sublevers can deter adoption. Executives can be wary of investing in solutions for commercial buildings even when their building managers make a strong business case for the upgrades. At the residential level, the complexity of the contracting, financing, and execution of upgrades can create a significant barrier to action. Policy has a role in the distribution of information and giving consumers unbiased perspectives to help them make educated decisions. There is also a role for government to execute pilot programs, serving as a positive example and illustrating

Figure 56
Prioritization of policy by potential for CO_2e reduction and business potential

Source: BCG analysis

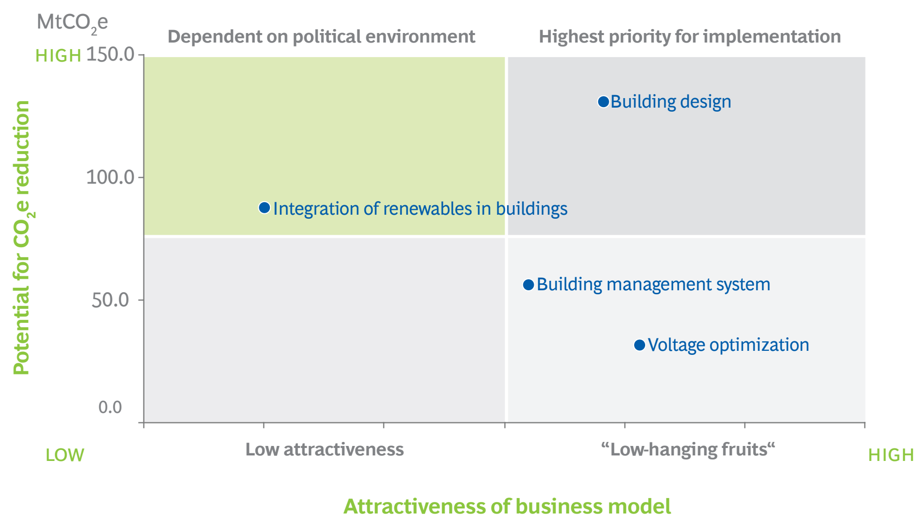


Table 20
Barriers to the adoption of ICT-enabled GHG abatement solutions in the buildings sector and policy steps to overcome them

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Financing	• Private and public customers don't have capital to cover high-up front costs • Financing and contracting is becoming an essential part of the customer offering • Performance contracting can help alleviate some problems, but must have partners willing to invest	Provide easy access to capital	• Create governmentally funded but privately controlled funds for large capital upgrades • Relax financial controls and taxes on money loaned for ICT enabled upgrades
Economics	• Certain technology and sublevers are not NPV positive • Other technology may be NPV positive but have too long of a pay-back period for private adoption	Promote technological innovation through R&D funding and programs	• Important role of ICT industry to lower prices or provide better performance at similar price • Advertise the potential of jobs through "green-growth" and opportunity of new industries/start-ups through innovation
		Change ecomomics through:	• Rebates for ICT enabled upgrades and solutions (target high-impact comm. sector) • Price carbon to encourage more green technologies (likely difficult to promote)
Behavior & education	• Due to the complexity of contracting, financing, and execution – customers need more education and hesitate to start projects because of lack of familiarity	Create incentives that support decision makers and business leaders	• Ensure access to information needed to make informed decisions • Use case-studies and examples to build credibility and make benefits clear
Split incentives (landlord/ tenant problem)	• Tenants or others that are renting cannot capture benefits of efficiency upgrades	Create regulatory structures that align incentives	• Encourage building owners to control energy costs • Support leasing and other financing options for renewables

to homeowners and the private sector that the implementation of these sublevers can be effective.

The final barrier, the landlord-tenant problem, is a result of split incentives. In many rental units in the U.S., the tenant pays for his or her energy costs, but does not have the authority to make energy efficiency upgrades to the building. Even if the tenant has the control to make upgrades, it may not make economic sense as they cannot ensure that they will live in the building long enough to cover the initial cost of the investment. The situation can be even more challenging for commercial spaces in which there may be many stakeholders involved within the same building (the tenant, the building manager, a real estate intermediary, the building owner, and so forth). Similar problems can even occur within companies' own facilities. The Uptime Institute recently published a report, the 2012 Data Industry Survey, finding that only 20 percent of organizations' IT departments pay their electricity bill—highlighting intercompany disconnects on creating an energy efficiency environment. Policy can assist in this through regulation to align incentives for the purchase of energy efficiency upgrades.


Germany

11 Germany

11.1 Context

Germany's GHG emissions have been declining over the last two decades. Further efforts, however, will be required to meet its ambitious GHG abatement targets, especially in the power sector. By 2022, Germany plans to phase out nuclear power generation, which constituted 22 percent of its total power generation capacity in 2010. There will be a big impact on Germany's overall GHG footprint if renewable energy scales up successfully to replace nuclear energy, or even goes beyond to replace fossil fuels.

According to UNFCCC data, Germany's GHG emissions in 2010 were 937 $MtCO_2e$,[149] or 1.9 percent of global emissions (see Figure 57). The power and manufacturing sectors contributed the biggest shares of emissions in 2010, at 34 percent and 26 percent, respectively. These two sectors were followed by the transport sector (17 percent), service and consumer sector (15 percent), and agriculture (8 percent).

Since 1990, however, emissions in Germany have been declining steadily, at a rate of 1.4 percent per year. Figure 57 shows the trend from 1990 to 2010. This trend is similar to the trend in the U.K., where emissions declined at a CAGR of 1.3 percent over the same time period. In 2010 Germany had 25 percent lower emissions than in 1990. Additionally, the global footprint has increased during the same period, but Germany's share of global emissions has decreased. In 1990, Germany's share of global emissions was 2.4 percent, but by 2010 its share had dropped to only 1.3 percent.

> German GHG emissions in 2010 had declined to 75 percent of 1990 levels

The manufacturing sector has led the reduction in Germany's emissions. The sector has contributed 64 percent of the total decline of 310 $MtCO_2e$ from 1990 to 2010. In 2010, the manufacturing sector's footprint was 248 $MtCO_2e$ as opposed to 447 $MtCO_2e$ in 1990. The primary driver of this reduction has been a continuously smaller share of the sector in the economy, primarily due to the deindustrialization of the former East Germany. The former East German industry was focused on energy-intensive basic industries. Additionally, energy efficiency was

149. Excludes "land use, land use change, and forestry"

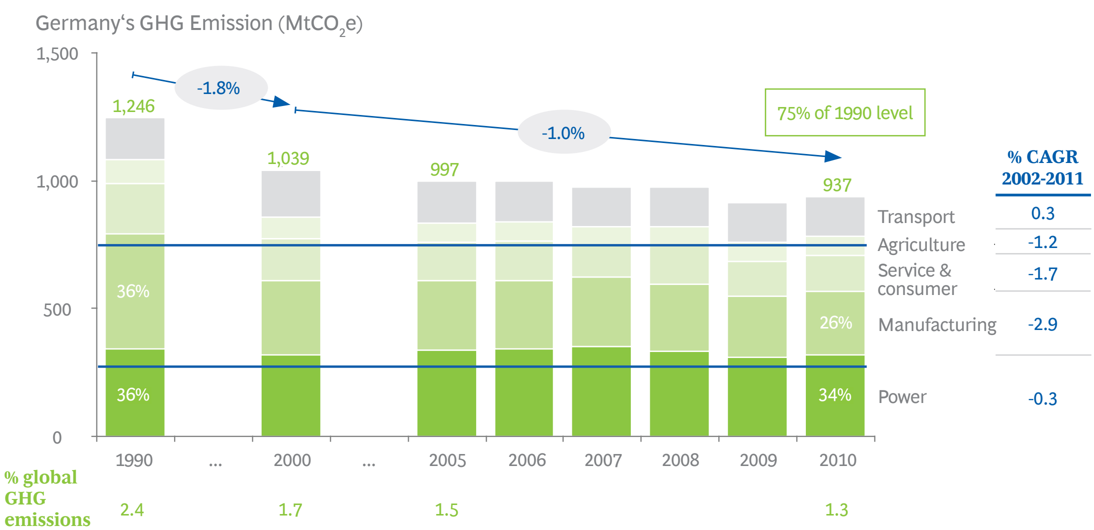


Figure 57
Germany's greenhouse gas emissions (1990-2010)

Source: BMWi, Destatis.de, EEA, NIR (Apr. 2012), OECD, UNFCCC, BCG analysis, BCG interviews, „Toward a Zero Carbon World" – BCG Perspectives; BCG analysis relatively low. Nonetheless, Germany remains one of the biggest industrial nations in the world, and further reductions in emissions in this sector are necessary to lessen overall global emissions.

Emissions in the service and consumer sector declined at 1.7 percent per year between 1990 and 2010, leading to a 30 percent overall decline. The agricultural sector's footprint in 2010 was 80 percent of the 1990 level.

The other sectors—transport and power—have seen the least improvement. Germany's power sector has stayed dependent on fossil fuels for power generation. Fossil fuels generated 347 TWh of electricity in 1990 and 350 TWh in 2010. The trends in the power sector are discussed in greater detail later in this chapter.

Current policy and emissions targets in Germany

State and public awareness regarding climate change is high in Germany. Accordingly, there is strong policy support for emissions abatement. As part of a plan called the Energiewende—energy transformation—clear targets have been set for reductions in GHG emissions, share of renewable energy sources in power generation, and energy efficiency (see Table 21).

A defining feature of the plan is its emphasis on targets related to renewable energy. The government plans to increase the share of power generated from renewable sources, with a target of 35 percent by 2020, 50 percent by 2030, and up to 80 percent by 2050.

If nuclear energy is phased out over the next decade as planned, then meeting even the 2020 renewable targets may have little impact on overall emissions. Like renewable energy, nuclear energy has a low emissions footprint.[150] Hence, replacing one with the other will not make a difference in overall emissions. The real impact of renewable energy sources will be felt onlyl if the share of fossil fuels goes down.

It is important to note that if emissions were to continue to decline at the same rate as they have over the last decade, it is unlikely that Germany will meet its 2020 emissions target, which is 40 percent below the 1990 level. Given the potential phase-out of nuclear energy and the lower rate of decline of manufacturing emissions, Germany will have to adopt new levers to achieve its emissions reduction targets. ICT-enabled solutions offer significant abatement potential in power, manufacturing, and other sectors, and could help accelerate Germany's emissions decline.

150. Nonetheless, the risk of nuclear accidents and problems with radioactive waste make nuclear energy a substantially less environment-friendly source of energy than renewables

Table 21
Energy targets set in the Energiewende

Source: Ministry of Economics and Technology, Germany

	Today	2020	2030	2040	2050
Reduction in greenhouse gas emissions (base year: 1990)	-27%	-40%	-55%	-70%	-80%
Share of renewable energies in total final energy consumption	10%	18%	30%	45%	60%
Share of renewable energies in electricity consumption	16%	35%	50%	65%	80%
Reduction of primary energy consumption (base year: 2008)	-5%	-20%			-50%
Reduction of electricity consumption (base year: 2008)	-1%	-10%			-25%
Reduction of final energy consumption in the transport sector (base year: 2008)		-10%			-40%

11.2 Impact of ICT on GHG emissions

Businesses and consumers use ICT widely in Germany. However, Germany still lags behind some other European countries in using ICT.[151] For instance, in 2010, the penetration of smartphones in Germany was 25 percent as opposed to 40 percent in the U.K. Similarly, the penetration of broadband services—both wired and wireless—is also lower in Germany than in other European countries: according to OECD data, there are approximately 33 wired broadband connections per 100 inhabitants in Germany, placing it ninth in Europe. The statistics are worse for wireless access: 35 subscriptions per 100 inhabitants puts Germany behind 19 other European countries.

ICT emissions in Germany were 32 $MtCO_2e$ in 2011 (see Figure 58). This translates to 0.39 tons of CO_2e per capita. This is a relatively low figure compared with the U.S., where ICT emissions were 0.66 tons per capita.

ICT use, however, is likely to increase with further adoption of smart devices, higher broadband penetration, and use of cloud-based services. Efficiency gains in end-user devices and networks infrastructure are anticipated. Specifically, wireless networks emissions are expected to stay relatively flat, while fixed network emissions are expected to decline to half the current levels because of large-scale optimization of network infrastructure. In contrast, data center emissions are expected to increase. This trend is similar to the expected trend in the rest of the world. The main driver of an increase in emissions is the expected explosion in stored data. As discussed in the chapter on global ICT emissions, several technological advances that improve the energy use of data centers are being tested. It is, however, difficult to predict which, if any, of these will come to fruition and have an impact. The net expected effect of the above trends is no growth in ICT emissions in Germany until 2020.

151. ITU's 2011 report titled "Measuring the Information Society" considered 11 sub-factors across three major categories (access, use, and skills) to assess ICT development within a country. Germany got a score of 7.27 out of 10, which placed it fifteenth-highest in the world, behind Sweden, Iceland, Denmark, Finland, Luxembourg, Switzerland, Netherlands, the U.K., and Norway.

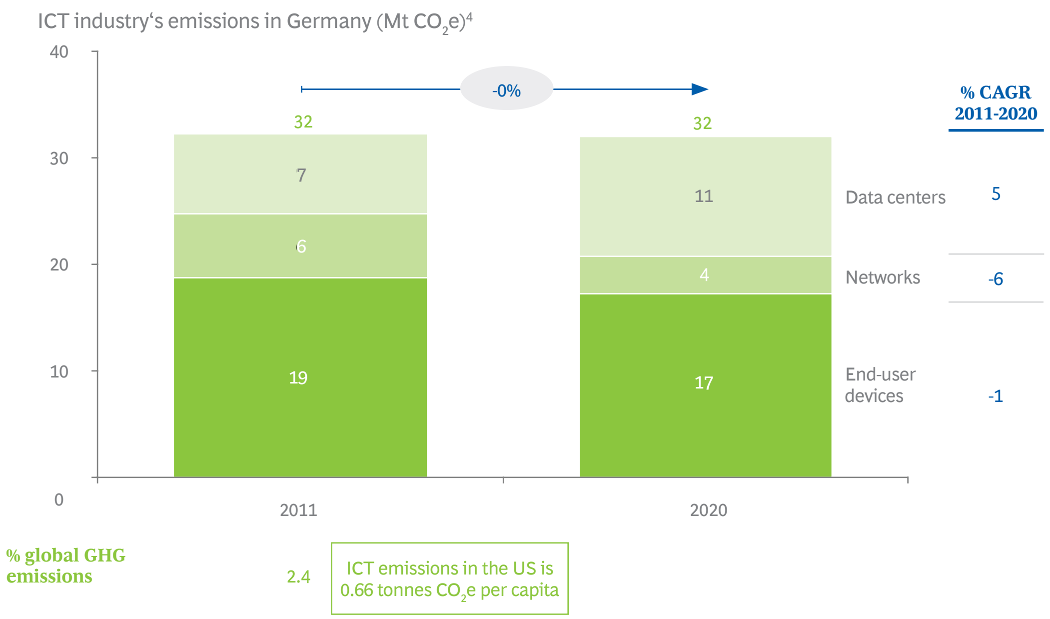


Figure 58
ICT industry's greenhouse gas emission in Germany

Source: Gartner, U.S. Census Bureau; IEA; Greentouch; Ovum; GSMA; SMART 2020: Germany Addendum; press search, BCG analysis

11.3 Abatement potential in power and manufacturing end-use sectors

The power and manufacturing sectors account for 60 percent of Germany's carbon footprint. Given their high contribution, this study focuses on these sectors to demonstrate the GHG abatement potential of ICT-enabled solutions.

While emissions have declined in the manufacturing sector, the rate of decline has reduced considerably since 2000. New levers are needed to further reduce emissions in this sector. On the other hand, there has been minimal reduction in emissions in the power sector because of continued dependence on fossil fuels. Given the impending nuclear phase out and its replacement by renewable energy sources, ICT-enabled solutions will play a vital role in this shift.

Power

Context

Germany's government is at the forefront of defining a roadmap to achieve its ambitious emissions, efficiency, and energy targets. The government outlined the Energiewende plan in "Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply," a policy document published in 2011.[152] As mentioned previously, Germany plans to phase out nuclear energy by 2022 under the Energiewende plan. The longer-term goal is to also eliminate the country's dependence on fossil fuels.

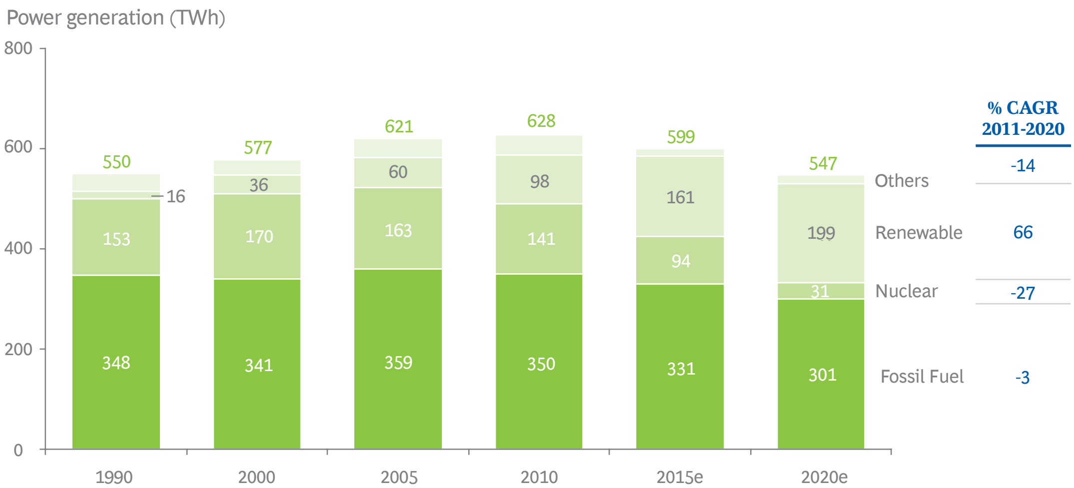
Figure 59 shows the historical trend in power generation by fuel source. The share of fossil fuels has decreased from 63 percent in 1990 to 56 percent in 2010. This decline not withstanding, fossil fuels contribute the biggest share in power generation, thereby indicating Germany's continued high dependence on them.[153] In 2010, nuclear energy contributed 22 percent of total power generation, while renewable energy sources contributed 16.8 percent. In 2011 the share of electricity from renewable sources reached 20.3 percent and it exceeded 25 percent for the first half of 2012.

152. This document was published in 2011 by the BMWi and BMU

153. Within fossil fuels, gas has marginally replaced coal; the share of coal has decreased from 57 percent in 1990 to 46 percent in 2010 as gas has gone up from 7 percent in 1990 to 14 percent in 2010

Figure 59
Power generation by fuel source in Germany (1990-2010)

Source: AGEE-stats, BMWi, Destatis, EEA, EWI, UNFCCC, BCG analysis, BCG interviews



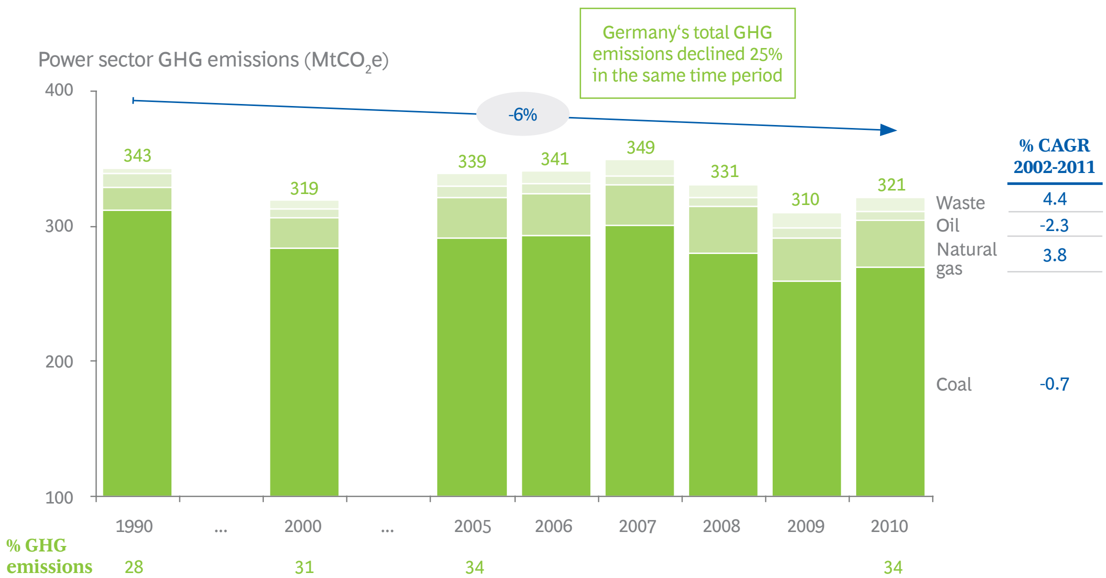


Figure 60
Greenhouse gas emissions of Germany's power sector

Source: AGEE-stats, BMWi, Destatis, EEA, EWI, UNFCCC, BCG analysis, BCG interviews

Figure 60 shows the emissions trend in the power sector. The power sector's footprint was only 6 percent lower in 2010 than in 1990; however, total emissions in Germany decreased by 25 percent in that same period. As a result, the share of the power sector in total emissions increased from 28 percent in 1990 to 34 percent in 2010. This has been driven by the consistently large share of fossil fuels in power generation, as discussed earlier.

As other sources of power generation are phased out, renewable energy will become increasingly important. The target for the share of renewables in power generation is 35 percent by 2020, 50 percent by 2030, and up to 80 percent by 2050. It is expected that wind energy—both onshore and off-shore —and, to a lesser extent, solar photovoltaic (PV) will play a key role in achieving these targets.[154]

Currently, Germany is a world leader in solar PV and wind energy. In 2011, the installed capacity for solar PV in Germany was the highest in the world at 25 GW. Wind capacity, onshore and offshore combined, exceeded the solar PV capacity by 4 GW, giving Germany the third highest wind capacity in the world at 29 GW (see Figure 61).

154. "Toward a Zero Carbon World," BCG Perspectives

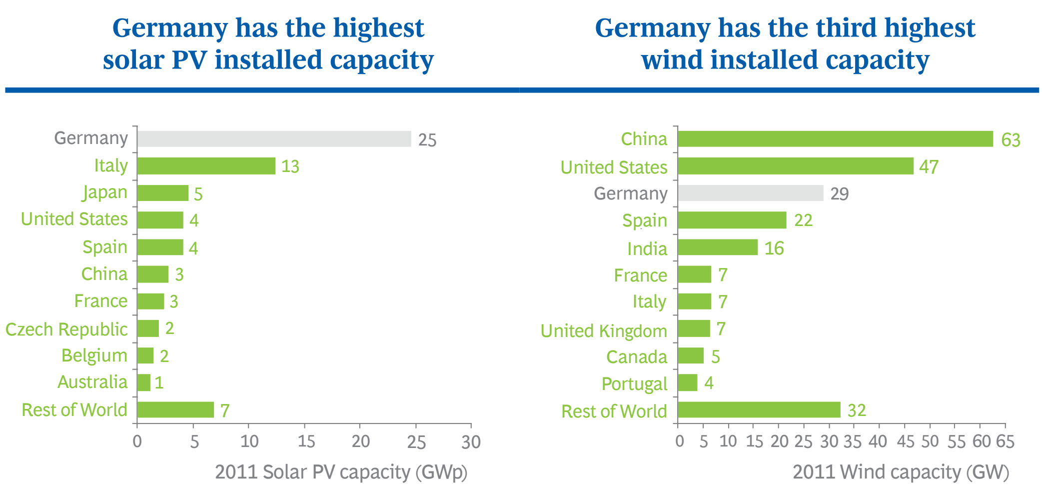
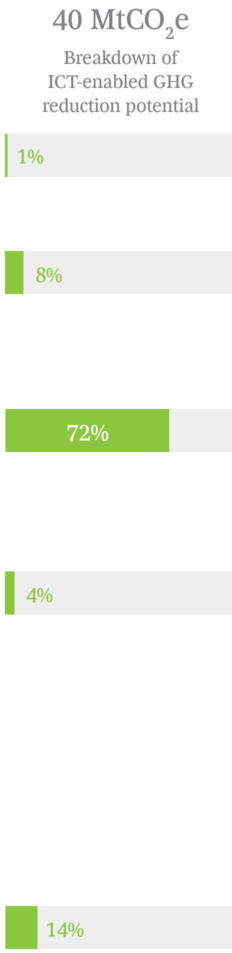


Figure 61
Solar PV and wind capacity by country (2011)

Sources: Global Wind Energy Council; EPIA Market Report 2011

Figure 62
ICT-enabled GHG reduction potential in the power sector

Sources: SMART 2020 Germany Addendum, BCG interviews, BCG analysis.



Sublevers	Drivers of sublevers
Demand management ($0.3\ MtCO_2e$)	• Little impact on carbon abatement potential but high importance for ensuring electricity supply security in Germany
Time-of-day pricing ($3.2\ MtCO_2e$)	• Reduces emissions by shifting peak consumption to base-load • Some potential in Germany due to the mandatory variable tariff offering from 2011 and the more pragmatic ways to balance peak consumption
Integration of renewables ($28.8\ MtCO_2e$)	• Increasing and optimizing the use of emission-neutral power • Absolute priority for Germany because of the nuclear phaseout – otherwise, additional fossil-fuel-fired plants would be necessary
Virtual power plant ($1.7\ MtCO_2e$)	• Limited impact on direct emissions reduction • Unlikely to be relevant for Germany as it requires advance grid infrastructure
Island grid ($0\ MtCO_2e$)	• Likely very little impact becuase of availability of reliable grid
Power-load balancing ($0.2\ MtCO_2e$)	• Balance peak demand via off-peak storage • Low potential in Germany because of efficient hydro and other pumped storage
Power grid optimization ($5.71\ MtCO_2e$)	• Some potential in Germany because of scope to minimize existing T&D losses in the grid

For Germany to reach its 2050 goal of generating 80 percent of power from renewables, a recent BCG study estimated that the best mix would be 130 GW of onshore wind (or 80 GW of onshore with 25 GW of offshore wind) and 65 GW of solar PV. [155]

Scaling up renewables to meet the 80 percent goal will create significant challenges for policy makers. High investments will be required to create the necessary infrastructure. This includes north-south transmission lines that can transmit the offshore wind energy generated in the North Sea. Further, integration of renewables will be a technological challenge because of the intermittence of solar and wind energy. Large-scale energy storage will be required to handle the peaks and troughs of energy production that necessarily accompany solar and wind-based power generation. Effective demand-side management will be needed to manage the imbalance of supply and demand. However, demand-side management requires installation of smart meters, which Germany has struggled with thus far, primarily as a result of the lack of a positive business case for utilities.

Power sector abatement potential

Figure 62 shows the abatement potential of each of the SMARTer 2020 sublevers for the power sector. The total abatement potential offered by these sublevers is 40 $MtCO_2e$ in 2020. Integration of renewables offers the highest potential at 72 percent of the total

155. "Toward a Zero Carbon World," BCG Perspectives

abatement. Power grid optimization is second at 14 percent, followed by time-of-day pricing at 8 percent.

ICT-based solutions are essential for the integration of renewables into the grid. If Germany does manage to scale up the use of renewables, this sublever will be a necessity to derive maximum gains from the use of renewables. It is important to note that if nuclear energy is indeed phased out, renewables will replace only nuclear energy and not fossil fuels. This means that instead of reducing emissions from the current level, this sublever helps avoid additional emissions that would have occurred if fossil fuels had replaced nuclear energy. Whatever the eventuality, this sublever offers an abatement potential of approximately 28 $MtCO_2e$ by 2020.

Germany has a reliable and modern power grid. However, as in the rest of the world, transmission and distribution losses do exist. This study assumes a 6 percent loss of power generated for this reason.[156] Based on this assumption, power grid optimization offers an abatement potential of approximately 28 $MtCO_2e$ by 2020.

Time-of-day pricing or variable pricing is also expected to play an important role. The abatement potential from this sublever is approximately 3 $MtCO_2e$ by 2020. However, realizing this goal will depend on the successful installation of smart meters. Because of a weak business case, Germany is currently struggling with installation of smart meters. Policy initiatives can help ensure that smart meters are successfully installed in Germany.

Other sublevers, such as demand management and virtual power plants, can be instrumental in ensuring electricity security. Because of the lack of infrastructure, however, they are unlikely to result in any sizeable GHG abatement by 2020.

156. The Energy and Resources Institute

Sublever	Attractiveness of investment	Return on investment	Risks and feasibility	Overall business case
Demand management	◔	◑	◑	◑
Time-of-day pricing	◑	◑	◑	◑
Integration of renewables	◔	◑	◔	◔
Virtual power plant	◔	◔	○	◔
Power-load balancing	◔	◔	◑	◔
Power grid optimization	◑	◕	◕	◕

Figure 63
Business case assessment of power sector sublevers

Source: BCG analysis

○ Low attractiveness
● High attractiveness

Case Study
Deutsche Telekom, T-City, and Friedrichshafen smart meters

Providing consumers with precise knowledge of how and when they are using electricity has long been a challenge for energy providers. Though consumers know how much energy they have used over the course of a month, they have not been able to systematically break down their energy consumption patterns, determine when they spend the most energy, or use ICT to moderate their consumption.

Smart meters, used in conjunction with smart grids, offer a solution. In the Oberhof and Windhag districts of Friedrichshafen, Deutsche Telekom, through its T-City program, worked with Technische Werke Friedrichshafen (TWF) to build the first intelligent energy network of the future, colloquially known as a smart grid. Using the smart grid, Deutsche Telekom was able to install over 2,000 smart electricity, water, and gas meters and connect them via ICT to energy providers—all to help consumers better understand their energy usage.

Smart electricity meters provide energy consumption information to energy suppliers, which then take the information and communicate it to consumers through an Internet portal. Consumers can access this portal through their computers and smart-phones, making personal energy consumption information readily accessible at all times. Consumers can identify which appliances use the most energy and also avoid energy consumption during periods of peak demand. Not only does this information benefit consumers, but it also is of great value to power generators. With the constant stream of information, power generators can better forecast demand and avoid utilizing unnecessary capacity.

By providing consumers and energy providers with more information on consumption patterns, money is saved, less energy is wasted, and fewer GHGs are released. The average household that uses smart meters has been able to save about 4 percent on their energy bills. Though dependent on the wider development of smart grids, ICT-enabled smart meters can yield significant GHG emissions savings in future.

Barriers and recommended policy steps to overcome them

Given the significant abatement potential offered by ICT-enabled sublevers, it is important to ensure that these are adopted and scaled up. However, not all of these sublevers are likely to be driven by the market, as several do not present a positive business case, especially when assessed individually.

The business case for most sublevers in the power sector is medium to weak. The primary drivers of this are the high up-front cost and although higher energy prices make the business case more attractive than in other countries with low energy prices such as the U.S. Power grid optimization presents the most favorable business case because of lower implementation risk and a more certain return on the investment. Power load balancing is not as favorable since Germany already uses pumped-hydro storage for peak power (both domestic and from Norway). Integration of renewables faces several challenges, as discussed later.

Figure 64 combines the business case analysis with the abatement potential analysis in the previous section. The key insight from the combined view is that the role of policy is likely the strongest in facilitating the integration of renewables. Germany already has among the highest solar PV and wind energy installed capacity. Integrating renewables into the grid can yield significant benefit if done successfully.

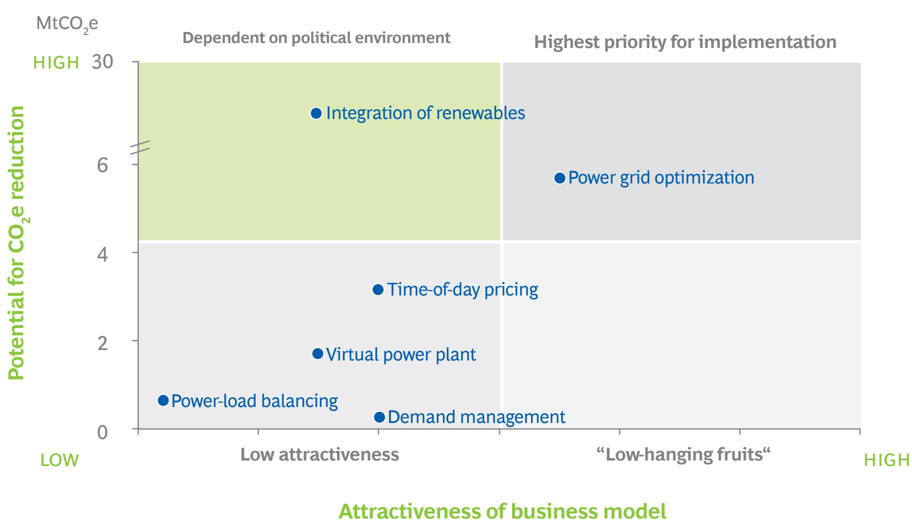


Figure 64
Power sector sublever prioritization by potential for CO_2e reduction and business potential

Source: BCG analysis

To better understand the dynamics behind the adoption of renewables in Germany, this study analyzes the key drivers, their interdependence, and the role of policy in enabling them. Figure 65 shows the driver tree for the adoption of renewables in Germany and highlights the role of policy.

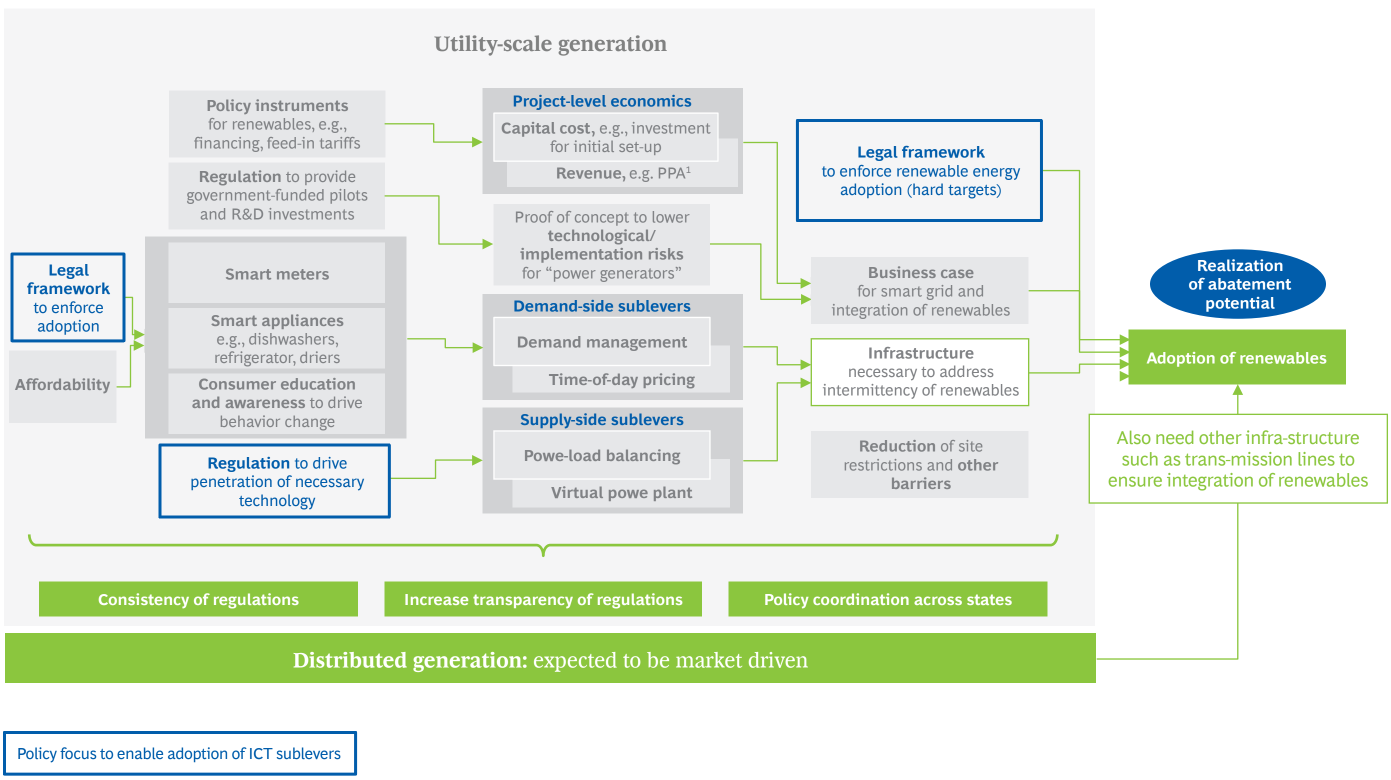
The key insight is that many policy levers will have to be enacted simultaneously to drive utility-scale power generation based on renewables. Only then will the full abatement potential offered by renewables be realized.

It is worth noting that distributed generation is likely to be driven by the market. High energy prices in Germany make the business case positive for consumers. Solar energy is already past grid-parity in Germany. The key barrier to full-blown scaling up is the unavailability of cheap storage. As technology progresses and storage becomes cheaper, further penetration of distributed generation can be expected without needing a regulatory push. In this model of power generation, consumers turn into "prosumers," that is, producers and consumers of electricity. These prosumers will not need to rely on smart meters, smart appliances, demand management, or other technologies for their own consumption. Such technologies are, however, necessary for utility-scale renewable-based power generation to achieve its full potential.[157]

157. "Toward a Distributed-Power World," BCG Perspectives

Figure 65
Policy makers will need to pull multiple levers simultaneously to drive adoption of renewables and realize abatement potential

1. Power Purchase Agreement
Source: BCG analysis



	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Demand-side management	• Requisite technology not in place, e.g., smart meters, smart appliances • Dynamic pricing, as required by EnWG1, not feasible without deployment of smart meters	Support deployment of smart meters and other technology	• Create necessary regulatory and legal framework to ensure deployment of smart meters and other necessary technology • Subsidies for R&D and pilot tests
High infrastructure investment	• High infrastructure investment needed to integrate renewables and enable long-distance transmission of wind energy • Large-scale energy storage will be necessary as and when share of renewables increases	Provide funding for creation of necessary infrastructure	• Policy to drive creation of infrastructure necessary for integration of renewables, as market unlikely to play a big part here
Regulations	• Lack of enforcement of targets set in EnWG 2011 could adversely affect realization of 2020 emissions target • Insufficient incentives for utilities to invest in ICT essential for a smart grid	Enforcement of existing targets Facilitate investment in ICT solutions for the smart grid	• Create necessary legal framework to ensure current EnWG targets are met • Create regulations to provide incentives to utilities to boost investment in ICT, e.g., tax incentives to help with the business case

Table 22
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome them

Based on this analysis, a few barriers to the adoption of utility scale power generation have been identified. Table 22 summarizes these barriers and the policy steps to overcome them.

Demand management and time-of-day pricing—the latter already mandated in the Energiewende—are not feasible without the installation of smart meters. Given the current lag in this process, policy steps could be taken to accelerate the penetration of smart meters. Specifically, a regulatory framework is required to ensure that smart meter installation is enforced. Further, government-funded research and development efforts could be initiated in areas in which technological gaps remain. Any early successes could be tested in state-sponsored pilot studies. This will allow mitigation of the technological risk associated with the new technologies and encourage private investment.

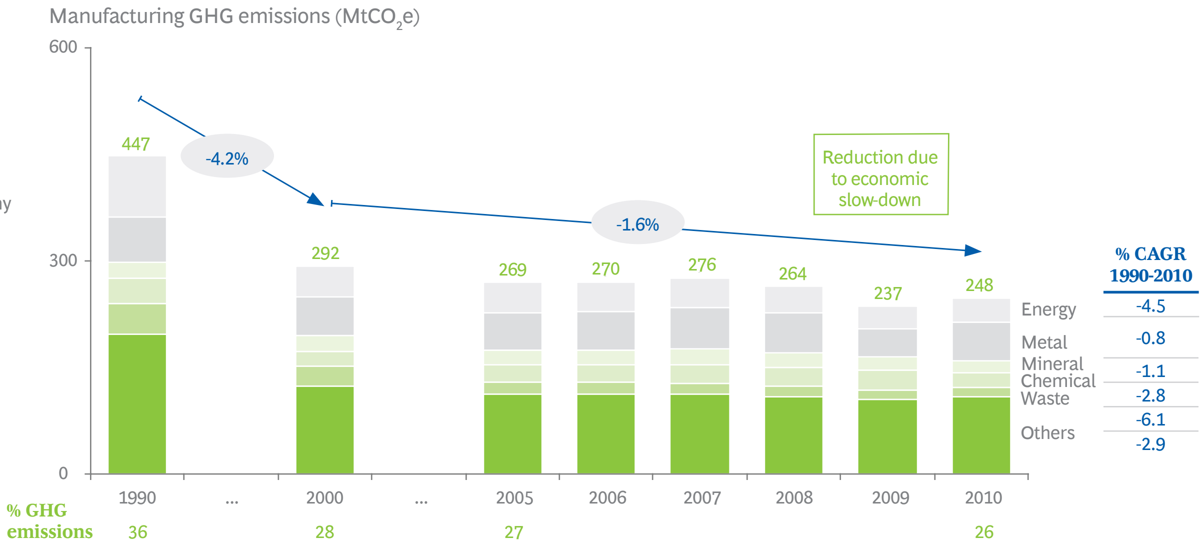
Further, Germany's power sector will require high infrastructure investment to integrate renewables. For instance, it will require installation of north-south transmission lines or development of large-scale energy storage. Providing funding for the creation of the necessary infrastructure will be crucial in ensuring renewables are successfully integrated into the grid. Also, it is important to ensure there is policy coordination across states. For instance, the plan to supply the south with off-shore wind energy from the north will not work if the states in the south plan for alternative sources for their power requirements.[158]

A legal framework is also required to ensure that the targets of the Energiewende are met. At the time of this study, the pace of progress on the ground is not as fast as required to meet Germany's emissions targets. There is a

158. There is also a problem with long approval procedures for new electricity distribution lines and unsolved liability questions with respect to off-shore wind should also be addressed

Figure 66
Greenhouse gas emissions of Germany's manufacturing sector

Source: BMU, BMWi, EEA, UNFCCC, SMART 2020 Germany Addendum, BCG analysis, BCG interviews



risk that without a legal framework to ensure enforcement, Germany will miss its 2020 targets.

Policy instruments could also be used to incentivize utilities to invest in ICT that is essential for a smart grid. Given the lack of a positive business case for a smart grid for utilities, utilities need incentives to invest in technologies that are essential for the shift to a smart grid. Currently, regulations do not provide for such incentives. Hence, policy makers need to pay attention to this issue.

Manufacturing

Context

Germany is a leading industrialized nation. In 2010, manufacturing accounted for 28 percent of the approximate USD2.9 trillion GDP of the German economy. However, the cost of this large economic footprint is a large emissions footprint. Figure 66 shows the emissions in this sector from 1990 to 2010. The footprint of the sector was 248 $MtCO_2e$ in 2010, or 26 percent of the total emissions in the country. This shows the low emissions intensity of the manufacturing sector: for instance, in the U.K., the GDP share of manufacturing is only 11 percent but it accounts for 27 percent of the emissions, whereas in Germany, manufacturing constitutes 28 percent of the economy and the total emissions share is only 26 percent.

The sector's emissions footprint has been declining over the last two decades: the footprint in 2010 was 45 percent lower than in 1990. While there have been energy-efficiency gains, the primary driver was the deindustrialization of the former East Germany. The primary causes were the closure of energy-intensive industries due to the loss of competitiveness and the breakdown of traditional export markets in Eastern Europe.

The rate of decline, unfortunately, has slowed since 2000. Emissions declined at a rate of 4.2 percent between 1990 and 2000. However, as the deindustrialization of the former East Germany had mostly taken place by 2000, the rate of decline slowed to 1.6 percent per year over the following ten years.

Given the magnitude of emissions from the sector, it is important to tap into any abatement potential possible. Currently, the government is supporting energy efficiency improvement with subsidies and other measures. For instance, SMEs can receive subsidized energy consultations. An "Ecotax" that rewards manufacturers for energy efficiency gains has been instituted. Further, the State-Enterprise Partnership aims to provide information and training to enterprises to improve their willingness and ability to increase energy efficiency.

Manufacturing sector abatement potential

ICT-enabled sublevers provide an abatement potential of 33 $MtCO_2e$ by 2020 (see Figure 67). Eighty-two percent of the abatement potential comes from the widespread adoption of variable-speed motors, while automation of industrial processes accounts for the rest.

Variable-speed motor systems comprise the actual motor plus a frequency converter. The frequency converter makes it possible to vary the rotational speed of the motor to better match the actual speed with the speed required. Optimizing the speed lowers the total energy use and thus indirectly helps with emissions abatement. Many such systems are readily available on the market today and awareness about these is high among engineers. Also, the business case in a typical setting is positive, with a payback period of only one year.[159]

Automation of industrial processes refers to the monitoring and control of industrial processes to optimize and automate for reducing energy usage. The business case is positive because of the high savings potential that can be achieved through the reduced utilization of resources—both material and personnel.

159. "SMART 2020 Germany Addendum: The ICT Sector as the Driving Force on the Way to Sustained Climate Protection," GeSI and BCG

33 $MtCO_2e$
Breakdown of ICT-enabled GHG reduction potential

	Sublevers	Drivers of sublevers
82%	Optimization of variable-speed motor systems (27 $MtCO_2e$)	• A frequency converter as add-on for the actual motor to vary the rotational speed and better match the energy use with required output • Important lever for Germany as one of the biggest industrial nations with a large number of existing electric motors • Economically attractive for the German industry because of short payback period and long reinvestment cycles
18%	Automation of industrial processes (6 $MtCO_2e$)	• Monitoring and control of industrial processes to optimize and automate to reduce the energy use • Also reduce utilization of personnel resources • Business case is positive because of high energy and labor costs

Figure 67
ICT-enabled GHG reduction potential in manufacturing sector

Source: SMART 2020 German Addendum, BCG analysis, BCG interviews

Barriers and recommended policy steps to overcome them

The market is expected to continue to drive the adoption of the solutions. The solutions are readily available in the market and have a positive business case for manufacturers, and the awareness and willingness to adopt advanced solutions is high. As a consequence, it is expected that further uptake will continue unabated.

The business case for both sublevers in the power sector is very strong. The primary drivers of this are the relatively low upfront cost and a short payback period, often as little as one year. However, outage costs are necessarily incurred from the shutdown of plants during modernization. This reduces the overall feasibility a bit.

Figure 69 combines the business case analysis with the abatement potential analysis in the previous section. The combined view reveals that indeed there is a limited role for policy. A strong business case is expected to be sufficient to drive market-based adoption.

Several minor barriers do exist, but policy can help in these situations. The investment cycles can be long when it comes to upgrading to variable-speed motor systems. In certain niche areas of the industrial sector, providing incentives for upgrades may accelerate the adoption rate.

Figure 68
Business case assessment of manufacturing sector sublevers

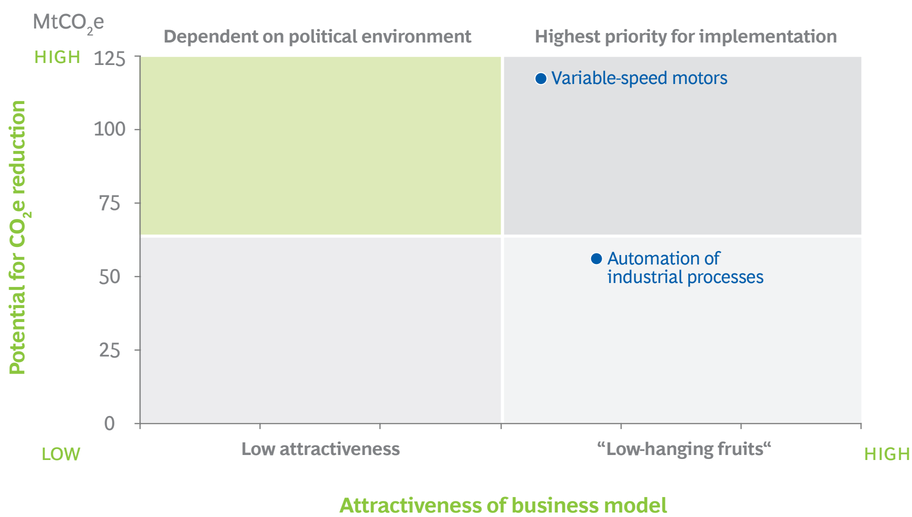
Source: BCG analysis

○ Low attractiveness
● High attractiveness

Sublever	Attractiveness of investment	Return on investment	Risks and feasibility	Overall business case
Optimization of variable-speed motors	●	●	◕	●
Automation of industrial processes	●	●	◕	●

Figure 69
Manufacturing sector sublever prioritization by potential for CO_2e reduction and business potential

Source: BCG analysis



Case study
Bosch Rexroth 4EE—Rexroth for Energy Efficiency

Over a quarter of German electricity needs are driven by demand from industrial plants and machines. Motors, pumps, and compressors are at the heart of the German industrial machine, but they are often inefficient, waste large amounts of electricity, and release large quantities of GHG emissions in the process. Because antiquated machines and motors do not adjust the amount of work they perform to the strain being placed on them at any particular moment, they operate at the same speed continuously. This continuous exertion leads to electricity overuse and unnecessary release of GHG emissions.

Bosch Rexroth AG, a German industrial goods firm, has designed systems that optimize variable motor systems to reduce unnecessary energy expenditures. The IndraDrive folding press system is a particularly innovative example of motor system optimization. Rather than operating at a constant rate, the IndraDrive system senses the weight of the load being put on the folding press and will lower its operating speed to zero during partial-load utilization or pauses. Additionally, the system's servo motors automatically switch into generator mode during load-free downward movements, which generates electricity that can be fed back into the system. Not only do these developments reduce the direct energy requirement, but also the heat generated by the system mostly eliminates the need for cooling systems.

These efficiency gains can be magnified when IndraDrive machines are combined into a circuit. When 20 IndraDrive machines were merged into a single system to form a package distribution system, the system was able to save 23,400 kWh of electricity annually. This translates into a CO_2 reduction of 14 metric tons per year.

Not only do these machines save energy and lower GHG emissions, but they also have the potential to save money for manufacturers. As manufacturers come to realize the economic viability of investing in such systems, optimizing variable motor systems will become more widespread and reduce GHG emissions from manufacturing.

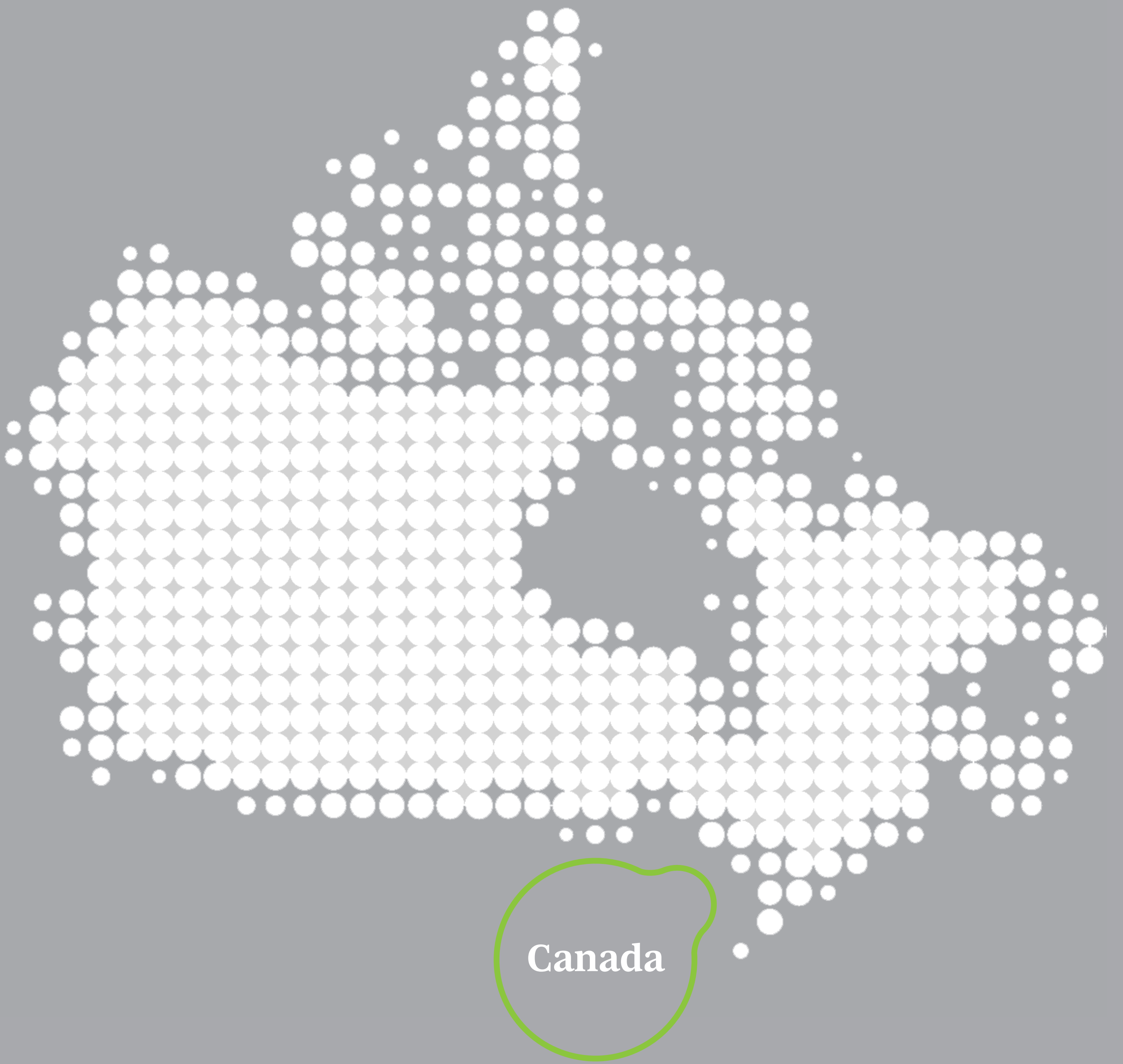
Faster market penetration of industrial-process automation is hampered primarily by outage costs arising from the required temporary shutdown of plants undergoing modernization. However, because of a strong business case, this should not prevent full realization of the abatement potential by 2020.

Most important, policy can help by setting tighter emissions and efficiency targets for the sector. In addition to the business case, the requirement to meet targets is an impetus in adoption. Currently, targets are based on historical values, which are too high relative to the long-term emissions-reduction goals of Germany. Therefore, tightening targets can be considered a boost to the adoption of these solutions.

However, it is important to note that as the German manufacturing industry shows comparably high energy efficiency, policy measures should take into account international competitiveness to avoid GHG leakage.

Table 23
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome them

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Ineffective emissions targets	• Current industrial-emissions budget is too high to have a big impact in terms of driving energy efficiency upgrades	Create tighter emissions budgets, targets, or both	• Necessary to set more aggressive emissions-reduction targets so that efficiency improvements become a necessity • At the same time, care must be taken to make targets economically and technically feasible • Improve energy efficiency standards across all industries
Economics	• Economics still not favorable in some niche areas, e.g., old paper mills	Provide incentives to improve economics	• Tax credit, investment credit, or subsidies could help improve the economics for industries that are lagging behind
Slow adoption	• Slow adoption due to likely long equipment and process change or upgrade cycles in some areas	Limited role for policy	


Canada

12 Canada

12.1 Context

Though Canada contributes only 1.7 percent to the world emissions total, it has one of the world's highest per capita emissions. Excluding land use changes, Canada has the eighth highest per capita emissions at 20.3 tons CO_2e per person, just below those of the United States. Its high per capita emissions signifies that Canada has significant potential to abate its GHG emissions by 2020.[160]

Canada has the eighth-highest per capita emissions in the world

While Canada's emissions are high, they have stabilized in recent years. In 2000, Canada's emissions—excluding land use—were 718 $MtCO_2e$; by 2010, emissions had declined to 692 $MtCO_2e$, even though the population rose by around 10 percent from 31 to 34 million.[161] This represents a 3.6 percent decline over the decade. Canadian emissions remained flat largely because of increases in the use of renewables to generate electricity, which helped offset emissions growth from transportation. Because Canadian emissions fell slightly as world emissions grew at 2.0 percent, its emissions as a percentage of the world total declined. In 2000, Canadians emitted 2.2 percent of the world's GHGs, and by 2010 that figure had dropped to 1.7 percent.

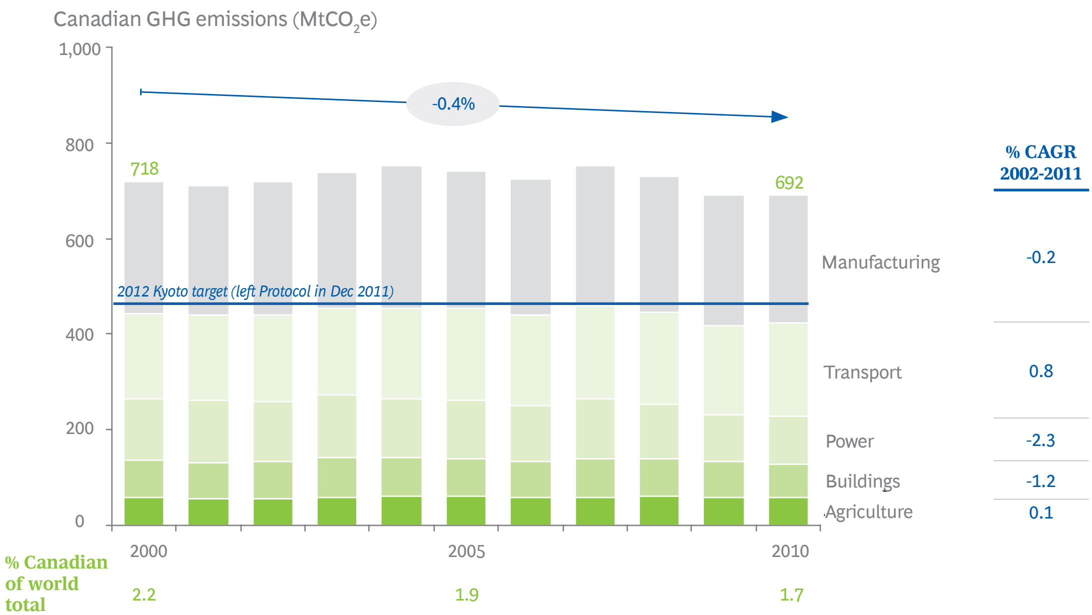
The transportation sector makes up 22 percent of Canada's total emissions. Much like the U.S.and Australia, Canada has relatively low population densities even in major cities and, by international standards, accordingly is dependent on cars. Emissions from passenger vehicles are relatively high but have stabilized at 79 $MtCO_2e$ and are projected to decline. Canada is also becoming increasingly dependent on heavy trucking as a means of moving cargo. Though railways move the most amount of cargo by tonnage, trucking emits nearly nine times more GHGs and is growing. Emissions from trucking are projected to grow to 20 percent, increasing from 80 $MtCO_2e$ in 2005 to 96 $MtCO_2e$ in 2020.[162]

The oil and gas sector is currently the second largest contributor to the GHG emissions total, emitting 21 percent of Canada's total emissions. Emissions from this sector are

160. National and Sectoral GHG Mitigation Potential: A Comparison Across Models, OECD 32
161. "Canada's Emissions Trends 2011", Environment Canada
162. Ibid

Figure 70
Canadian total greenhouse gas emissions, 2000-2010

Source: Environment Canada



particularly high because of the energy intensity required to extract and refine Canada's hydrocarbon resources. One resource that Canada has in abundance is tar sands, which is sand, clay, and water that is saturated with a particularly dense form of petroleum and is found in abundance in the northern part of the Alberta province. Because the petroleum is mixed with so many different solids, it requires large amounts of natural gas for extraction and more energy to refine than traditional petroleum. Tar sands extraction only recently became economically viable when international oil prices rose in the middle of the last decade, which pushed Canadian oil and gas emissions higher. The recently developed process of "fracking" for natural gas, or using large volumes of water at high pressures to force gas out of the ground, has also increased oil and gas emissions. The process allows the escape of methane, which is a potent GHG. Because of high worldwide energy prices, the use of these techniques is projected to continue and Canadian oil-and-gas emissions are expected to rise from 153 $MtCO_2e$ in 2005 to 199 $MtCO_2e$ in 2020, an increase of 30 percent.

The Canadian power sector contributes 17 percent to the overall emissions total, a low percentage relative to other industrialized nations. Hydropower produces 58.2 percent of Canadian electricity while nuclear, wind, solar, and other renewables constitute another 16 percent. Overall, 74.2 percent of Canadian electricity comes from low-carbon sources.[163] This trend toward decarbonization of the electricity sector is projected to continue. Even as capacity is expected to grow between 629 TWh in 2010 to 734 TWh in 2020, emissions are expected to decline from 107 $MtCO_2e$ to 95 $MtCO_2e$ over the same period.

Finally, the buildings sector emitted 79 $MtCO_2e$ in 2010, which was 11 percent of Canada's overall emissions, having decreased from 85 $MtCO_2e$ in 2005. (On a per inhabitant basis, this figure is lower than buildings emissions figures for other industrialized countries; the discrepancy results from differences in emissions accounting used across countries.) Emissions from residential buildings grew very slowly between 2005 and 2010, from 42 $MtCO_2e$ to 44 $MtCO_2e$, even as 1 million new households were added. The reason for the small magnitude of the increase is that that energy efficiency increases in existing homes helped offset the emissions increases from new homes. The small growth of emissions from the residential subsector is expected to continue until 2020, when residential emissions are expected to reach 46 $MtCO_2$. Emissions from buildings in the commercial sector have actually declined since 2005. In 2005, emissions were 38 $MtCO_2e$, and by 2010 they had declined to 36 $MtCO_2e$. As with the residential sector, emissions decreased because of gains in efficiency despite new added capacity. Most of these efficiency gains have been realized, however, and emissions from the commercial sector are expected to climb to 40 $MtCO_2e$ by 2020 as a result of an increase of 170 million m2 in floor space.

12.2 Impact of ICT on GHG emissions

The Canadian ICT sector may not be as well-positioned as other high-income countries to offer GHG abatement solutions. In an annual survey conducted by the International Telecommunications Union that measures uptake rates and growth potential of ICT readiness, Canada was ranked twenty-sixth.[164]

The principle concerns for Canada are relatively low ICT uptake by businesses and low economic impact. Though Canada's business uptake is only slightly below the high-income country average, lower-than-average uptake could present challenges for ICT-enabled abatement solutions. Adoption by businesses is critical to ensuring the success of many of the sublevers, and emissions reductions will not reach their maximum potential if business penetration remains low. The principle

163. "Electric Power Generation—Transmission and Distribution," Statistics Canada

164. UN/ITU "Measuring the Information Society," 2011 report

concern of many businesses surrounds data security. Some businesses are wary of information theft and many are not yet comfortable with trusting their most sensitive data to external companies. However, this is a problem that can be alleviated over time as businesses learn from the experience of others that data security is generally not a concern. Moreover, the ICT sector may be able to increase business penetration by promoting profitable abatement solutions that will increase businesses' efficiency. Another concern that could be suppressing business uptake is that broadband Internet connectivity is significantly more expensive in Canada than in industrialized nations.[165] Using data-intensive applications could be significantly more expensive for Canadian firms than international competitors, given the current business climate.

The ICT sector also has a lower economic impact than ICT sectors in other developed economies. While Canada has higher levels of connectivity and a superior business environment (in terms of the resources required to start a business, corporate tax rate, and quality of its managers) than the U.S., the U.S. ICT sector contributes more as a percentage of GDP than does Canada's.[166] The principal reason for this is the superior innovative capacity of the U.S. and its enhanced ability to develop and distribute groundbreaking technologies.[167]

The Canadian ICT sector is in a period of transition. The manufacture of devices to export abroad, primarily to the U.S., used to be a more significant component of the Canadian ICT sector but in recent years there has been a shift away from manufacturing toward the provision of services. Since 2002, manufacturing revenues have declined 17 percent while revenues from service firms have grown 57 percent. As a result, ICT manufacturing as a share of total ICT revenues has slipped to 6.0 percent as software and computer services (80.9 percent), ICT wholesaling (9.2 percent), and communication services (3.8 percent) have grown to represent 94.0 percent of the sector.[168] The shift toward services has also changed the composition of businesses that make up the ICT sector. As service firms generally tend to be smaller than manufacturing firms, the sector is becoming increasingly fragmented and dominated by smaller companies. A significant number of Canadian ICT firms, 83.4 percent, have between one and nine employees, while only 1.7 percent have more than 100 employees.[169] As the sector is dominated by smaller firms that have less access to capital and fewer employees to leverage, it may be challenging for these smaller firms to adapt their offerings to provide greater access to GHG abatement technologies as market demand changes.

165. "The Cost of Bandwidth: Canada vs. the World", Chris Stavropoulos, Xcrew

166. The Global Information Technology Report 2012, 309

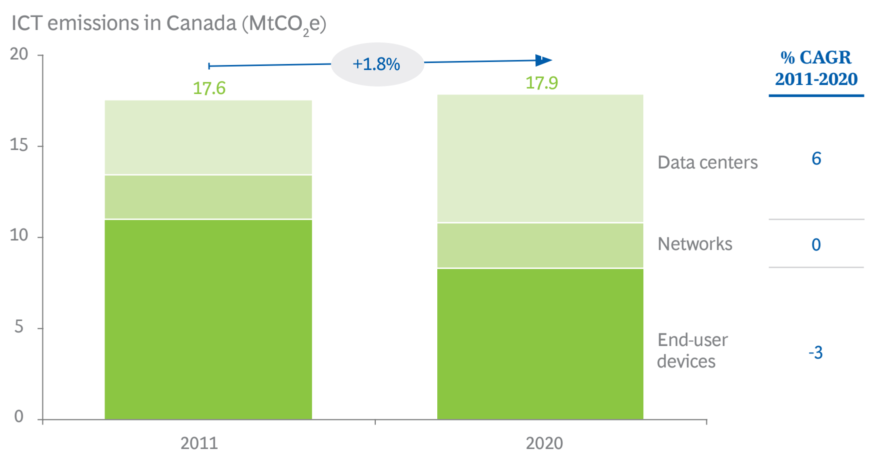
167. The Global Information Technology Report 2012, 19

168. Industry Canada, Canadian ICT Statistical Overview

169. Canadian ICT Sector Profile, Industry Canada

Figure 71
ICT industry's greenhouse gas emissions in Canada

Source: Gartner, BCG analysis



As ICT penetration is expected to grow, so too will Canada's direct ICT emissions. Emissions are slated to rise slightly from 17.6 $MtCO_2e$ in 2011 to 18.0 $MtCO_2e$ in 2020, which represents growth of 1.8 percent over current levels. The principal driver of the rise in emissions is a 72 percent increase in the direct emissions coming from data centers. Emissions from data centers are rising because of large increases in data demand. The growth of data center emissions is partially offset by the decline in emissions from end-user devices. Penetration of ICT devices is expected to increase only moderately as new devices are becoming increasingly efficient, leading to a direct emissions decline from 11.0 $MtCO_2e$ in 2011 to 8.33 $MtCO_2e$ in 2020.

12.3 Abatement potential in transportation and buildings end-use sectors

Though the oil and gas sector is projected to become Canada's largest source of GHG emissions, the potential for abatement in that sector is low, meaning ICT technology will likely not have a large impact on reducing emissions from that sector. As a result, we will consider the Canadian transportation and building end-use sectors. The Canadian transportation sector is currently the largest source of emissions, and ICT has the potential to yield large emissions reductions in this sector. The building end-use sector is in the process of adding capacity, and leveraging ICT to make new buildings more energy efficient is an easy application that can yield large GHG savings. ICT can also lead to large reductions through retrofits and changing energy consumption patterns within buildings.

> Transportation represents the largest source of GHG emissions in Canada

Transportation

Context

The Canadian transportation sector represents the largest source of GHG emissions because of Canada's heavy reliance on road transportation as a means of moving passengers and cargo. Much like the U.S. and Australia, Canada has a low population density even in its largest cities. As a result, Canada's public transit system was not sufficiently developed and cars became the primary mode of transportation. Only 8 percent of Canadians use public transportation on a daily basis; in the U.K., one of Europe's most car-dependent nations, the rate is double that of Canada's.[170] Because of few developments in public transportation in recent years, Canada's reliance on cars has only grown.

170. 1. Greendex 2009: Consumer Choice and the Environment – A Worldwide Tracking Survey
2. Canada's Emissions Trends, 24

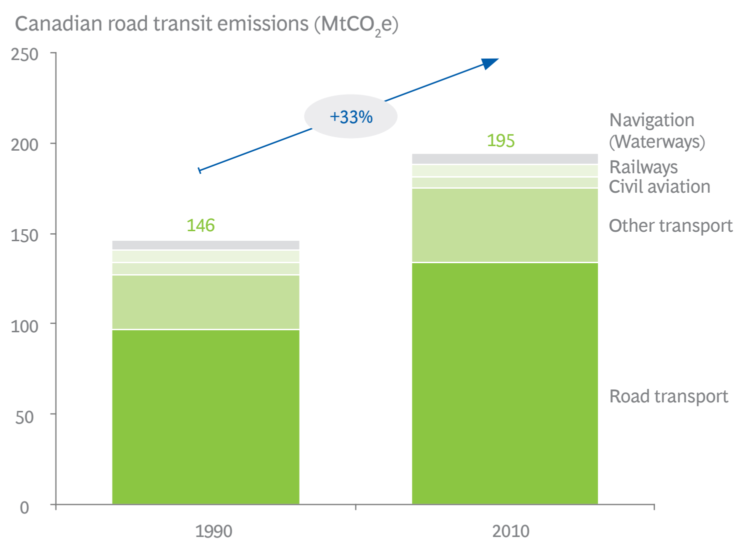


Figure 72
Canadian transportation sector greenhouse gas emissions

Source: Environment Canada

As Canada has become increasingly reliant on private transportation, emissions from transportation grew 33 percent between 1990 and 2010. Several factors have Canada's[171] pushed emissions from private transportation higher. The first is that there are more vehicles on the road. Between 1990 and 2010, the driving -age population increased 22 percent, and, given Canada's lack of efficient public transportation, this caused an increase in the number of cars. The population increase, combined with families purchasing more than one car, increased the number of vehicles on Canadian roads by 44 percent over that 20-year period.[172] There was also an overall change in the vehicle mix. Canadians became increasingly dependent on SUVs and light trucks, which emit more per kilometer driven than a smaller passenger vehicle. The third contributing factor is that Canadians were also driving more miles with vehicles that were already on the road—30 percent more on a kilometers-per-passenger basis.[173]

171. Greenhouse Gas Inventory 1990-2010, Environment Canada

172. Canadian Emissions by Sector, Climate Change Connection

173. Ibid

Figure 73
ICT-enabled GHG reduction potential in the transportation sector

Source: BCG analysis

55 $MtCO_2e$ Breakdown of ICT-enabled GHG reduction potential	Sublevers	Drivers of sublevers
20%	Eco-driving	• Applications integrated into vehicle provide drivers with feedback on fuel usage and driving style, and can help anticipate upcoming traffic
2%	Real-time traffic alerts	• Current high penetration of real-time traffic alerts in Canada diminish the importance of this sublever
1%	Apps for public transit	• Could induce a higher percentage of Canadians to consider public transit as an alternate means of getting to work
3%	Crowd sourcing	• Allows urban residents areas to share transit resources through car and ride sharing
7%	Video-conferencing	• Allows for meetings to be conducted over the Internet through A/V equipment even if participants are within driving distance
21%	Telecommuting	• Reduces the number of times that Canadians need to physically commute to work, which is the source of large amounts of emissions
9%	Truck route optimization	• Utilizing real-time traffic reports can help trucks avoid congestion and closed routes
26%	Logistics network optimization	• Prevents trailers from going empty by ensuring coordination among truckers in a given area, which is crucial given the large increase in Canada's heavy trucking volume
6%	Integration of EVs	• When used in conjunction with ICT, EVs can provide power back to the grid, reducing the need for peaking power plants during periods of high power demand
1%	Intelligent traffic management	• Reduces the amount of time that drivers burn fuel on congested roadways
3%	Fleet management	• Allows a centralized fleet manager to ensure that drivers are driving at the appropriate speed, are braking correctly, and have the right tire pressure

Despite the emissions growth in recent years, emissions from passenger cars are projected to decline by 2020. Increasing fuel efficiency standards, modeled after the more stringent Corporate Average Fuel Efficiency (CAFE) standards passed in the U.S. in August 2012, will lower Canada's passenger car emissions from 22 kg CO_2e/100 km in 2010 to 19 kg CO_2e/100 km by 2020. Though these emissions are still high by European standards (the EU25 had already reached an average emissions level of 16 kg CO_2e/100 km by 2006, for instance), it will still be an improvement over the current efficiency levels of the Canadian fleet.[174] These efficiency gains will decrease Canada's passenger car emissions from 79 MtCO_2e to 73 MtCO_2e over the same period.[175]

Reliance on road transportation to move cargo has grown as well. Canada has well-developed rail and marine networks that move the majority of its cargo, but the use of heavy trucking is growing quickly. At 44 freight ton-kilometers in 2009, railways move the most cargo by tonnage which, from an emissions characteristic, is a positive characteristic.[176] Railways are still more energy efficient than heavy trucks despite improvements in the efficiency of road transportation, and high energy efficiency standards for rail are projected to continue pushing emissions lower. However, the amount of cargo being moved via rail is declining; since 2000, there has been a decline of 5 freight ton-kilometers moved by rail. Marine transportation is Canada's most important means of international trade in terms of both volume and value. Marine transportation moved 27 freight ton-kilometers in 2009 but, like rail, is lessening in importance. Trucks moved 34 freight ton-kilometers in 2009, which is behind rail in terms of cargo moved but nonetheless the largest source of cargo transit emissions. Heavy trucks emitted 80 MtCO_2e in 2008, and these emissions will rise to roughly 96 MtCO_2e by 2020 as the amount of cargo moved by heavy trucks increases.[177]

Transportation Abatement Potential

Because of the relative size of Canada's transportation sector, ICT could yield 55 MtCO_2e of GHG abatement, which is over a quarter of current transportation emissions. Of the 11 available transportation sublevers, logistics network optimization, truck route planning, telecommuting, and eco-driving stand to have the most significant impact. (Because of the conservative nature of the Canadian government's emissions accounting for buildings, the buildings abatement potential is similarly conservative. The buildings abatement potential could be higher than the 55 MtCO_2e stated).*

Logistics network optimization has the potential to yield 14.3 MtCO_2e of abatement, or 26 percent of the total ICT-enabled reductions in transportation. Logistics in Canada has such high abatement potential because of the growing importance of heavy trucking as a means of moving cargo and the logistics system's relative inefficiency compared to that of the U.S. If business continues as usual, emissions from heavy trucks will rise by 20 percent between 2011 and 2020 as the amount of cargo transported by heavy trucks grows. Meanwhile, Canadian logistics system managers are struggling to reduce inventory and bring down fuel costs. Canadian logistics costs were 12 percent higher for manufacturers, 18 percent higher for wholesalers, and 30 percent higher for retailers than those of their U.S. counterparts,[178] all despite lower fuel prices in Canada.[179] These higher costs result from higher fuel and inventory expenditures, which signify the release of unnecessary emissions. More effective implementation of logistics systems using ICT systems can make inventory flows more predictable, coordinate shipments to reduce empty trailer space, and ensure that drivers are driving in an eco-friendly fashion to bring down logistics costs and reduce trucking emissions.

In the same vein, truck route planning has the ability to decrease emissions by 5.0 MtCO_2e,

*Note: because of the conservative nature of the Canadian government's emissions accounting for buildings, the buildings abatement potential is similarly conservative. The buildings abatement potential could be higher than the 55 MtCO_2e stated

174. "Germany's Efforts to Reduce Carbon Dioxide Emissions From Cars: Anticipating a New Regulatory Framework and Its Significance for Environmental Policy", Kerry Rogers

175. Canada's Emissions Trends, Environment Canada, 24

176. Transportation in Canada 2011, Transit Canada

177. Canada's Emissions Trends, Environment Canada, 24

178. State of Logistics: The Canadian Report 2008, Industry Canada

179. State of Logistics: The Canadian Report 2008, Industry Canada

Case Study
Telecommuting
and Bell Canada

Source: "Innovating toward a low-carbon Canada: Using technology to transform tomorrow," World Wildlife Fund, 9

At Bell Telecom, almost half of the company's 48,550 employees are equipped to work remotely but a survey revealed that only 6 percent of workers choose to exercise this option. The typical worker only does so occasionally, and the average number of days worked offsite for telecommute-enabled workers is 4.8 days per month (measured over 18 workable days including holidays, sickness, and so on). Regular telecommuters will work from home far more frequently, averaging 13.5 days per month.

Despite worries about productivity losses, both workers and management have come to embrace telecommuting. Workers cite lifestyle improvements as a major source of satisfaction and managers have seen that the use of technology has led to more efficient interactions. One Bell manager was quoted as saying, "The fact is some teleworkers can be more efficient than office workers through elimination of commuting, and reduced disruptions associated with normal office environments. Phone calls are more focused and shorter. Use of Instant Messaging has grown to replace e-mail and phone calls for obtaining info and permits more multitasking."

Telecommuting at Bell has yielded large energy savings. Twenty percent of workers commute 60 to 90 minutes each way, which is very resource intensive in terms of both time and gasoline. Bell estimates that their telecommuting policy has led to emissions reductions of 20,000 tons CO_2e annually.

Teleworking also allows Bell business to be more resilient by ensuring remote work access during any potential emergency situation.

which represents emissions reductions of 9 percent of the transportation total. Although many truckers may check to make sure they take the shortest route possible, this is not always the most fuel-efficient route because of terrain changes, speed limit changes, traffic, and tolls. Advanced ICT software can help truckers minimize their fuel costs and maximize profits by determining the most fuel-efficient route between two places.

Telecommuting can yield up to 11.6 $MtCO_2e$ in GHG abatement because of Canada's heavy reliance on private cars for commuting. Canadians tend to drive large cars, drive to work alone, and live in low-density communities, and therefore large quantities of fuel are consumed as people physically commute to work. Allowing people to work from home via mobile computers and the Internet makes a round trip commute to the office unnecessary. Telecommuting also enables employers to pay for less office space and accordingly lower their heating and energy bills.

The eco-driving sublever has an abatement potential of 11.0 $MtCO_2e$, representing 20 percent of the transportation total. Modifying the way a person drives and maintains her car has significant potential to increase fuel efficiency. Making small modifications to behavior, such as driving 55 mph on the highway rather than 75 mph, can yield significant energy savings, increasing fuel efficiency by 25 percent.[180] Remembering to close windows when driving over 50 mph can reduce wind drag and increase energy efficiency, as can moderating air conditioning and heater use. Drivers can also increase energy efficiency by engaging in regular vehicle maintenance, such as keeping tires properly inflated and changing oil regularly. ICT can make it easier to adopt eco-driving techniques by integrating technology into cars that would inform drivers when they are driving inefficiently and when to perform maintenance. Apps on smartphones and tablet computers could also perform a similar role without being directly built into a car.

Business case

Most of the transportation sublevers are reasonable investments in Canada. Truck route optimization has the strongest business case because of the low up-front costs and reasonable return on investment. Fleet management and logistics optimization are also sensible investments because of the inefficiencies in Canada's logistics systems and its high costs relative to its southern neighbor. Videoconferencing is also particularly attractive, as up-front costs are only the purchasing of A/V equipment and it allows employers to make a marked reduction in the number of flights required for business. Telecommuting has similarly low up-front costs and has a high return on investment, but the attractiveness of investment for employers is low because of the split-incentives problem. Eco-driving is easy to implement and has low up-front costs, but the absolute return on investment may be too low to induce major behavioral changes. Traffic management and real-time traffic alerts are also attractive, which explains their already high penetration in Canada. Integration of EVs is again the least attractive transportation sublever, as the projected energy savings are not significant enough to offset the large initial investments required by the Canadian government to improve infrastructure.

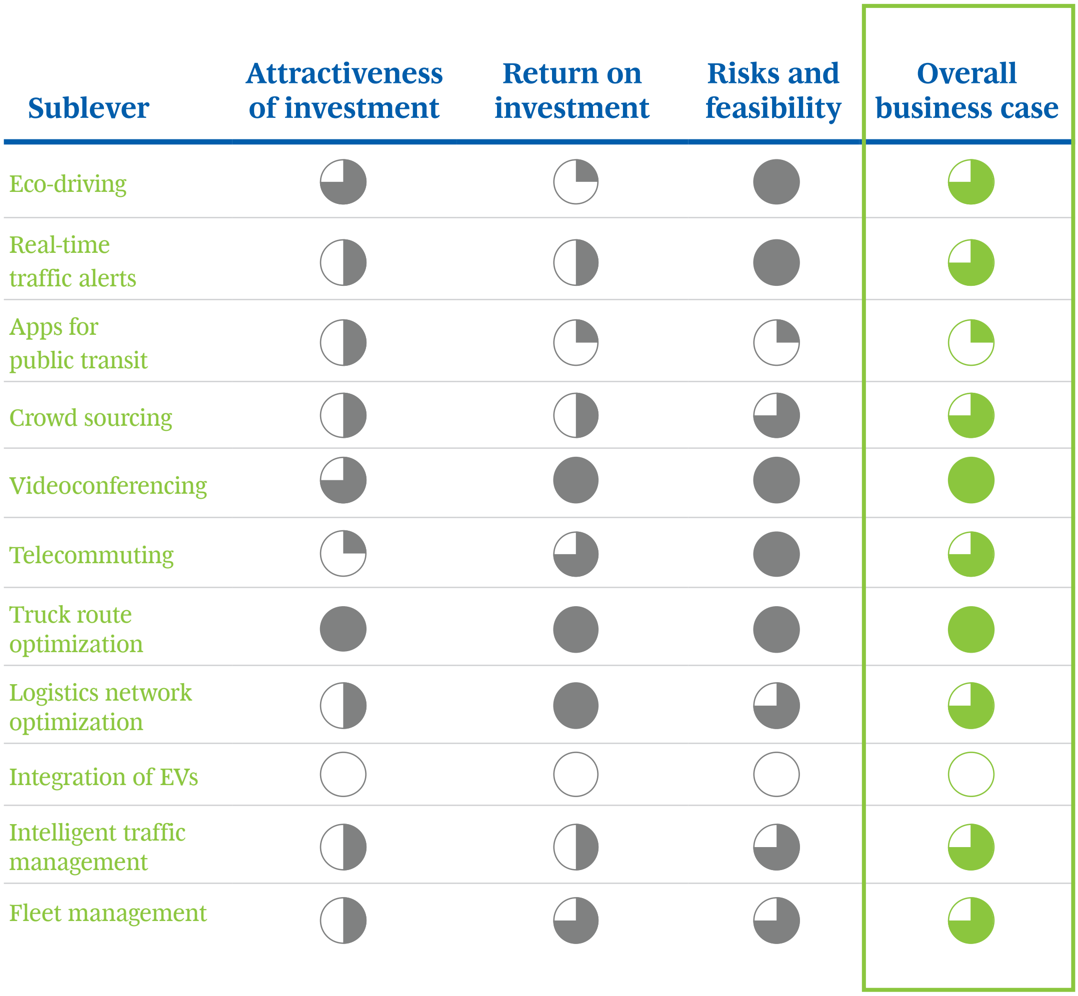
Videoconferencing has a particularly strong business case in Canada, particularly given the long flights that connect Canada's major cities. Depending on a business's access to capital and its willingness to spend on videoconferencing systems, up-front videoconferencing costs can range between very inexpensive to moderately expensive. For example, at Bell Canada in 2011, employees conducted more than 1.1 million teleconferences and also substituted Web and videoconferences for travel. That reduced travel costs and eliminated the emission of an estimated 2,300 tonnes of greenhouse gases during the year. On the low end would be a

180. California Energy Commission, Consumer Energy Center

Figure 74
Business case assessment of transportation sector sublevers

Source: BCG analysis

Low attractiveness
High attractiveness



Web-enabled PC, tablet, or smartphone with a webcam that can connect people via cost-effective or even free programs found on the Internet. Systems like HP's Halo videoconferencing system can cost up to $350,000 but are so technologically advanced that it can feel as though all the participants are in the same room.[181] While video conferencing cannot replace all business travel, it can decrease the number of less essential trips taken and has been estimated to reduce business travel by 11 percent per year.[182] Even the most expensive video conferencing systems can pay for themselves over a year, meaning that video conferencing systems can yield large savings over the course of the device's lifetime.

Barriers and policy solutions

Despite the environmental benefits associated with adopting ICT to help lower GHGs, there are obstacles that may prevent widespread adoption of these technologies. However, different policies at the national and provincial levels could help incentivize their uptake.

One of the most significant barriers to the uptake of logistics systems is the unclear return on investment and trouble with financing. The problem with logistics expenditures is that they represent high upfront costs, meaning that they can be difficult to finance and have significant, potentially adverse balance sheet implications.[183] Though most logistics investments will pay for themselves over time,

181. "Will Video Conferencing Kill the Road Warrior?", the Economist

182. Ibid

183. "Chapter 3: Measuring logistics costs and performance," Supply Chain Management

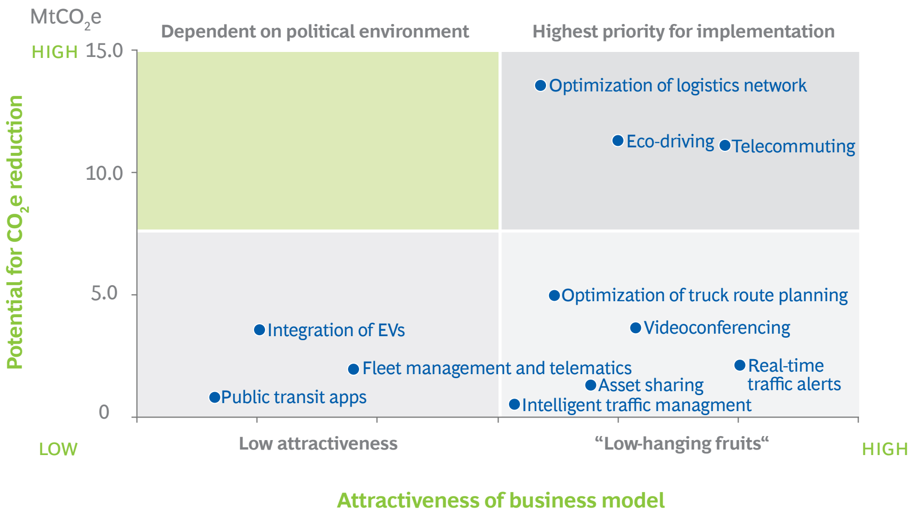


Figure 75
Prioritization of policy by potential for CO_2e reduction and business potential

Source: BCG analysis

Table 24
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome them

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Behavior	• ICT-enabled GHG reductions in transit require large behavioral shifts	**Use economic incentives to facilitate good behavior**	• Increases in gasoline tax or implementation of a carbon tax could be unpopular politically • Given the infrastructure in place, economic incentives may not be enough to induce desired behavior, i.e., in public transit
Economics	• Return on investment for logistics systems unclear • Break-even point takes too long to reach	**Allow for tax write-offs of logistics equipment**	• Fiscal implications of allowing for equipment tax write-offs
Missing infrastructure	• Dependence on limited public-transit system	**Make funds available for public transit investments**	• Despite investments, low population density of Canadian cities could keep public transit use low
Split incentives	• Workers benefit from telecommuting, but management is concerned about lost productivity and harm to culture	**Reward businesses monetarily if percentage of work days are done via telecommuting**	• Determine what percentage will be set for monetary incentive • Incentive must be large enough to offset telecommuting capital costs

the payback period can vary widely. Each company's situation is unique, inventory can fluctuate substantially, and it is difficult to accurately project future fuel costs. As a result, a company cannot be sure of exactly how long it will take to recoup its initial investment. With warehouse management systems, for instance, some firms can reach the break-even point within three months whereas for other firms it can take well over 18 months.[184] Because many companies are wary of making large investments that have an uncertain, potentially long payback period, they may choose to forego investing in logistics systems.

To incentivize the use of logistics systems, the government can take several steps. One easy step is allowing businesses to write off third-party logistics expenses. If a company wants to improve its logistics to increase efficiency and reduce its emissions but is concerned with investing in logistics technology itself, collaborating with a non-asset-based logistics firm is a low-risk way of doing so. This option will be attractive for many companies (particularly retailers) as China is becoming an increasingly important, though unpredictable, trading partner.[185] Contracting with external firms can help companies manage the risk of unpredictable inventory fluctuations coming from China. The government can incentivize collaboration between non-asset-based logistics firms and companies by allowing for companies to write off their third-party logistics expenses. There is a risk, however, that reducing the cost of contracting with logistics firms could facilitate offshoring and increase demand for transportation, both of which could cause emissions increases.

Additionally, to incentivize transportation companies to invest in their own logistics equipment and to bypass third-party providers, the government could offer low-cost financing to decrease the upfront costs associated with setting up logistics systems. Finally, the government could make logistics systems more financially attractive by increasing gasoline taxes. Though this would further make the case for logistics improvements, increased gasoline taxes are very unpopular politically, particularly because Canada is highly reliant on cars. It would be most prudent for policy makers to enact the first two solutions before raising gasoline taxes.

Inducing behavioral changes is another barrier to ICT adoption, particularly with regard to eco-driving. Eco-driving requires changing ingrained driving behaviors, which can be difficult to do even when it makes economic sense. Although there is little the government can do to force people to change their behavior aside from more stringent enforcement of speed limits, it can lead by example and provide the necessary information to make informed decisions. The federal and provincial governments can mandate that their employees utilize eco-driving applications to reduce fuel consumption and possibly induce other Canadians to follow their example. The national and regional departments of transportation could also provide information about the benefits of eco-driving by mandating that information on eco-driving be included as part of drivers' education programs and that its benefits be displayed in point-of-contact displays when people renew their licenses.

Alternatively, the government could mandate the inclusion of eco-driving ICT in vehicles. The Canadian government has mandated specific modifications to Canadian vehicles (when it mandated daytime running lamps in all cars beginning in 1990, for instance) and could do so again with eco-driving technology. While this would be an effective means of ensuring uptake, it could meet significant resistance from manufacturers and consumers, as the inclusion of the technology would drive up the sticker price of automobiles.

184. "Top Five Ways Warehouse Management Systems Deliver ROI," Inbound Logistics Magazine

185. State of Logistics: The Canadian Report 2008, Industry Canada

With telecommuting, there is a split incentives barrier. Telecommuting helps workers reduce their spending on energy because they do not have to pay to get to work and it saves them time in transit. However, employers see few benefits (slightly lower office space and energy requirements) and incur some costs from of telecommuting. Telecommuting requires that employers pay for the ICT technology that allows employees to work from home and there is a perception among many employers that they will bear costs associated with productivity loss and workplace culture deterioration. To align incentives so that employers also have an interest in letting workers stay at home, the government should allow for a tax credit if businesses allow a certain percentage of work days to take place from home. This credit must be large enough to compensate for both the hard cost of ICT systems upgrades and the associated soft costs.

Lastly, the lack of infrastructure is a particularly difficult challenge to address. Upgrades to infrastructure must be funded for people to start using electric vehicles or to more readily use public transit. Using ICT to integrate EVs with a smart grid does not work if there is not a smart grid in place, and commuters will not use apps to make public transit more predictable if public transit remains highly inefficient. To address these concerns, the federal government should allocate more funds for smart grid construction and increase funding for public transit infrastructure upgrades while also exploring public-private infrastructure ventures to bring down the cost of infrastructure investments. These types of infrastructure upgrades are an expensive proposition, however. Given that funds are limited, these policy solutions should be deprioritized because of their high cost and relatively low abatement potential.

Buildings

Context

Canadian buildings emitted 79 $MtCO_2e$ in 2010, which was 11.4 percent of Canada's total emissions. These emissions are driven by the fact that Canadian buildings are far larger than the global average and heating needs are

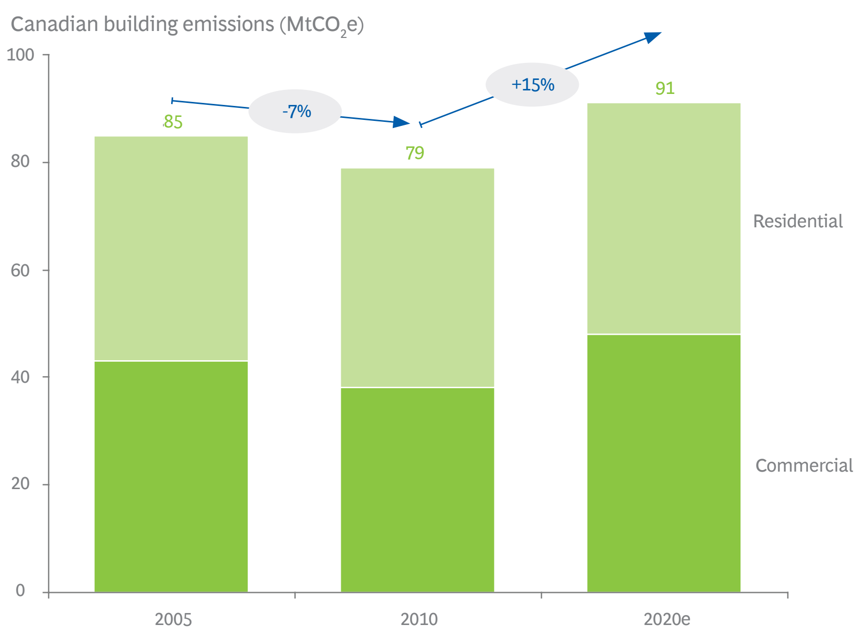


Figure 76
Canadian buildings sector greenhouse gas emissions

Source: Environment Canada

high because of the cold climate; heating in Canada consumes roughly 63 percent of all energy used in buildings.[186] Emissions from commercial and residential buildings each make up roughly half of total buildings emissions, commercial buildings having emitted 38 $MtCO_2e$ in 2010 while residential buildings emitted 41 $MtCO_2e$.

Buildings emissions have been on the decline since 2005. Emissions have gone down 6 $MtCO_2e$, which represents a 7 percent reduction. These reductions resulted primarily from energy efficiency gains from commercial buildings, which saw emissions decline from 43 $MtCO_2e$ in 2005 to 38 $MtCO_2e$ in 2010. These emissions have been occurring as a result of government efficiency programs in spite of increases in capacity. Between 2005 and 2010, Canada added 900,000 new households and 1.24 million m2 of commercial floor space.

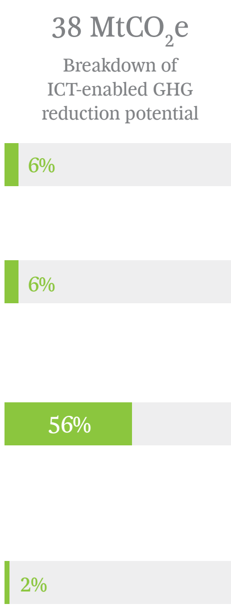
The federal government and numerous provincial governments have instituted a number of programs aimed at increasing the energy efficiency of buildings. The National Energy Code for Buildings, which sets minimum efficiency standards for buildings, increased its standards for new buildings by 25 percent between 1997 and 2011. Many builders have aimed for efficiency standards 25 percent higher than the minimum required by the government, leading to further emissions reductions.[178] The federal government also ran the ecoENERGY program with its provincial equivalents to help homeowners pay for energy saving retrofits between April 2007 and March 2012. Under this program, homeowners could receive up to CAD 5,000 in grants to help save energy, assuming that they met several criteria. Programs like these and their commercial equivalents helped decrease buildings emissions.

Many of the easiest efficiency gains have already been realized and government programs to aid with retrofits are beginning to wind down, meaning that building efficiency gains are projected to stall. Moreover, Canada is expected to add another 1.8 million new households and 1.8 million m2 of new commercial floor space between now and 2020. The combination of slowing efficiency gains and more capacity means that emissions are expected to rise by 15 percent to 91 $MtCO_2e$ by 2020.

186. "Energy Efficiency Trends in Canada, 1990 to 2007," Chapter 3, Office of Energy Efficiency

Figure 77
ICT-enabled GHG reduction potential in the building sector

Source: BCG analysis



Sublevers	Drivers of sublevers
Integration of renewables ($7.3\ MtCO_2e$)	• Wide-scale renewable use, particularly increased use of hydro and wind, is an opportunity to switch from coal-generated power to carbon-free energy sources
Building management system ($4.0\ MtCO_2e$)	• Would provide savings for nearly every type of building – very large addressable market but depends on quality technology and favorable economics
Building design ($10.9\ MtCO_2e$)	• Large addressable market because of current inefficient design and high penetration because of low costs • Important to incorporate to diminish the impact of Canada's new building capacity
Voltage optimization ($3.4\ MtCO_2e$)	• Large potential due to high electricity use in buildings, but dependent on smart grid construction

Buildings abatement potential

There are significant opportunities for abatement using ICT within the buildings sector, yielding a total of 26 $MtCO_2e$ in possible abatement. This represents a reduction of nearly a third of 2010's total building emissions. The two most significant abatement opportunities are optimized building design and the integration of renewables.

Building design holds the potential to reduce emissions by 11.2 $MtCO_2e$, which is 43 percent of the total abatement potential for buildings. ICT can address GHG emissions through building design in two ways. First, much of the advanced technology installed to reduce energy consumption relies on ICT. Seemingly small factors in a building's design can have enormous implications for energy consumption levels. The challenge, however, is that there are so many different factors to take into consideration that it is more difficult to maximize energy efficiency using traditional architecture tools. One of the ways ICT can lower buildings emissions is by allowing architects and developers to use computerized simulation, modeling, analysis, monitoring, and visualization tools to determine how different factors would affect energy consumption.[187] The use of these tools will be particularly helpful in Canada as the country continues to add building capacity. Second, ICT can be leveraged to determine the energy performance of buildings and identify common inefficiencies. Policy makers can then use this information to determine best practices and opportunities and pass legislation that aims to promote these best practices.

The integration of renewables has the potential to reduce emissions by 7.5 $MtCO_2e$, which is 29 percent of the abatement potential for buildings. Canada has incredible resources to leverage with regard to renewable energy, particularly wind energy and, despite its northerly latitude, solar energy.[188] Particularly for commercial and farm buildings, where there is more land available for renewable energy installations, on-site renewable technologies stand to make a significant contribution toward reducing GHGs. Solar appliances and wind turbines can provide significant amounts of power in rural areas and photovoltaic panels can be installed profitably throughout much of southern Canada.[189] For these technologies to work, however, they require smart home energy meters and monitoring technology. Because many of these technologies will not supply 100 percent of a building's energy needs, they must be connected to an electricity meter that accounts for the renewables' contribution to the building's energy use. Smart building energy meters track total electricity consumption and subtract from that the amount of power provided by renewable sources. ICT is also required to ensure that renewable power sources are functioning correctly. If a solar panel stops working or a wind turbine goes offline, ICT is required to let the building owner know that the renewable energy generator is not functioning as it should.

Building management systems have the potential to yield 4 $MtCO_2e$ in abatement, which is 16 percent of the buildings total. Building management systems control a wide variety of building components, such as power systems; heating, ventilation, and air conditioning; and plumbing. They can reduce energy use and emissions by ensuring that resources are conserved by turning lights off when occupants are not in the room, reducing heating and cooling at night, and using smart sensors to reduce water waste. Because of the high heating requirements in Canada, building management systems stand to make a significant reduction in heating requirements. Building management systems are characterized by hardware connected to computers and software that oversee and maintain the building.

187. "Information Society: ICT for Sustainable Growth," European Commission

188. "Solar Energy Overview," Centre for Energy

189. Ibid

Case Study
Manitoba Hydro Place

When the developers of the Manitoba Hydro Place wanted to build one of the most energy efficient buildings in North America in Winnipeg, Manitoba, they knew it was bound to be a challenge. During the winter, temperatures in Winnipeg regularly dip below zero Fahrenheit and buildings must withstand a stiff southerly wind. Keeping energy use, particularly energy for heating, down to a minimum in spite of the adverse climate is not easily achieved.

Despite the difficulty, the use of ICT throughout the design process helped the architects reach their conservation goals. After conducting a number of computerized site evaluations, the builders were able to settle on a site that would take advantage of Manitoba's unique sunny winters and strong winds. By designing the building so no office was more than 30 feet from a window, the architects were able to cut down on power requirements for lighting and even used Manitoba's stiff winds to naturally circulate air throughout the building without relying on systems powered by electricity. The structure also has system features to naturally cool it during warmer months. For instance, when the temperature in the building rises above a certain threshold, sensors will communicate with automated windows that open to allow warm air to escape. All these ICT-enabled solutions have yielded energy savings for Manitoba Hydro of roughly 66 percent over usage in similar buildings in the area.

Not only is this building extremely energy efficient, but it has also integrated renewable energy sources into its energy supply. The building is powered primarily by geothermal wells and relies on solar power and hydropower to meet demand as required. The Manitoba Hydro Place's high levels of efficiency combined with the use of renewable energy greatly reduces the amount of GHGs released by the building. The use of ICT in new constructions across Canada can help combat emissions growth even as Canada continues to add more building capacity.

Finally, voltage optimization can reduce GHGs in Canada by 3.4 $MtCO_2e$, 14 percent of the buildings' total abatement. Many appliances function best on a lower voltage than what is actually supplied by the grid, and voltage optimization decreases incoming voltage to reduce energy use, power demand, and reactive power demand. Losses within the devices are reduced and the equipment operates at its peak efficiency level. Voltage optimization extends the life of the electrical equipment and reduces GHG emissions.

Business case

The building design sublever is by far the most attractive investment opportunity. Hiring architects and engineers that have the expertise and tools required to design a more energy efficient building may be more expensive than hiring less specialized professionals, but this relatively small upfront investment can yield large dividends over the course of the building. Moreover, it is easier to build a new building that incorporates efficient technology than it is to retrofit an older building. Building management systems require a relatively high initial investment, but have been proved to help reduce heating, cooling and lighting costs and are likely to yield a positive return. Voltage optimization requires a lower up-front investment than building management systems, but the return is likely to be lower and the payback period longer. Integration of renewables is the least attractive of the sublevers from a business perspective.

Renewable integration is not particularly attractive in the absence of government assistance. Power generation from coal and hydro is cheaper per kWh than power generated from wind and solar if there are not feed-in tariffs to make up for the disparity in cost (the disparity being dependent on several local factors). And, by virtue of the fact that renewable power generation is dependent on local environmental conditions (that is, sunshine and wind gusts), knowing with certainty the return on investment of a renewable energy system at a particular location is impossible. Moreover, investing in home renewable-energy systems represents a significant upfront investment that most households cannot make. Commercial lenders are often reluctant to finance such purchases because of the unclear return on investment. Government lending, which is currently on hold, is often required to spur the purchase of home renewable energy systems.

Barriers and recommended policy solutions

Most of the difficulties surrounding ICT adoption in buildings involve financing and economics. Many homeowners and small businesses may not be able to gain access to the capital they need to fund energy efficiency upgrades. For small-scale energy efficiency projects, it can often be difficult to secure funding from retail banks and, as a result, policy intervention is needed. To ensure that homeowners can continue to invest in energy efficiency, the federal and provincial governments should reinstate and expand the ecoENERGY programs that were suspended in early 2012. This would allow Canadians that did not take advantage of the program the first time around to have the opportunity of investing in energy efficiency. It should also raise the program cap to a level higher than CAD 5,000 so that more expensive projects, such as home renewable energy systems, that were not initially covered would yield additional efficiency gains. And, as funds are not unlimited, policy makers should focus their efforts and funds on those projects that will yield the highest abatement potential per dollar spent.

The government should also consider extending financing through the program to larger businesses. If the payback period for certain energy-efficiency investments is too

Figure 78
Business case assessment of building sector sublevers

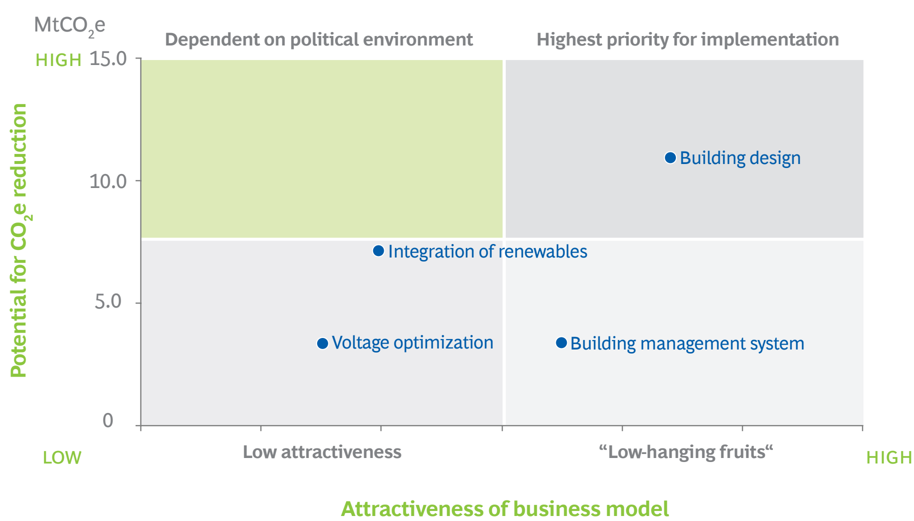
Source: BCG analysis

○ Low attractiveness
● High attractiveness

Sublever	Attractiveness of investment	Return on investment	Risks and feasibility	Overall business case
Integration of renewables	◔	◔	◔	◔
Building management systems	◑	◕	◕	◕
Building design	●	●	●	●
Voltage optimization	◕	◔	◑	◑

Figure 79
Prioritization of policy by potential for CO_2e reduction and business potential

Source: BCG analysis



long or uncertain, businesses may balk at the investment. Providing low-cost financing could make the investment opportunity more attractive for uncertain investments.

From an economics perspective, some technologies and sublevers may not yield high enough energy savings to be profitable at a small scale. There are two things that can remedy this situation: one is to raise the price of energy and the other is to lower the cost of the technology. Raising the price of energy through a CO_2e tax or permit system is easier technically to implement and requires less time to induce people to take up the technology. The problem, however, is that incorporating the externalities of GHG emissions into the price of energy is politically very unpopular and would be challenging to do in the absence of an international GHG reduction treaty. Lowering the price of the sublevers by encouraging innovation is much more popular politically but is more

Table 25
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome them

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Financing	• High up-front costs of some solutions prevent mainstream adoption • Low availability of financing for small-scale projects	Provide easy access to capital	• Create governmentally funded but privately managed green finance fund to ensure that NPV-positive projects can proceed
Economics	• Certain technologies and sublevers are not NPV-positive at small scale, e.g., Building Maganagement Systems	Change economics through:	• Promoting technological innovation that drives down costs at small scale or improves performance • Offereing Tax rebates for EE upgrades
	• No incentives for companies to source energy generated from renewable sources	Provide incentives to purchase renewable energy	• Implementation of a carbon market • Renewable-energy-portfolio standards for power providers
Awareness & education	• Lack of awareness can be abarrier in some cases even if the solutions do not involve high cost and the economics work, e.g. Voltage Optimization	Expand the EnerGuide program targeted at educating consumers	• Expand the program to include more devices • Legislate that ratings be more prominently displayed • Increase public visibility of the program through advertising
Split incentives (landlord/tentant problem)	• Tenants or others who are renting capture benefits of efficiency upgrades but the owner will not make the investment unless ROI is guaranteed • Complex ownership structure for large buildings prevents pushing abatement solutions as far as is economically reasonable or possible	Create regulatory structures that align incentives	• Encourage building owners to implement carbon abatement solutions by transferring some of the energy cost savings from tenants to owners • Implementation of property taxation based on energy efficiency

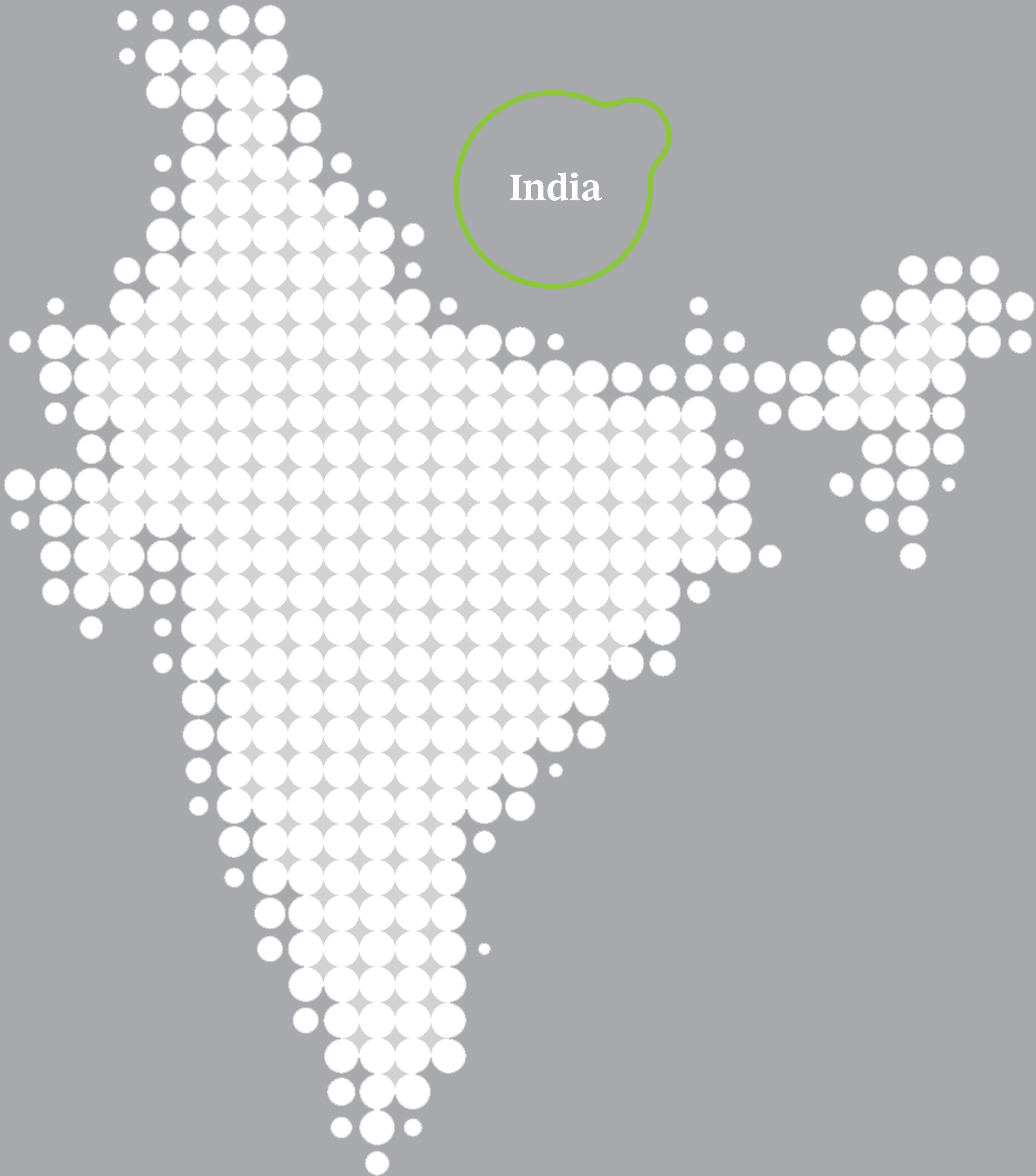
challenging to achieve. Creating an environment that allows for technological development by providing tax breaks for R&D and increasing intellectual property protections for GHG abatement technology takes years to yield results and will not immediately address the economic concerns that are hampering uptake.

A second concern surrounding the economics of ICT uptake in buildings is that there are limited incentives for consumers and businesses to integrate renewable energy into their power supply. In the absence of government policies, it is easier and often cheaper for most building owners to get their power from utilities that produce electricity from fossil fuels. Feed-in tariffs or guaranteed payments per kWh of electricity produced from renewable sources are an excellent way of convincing many building owners to install renewable energy capacity on site. Feed-in tariff rates are set by policy makers to cover the cost of a device's installation and ensure a reasonable return on investment. Ontario already has a feed-in tariff program for small-scale renewable projects called microFIT, which pays a guaranteed price for renewable energy installations with a capacity of 10 MW or under for 20 years.[190] Though renewable energy systems are not viable investments for all buildings given their local conditions, feed-in tariff programs like microFIT can reduce the risk of installing such systems for homeowners where renewable energy systems are viable. To promote renewable energy integration in buildings across Canada, the federal government and other provinces should adopt feed-in tariffs modeled after Ontario's. However, feed-in tariff programs can be expensive and provinces will need to take into account their individual fiscal situations when determining the size of the program.

There is also concern surrounding a lack of awareness of energy abatement solutions. Many people may not be aware that ICT-enabled technologies exist to reduce home and commercial energy use. Even when people are aware of different means to reduce energy consumption, they may not understand the magnitude of the energy and money savings. As a result, it is important that policy-makers help consumers and businesses understand the potential savings by adopting energy efficient technology. The Canadian government already has a program called EnerGuide that allows people to compare the relative energy efficiency of different appliances and provides home-energy-efficiency tips, such as using insulation to reduce heating costs. EnerGuide should be expanded to include ICT-enabled energy solutions so that consumers have a better idea of how much money they can save. It should also provide information to builders and designers about how they can leverage ICT in the design of energy-efficient buildings.

Finally, there is a split incentives problem for landlords and tenants when investing in energy-efficient technologies. Although some tenants have their utilities included as part of their rent, many tenants are paying their own energy bills, and the landlords, who typically are the ones investing in energy efficiency improvements, have little incentive to do so in this case. Given that they do not capture the energy savings, there is no rationale for them to do so. As a result, policymakers should create regulatory incentives that align the interests of landlords and tenants. One way they could do this is by transferring some of the energy cost savings from tenants to owners through a small rent increase or through some other contractual measure. Alternatively, localities could index their property taxes to energy efficiency to incentivize energy efficiency upgrades.

190. "What is microFIT?", Ontario Power Authority


India

13 India

13.1 Context

India's rapid economic growth has led to high growth of greenhouse gas (GHG) emissions. In 1994, India's total GHG emissions were 1,252 $MtCO_2e$; by 2007 those emissions had reached 1,905 $MtCO_2e$, which represents an increase of 52 percent over that period.[193]

A longer time-series of GHG emissions is not available, but a look at CO_2 emissions show s that rate of emissions growth has increased since 2005 as a result of faster rate of economic expansion since 2005. CO_2 emissions increased by 4.6 percent CAGR between 1990 and 2005 while Indian GDP growth averaged 6 percent per year, and CO_2 emissions growth rose to 7.3 percent between 2005 and 2011 while GDP growth accelerated to 8 percent per year (see Figure 80).[194]

India emitted 5.6 percent of the world's total CO_2 emissions in 2010, making it the world's third largest emitter behind China and the U.S.[195] On a per capita basis, India's emissions are much lower when compared to developed countries: India's 2010 CO_2 emissions were 1.5 tons per capita, as opposed to the EU-27 per capita figure of 8.1 tons. India's per capita emissions are low even compared to other big developing economies. For comparison, China had per capita emissions of 6.8 tons in 2010 and Brazil's per capita emissions were 1.9 tons.[196] With regard to emissions intensity, India is roughly the median of the developing economies. India's 2005 emissions intensity of .37 kg CO_2e per USD of GDP is between that of Brazil and China and has recently been on the decline; between 1994 and 2007, India's emissions intensity decreased by more than 30 percent.[197] The Indian government is hoping to maintain the downward trajectory of its emissions intensity and has stated a reduction target of between 20 and 25 percent of the 2005 level by 2020.[198]

Emissions have grown in almost all sectors (with the exception of agriculture), but the most significant sources of emissions growth have been from the power and industrial sectors. Emissions from the power sector grew from 355 $MtCO_2e$ in 1994 to 719 $MtCO_2e$ in 2007, a CAGR of 5.6 percent. This emissions growth has been driven by increases in

193. "India: Greenhouse Gas Emissions 2007," Ministry of Forests and Environment, Government of India. Note: these figures exclude land use changes

194. World Bank

195. EDGAR

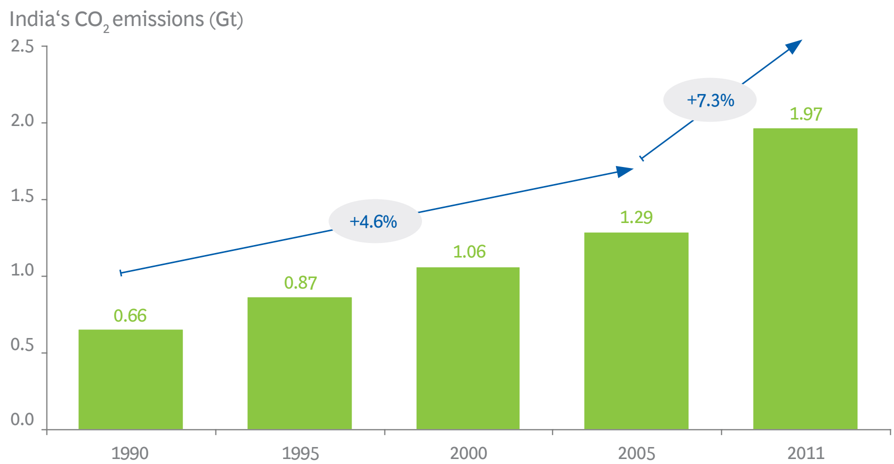
196. "Long-term Trend in Global CO_2 emissions, 2011 report," JRC European Commission, 16

197. 1. Ibid, 2. "Summary of GHG Reduction Pledges Put Forward by Developing Countries", World Resources Institute

198. "India Announces Plan to Slow Emissions," The New York Times

Figure 80
India's CO_2 emissions accelerating due to faster economic growth since 2005

Source: 1. xxxxx



	1990	1995	2000	2005	2011
% of global CO_2 emissions	2.9	3.7	4.2	4.4	5.8
GDP ($ Tn)[1]	.27	.35	.47	.65	1.03

electricity demand. As incomes have grown in India, the demand for electrical appliances such as TVs, refrigerators, and air conditioners has increased. Increased power demand in the commercial and manufacturing sectors has also pushed electricity use higher. As the energy demands from homes, stores, and factories have grown as a result of India's modernization, so too have the emissions from the power sector.

Emissions growth in the power sector was exacerbated by two factors: the inefficiency of the Indian power grid and the use of coal to meet demand increases. The Indian power grid is highly inefficient by international standards. The Indian national average transmission and distribution (T&D) loss is 22 percent of generated power, and in some states this figure can be as high as 50 percent.[199] By comparison, in China this figure is only 6 percent.[200] T&D losses are high in India because of a combination of high levels of electricity theft (particularly in rural areas) poor management of power generators, and grid infrastructure. Because of the highly inefficient grid, India must add additional generation capacity and generate more emissions to meet demand. Moreover, India has primarily relied upon fossil fuels when adding additional capacity. Estimates vary, but in 2009 electricity generated from coal, natural gas, and oil comprised between 65 and 84 percent of India's supply, with energy from renewables (excluding hydro) making up approximately 2 percent of India's electricity supply.[201]

Industrial emissions, particularly those from steel, cement, and chemical production, are becoming an increasingly significant source of India's emissions.[202] GHG emissions from industry rose to 413 $MtCO_2e$ in 2007, up 49.0 percent from 277 $MtCO_2e$ in 1994, representing a CAGR of 3.1 percent.[203] Of the rise in industrial emissions, 51.6 percent can be attributed to increases in cement production. As India has become increasingly urban, high domestic demand for cement has made India the second-largest cement producer after China and has pushed emissions higher.[204]

Transportation emissions are also on the rise because of a more than an eighteenth-fold increase of the number of vehicles on India's roads since 1985. In 1985, there were 5.4 million registered vehicles on India's roads, and by 2007 that number had exploded to 99.6 million.[205] Eighty-seven percent of the emissions come from road vehicles, 7 percent come from aviation, 5 percent from the rail system, and 1 percent from water transport. Diesel, which is highly polluting, is the dominant fuel used for road transportation in India. It makes up 65 percent of the total fuel used in road transportation, while gasoline makes up only 24 percent.[206] Emissions from transportation remain a relatively small portion of India's overall emissions, at 7.5 percent of the total. Nonetheless, transportation emissions are growing significantly faster at 4.5 percent CAGR than the 2.9 percent CAGR growth of total emissions. Transportation emissions are growing faster than the overall total because of the rapid increase in the number of vehicles, a shift in vehicle mix toward more passenger cars, and a heavier reliance on trucking. The sector's emissions will likely continue to grow rapidly as a result of huge latent demand. In 2009, India was ranked one hundred thirty-ninth in the world in terms of per capita car ownership in 2009, with 18 cars per 1000 people. In the U.S., that rate is 812 cars per 1,000 people.[207]

Agricultural and land use emissions, though declining both in absolute and relative terms, remain India's third-largest source of emissions. The sector's footprint in 1994 was 355 $MtCO_2e$, which represented 27.6 percent of total emissions, but by 2007 it had declined to 334 $MtCO_2e$, representing 17.6 percent of total emissions. The majority of India's agricultural emissions result from the raising of livestock (64 percent), which is a particularly emissions-intensive process because livestock release methane as a byproduct of digestion. Rice cultivation, crop soils, and crop residue

199. "Transmission and Distribution Losses (Power)," The Energy Resources Institute

200. Ibid

201. "World Energy Outlook 2011," IEA

202. Over 69.6 percent of the sector's emissions are generated by cement, metal, and chemical production.

203. "India: Greenhouse Gas Emissions 2007," Ministry of Forests and Environment, Government of India

204. "Indian Cement Industry," Binal R. Vora

205. "India: Greenhouse Gas Emissions 2007" Ministry of Forests and Environment, Government of India. Note: by 2008, this figure had risen to 106 million registered vehicles [source: Department of Road Transport and Highways]

206. Ibid

207. "Motor vehicles (per 1000 people)", World Bank

burning comprise 21 percent, 13 percent, and 2 percent of total agricultural emissions, respectively. Much of the decline in agricultural emissions resulted from the decline in emissions from livestock. The number of cattle decreased by 1.2 percent CAGR between 2003 and 2007, leading to lower methane emissions.[208] More irrigation use in rice cultivation increased methane emissions, but not enough to offset the decline in emissions from livestock. And, unlike in many tropical developing countries such as Brazil and Indonesia, emissions from land use changes are not as serious a concern in India. In fact, through reforestation and reclaiming land to be used as grassland, India saw an increase in the carbon stock of its land by 67.8 $MtCO_2e$.

Current policy environment in India

At the national level, the Indian government has set goals that seek to moderate its GHG emissions. The National Action Plan on Climate Change (NAPCC), passed in 2008, is India's flagship climate change program. It has set eight missions that aim to improve India's environmental conditions by 2017.[209] One component of the NAPCC is the national solar mission, which seeks to promote the development of solar energy and has set a goal of increasing solar PV production to 1,000 MW/year by 2017. A second mission is to increase energy efficiency, which the government hopes will yield 10,000 MW/year energy savings through economic incentives for more energy efficient appliances and by mandating efficiency increases in large energy-consuming sectors. The government is also seeking to reduce emissions from waste disposal, particularly in urban areas, by encouraging recycling and by using more fuel-efficient waste collection vehicles. A fourth goal is to increase forest coverage from 23 percent of India's land mass to 33 percent.

As mentioned earlier, the Indian government has stated a targeted reduction of 20 to 25 percent of the 2005 level by 2020.[210] While these goals are ambitious and would help reduce India's emissions intensity, the legislation states that these goals should not interfere with economic growth and efforts to raise living standards.[211] The legislation explains that these goals were set because the government believes that they would yield both economic and environmental benefits. The federal government has pledged, however, that at no point during its development will India's emissions exceed the per capita levels currently seen in developed nations.

13.2 Impact of ICT on GHG emissions

In recent years, India has made some progress toward broader and deeper penetration of ICT, but the country's track record is mixed. Low usage rates and a poor regulatory environment continue to plague Indian uptake of ICT, but there are encouraging signs that ICT is being used as a base upon which a significant economic transformation is being built.[212]

India has significant improvement to make in terms of individual ICT usage. There were 612 mobile subscriptions per 1,000 Indians in 2011, which is low by international standards; this figure puts it in one hundred seventeenth place out of 142 countries considered. However, the number of subscribers is substantially lower since many consumers have multiple phones to take advantage of rate differences between carriers. As a result, only 26 percent of Indians are unique mobile phone subscribers.[213] However, it is important to note that even a low penetration rate implies a large number of subscribers given India's large population.

India performs even more poorly when Internet usage is considered.[214] Only 7.5 percent of individuals regularly use the Internet, placing India in 124th place in terms of Internet usage.[215] A lack of fixed and mobile broadband availability is the key driver of the low personal use of the Internet. For instance, only 2 percent of the population uses broadband. To overcome

208. Ibid

209. "Impact of Climate Change Policies on the Growth of the Indian Economy"

210. "India Announces Plan to Slow Emissions," The New York Times

211. "Summary: India's National Action Plan on Climate Change" Center for Climate and Energy Solutions

212. "The Global Information Technology Report 2012," World Economic Forum, 22

213. "GSMA Announces New Global Research that Highlights Significant Growth Opportunity for the Mobile Industry,"GSMA

214. "The Global Information Technology Report 2012," World Economic Forum, 230

215. Ibid

this problem, the government launched a program in February 2012 called the Bharat Broadband Network Limited, which aims to increase broadband connectivity to 600 million connections by 2020.[216] A second encouraging trend is that mobile broadband subscriptions surpassed fixed broadband subscriptions within 18 months of it first being available, suggesting that Indians are recognizing the potential of mobile devices as a means of driving economic growth and improving quality of life.

Despite the sector's challenges, there are many reasons for optimism. One is that India is the world leader in innovative, low-cost ICT offerings. India has pioneered the world's most inexpensive computers targeted at consumers, including the USD 35 touch screen computer developed in 2010, which seeks to increase the computer literacy of India's school children.[217] The cost of using high-speed Internet is declining as well; broadband data network providers have managed to pioneer a service that offers high-speed mobile access for less than USD 2 per month.[218] Further, mobile phone service rates are among the lowest in the world at USD 0.01 per minute.[219] Increased availability of low-cost ICT devices and services should help drive uptake as Indians grow progressively wealthier.

And, despite relatively low uptake by individuals, uptake by business and government is high by lower-to-middle income country standards, placing Indian businesses as the fourty-seventh most ready adopters of ICT of the 142 countries considered.[220] The government has also focused on ICT as a means of addressing many of India's most serious concerns, including job creation, corruption, and education; government use of ICT is accordingly higher than the income group average. Moreover, the government is seeking to base a broader economic transformation on ICT and the sector has a more significant economic impact than in peer countries. Nonetheless, whether the sector will serve as a base for broader economic changes remains to be seen.

Figure 81 shows ICT emissions in India. Emissions in 2011 were 55 $MtCO_2e$ and are expected to rise 9 percent CAGR to reach 118 $MtCO_2e$ by 2020. Though emissions increases will be seen from all three components of direct ICT emissions, 80 percent of the increase in emissions will result from greater use of end-user devices, as higher levels of affluence drive higher levels of device uptake.

The emissions increases from the ICT sector are exacerbated by the high inefficiency levels

216. "Frequently Asked Questions,"Bharat Broadband Network Limited

217. "India develops the world's cheapest laptop at $35," Reuters

218. "The Global Information Technology Report 2012," World Economic Forum, 82

219. Open Technology Initiative (http://newamerica.net/publications/policy/an_international_comparison_of_cell_phone_plans_and_prices)

220. "The Global Information Technology Report 2012," World Economic Forum, 22

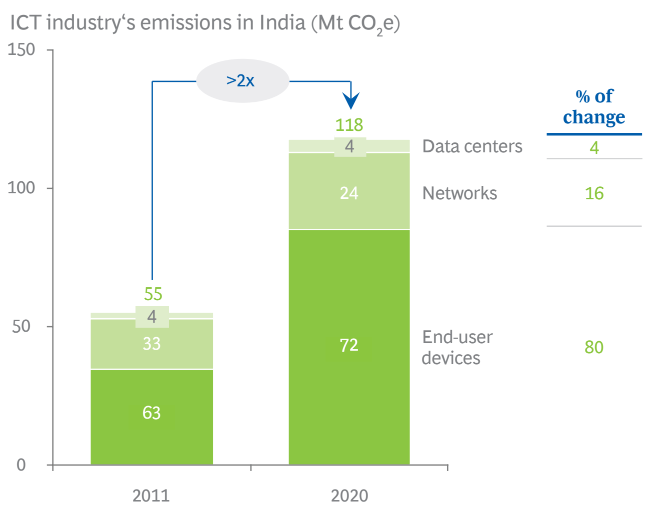


Figure 81
ICT emissions in India, 2011 and 2020

of the power sector. For instance, limited grid connectivity necessitates high diesel use to run cell phone towers in India. This leads to a large footprint of the mobile phone network operators. A recent study by the Telecom Regulatory Authority of India (TRAI) study found that 60 percent of the 400,000 towers run on diesel generators, emitting over 10 Mt of CO_2 annually. However, in April 2011. TRAI mandated that 50 percent of all rural towers and 20 percent of urban towers must be run on hybrid power (renewables and grid power) by 2015, with a further increase to 75 percent of rural towers and 33 percent of urban towers by 2020. [221]

13.3 Abatement potential in power and transportation end-use sectors

For India, this study focuses on the abatement potential in the power and transportation sectors because of their growing contribution to the overall emissions total and the ability of ICT to contribute to emissions abatement. The power sector is the largest contributor to India's emissions and they are projected to continue growing quickly as India experiences economic growth. Moreover, particularly through grid optimization, ICT stands to make significant abatement contributions in that sector. The transportation sector, though a relatively small portion of emissions currently, is growing as a share of overall emissions, and ICT can help improve the highly inefficient logistics network. The manufacturing sector, though the second-largest contributor to GHG emissions, was not considered because ICT-enabled abatement is more challenging as it produces primarily cement, steel, and chemicals, leaving less applicability for the identified sublevers, and low Indian wages make automation of industrial processes less attractive from a business perspective. The agriculture and land use sector, the third-largest contributor to GHG emissions, was not selected because it is declining as a share of India's overall emissions, and low incomes and the lack of infrastructure in rural areas presented a challenge for ICT uptake. As India is still developing, buildings are smaller and consume less energy, and the sublevers identified may be too costly given Indian income levels. The emissions from the service and consumer sector were lower than the other considered end-use sectors and were therefore not used.

Power

Context

As India has experienced rapid economic growth, the demand for electricity from consumers, businesses, and industry has grown quickly. Consumer demand has been driven by the desire to use electric lighting, TVs, refrigerators, and, of particular importance in India, air conditioning.[222] Only 3 percent of Indians had air conditioning in 2008, but use is expected to increase dramatically as there is huge latent demand; by 2015, this figure is expected to rise to 5 percent.[223] According to some estimates, the electricity required for cooling the city of Mumbai could potentially equal a quarter of all the power used for air conditioning in the U.S.[224] India's industrial sector has also helped drive demand higher. Because cement, steel, and chemicals, the backbone of India's industrial sector, are very energy-intensive industries, their electricity needs have risen accordingly. Higher income levels and subsequently high consumption allowed electricity use to surge 44 percent between 2000 and 2010, rising from 416 billion kWh to 601 billion kWh.[225]

This rise in demand, however, has outpaced increases in supply. 40 percent of Indians remain unconnected to the power grid, and even those who are connected regularly experience blackouts, particularly in rural areas.[226] India routinely runs energy supply deficits that are 10 percent of peak demand levels, leading to cascading blackouts.[227] Not even India's major cities are immune, as

221. "Recommendations on approach towards green telecommunications" – TRAI (April 2011)

222. "The Cost of Cool" The New York Time, Elisabeth Rosenthal

223. "Factors Favour Indian AC Market", The Economic Times, Sanjeev Sinha

224. "The Cost of Cool" The New York Time, Elisabeth Rosenthal

225. CIA World Factbook, note: this is beyond the population growth of 18% over the same time period

226. "Country Analysis Briefs: India," Energy Information Administration

227. "Background and Impacts of World's Largest Blackout in India," the Institute of Energy Economics, Japan

evidenced by the largest blackout in history that took place on July 30 and 31, 2012, which left 670 million people (roughly 10 percent of the world's population) in the dark.[228] These blackouts carry significant economic consequences. Not only do they cause productivity losses, but they also affect long-term economic decisions. Having to build emergency power capacity to cope with the challenges posed by supply disruptions is a burden on business and hinders economic growth.

The need to increase the electricity supply is exacerbated by the poor state of India's power infrastructure. The Indian power grid is highly inefficient, and much of the generated power is lost to transmission and distribution (T&D) losses. Though estimates vary, the Indian national T&D loss of electricity is approximately 22 percent. In some Indian states such as Jammu and Kashmir, the T&D losses reach nearly 50 percent.[229] By comparison, T&D losses in both Canada and China are 6 percent.[230] As a result, Indian power generators must increase supply by a significant margin over demand increases to meet demand requirements.

To meet most of the increase in electricity demand, Indian utilities have boosted their fossil fuel-based capacity. Estimates vary, but between 68 and 84 percent of India's electricity was generated by fossil fuels while renewables make up between 2 and 12 percent of electricity generation.[231] The government is hoping to change the situation surrounding renewables rapidly, however. India has set ambitious targets for renewable electricity generation to ensure that renewables become a more significant component of the effort to meet increased demand. The government plans to increase the share of renewables as a portion of the power supply by 1 percent per year to ensure that 15 percent of all electricity in India comes from renewable sources by 2020.[232]

The principal way the government is looking to increase renewable energy generation is by increasing wind and solar power generation. Under the NAPCC, the Ministry of New and Renewable Energy plans to almost double wind energy production from 13,900 MW in 2011 to 27,300 MW in 2017. The ministry wants to expand solar in a dramatic fashion as well,

228. "2nd Day of Power Failures Cripple Wide Swath of India," the New York Times

229. "Transmission and Distribution Losses (Power)," The Energy Resources Institute

230. Ibid

231. 1. National Action Plan on Climate change (2008), 2. CIA World Factbook, 3. IEA, 4. "India is committed to increasing share of renewable energy," Government of India Press Information Bureau

232. "Strategic Plan for New and Renewable Energy Sector for the Period 2011-17," Ministry of New and Renewable Energy

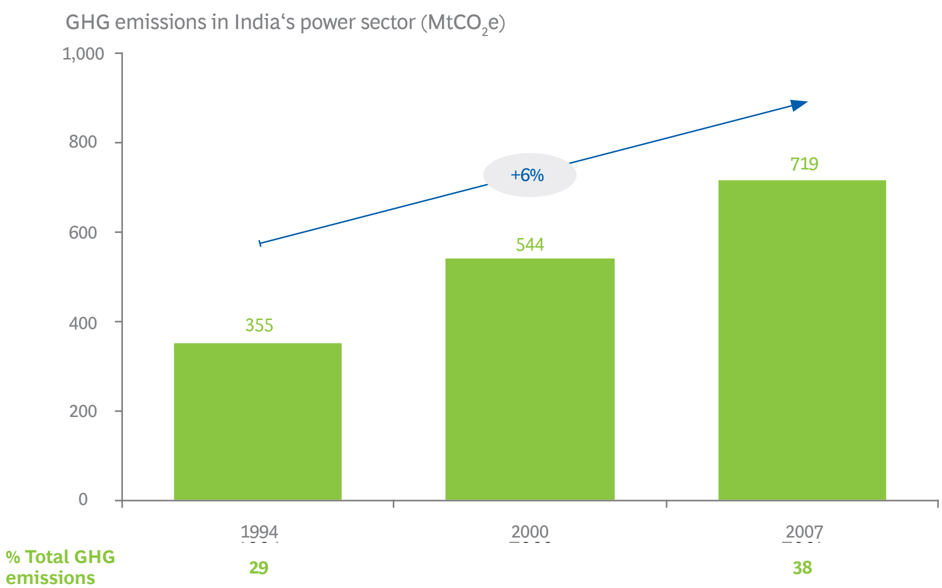


Figure 82
GHG emissions in India's power sector, 1994-2007

from 35 MW today to 4,035 MW by 2017, which goes well beyond the target of 1,000 MW set in the national solar mission in the NAPCC.[233] An important aspect of renewables as an energy source is that they are inherently decentralized forms of energy production, and as such, they can be particularly helpful in electrifying rural areas. Even if this increase in renewable energy capacity is realized, the share of renewables as a percentage of total electricity-generation capacity will remain low relative to fossil fuels, constituting only 15.9 percent of electricity production by 2022.[234]

Despite increasing use of renewables, higher demand for electricity and consistent reliance on fossil fuelshas pushed the power sector's emissions higher over the course of India's economic ascent. In 1994, the emissions from the power sector were 353 $MtCO_2e$ and by 2007 emissions from electricity generation had more than doubled to 719 $MtCO_2e$. The CAGR of emissions growth from the electricity sector of 5.9 percent is more than double that of total emissions growth, which had a CAGR of 2.9 percent (including land use changes).[235] Ensuring that emissions growth from the power sector is moderated requires increasing integration of renewable energy into the supply as well as modifications to the power infrastructure to bring T&D losses more in line with international levels.

233. Ibid

234. "Energy Scenario and Vision 2020 in India", Journal of Sustainable Energy & Environment, 16

235. "India: Greenhouse Gas Emissions 2007," Ministry of Forests and Environment, Government of India

Figure 83
Power sector abatement potential, 2020

141 $MtCO_2e$ Breakdown of ICT-enabled GHG reduction potential	Sublevers	Drivers of sublevers
1%	Demand response (1 $MtCO_2e$)	• Reduction of peak load electricity • Lack of necessary technological infrastructure expected to be a hindrance
10%	Time-of-day pricing (14 $MtCO_2e$)	• Could be useful to lower the peak demand, especially in urban areas where the peak is caused by heavy air-conditioner use • Reduction potential due to removal of highly polluting 'peaker plants'
7%	Power load balancing (10 $MtCO_2e$)	• Some potential to reduce total capacity required • Especially valuable if renewables are indeed scaled up to meet 15% of power demand as planned
65%	Power grid optimization (91 $MtCO_2e$)	• Use of ICT-enabled technologies to detect and reduce T&D losses • Large potential in India due to massive T&D losses (22%)
17%	Integration of renewables (24 $MtCO_2e$)	• Large potential in India due to big solar and wind resource • Low reach of the grid also makes it an attractive option to reach the unconnected population
1%	Integration of storage into off-grid applications (2 $MtCO_2e$)	• Important for niche applications like replacing diesel use to run cell phone towers (6 $MtCO_2$ emissions from cell phone towers today)

Power sector abatement potential

When considering the ICT-enabled abatement potential within the power sector, the seven sublevers offer a combined 143 $MtCO_2e$ of abatement. The most significant opportunities result from the optimization of the power grid and the integration of renewables. Time-of-day pricing and power-load balancing also offer significant abatement opportunities, though the abatement potential is lower.

The use of ICT to optimize the state of the power grid stands to yield enormous CO_2e abatement because of its poor state of repair. Even if T&D losses are reduced by just a third, to levels still high by international standards, optimizing the power grid would yield 91.4 $MtCO_2e$ of abatement. ICT can play a role in power grid optimization by gathering information on suppliers, consumer behavior, and grid inefficiencies. Power generators, transmitters, and distributors can then use that information to analyze and address areas where T&D inefficiencies arise. Though the development of a smart grid would likely occur in phases over a period of time, using smart meters to determine efficiency losses would be among the first steps of development and is one of the easiest applications of smart grid technology.[236] While smart grid implementation is not the only way of addressing T&D losses, it is the easiest way to simultaneously detect those efficiency losses and discover power theft.

The integration of renewables is another significant opportunity for GHG abatement in the Indian power sector, offering 23.8 $MtCO_2e$ in abatement. This is particularly important as demand for electricity is expected to rise 91.7 percent between 2009 and 2020; renewables can play an important role in meeting demand increases, particularly for rural areas that are currently not connected to the power grid.[237] There are a number of challenges with relying on renewables as a source of power, primarily that production is often not synchronized when demand is highest. For instance, if large amounts of solar power are produced during the day and cannot be used to meet peak energy demand at night, the renewable energy production does not help offset the need for fossil fueled electricity generation. By better synchronizing renewable energy supply with demand, ICT can ensure that renewables are a viable alternative to fossil fuel energy sources and help India meet its ambitious goal of 15 percent of electricity being sourced from renewables by 2020.

Time-of-day pricing has the potential to yield 13.8 $MtCO_2e$ of abatement in India by 2020, which represents 9.9 percent of the Indian power sector abatement potential. Time-of-day pricing, which requires the use of an advanced ICT-enabled smart grid to coordinate supply and demand fluctuations and prices, would help reduce demand at peak periods by encouraging consumers and businesses to consume electricity when demand is lower. This would help prevent the addition of extra capacity to meet peak demand and utilization of highly polluting peaking plants.

Power-load balancing could yield 9.6 $MtCO_2e$ of abatement in India, which represents 6.7 percent of the power sector's total abatement potential. Power-load balancing would also require the use of an advanced ICT-enabled smart grid to communicate fluctuations in demand to a power plant. Using this technology, the power plant could then store electricity during off-peak periods and release it during periods of high demand. ICT plays an essential role in this process by ensuring that this power is stored and released at the right time. Power-load balancing would prevent highly polluting peaking plants from being online to meet peak demand, which would accordingly reduce emissions.

236. "Smart Grids White Paper, " Center of Study of Science, Technology and Policy, 4

237. IEA World Energy Outlook 2011 Annex A Tables for Scenario Projections, India

Figure 84
Business case for power sector sublevers

Source:

Low attractiveness
High attractiveness

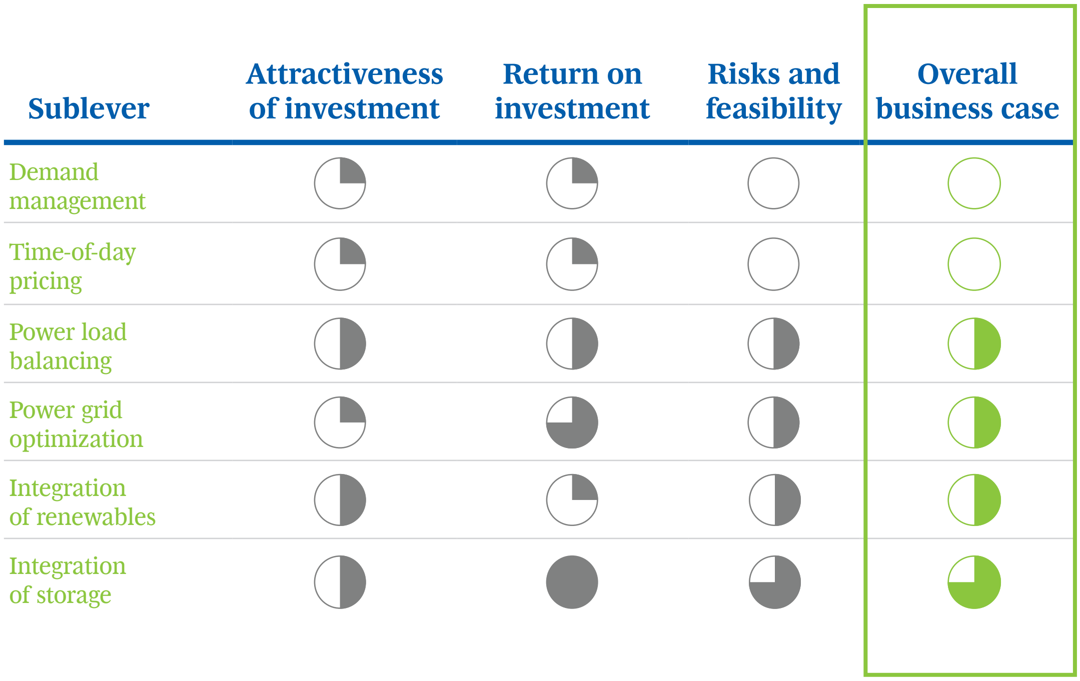
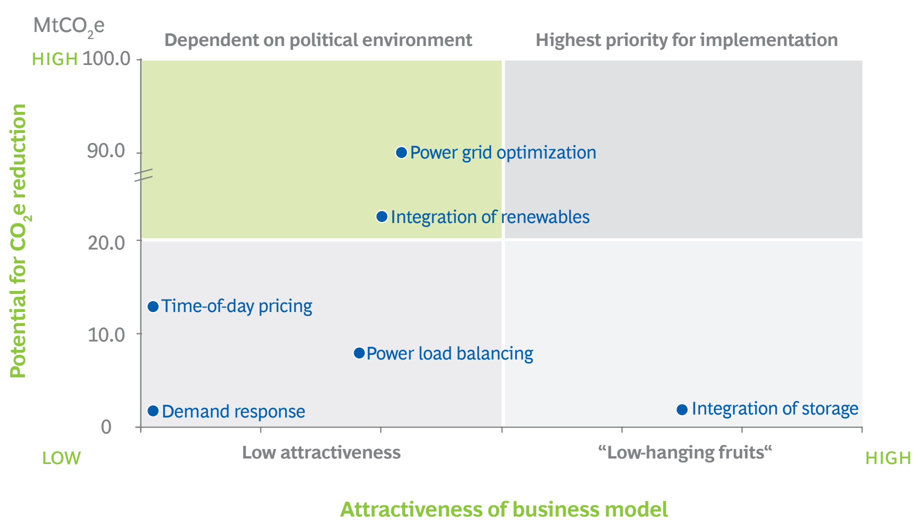


Figure 85
Power sector sublever prioritization by potential for CO_2e reduction and business potential



Business case

The business case for most of the sublevers identified is not particularly strong, mostly because they rely on infrastructure (such as a highly developed smart grid) that is not yet widely available or has high upfront costs. As a result, policy can play a significant role, particularly with regards to the adoption of power grid optimization and the integration of renewables.

Demand response requires advanced smart-grid technology that enables power suppliers, consumers, and appliances to communicate with one another to change electricity consumption in response to supply fluctuations; this requires grid technology that is technically advanced, expensive, and likely to be limited in India by 2020.[238] Similarly, time-of-day pricing of electricity requires a smart grid that communicates price fluctuations to consumers and appliances and will be difficult to implement. Power-load balancing is more feasible, but the return on investment is dependent on individual equipment conditions and is therefore difficult to predict. Power grid optimization has the potential to yield huge savings in India because of high T&D losses and electricity theft, but installing grid monitoring and optimization systems is an expensive proposition and many utilities would find financing such upgrades challenging. Integrating renewables into the power supply has a strong business case in some circumstances (such as in remote villages far from a power grid connection), but renewables are often not competitive with coal and other sources in terms of price. Moreover, successful integration of intermittent renewables is dependent on advanced smart grid technology. The integration of storage into off-grid power sources has the strongest business case of the sublevers, as the high fuel prices in India makes diesel power generators less economically competitive.

Time-of-day pricing demonstrates the nonfeasibility of certain power sector sublevers in the absence of advanced smart-grid technology. Time-of-day pricing requires that electricity supply and demand be equilibrated through fluctuations in price. Though this seems reasonably straightforward, it requires information coordination among power generators, transmitters, distributors, and consumers.[239] Currently, Indian utilities are focused on using ICT to reduce T&D losses, if they are considering using ICT monitoring at all, and this type of ICT integration is far beyond the capabilities of Indian utilities today.[240] Moreover, consumers, businesses, and industries need monitors that convey price fluctuations so that they can change consumption decisions, or they need to have ICT-enabled smart appliances that operate only when energy prices are low. As only 7.5 percent of Indians regularly use the Internet, it is highly unlikely that consumer demand will induce utilities to invest in advanced smart-grid technology.[241] So, although time-of-day pricing could help reduce electricity demand and emissions in the future, the realization of its full potential by 2020 is unlikely.

Barriers and recommended policy steps to overcome them

There are several barriers that require policy intervention to drive uptake of ICT technologies. The multiple barriers to smart grid development are the most serious impediments to widespread ICT-enabled abatement-solution adoption. All the identified sublevers rely at least partially on deployment of a smart grid for proper functionality, which means that fostering smart grid growth should be prioritized. Although deploying smart grid technology would have a large impact on T&D losses, significantly help reduce additional capacity development needs, and could eventually reduce energy usage from consumers, the current state of the Indian power sector makes widespread smart grid deployment quite challenging.

One of the most challenging aspects of advanced smart grid development is the fractured nature of the power distribution network. Currently there are 78 different utilities across India, most of them smaller companies, with several large, state-owned utilities distributing most of the power, all overseen by a complex

238. "Technology: Enabling the Transformation of Power Distribution," Infosys, 32

239. "Technology: Enabling the Transformation of Power Distribution," Infosys, 36

240. Ibid

241. "The Global Information Technology Report 2012," World Economic Forum, 230

Table 26
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome these barriers

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Stakeholder fragmentation	• A large number of utilities across India (78 in all), overseen by a complex regulatory framework • Utilities, businesses, and consumers all must interface with advanced smart grid • Adoption of uniform technological standards can be a challenge	Government leadership via state-owned utilities and regulatory boards	• State-owned utilities distribute 75% of all power, which enables the state to lead the setting of technological standards • Electricity board regulatory bodies have the authority to set standards for grid technology
Financing	• Installing a full-blown smart grid or individual constituent technologies requires large investment • Likely beyond the financial capabilities of most utilities	Provide low-cost loans to help with high up-front investment	• Prioritizing installation of smart grid is an important lever to deal with India's power challenges • Need political will to prioritize availability of capital for the power sector
Economics	• The NPV of some sublevers may be questionable given the sheer size of the investment required	Subsidize investment to encourage adoption	• Economic feasibility for the government should be assessed given the already high public debt
Awareness/ technical capability	• Knowledge and awareness of ICT-enabled solutions is often lacking among utilities • If awareness is not a problem, a lack of technical skills is a hindrance	Provide and promote educational programs Hire needed talent	• Provision of necessary training to handle advanced technology is a prerequisite • Most utilities have had a 15-year moratorium on hiring

regulatory framework.[242] In addition to utilities, there are many other players that would be a part of the advanced smart grid system, including transmission control centers, businesses, and consumers. Coordination among these parties to ensure smart grid interoperability within the sector is vital to its functionality, but fractured institutions could jeopardize that standardization.[243]

Policy-makers can play a significant role in the setting of national smart grid standards. First, given that the state-run electricity distributors provide more than 75 percent of India's electricity, they have significant power in selecting the most efficient technology standards that can then be adopted nationwide.[244] The Power Grid Corporation of India, which is administered by the Ministry of Energy and regulates interstate power transmission distribution, can mandate that the standards set by the largest state-run utilities are those that are used to connect all interstate grid elements together. However, as not all grids operate across state lines, the regulatory bodies that oversee intrastate electricity transmission must also ensure that those smart grid technical standards are adopted at the state level to achieve uniformity. Given that the construction of the smart grid is a long-term process that will involve trial and error to determine the best technologies and practices, policy makers should allow utilities to experiment with their own standards at a small scale to learn which would work best for India before scaling up those solutions to the national level.[245]

242. "Can a Smart Grid Help India?," Katherine Tweed, Green Tech Media
243. "Technology: Enabling the Transformation of Power Distribution," Infosys, 38
244. "India power cut hits millions, among world's worst outages," Reuters
245. "Technology: Enabling the Transformation of Power Distribution," Infosys, 44-45

A second concern is that economically distressed power distributors may not have the financial resources or will to begin the process of smart grid deployment. Currently, utilities do not pursue instances of power theft in rural areas and the government does not pay for the power it consumes, leaving the state-run power companies in poor financial shape. Though power distributors are likely to see positive returns by losing less power to inefficiency and decreasing power theft, they likely would not be able to finance the infrastructure upgrades themselves.[246] Across the state-run power sector, for instance, the rate of return is -18 percent, largely because of T&D losses and theft hurt profitability. Though smart grid technology would likely put them on better financial footing over the next several decades, as shown by positive net present value returns on smart grid investments in other countries, smart grid investments are out of reach financially for many utilities.[247] Additionally, even if utilities can finance smart grid purchases, many are not even aware of the potential to use ICT to reduce inefficiencies and emissions; even if they are, expanding grid access is prioritized over increasing the efficiency of the grid currently deployed.[248]

Addressing the financial concerns surrounding smart grid deployment is more challenging than ensuring standardization. For the state-run corporations, the government could provide low-cost financing or simply allocate funds from the budget to pay for smart grid upgrades to the existing grid. For private corporations, the government could provide grants and low-cost financing for smart grid projects that use the technology and mirror the efforts of the state-run power companies. Of course, it is important to bear in mind that finances are limited, particularly in India where there are so many development concerns competing for financial assistance, but smart grid deployment is something that should be designated a high priority. As smart grid technology would help reduce emissions, increase efficiency, reduce the need to add more electricity capacity, and is vital to ensuring continued economic growth, there is a strong case for diverting funds to smart grid construction.

The Ministry of Power has developed the Restructured Accelerated Power Development and Reforms Program (R-APDRP) to promote basic smart-meter deployment in two phases and offers financing to help pay for the infrastructure upgrades.[249] It is primarily focused on increasing the efficiency, accountability, and transparency of the grid rather than allowing for bi-directional flows of electricity and greater communication among different actors in the sector. For this program to meet its targets, however, it is imperative that the funds are available as promised and that the program is appropriately administered. Moreover, as this first stage of smart grid development nears completion, a second legislative program will need to be passed to help with the deployment of more advanced smart grid technology.

Though promoting smart grid development is the most significant barrier to power sector ICT-adoption, there are other policy concerns as well. The economics surrounding the use of renewable energy presents a challenge, for instance. Though the price of coal is expected to rise because of decreased mine productivity and difficulties surrounding coal exploration, it is still significantly cheaper as a fuel source than renewables like solar and wind energy. In an extreme example, in 2008 solar PV generation could be up to 20 times more expensive than generating electricity from coal.[250] As a result, the government must make solar PV and wind energy more competitive economically to combat emissions through renewable energy integration. The National Tariff Policy (2006) attempts to make renewable energy sources more economically competitive with fossil fuels and mandates that utilities purchase a certain amount of energy from renewable sources.[251] Though this is a good start, the feed-in tariff structure is not entirely clear and has not significantly contributed to renewable energy development in India.[252] The feed-in tariff policy should be rewritten with a clearer and more significant incentive structure.

246. "Technology: Enabling the Transformation of Power Distribution," Infosys, 6

247. "The Smart Grid Return on Investment (ROI): A Catalog of Consumer and Utility Company Benefits," NEMA, 2-3

248. "Can a Smart Grid Help India?" Katherine Tweed, Green Tech Media; "Technology: Enabling the Transformation of Power Distribution," Infosys, 5

249. "Guidelines for the Re-structured Accelerated Power Development and Reforms Programme (APDRP) during XI Plan," Ministry of Power

250. "Indian Renewable Energy Status Report," National Renewable Energy Laboratory, 19

251. "Analysis of Renewable Promotional Policies and Their Current Status in Indian Restructured Power Sector," Institute of Electrical and Electronics Engineers

252. "The Development of Renewable Energy Power in India: which Policies have been Effective?" Gisele Schmid, 29

Another concern is lack of awareness within the power sector about the ability of ICT to increase efficiency and reduce emissions. The power sector is marked by an aging workforce and a lack of skilled workers. Because of higher incomes in other sectors, talent has been siphoned and the average age of the employees at the state electricity boards is over 50.[253] As much of the workforce at both utilities and their regulatory bodies lack the knowledge and the motivation to significantly transform the power sector, few changes will occur until new talent is acquired. At many of the state-owned utilities, hiring as been restricted or banned for the last 15 years; this practice should be reversed to bring in workers who have the technical expertise and exposure to ICT required to transform the power sector. Educational initiatives to explain the current poor state of the power sector and how technology can help alleviate its problems should also be offered to employees. A more radical step would be to privatize the state-owned utilities. Although this would need to be intricately planned and the impact on consumers carefully considered, it would make the sector more competitive and raise wages to attract new talent.

Transportation Sector

Context

Emissions from transportation remain a relatively low percentage of India's overall emissions total. The Indian transportation sector accounted for 142 $MtCO_2e$ in 2007, which was 7.5 percent of India's overall emissions in that year. India's transportation emissions are expected to rise in both absolute terms and as a percentage of overall emissions, as transportation emissions have grown 4.5 percent CAGR between 1994 and 2007 while overall emissions grew 2.9 percent CAGR over the same period. The trends that have been driving fast transportation growth—namely, an increase in the number of vehicles, greater reliance on trucking, and an unfavorable change in vehicle mix—are projected to continue, pushing emissions 90.5 percent higher than 2009 levels by 2020.[254]

Road emissions, which made up 94.3 percent of India's domestic transportation emissions in 2010, have been growing rapidly as a result of several trends.[255] There has been a dramatic rise in the overall number of vehicles on India's roads, and growth is expected to continue. There were 99.6 million vehicles on India's roads by 2007 and there are expected to be approximately 140 million vehicles on the road by 2020.[256] Even though this represents a 40 percent increase, Indian car usage will still be low by international standards and the number of

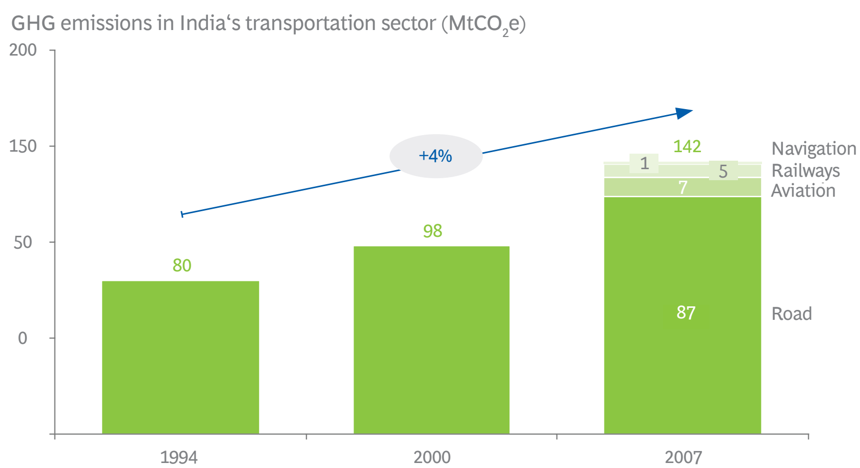
253. "Technology: Enabling the Transformation of Power Distribution," Infosys, 11

254. Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium

255. "Reducing Transport Greenhouse Gas Emissions: Trends and Data 2010," International Transportation Forum

256. "Energy & Emissions Outlook for the Transport Sector in India, " Dr. Sarath Guttikunda

Figure 84
GHG emissions in India's transport sector, 1990-2007



Case study

Gram Power and smart grid integration of renewable energy in Rajasthan

Sources: "Indian blackout held no fear for small hamlet where the power stayed on," The Guardian; "Gram Power: Yashraj Khaitan's 'smart microgrid' produces, stores renewable energy on location," The Economic Times

As 40 percent of Indians currently have no access to the electricity grid, ensuring universality of grid access is a principal goal of the Indian government. The challenge, however, is that connecting small remote villages to the power grid can be expensive and economically difficult to justify.

A pair of recent engineering graduates from the University of California, Berkeley, noticed during a summer trip to India the challenges faced by rural Indians who lacked reliable access to electricity, and they felt compelled to help. After graduation, the pair moved to the Indian state of Rajasthan and founded Gram Power, a start-up company that uses low-cost smart meters and renewable energy generation to electrify villages far from the nearest power grid. They managed to develop a smart microgrid system that relies entirely on renewable energy sources (solar PV, wind, and biomass) and that is distributed using a smart grid. And, rather than developing a system that can power only a few LED lights, the Gram Power system provides a standard 240VAC connection, which sets it apart from its competitors. By helping consumers switch away from kerosene-based electricity generation or from needing to connect to the coal-dependent grid, the use of island microgrid helps mitigate GHG emissions.

Gram Power distributes its electricity on a pay-as-you-go basis, and a household can purchase nine hours of lighting, six hours of a ceiling fan and television, and enough power to charge a cell phone—for approximately USD0.19 per day. Smart monitors allow Gram Power to bill its customers effectively and can detect theft and pilferage, which helps to keep prices down for paying customers. Because of clever financing and low T&D losses, the price of electricity from Gram Power is less expensive and more reliable than that provided by the government.

Gram Power had electrified 200 homes by the middle of 2012, but the company is hopeful that it will be able to power 500 households by the end of the year. Expansion is expected to occur even more rapidly in 2013. Through partnerships with the state and central renewable-energy ministries, the company hopes to have deployed 20 smart grids with 250 kW peak of generation to cater to 40,000 people by September 2013.

This innovative approach to electrifying rural villages has attracted attention around the world, winning more than ten prestigious international entrepreneurship awards, and provides a way of addressing rural electrification concerns while preventing the rise of GHG emissions on the path to development.

vehicles will continue to rise as economic growth continues.[257]

Moreover, the vehicle mix in India is changing from smaller vehicles, such as two-wheelers and auto rickshaws, to larger cars. Though two-wheelers will remain the majority of the Indian fleet by 2020, the share of passenger cars is expected to rise dramatically.[258] The share of cars as a percentage of passenger transport will increase from 7 percent in 2005 to 22 percent in 2020.[259] And, as passenger cars emit significantly more emissions than two-wheeled vehicles, this shift will contribute significantly to emissions. Passenger cars, which contributed 24 percent of transportation emissions in 2010, are expected to be the largest source of GHG emissions in 2030, contributing 47 percent of transportation emissions in that year.[260]

Higher reliance on trucking is also pushing road emissions higher. In 1990, the rail system handled 61 percent of cargo by weight and the remaining 39 percent was split between trucking and water transportation. Capacity constraints have caused the rail system to become relatively less important in cargo transportation, however, as trucking rose to handle 45 percent of all cargo by 2005. By 2020, trucking is expected to transport 68 percent of all Indian freight.[261] Trucks represent a small fraction of the vehicles on the road, but they are a significant contributor to GHG emissions. In 2010, trucks represented 3 percent of the vehicles on the road but accounted for 35 percent of India's transportation emissions.[262]

The rail system in India plays a significant role in carrying passengers and cargo across India's vast territory, but is marked by inefficiencies and capacity constraints. India has the fourth-largest rail network, nearly all of which is run by Indian Railways, a state-owned corporation that is one of the world's largest railway systems under single management.[263] It carries 17 million passengers and 2 million tons of freight daily and is one of the world's largest employers.[264] Because of the sheer number of people and cargo, however, the rail system often handles more than twice the capacity for which it was designed.[265] India needs to expand its rail capacity, but limited financial resources have prevented the infrastructure expansion required to adequately meet demand.

Public transportation is used heavily, but overcrowding, inefficiencies, and rising incomes are leading to its relative decline. Indian cities rely on buses for 90 percent of their public transportation needs, but bus services are marked by undependable services, congested roadways, and a chaotic, uncoordinated operating environment.[266] During rush hour, bus speeds can drop to 6 to 10 km/hr in the most crowded cities. Public-transportation -related accidents are common, and tens of thousands of passengers are killed annually. Despite poor service, most Indians cannot afford other means of transportation. Rising incomes will facilitate a shift to using private transportation and will cut down on the number of rides being taken via public transit. In 2005, 71 percent of all passenger -kilometers occurred on buses and trains; but by 2020, that figure is projected to be only 48 percent.[267]

A positive trend in public transportation is the development of mass rapid-transit systems in urban India. The Delhi Metro, which first began operations in 2002, is India's most developed metro system to date. The system has 193 km of track, carries 2.06 million riders daily and is continuing to expand; by 2021, the system is expected to have expanded to 413 km of track.[268] Other Indian cities are following Delhi's example. Kolkata, Chennai, and Bangalore have operational metro systems that are in the process of expanding and metro systems in another six cities are under construction and are scheduled to begin operation by 2014. Despite rapid expansion, overcrowding and unreliability of service on Indian metro systems are becoming increasingly common.[269] Though the development of metro systems is likely to help alleviate private transportation needs to a degree, it is unlikely that they alone will be able handle all increases in transportation demand.

257. "Energy & Emissions Outlook for the Transport Sector in India, " Dr. Sarath Guttikunda

258. Ibid

259. "An Assessment of India's 2020 Carbon Intensity Target," Grantham Institute for Climate Change

260. "Energy & Emissions Outlook for the Transport Sector in India," Dr. Sarath Guttikunda

261. "An Assessment of India's 2020 Carbon Intensity Target," Grantham Institute for Climate Change

262. Ibid

263. "The World Factbook: Country Comparisons: Railways," CIA

264. "India Transportation Sector Overview," World Bank

265. "The Crisis of Public Transport in India: Overwhelming Needs but Limited Resources," John Pucher and Nisha Korattyswaroopam

266. Ibid

267. "An Assessment of India's 2020 Carbon Intensity Target," Grantham Institute for Climate Change

268. "Annual Report", Delhi Metro Rail Corporation

269. "Overcrowding is a challenge", The Sunday Times

Transportation sector abatement potential

Across the 11 transportation sublevers, there is a total of 80.2 $MtCO_2e$ of ICT-enabled abatement potential. The sublevers that offer the most abatement potential are the optimization of logistics networks, eco-driving, telecommuting, and the optimization of truck routing.

The optimization of logistics networks offers 22.4 $MtCO_2e$ of abatement potential, or 28 percent of the transportation total. Particularly as trucking is projected to exceed the importance of railways as a means of moving cargo, the rapidly changing cargo transportation sector offers many opportunities for efficiency gains and GHG abatement. Advanced logistics networks are currently very nascent in India, contributing to fuel waste, loss of cargo, and high GHG emissions. Consider the transportation of food, for instance. Despite facing chronic food shortages, India loses between 20 and 40 percent of all food produced because of its poor roads, lack of proper storage, and poor intermodal connection facilities.[270] And, despite the lack of basic logistics infrastructure, investment in logistics systems is still below what is required to meet growing demand.[271] Though the current lack of infrastructure presents a significant challenge, the high levels of inefficiency present an opportunity to use ICT to reduce fuel costs, unnecessary waste, and, subsequently, GHG emissions. Leveraging ICT to minimize the time that goods sit in storage is a principal way that waste can be diminished and emissions reduced. Facilitating intermodal transfers is another significant way that ICT can improve logistics efficiency, particularly as trucking and rail systems must effectively interface with one another to move cargo. Moreover, given the current poor quality of India's roads and the energy necessary to move cargo via trucking (it takes trucks five to six days to cover the 2,061 kilometer route between Bangalore and Delhi, for instance), using ICT to coordinate among drivers, ensuring trucks are carrying full loads, will be particularly important.[272]

The optimization of truck routing, which has an abatement potential of 7.6 $MtCO_2e$, is of particular importance in India. India's highways are narrow, congested, have poor surface quality, and many are not accessible under all weather conditions. Forty percent of Indian villages are not connected to the highway system using all-weather roads and the unpredictability of road conditions presents a significant transportation challenge. As these conditions can drastically affect the amount of time it takes to move cargo, route planning systems that take these factors into account can substantially reduce emissions.

Telecommuting has the potential to contribute 12.5 $MtCO_2e$ toward abatement in the transportation sector. Generally, service workers that have the technology to telecommute are also those most likely to use private transportation to commute. Given the congested nature of large Indian cities, long commutes are relatively common and cutting the number of trips to the office would have a large impact on GHG emissions. Twenty-six percent of Indians spend over 90 minutes commuting every day and 12 percent spent over two hours commuting.[273] Particularly as passenger cars become an increasingly important part of India's vehicle mix, allowing employees to work from home will help temper the rise of emissions from private vehicles.

Eco-driving offers 12.1 $MtCO_2e$ of abatement potential, which is 15.1 percent of the transportation abatement potential. As the vehicle mix in India shifts toward higher use of passenger cars, ensuring that people are using their cars in the most fuel-efficient manner will be critical to reducing emissions growth. By installing eco-driving systems in new vehicles or by using eco-driving apps through mobile devices, car owners can make sure that they are driving at the right speed, have the correct tire pressure, and are appropriately servicing their vehicles to cut down on fuel consumption and GHG emissions.

270. "Sustainable approaches to reducing food waste in India," MIT News

271. "Current status of logistics infrastructure and key demand drivers of logistics," Infrastructure Development Corporation Limited

272. "Logistics in India," DHL

273. "1 in 4 workers in India commute over 90 mins/day," Rediff Business

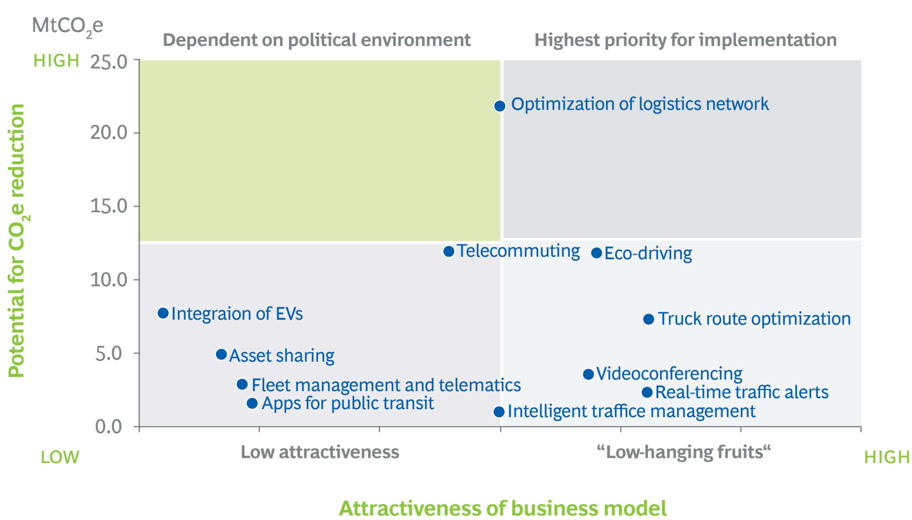
Figure 85
Business case for transportation sector sublevers

Source: BCG analysis

○ Low attractiveness
● High attractiveness

Sublever	Attractiveness of investment	Return on investment	Risks and feasibility	Overall business case
Eco-driving	◕	◑	◕	◕
Real-time traffic alerts	◑	◕	◕	◕
Apps for public transit	◑	◔	◔	◔
Crowd sourcing	◔	◔	◔	◔
Videoconferencing	◕	◕	◑	◕
Telecommuting	◑	◔	◕	◑
Truck route optimization	●	●	●	●
Logistics network optimization	◑	◕	◑	◑
Integration of EVs	○	○	○	○
Intelligent traffic management	◑	◑	◑	◑
Fleet management	◔	◑	◔	◔

Figure 86
Transportation sector sublever prioritization by potential for CO_2e reduction and business potential



Business case

Within the transportation sector there is wide variance in the ability of the market to drive uptake of the identified sublevers. For some, such as truck route optimization, the business case is strong enough where little to no policy intervention would be required to ensure that its use becomes widespread. For others, such as the integration of EVs, even significant policy interventions are unlikely to guarantee widespread use by 2020.

Eco-driving offers a low-cost way for drivers to reduce their fuel consumption but requires that they have smartphone or onboard technology capabilities, which cannot be broadly assumed in India; moreover, eco-driving apps may need to be adapted given the country's unique vehicle fleet mix. Real-time traffic alerts are relatively easy to implement, though if the Ministry of Road Transport and Highways is expected to be the principal driver of uptake it may find that its funds are better used elsewhere. Apps for intermodal and public transportation are unlikely to make a big contribution to emissions reductions, given the poor coordination of Indian public transportation systems, the lack of smart fleet monitoring, and the fact that public transportation ridership is well over capacity in many cities.

Asset sharing and crowd sourcing is viable given that many are seeking an alternative to using public transportation but cannot afford their own vehicles, but there are relatively high upfront costs associated with purchasing some assets (such as fleets of cars) that may dampen uptake.

Relatively low upfront costs and a high return on investment should allow videoconferencing to steadily become an alternative to physical travel. Telecommuting offers significant abatement potential and is particularly attractive to employees, but policy efforts may be required to overcome employer reluctance to allow working remotely.

Optimization of truck route planning offers significant emissions and fuel use reductions in India given the unpredictable quality of its roads, and low upfront costs should help route planning to be widely used by 2020. The highly inefficient logistics network in India signifies that logistics network optimization has the potential to yield significant savings, but certain optimization solutions have high upfront costs or are reliant upon mobile data networks that are still in development.

The integration of EVs by 2020 is unlikely to occur because of a lack of advanced smart grid technology and the high cost of EVs relative to conventional vehicles.

Real-time traffic alerts have a reasonably strong business case, particularly in India's most congested cities. Real-time traffic alerts are typically generated by computerized monitoring systems on highways and by communicating with local police and can be disseminated in a variety of ways. Alerts can be communicated to commuters through electronic billboards on large roadways and highways, through commercial providers such as TV and radio systems and, increasingly, from the government itself. In Pune, for instance, the traffic police have begun an SMS service that informs drivers of rush hour road conditions, while the police in Bangalore use social media to communicate traffic information to local residents.[274] Though traffic updates have been adopted in India's seven largest cities, it may be more challenging to implement in smaller cities. Given the extreme infrastructure upgrades required in many cities, real-time traffic updates may be deprioritized as local departments of transportation use their funds on other projects.

Barriers and recommended policies to overcome those barriers

Despite the potential of the market to drive the uptake of some of the sublevers, policy makers will play a key role in addressing the barriers that will impede the use of the others. One of the most significant concerns is the

274. "Traffic alerts service begins," The Times of India, Pune; "Now real-time traffic on Google Maps," The Indian Express

lack of mobile data network availability in many parts of India, particularly in rural areas. As being able to collect and analyze data on the go is a key component of many of the transportation sublevers, the lack of network availability presents a barrier to use. Mobile broadband networks only became available in late 2009 and their utilization is becoming increasingly widespread, but they are still in the midst of development.[275] India ranks 111th in terms of mobile network coverage, with only 83 percent of Indians covered, and mobile broadband network penetration is even lower.[276] To ensure ICT-abatement solutions are not overlooked for lack of network coverage, the government should take steps to ensure broad network coverage across all of India.

A second concern surrounds the economics of some sublevers. Some ICT-enabled abatement solutions in the transportation sector have costs that are simply too high. Fleet management systems, for instance, require the development of logistics centers that can analyze and process data inputs coming from the logistics network and then communicate with elements of the logistics network to optimize fleet performance. This requires large capital investments in fitting the vehicles of the fleet with ICT as well as an investment in the coordination center itself. Though possible, these upfront costs are relatively larger in India than in more developed nations, which have made few businesses willing to accept the risk associated with such expenditures.[277] The logistics industry in India is highly fragmented, and has many small players who cannot afford these solutions due to their small scale.

To lower the upfront costs and associated risk involved with adopting some of the sublevers, the government could reduce ICT costs by reducing the tariffs on ICT imports. As much of the required technology for the abatement solutions must be imported from abroad, reducing the tariff schedule would help reduce upfront costs. Moreover, as India is the world leader in developing affordable ICT solutions, it should promote the local development of ICT-enabled abatement solutions for transportation. For instance, logistics network optimization uptake could be increased by developing lower cost on-board trucking monitoring systems designed for Indian vehicles. The government can assist in these efforts by providing grants and research aid to projects that are seeking to use technology to reduce GHG emissions.

Even if businesses are comfortable with incurring the necessary upfront costs, a lack of financing can often scuttle investment plans.[278] This challenge is particularly evident for logistics network optimization and fleet management systems, which large upfront costs. Given the highly fragmented nature of the Indian trucking system, many smaller trucking companies and individual truckers will find it difficult to afford the equipment upgrades without financing. To help remedy this concern, the government can provide low-cost financing to trucking and logistics firms that are interested in using ICT to reduce their emissions and fuel costs.

The split incentives concern surrounding telecommuting must also be addressed in India. Employees that have network connectivity at home have an interest in reducing the number of trips they need to take to the office because it saves them both time and fuel expenses. Though businesses benefit from telecommuting to a degree in that it can cut energy costs and can somewhat reduce office space, many fear productivity losses and must incur the technical costs of ensuring that employees can work remotely. To align the interests of employees and their employers, the government should create a financial incentive that rewards businesses if a certain percentage of their employee's work days are completed remotely.

275. "The Global Information Technology Report 2012," World Economic Forum, 69

276. "The Global Information Technology Report 2012," World Economic Forum, 230

277. "Logistics in India," DHL

278. "ICT's Contribution to India's National Action Plan on Climate Change," DESC, 10

Finally, there is a general lack of awareness about the emissions abatement and monetary savings that ICT offers, particularly among individuals.[279] Because of relatively low penetration of basic ICT, many are not familiar with how more advanced ICT can be leveraged to their benefit. Even businesses, which tend to embrace technology adoption more readily than consumers, are often unaware of the abatement opportunities offered by ICT. As a result, policy makers should seek to increase awareness of ICT-enabled abatement solutions by promoting them through government publications. In a Ministry of Road Transport and Highways report on the state of the Indian logistics network, for instance, the Ministry has an opportunity to educate interested parties as to how using logistics network optimization can increase efficiency, lower costs, and mitigate adverse environmental impacts. The state governments should also seek to change consumer driving behavior by sharing information on the benefits of ICT-enabled transportation solutions every time people apply for a new driver's license or registers their vehicle.

279. Ibid

	What stands in the way?	What should happen?	
	Challenges	**Policy**	**Key considerations**
Infrastructure	• Mobile broadband networks required for some sublevers are not well-developed, particularly in rural India[1]	Promote mobile broadband network development	• Removing regulatory barriers for broadband network construction • Subsidies for network construction in rural areas where not economically feasible
Economics	• Cost of some sublevers is too high given Indian income levels[2]	Reduce cost of imports	• Reducing technology import costs by eliminating tariffs on ICT that reduces GHG emissions
		Promote India specific solutions	• Promote development of lower cost abatement solutions through research grants and aid
Financing	• Logistics network optimization has high upfront costs that businesses may not be able to afford outright[3]	Provide financing for logistics network optimization	• Availability of funds
Split incentives	• Employers bear perceived costs of telecommuting but employees realize the economic gains	Financial reward if a percentage of workdays are done via telecommuting	• Ensuring the reward is sufficient enough to compensate for both tangible and intangible costs
Awareness	• Lack of familiarity with the abatement and savings opportunities that ICT presents[4]	Promote ICT-enabled abatement solutions through government publications	• Promotion of consumer-targeted sublevers when a vehicle is registered or a driver's license is applied for • Promotion of business-targeted sublevers through Ministry of Road Transport and Highways publications

Table 27
Barriers to adoption of ICT-enabled GHG abatement solutions and policy steps to overcome these barriers

1. „The Global Information Technology Report 2012", World Economic Forum, 156 2. „ICT's Contribution to India's National Action Plan on Climate Change" DESC, 10 3. Ibid 4. Ibid

Case study
GIS route planning and mass transit in Jaipur

Brisk economic growth and high levels of population growth were leading to increased mass transportation demand in the city of Jaipur, a city of 3 million. As in many other rapidly growing Indian cities, the public transportation planning that had been used for decades was not sufficient to deal with changes in the urban landscape brought on by modernization. Increased traffic congestion and road safety concerns began to hinder the system's effectiveness, and the city recognized the need to alter its transportation model. As a result, the city turned to Geographic Information Systems (GIS) to model transportation flows within the city and optimize routes being taken by its public transportation vehicles.

By using encoding, management, analysis and reporting functions offered by GIS software, the Mass Rapid Transit System (MRTS) was able to efficiently capture, store, and analyze a broad array of data to optimize its MRTS corridors. GIS operates by layering different levels of information on top of one another to determine how various factors interact in the aggregate. Urban planners first employed the available land use map to get a better understanding of how topographical factors would impact the system's functionality. They then added a layer that considered population density, as that is an important indicator of public transportation demands. By then incorporating data that expressed vehicle flow patterns, planners were able to determine peak hour traffic flows. By analyzing commuter flows, the MRTS was then able to optimize its transit corridors to cut down on transit times and provide the most reliable, effective service. And, as GIS allows users to recombine the collected data and analyze various different scenarios, city planners were able to use future transportation projections to ensure that the chosen routes would be the most effective for the foreseeable future.

Though the city government is only in the first phase (out of four) of implementing the best routes determined through the GIS survey, the safety, reliability and, most significantly, environmental impacts have already been substantial. Even though only approximately 15 percent of the system has been implemented, the bus system has become significantly safer, with accidents involving buses declining 12 percent. Bus speeds have increased substantially to 25 km/h and service has become more frequent and reliable. All of these public transit system improvements have led to greater customer satisfaction, and increased ease of use translates to fewer private vehicles on the road. As a result, the efficiency improvements that resulted from GIS-enabled route planning led to lower levels of fuel consumption and fewer GHG emissions.

14 Conclusion

Not only has ICT enhanced the quality of life around the globe, but it also provides solutions, tools, and technologies to tackle climate change and reduce GHG emissions. Because of greater utilization of ICT around the world, the direct emissions from ICT are slated to grow from 1.9 percent of total global emissions in 2011 to 2.4 percent of global emissions by 2020. But while ICT emissions are growing faster than average global emissions growth, ICT has the potential to abate 16.5 percent of the world's total emissions by 2020; this represents a GHG savings of 9.10 $GtCO_2e$, which is over seven times greater than the direct GHG emissions footprint of the ICT sector itself. These savings will be generated through the use of ICT in the agriculture and land use, buildings, manufacturing, power, service and consumer, and transportation sectors around the world.

In the agricultural and land use sector, ICT will allow farmers to more accurately use irrigation and fertilizer to control emissions and can reduce methane emissions from livestock. With buildings, architects and builders can design more efficient buildings from the outset and ICT can be incorporated into a building's management system to allow for even more efficient energy use. In factories, ICT will enable the increasing automation of industrial processes and will make it possible for machines to communicate with one another to allow them to work together at the optimal level. ICT will allow for the creation of a more dynamic power sector that will better synchronize supply and demand to avoid overproduction and will more easily integrate renewables into the power supply. In the service and consumer sector, ICT links consumers and merchants through e-commerce, avoiding the need to meet face-to-face; it can also eliminate unnecessary waste associated with the production and distribution of goods. Finally, ICT in transportation can improve the efficiency of logistics and reduce cargo transport emissions, and can even reduce transportation needs altogether through video conferencing and telecommuting.

The adoption of many of these technologies will be driven by a strong business case. The energy savings of variable speed motors, logistics systems, and advanced building design, for instance, more than compensate for the upfront cost associated with the implementation of each of those technologies; as a result, businesses and consumers will invest in those sublevers because of the positive and significant return on investment. Some of the other sublevers, however, have a weaker business case and adoption will not be driven by the market. Livestock management systems, for example, will not be taken up by ranchers because eliminating methane emissions has no economic bearing on them in the absence of GHG abatement targets. For less attractive sublevers, policy interventions must occur to ensure adoption rates.

To accelerate adoption, an international climate favorable to GHG abatement should be created. The setting of binding emissions targets, the development of international CO_2e markets, and the institution of financial assistance programs to help developing countries with emissions abatement are all developments that would create an environment in which combating climate change is taken seriously. Ultimately, however, the policies that most effectively change the economics surrounding a sublever are developed at the national level. To ensure that the abatement potential of 9.10 $GtCO_2e$ is reached by 2020, much responsibility lies with national policy makers to create the required incentives to drive GHG abatement through ICT-enabled solutions for the end-use sectors identified. By working together, the ICT sector and policy makers can make serious strides toward mitigating the effects of climate change and building a world economy grounded in the principle of sustainable growth.

15 Appendix

15.1 Definition of greehouse gases

Although CO_2 is the most widely known and most frequently emitted of the greenhouse gases, there are many other gases that contribute to climate change, including (but not limited to) methane (CH4), nitrous oxide (NOx), and ozone (O3). Because each of these gases has chemical properties that differ from those of CO_2, they trap heat in the atmosphere differently. As a result, one molecule of one gas may trap more or less heat than one molecule of another. One molecule of methane, for instance, traps 21 times as much heat as one molecule of CO_2.

As a result, to ensure that all GHGs are accounted for and discussed using the same terminology, we have converted the warming potential of all non-CO_2 gases into what their equivalent warming potential in tons of CO_2 would be; hence the report uses the term CO_2e to talk about GHG emissions collectively. For example, one ton of methane would be equivalent to 21 tons CO_2e. Using CO_2e rather than CO_2 alone allows us to talk about all emissions sources and better grasp their contribution to climate change.

15.2 UNFCCC categories and sector segmentation

Sector	UNFCCC category	Description of category
Power	1.A.1.a Public electricity and heat production	Emissions from public electricity generation, public combined heat and power generation, and public heat plants
Manufacturing	1.A.1.b Petroleum refining	All combustion activities supporting the refining of petroleum products
	1.A.1.c Manufacture of solid fuels and other energy industries	Combustion emissions from fuel use during the manufacture of secondary and tertiary products from solid fuels including production of charcoal
	1.A.2 Manufacturing industries and construction	Emissions from combustion of fuels in industry including combustion for the generation of electricity and heat
	1.A.5 Other fuel combustion activities	All remaining emissions from non-specified fuel combustion
	1.B Fugitive emissions from fuel	Intentional or unintentional releases of gases from anthropogenic activities
	2 Industrial processes	By-product or fugitive emissions of greenhouse gases from industrial processes
	3 Solvent and other product use	NMVOC emissions resulting from the use of solvents and other products containing volatile compounds
	6 Waste	Total emissions from solid waste disposal on land, wastewater, waste incineration, and any other waste management activity
Transport	1.A.3 Transport	Emissions from the combustion and evaporation of fuel for all transport activity, regardless of the sector
Service/Center	1.A.4.a Commercial/Institutional	Emission from fuel combustion in commercial and institutional buildings
	1.A.4.b Residential	All emissions from fuel combustion in households
Agriculture	1.A.4.c Agriculture/Forestry/Fishing	Emissions from fuel combustion in agriculture, forestry, or domestic inland, coastal and deep-sea fishing
	4 Agriculture	Al anthropogenic emissions from this sector except for fuel combustion and sewage emissions

Note: The UNFCCC category "Land use change and Forestry" is excluded from the calculation
Source: UCFCCC, BCG Analysis

15.3 Description of sublevers by change-lever

Description of sublevers for digitalization and dematerialization change-lever

Sublever	Sector	Description of category	Target emissions
Video conferencing	Transportation	Use collaborative tools such as video-conferencing to replace an in-person meeting that would involve travel	Road, train, and airline transportation. Also building emissions —hotels, conference centers
Telecommuting	Transportation	Work arrangement in which an employee does not commute to a central place of work for at least part of their workweek	Mostly road, train, subway, and some airline transportation, and some office emissions (as the result of less office space needed)
E-paper	Service/Consumer	Reduction of paper use and printing as a result of e-readers and other technology	Paper use (also transport of paper goods and finished paper media) and printing emissions
E-commerce	Service/Consumer	Buying and selling of products or services over the Internet—results in a more efficient market for commerce	Commerce/retail related transport and commercial building and inventory space
Online media	Service/Consumer	Elimination of all hard media as a result of digitalization	CDs, DVDs (and related transport, storage, etc. needs)

Description of sublevers for the data collection and communication change-lever

Sublever	Sector	Description of category	Target emissions
Demand management	Power	Mechanisms to manage consumer and enterprise consumption of electricity in response to supply conditions	Non-base load electricity
Time-of-day pricing	Power	Communication through mobile devices or other systems of different pricing for electricity during different times in the day—allows consumers and enterprises to adjust load during peak demand and thus reduce overall demands on the grid	Non-base load electricity
Eco-driving	Transportation	Adopting a driving style as a result of alerts and other technology to improve overall efficiency of the car	Road transportation
Real-time traffic alerts	Transportation	Alerts that help drivers avoid traffic delays and drive more efficiently	Road transportation in traffic congested areas
Apps for intermodal travel/public transportation	Transportation	Apps that improve the adoption of public transportation through increased awareness and information	Transportation emissions
Weather forecasting	Agriculture/ Land use	The use of ICT to make smarter decisions about the impact of weather on farming	Agricultural emissions
Smart water	Service/Consumer	Water infrastructure that uses ICT to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of water	Emissions from residential and commercial water use
Smart water	Agriculture/ Land use	Water infrastructure that uses ICT to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of water	Emissions from water use
Public safety/ Disaster management	Service/Consumer	Leverage communications, HD cameras and intelligent sensor networks for video surveillance, video imaging sensors to identify pending weather, natural disasters, terrorist attacks, or other safety concerns	Emissions from accident/ incident occurrences
Asset sharing/ crowd sourcing	Service/Consumer; Transportation	Knowledge of assets and how they can be effectively shared or reused through the use of social networks or other communication tools	Emissions avoidance based on reduced manufacturing and extended use

Description of sublevers for the system integration change-lever

Sublever	Sector	Description of category	Target emissions
Integration of renewables in power generation	Power	ICT that allows for the integration of renewables into the grid or the more effective use of renewables	Electricity generation
Virtual power plant	Power	Technology that enables and collectively runs a cluster of distributed generation installations (such as microCHP, wind-turbines, small hydro, back-up gensets, etc.)	Electricity generation
Integration of EVs and biofuels	Transportation	ICT that promotes the use of EVs or bio-fuels	Road transportation
Intelligent traffic management	Transportation	Use of ICT to remotely monitor and control automobile traffic	Road transportation
Fleet management and telematics	Transportation	More efficient use of a fleet through vehicle maintenance, vehicle telematics (tracking and diagnostics), driver management, speed management, and fuel management	Road transportation
Integration of renewables in commercial and residential buildings	Service/Consumer	ICT that allows for the integration of renewables into the energy use of commercial or residential buildings	Commercial and residential building energy use
Building management system	Service/Consumer	A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment (i.e. ventilation, lighting, power systems, fire systems, and security systems)	Commercial and residential building energy use
Integration of storage into off-grid applications	Power	ICT technology that enables the integration of storage into off-grid power loads (e.g. isolated telecom tower)	Emissions from off-grid power loads

Description of sublevers for the process, activity, and functional optimization change-lever

Sublever	Sector	Description of category	Target emissions
Power load balancing	Power	Use of various techniques by electrical power stations to store excess electrical power during low demand periods for release as demand rises	Non-base load electricity
Optimization of truck route planning	Transportation	The use of software and other technologies to improve the efficiency of delivery trucks (includes optimization of truck itinerary planning)	Commercial road transportation
Optimization of logistics network	Transportation	The use of software and other technologies to improve the efficiency of a logistical network	Commercial road transportation
Optimization of variable speed motor systems	Manufacturing	Control of a motor system to better match its power usage to a required output	Industrial energy use
Automation of industrial process	Manufacturing	The monitoring and control for large industrial process with technology to optimize and reduce the energy use of the process	Industrial energy use
Minimization of packaging	Service/ Consumer	Smarter packaging of goods to reduce the total amount of materials required	Commercial material, transportation, and storage use
Building design	Service/ Consumer	Improved initial design of a building to make it more energy efficient	Commercial and residential building energy use
Voltage optimization	Service/ Consumer	Systematic controlled reduction in the voltages received by an energy consumer to reduce energy use, power demand, and reactive power demand	Commercial and residential building energy use
Reduction in inventory	Service/ Consumer	Optimization of the delivery of goods, which results in less need to store inventory	Warehouse building energy use and commercial transportation
Smart farming	Agriculture/ Land use	ICT that improves the efficiency and reduces the energy use of agriculture activities (e.g. precision farming, efficient crop rotation and analysis, and other eco-technology)	Agricultural emissions
Livestock managment	Agriculture/ Land use	ICT that reduces the emissions from livestock through optimization of grazing and other techniques	Livestock-related emissions
Power grid optimization	Power	Electrical grid that uses ICT to gather and act on information to optimize the infrastructure reduce inefficiencies with the transmission and distribution of electricity (i.e., T&D-related smart grid applications)	Emissions from power generation
Power-load balancing	Power	Use of various techniques by electrical power stations to store excess electrical power during low demand periods for release as demand rises	Non-base load electricity

15.4 Details for estimation of global ICT direct emissions

15.4.1 Scope

Range of ICTs covered

This study covers the same range of ICTs as in the previous SMART 2020 study published in 2008, with additions such as tablets and smartphones to account for the new developments since 2008.

ICTs are divided up into three categories:

End-user devices
Includes PCs (desktops, laptops), mobile devices (tablets, smartphones, regular mobile phones), and peripherals (external monitors, printers, set-top boxes, routers, IPTV boxes)

Telecommunication networks
Includes both fixed or wireline networks and wireless networks (excludes local Wi-Fi networks)

Data centers
Includes all small, medium-sized and large enterprise data centers. All IT systems (servers and storage) and cooling systems are included

Range of ICT compared with OECD's definition of ICT

The scope of ICTs used in this study differs from that defined by the OECD. [191] The scope used in this study is as in SMART 2020 to maintain consistency. The following table shows the scope of ICT defined by the OECD. Further details can be found on OECD's website

191. "Information Economy product definitions based on the central product classification (Version 2)" -- OECD

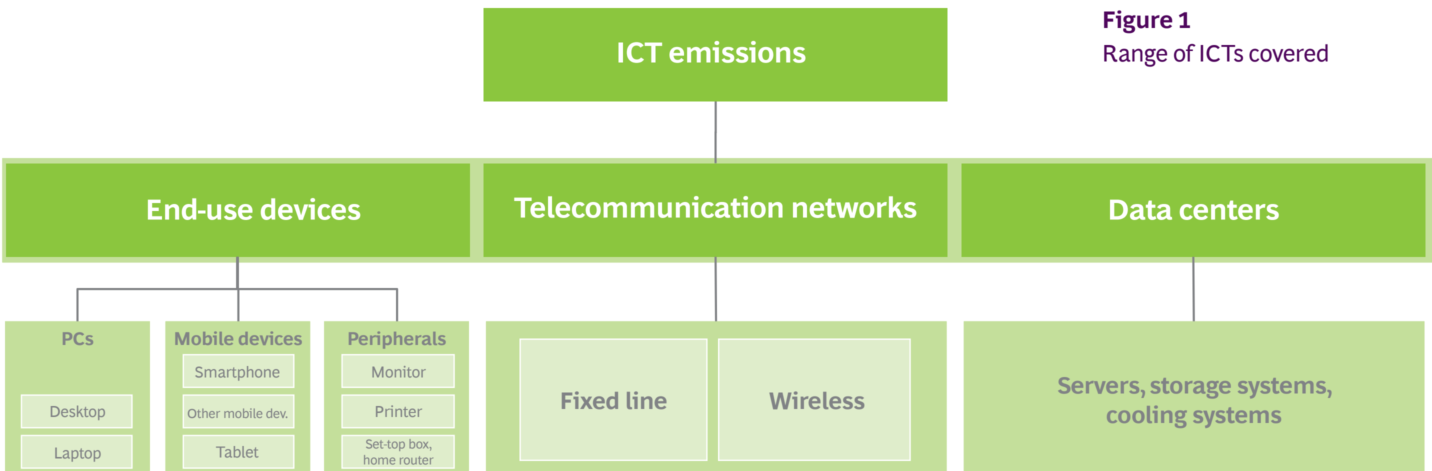


Figure 1
Range of ICTs covered

Table
Broad level categories for ICT products

Source: CPC stands Central Product Classification

Broad level categories	Number of CPC subclasses (products)
Computers and peripheral equipment	19
Communication equipment	8
Consumer electronic equipment	11
Miscellaneous ICT components and goods	14
Manufacturing services for ICT equiptment	5
Business and productivity software and licensing services	11
Information technology consultancy and services	10
Telecommunications services	12
Leasing or rental services for ICT equipment	3
Other ICT services	6
Total	**99**

Scope of emissions as defined by the Greenhouse Gas Protocol

To account for ICT's emissions, this report takes the most-inclusive possible route. This means that not only did we account for the emissions that occurred at the location where ICT exists but also for emissions that were generated elsewhere that directly resulted from ICT activities. The GHG Protocol characterizes direct and indirect emissions in three different scopes; to avoid the risk of understating ICT's emissions contribution, we calculated emissions using most-inclusive criteria, which involved incorporating all three scopes:

Scope 1

All direct GHG emissions

Scope 2

Indirect GHG emissions from consumption of purchased electricity, heat or steam

Scope 3

Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (i.e. transmission and distribution losses) not covered by Scope 2, outsourced activities, waste disposal, etc.

As a result, our ICT emissions total includes emissions from ICT devices themselves, from the electricity generated to run them, and from the process required to extract and refine fuel for electricity production.

Nonetheless, the inclusivity of each individual figure is dependent on the source of the data from which we derived the information. For more information on the scope of a particular figure, please consult the source cited.

15.4.2 End-user devices

The GHG emissions footprint of all end-user devices is broken up into usage footprint and embodied footprint. The former refers to indirect emissions from the consumption of electricity to run the devices, and the latter refers to all direct and indirect emissions from the production, transportation and disposal of these devices.

Figure 2 shows the driver tree for the estimation of the footprint of these devices, both for 2011 and 2020. All data are from publically available sources, and have been mentioned. Where appropriate, data have been triangulated using multiple sources, and the most reasonable estimates have been used. Where data weren't available, assumptions have been made or extrapolations from trends have been done as necessary. All assumptions and extrapolations have been stated as such in Figure 2. Further, these assumptions and extrapolations have been discussed and vetted with industry experts.

2020 installed base projections imply following global 2020 penetration rates[10]. PCs 37%, Tablets 16%, Smartphones 37%, other mobile phones 55%

Figure 2
End-user devices emissions estimation

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

			2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
PCs and mobile devices	Usage footprint	Installed base (B)[1]	1.53[7]	0.07	0.66	3.65	2.81[8] (+7%)	1.18 (+37%)	2.80 (+17%)	4.17 (+2%)
		× Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] (-8%)	15.60	5.45	2.50
		× Emissions factor[3] (kg CO_2e/kWh)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	+ Embodied emissions	Shipments (B)[1]	0.39[7]	0.07	0.36	1.41	0.788 (+8%)	0.68 (+29%)	1.23 (+15%)	1.38 (-0.2%)
		× Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 (-3%)	74.12 (-3%)	21.19	8.89 (-3%)
		Total emissions ($MtCO_2e$)	330	7	10	22	367	61	35	19

			2011 Peripherals	2020 Peripherals
Printers	Usage footprint	Total electricity used (TWh)[2]	13[1]	131[9]
		× Emissions factor[3] (kg CO_2e/kWh)	0.6	0.6
	+ Embodied emissions	Shipments (B)[2]	0.12	0.14[9] (+1%)
		× Emissions/device (kgCO2e/yr)	68[5]	68
	+ Distribution of printed media	Paper shipped[2] (tonnes)	96.6	96.6[9]
		× Emissions/ tonne paper (tonne CO_2e)	0.15[6]	0.15[9]
Others[11]		% overall end-user device emissions	13%[5]	13%[5]
		Total emissions ($MtCO_2e$)	179	206

1. Gartner, Forrester
2. Gartner
3. Global electricity emission factor (IEA)
4. Lowered to reflect efficiency gains, fewer hours spent on PCs due to emergence of smart devices, and greater use of laptops vs. desktops
5. Assumed same figure as in 2007 ("Greenhouse Gas Emissions and Operational Electricity Use in the ICT and E&M Sectors" by Jens Malmodin et al, 2010)
6. Lowered from 0.19 in 2007 to allow for improvement in fleet efficiency
7. 45% laptops
8. 70% laptops
9. Printers industry trends assumed flat
10. Assuming 2020 world population of 7.6 B (U.S. Census Bureau)
11. Includes set top boxes, home routers and modems and other computer peripherals

15.4.3 Networks

The GHG emissions footprint of all wireless is broken up into usage footprint and embodied footprint. The former refers to indirect emissions from the consumption of electricity to run the networks equipment and infrastructure, and the latter refers to all direct and indirect emissions from the production, transportation and disposal of these equipment and infrastructure.

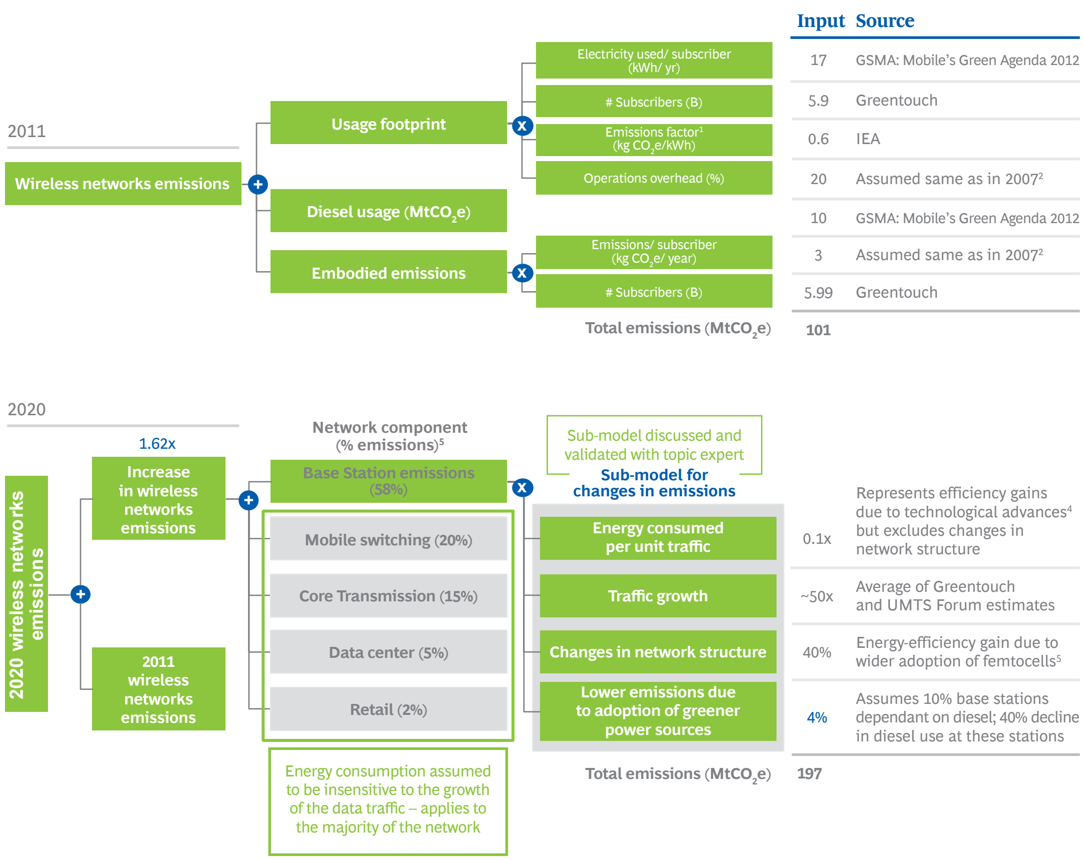
All data are from publically available sources, and have been mentioned. Where appropriate, data have been triangulated using multiple sources, and the most reasonable estimates have been used. Where data weren't available, assumptions have been made or extrapolations from trends have been done as necessary. All assumptions and extrapolations have been stated as such. Further, these assumptions and extrapolations have been discussed and vetted with industry experts.

Wireless networks

Figure 3 shows the driver tree for the estimation of the footprint of mobile networks, both for 2011 and 2020. Since it's difficult to predict the evolution of the key drivers, the study models the 2020 footprint as a multiple of the 2011 footprint. The key driver is the growth of mobile IP traffic, assumed to grow to 50 times that of the 2011 level by 2020. The model details are presented in Figure 3.

Figure 3
Wireless networks emissions estimation

Third-party reports/ estimates
BCG analysis



Note: Key assumptions triangulated and reviewed with experts as possible

1. Global electricity emission factor (IEA)
2. 2007 data from "Greenhouse Gas Emissions and Operational Electricity Use in the ICT and Entertainment & Media Sectors" by Jens Malmodin et al, 2010
3. BCG analysis
4. "Power Trends in Communication Networks" by Dan Kilper; data for North America, but similar trends expected in other markets
5. Saving the Planet – The Rationale, Realities, and Research of Green Radio); Expert interview
6. Multiple input Multiple output

Fixed or wireline networks

Figure 4 shows the driver tree for the estimation of the footprint of fixed networks, both for 2011 and 2020. Fixed networks are divided up into home access networks, enterprise networks, and data transport networks following the methodology used in Malmodin et. al. (2010).[192]

192. "Greenhouse Gas Emissions and Operational Electricity Use in the ICT and Entertainment & Media Sectors"-- Jens Malmodin, Asa Moberg, Dag Lunden, Goran Finnveden, and Nina Lovehagen

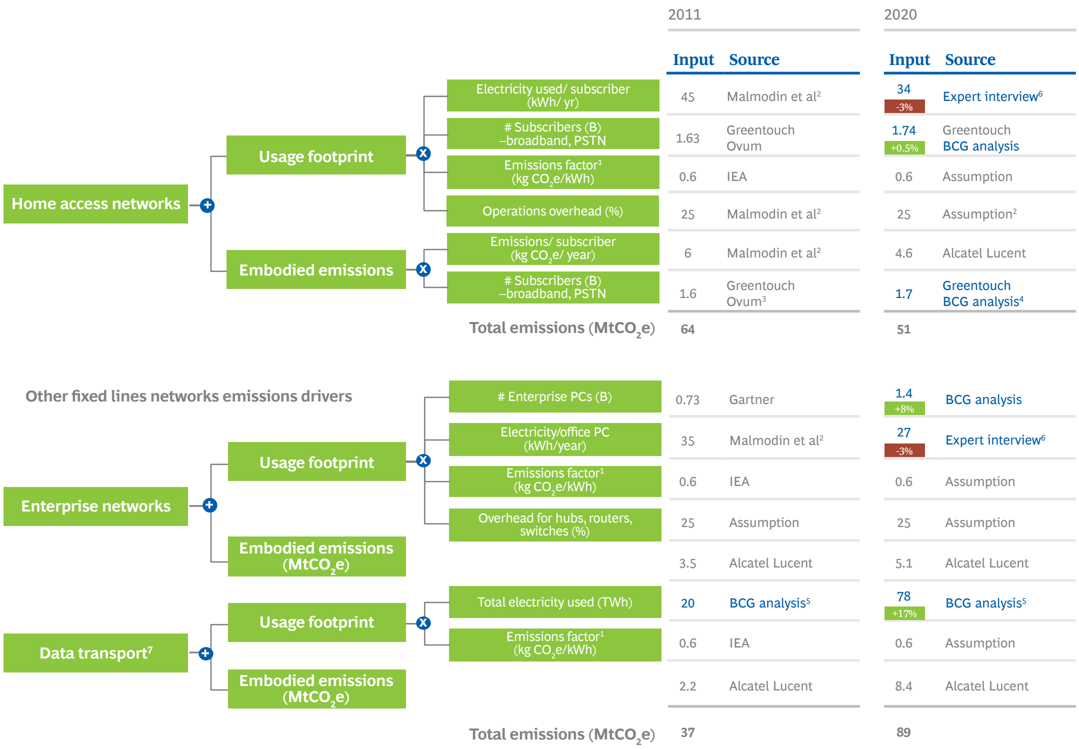


Figure 4
Wireline networks emissions estimation

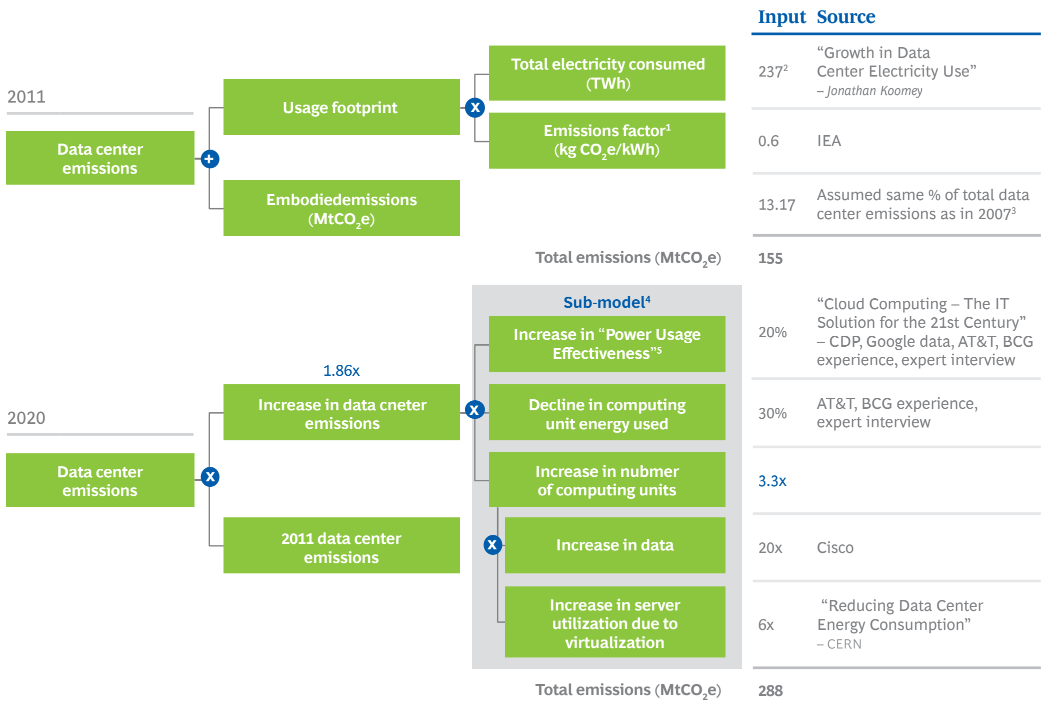
Third-party reports/ estimates
BCG research

15.4.4 Data Centers

Figure 5 shows the driver tree for the estimation of the footprint of mobile networks, both for 2011 and 2020. Since it's difficult to predict the evolution of the key drivers, the study models the 2020 footprint as a multiple of the 2011 footprint. The key driver is the growth of data stored in data centers, assumed to grow to 20 times that of the 2011 level by 2020. The model details are presented in Figure 5.

Figure 5
Data center emissions estimation

Third-party reports/ estimates
BCG research



Note: Key assumption triangulated and reviewed with experts as possible

1. Global electricity emission factor (IEA)
2. 2010 data
3. 2007 data from "Greenhouse Gas Emissions and Operational Electricity Use in the ICT and Entertainment & Media Sectors" by Jens Malmodin et al, 2010
4. „Cloud Computing – The IT Solution for the 21st Century" – CDP
5. Defined as ratio of energy consumed by a data center and energy required to run the IT equipment; assumes CAGR of -2.5%

15.5 Details for estimation of ICT direct emissions by country

The U.K.

Figure 6.1
U.K. ICT emissions estimation: end-user devices

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

PCs and mobile devices = Usage footprint + Embodied emissions

		2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
Usage footprint (×)	Installed base (B)[1]	0.06	0.003	0.03	0.04	0.07 (+2%)	0.05 (+35%)	0.07 (+11%)	0.02 (+2%)
	Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] (-8%)	15.60	5.45	2.50
	Emissions factor[3] (kg CO_2e/kWh)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Embodied emissions (×)	Shipments (B)[1]	0.01	0.002	0.02	0.02	0.02 (+2%)	0.02 (+27%)	0.05 (+9%)	0.02
	Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 (-3%)	74.12 (-3%)	21.19	8.89 (-3%)
Total emissions ($MtCO_2e$)		10.16	0.23	0.50	0.28	7.18	1.66	1.12	0.23

Printers = PC emissions / Global ratio of PC to printers emissions

	2011 Peripherals	2020 Peripherals
PC emissions ($MtCO_2e$)	10.16	7.18
Global ratio of PC to printers emissions	3.2	3.6
Others[3]	13%[5]	13%[5]
Total emissions ($MtCO_2e$)	5.40	3.71

1. Gartner
2. IEA
3. Includes set top boxes, home routers and modems, other computer peripherals and IPTV related emissions

Figure 6.2
U.K. ICT emissions estimation: networks and data centers

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends/ previous estimates

Networks = Wireless + Wired; Wireless = Global emissions / Share of global subscriptions; Wired = Global emissions / Share of global subscriptions

		2011 Input	2011 Source	2020 Input	2020 Source
Wireless (/)	Global emissions ($MtCO_2e$)	101	BCG analysis	164	BCG analysis
	Share of global subscriptions	1%	Greentouch Ovum	1%	BCG analysis
Wired (/)	Global emissions ($MtCO_2e$)	100	BCG analysis	139	BCG analysis
	Share of global subscriptions	3%	Greentouch Ovum	3%	BCG analysis
Networks		4.6		4.6	

Data centers = Global emissions / Share of global installed servers

	2011 Input	2011 Source	2020 Input	2020 Source
Global emissions ($MtCO_2e$)	155	BCG analysis	299	BCG analysis
Share of global installed servers	4%	Gartner	4%	BCG analysis
Data centers	6.0		11.9	

Brazil

Figure 7.1
Brazil ICT emissions estimation: end-user devices

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

1. Gartner
2. IEA
3. Includes set top boxes, home routers and modems, other computer peripherals and IPTV related emissions

PCs and mobile devices = Usage footprint + Embodied emissions
Usage footprint = Installed base × Electricity used/device × Emissions factor
Embodied emissions = Shipments × Emissions/device

	2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
Installed base (B)[1]	0.04	0.00	0.03	0.21	0.11 (+13%)	0.06	0.09 (+14%)	0.18 (-1%)
Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] (-8%)	15.60	5.45	2.50
Emissions factor[3] (kg CO_2e/kWh)	0.11	0.11	0.11	0.11	0.4	0.4	0.4	0.4
Shipments (B)[1]	0.02	0.00	0.01	0.04	0.05 (+13%)	0.02	0.02 (+10%)	0.04
Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 (-3%)	74.12 (-3%)	21.19	8.89 (-3%)
Total emissions ($MtCO_2e$)	6.64	0.01	0.18	0.49	9.54	1.88	0.71	0.26

Printers = PC emissions / Global ratio of PC to printers emissions

	2011 Peripherals	2020 Peripherals
PC emissions ($MtCO_2e$)	16.4	14.22
Global ratio of PC to printers emissions	3.2	3.6
Others[3]	13%[5]	13%[5]
Total emissions ($MtCO_2e$)	3.47	6.66

Figure 7.2
Brazil ICT emissions estimation: networks and data centers

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends/ previous estimates

Networks = Wireless + Wired
Wireless = Global emissions / Share of global subscriptions
Wired = Global emissions / Share of global subscriptions

		2011 Input	2011 Source	2020 Input	2020 Source
Wireless	Global emissions ($MtCO_2e$)	101	BCG analysis	164	BCG analysis
Wireless	Share of global subscriptions	4%	Greentouch Ovum	4%	BCG analysis
Wired	Global emissions ($MtCO_2e$)	100	BCG analysis	139	BCG analysis
Wired	Share of global subscriptions	3%	Greentouch Ovum	4%	BCG analysis
Networks		7.7		11.0	

Data centers = Global emissions / Share of global installed servers

	2011 Input	2011 Source	2020 Input	2020 Source
Global emissions ($MtCO_2e$)	155	BCG analysis	299	BCG analysis
Share of global installed servers	2%	Gartner	2%	BCG analysis
Data centers	2.8		4.8	

China

Figure 8.1
China ICT emissions estimation: end-user devices

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

PCs and mobile devices = Usage footprint + Embodied emissions; Usage footprint = Installed base × Electricity used/device × Emissions factor; Embodied emissions = Shipments × Emissions/device

	2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
Installed base (B)[1]	0.27	0.002	0.08	0.97	0.69 (+11%)	0.31 (+75%)	0.54 (+24%)	1.26 (+3%)
Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] (-8%)	15.60	5.45	2.50
Emissions factor[3] (kg CO_2e/kWh)	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Shipments (B)[1]	0.08	0.002	0.03	0.41	0.19 (+11%)	0.15 (+65%)	0.19 (+22%)	0.54 (+1%)
Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 (-3%)	74.12 (-3%)	21.19	8.89 (-3%)
Total emissions ($MtCO_2$e)	80.64	0.19	1.05	7.09	115.22	15.70	6.70	7.74

Printers = PC emissions / Global ratio of PC to printers emissions; Others[3]

	2011 Peripherals	2020 Peripherals
PC emissions ($MtCO_2$e)	80.64	115.22
Global ratio of PC to printers emissions	3.2	3.6
Others[3]	13%[5]	13%[5]
Total emissions ($MtCO_2$e)	44.6	61.8

1. Gartner
2. IEA
3. Includes set top boxes, home routers and modems, other computer peripherals and IPTV related emissions

Figure 8.2
China ICT emissions estimation: networks and data centers

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends/ previous estimates

Networks = Wireless + Wired; Wireless = Global emissions / Share of global subscriptions; Wired = Global emissions / Share of global subscriptions

		2011 Input	2011 Source	2020 Input	2020 Source
Wireless	Global emissions ($MtCO_2$e)	101	BCG analysis	164	BCG analysis
Wireless	Share of global subscriptions	16%	Greentouch Ovum	12%	BCG analysis
Wired	Global emissions ($MtCO_2$e)	100	BCG analysis	139	BCG analysis
Wired	Share of global subscriptions	26%	Greentouch Ovum	26%	BCG analysis
Networks		42.5		55.9	

Data centers = Global emissions / Share of global installed servers

	2011 Input	2011 Source	2020 Input	2020 Source
Global emissions ($MtCO_2$e)	155	BCG analysis	299	BCG analysis
Share of global installed servers	13%	Gartner	22%	BCG analysis
Data centers	20.7		63.0	

U.S.

Figure 9.1
U.S. ICT emissions estimation: end-user devices

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

1. Gartner
2. IEA
3. Includes set top boxes, home routers and modems, other computer peripherals and IPTV related emissions

PCs and mobile devices = Usage footprint + Embodied emissions
Usage footprint = Installed base × Electricity used/device × Emissions factor
Embodied emissions = Shipments × Emissions/device

	2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
Installed base (B)[1]	0.33	0.04	0.11	0.22	0.34	0.35 (+27%)	0.20 (+7%)	0.23 (+1%)
Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] (-8%)	15.60	5.45	2.50
Emissions factor[3] (kg CO_2e/kWh)	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Shipments (B)[1]	0.07	0.03	0.10	0.08	0.08	0.13 (+17%)	0.14 (+4%)	0.08
Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 (-3%)	74.12 (-3%)	21.19	8.89 (-3%)
Total emissions ($MtCO_2$e)	72.99	3.50	2.56	1.34	42.16	13.00	3.80	1.13

Printers = PC emissions / Global ratio of PC to printers emissions

	2011 Peripherals	2020 Peripherals
Printers: PC emissions ($MtCO_2$e)	72.99	42.16
Printers: Global ratio of PC to printers emissions	3.2	3.6
Others[3]	13%[5]	13%[5]
Total emissions ($MtCO_2$e)	46.34	32.60

Figure 9.2
U.S. ICT emissions estimation: networks and data centers

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends/ previous estimates

Networks = Wireless + Wired
Wireless = Global emissions / Share of global subscriptions
Wired = Global emissions / Share of global subscriptions

	2011 Input	2011 Source	2020 Input	2020 Source
Wireless: Global emissions ($MtCO_2$e)	101	BCG analysis	164	BCG analysis
Wireless: Share of global subscriptions	6%	Greentouch Ovum	3%	BCG analysis
Wired: Global emissions ($MtCO_2$e)	100	BCG analysis	139	BCG analysis
Wired: Share of global subscriptions	12%	Greentouch Ovum	9%	BCG analysis
Networks	18.1		17.9	

Data centers = Global emissions / Share of global installed servers

	2011 Input	2011 Source	2020 Input	2020 Source
Global emissions ($MtCO_2$e)	155	BCG analysis	299	BCG analysis
Share of global installed servers	38%	Gartner	35%	BCG analysis
Data centers	59.2		100.9	

Germany

PCs and mobile devices		2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
Usage footprint	Installed base (B)[1]	0.06	0.004	0.02	0.08	0.08 +4%	0.06 +36%	0.05 +9%	0.08
	Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] -8%	15.60	5.45	2.50
	Emissions factor[3] (kg CO_2e/kWh)	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Embodied emissions	Shipments (B)[1]	0.01	0.003	0.01	0.02	0.02 +4%	0.02 +24%	0.03 +10%	0.02
	Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 -3%	74.12 -3%	21.19	8.89 -3%
	Total emissions ($MtCO_2e$)	**11.61**	**0.31**	**0.31**	**0.31**	**9.54**	**1.88**	**0.71**	**0.26**

		2011 Peripherals	2020 Peripherals
Printers	PC emissions ($MtCO_2e$)	11.16	9.54
	Global ratio of PC to printers emissions	3.2	3.6
Others[3]		**13%[5]**	**13%[5]**
	Total emissions ($MtCO_2e$)	**6.21**	**4.92**

Figure 10.1
Germany ICT emissions estimation: end-user devices

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

1. Gartner
2. IEA
3. Includes set top boxes, home routers and modems, other computer peripherals and IPTV related emissions

			2011 Input	2011 Source	2020 Input	2020 Source
Networks	Wireless	Global emissions ($MtCO_2e$)	101	BCG analysis	164	BCG analysis
		Share of global subscriptions	2%	Greentouch Ovum	1%	BCG analysis
	Wired	Global emissions ($MtCO_2e$)	100	BCG analysis	1.85	Half of 2011 estimates (based on Deutsche Telekom analysis)
		Share of global subscriptions	4%	Greentouch Ovum		
			5.6		**3.5**	

		Input	Source	Input	Source
Data centers	Global emissions ($MtCO_2e$)	155	BCG analysis	299	BCG analysis
	Share of global installed servers	5%	Gartner	4%	BCG analysis
		7.5		**11.2**	

Figure 10.2
Germany ICT emissions estimation: networks and data centers

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends/ previous estimates

Canada

Figure 11.1
Canada ICT emissions estimation: end-user devices

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

1. Gartner
2. IEA
3. Includes set top boxes, home routers and modems, other computer peripherals and IPTV related emissions

PCs and mobile devices			2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
+	Usage footprint (×)	Installed base (B)[1]	0.04	0.00	0.01	0.02	0.04	0.01 (+17%)	0.02 (+7%)	0.02 (+2%)
		Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] (-8%)	15.60	5.45	2.50
		Emissions factor[3] (kg CO_2e/kWh)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Embodied emissions (×)	Shipments (B)[1]	0.01	0.00	0.01	0.003	0.02	0.01 (+15%)	0.01 (+6%)	0.003 (+1%)
		Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 (-3%)	74.12 (-3%)	21.19	8.89 (-3%)
		Total emissions ($MtCO_2e$)	6.90	0.27	0.19	0.04	4.88	0.71	0.32	0.04

		2011 Peripherals	2020 Peripherals
Printers (/)	PC emissions ($MtCO_2e$)	6.90	7.18
	Global ratio of PC to printers emissions	3.2	3.6
Others[3]		13%[5]	13%[5]
	Total emissions ($MtCO_2e$)	3.62	3.71

Figure 11.2
Canada ICT emissions estimation: networks and data centers

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends/ previous estimates

Networks (+)			2011 Input	2011 Source	2020 Input	2020 Source
	Wireless (/)	Global emissions ($MtCO_2e$)	101	BCG analysis	164	BCG analysis
		Share of global subscriptions	0.4%	Greentouch Ovum	0.3%	BCG analysis
	Wired (/)	Global emissions ($MtCO_2e$)	100	BCG analysis	139	BCG analysis
		Share of global subscriptions	2%	Greentouch Ovum	1%	BCG analysis
			1.4		2.5	

Data centers (/)	2011 Input	2011 Source	2020 Input	2020 Source
Global emissions ($MtCO_2e$)	155	BCG analysis	299	BCG analysis
Share of global installed servers	3%	Gartner	2%	BCG analysis
	4.1		7.1	

India

Figure 12.1
India ICT emissions estimation: end-user devices

PCs and mobile devices = Usage footprint + Embodied emissions

Usage footprint = Installed base × Electricity used/device × Emissions factor

Embodied emissions = Shipments × Emissions/device

		2011 PCs	2011 Tablets	2011 Smart-phones	2011 Mobile phones	2020 PCs	2020 Tablets	2020 Smart-phones	2020 Mobile phones
Usage footprint	Installed base (B)[1]	0.05	0.0001	0.02	0.45	0.17 (+14%)	0.20 (N/A)	0.33 (+34%)	0.87 (+8%)
	Electricity used/device (kWh/yr)	218.98	15.60	5.45	2.50	101.66[4] (-8%)	15.60	5.45	2.50
	Emissions factor[3] (kg CO_2e/kWh)	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
Embodied emissions	Shipments (B)[1]	0.01	0.0001	0.01	0.17	0.07 (+14%)	0.07 (N/A)	0.20 (+37%)	0.16 (-1%)
	Emissions/device (kgCO2e/yr)	332.38	97.5	21.19	11.70	252.68 (-3%)	74.12 (-3%)	21.19	8.89 (-3%)
	Total emissions ($MtCO_2e$)	19.80	0.01	0.42	3.62	42.26	9.41	6.71	4.55

Printers = PC emissions / Global ratio of PC to printers emissions

		2011 Peripherals	2020 Peripherals
Printers	PC emissions ($MtCO_2e$)	19.80	42.26
	Global ratio of PC to printers emissions	3.2	3.6
Others[3]		13%[5]	13%[5]
	Total emissions ($MtCO_2e$)	10.99	22.24

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends

1. Gartner
2. IEA
3. Includes set top boxes, home routers and modems, other computer peripherals and IPTV related emissions

Figure 12.2
India ICT emissions estimation: networks and data centers

Networks = Wireless + Wired

Wireless = Global emissions / Share of global subscriptions

Wired = Global emissions / Share of global subscriptions

		2011 Input	2011 Source	2020 Input	2020 Source
Wireless	Global emissions ($MtCO_2e$)	101	BCG analysis	164	BCG analysis
	Share of global subscriptions	15%	Greentouch Ovum	11%	BCG analysis
Wired	Global emissions ($MtCO_2e$)	100	BCG analysis	139	BCG analysis
	Share of global subscriptions	3%	Greentouch Ovum	7%	BCG analysis
Networks		18.1		27.9	

Data centers = Global emissions / Share of global installed servers

		Input	Source	Input	Source
Data centers	Global emissions ($MtCO_2e$)	155	BCG analysis	287	BCG analysis
	Share of global installed servers	1.5%	Gartner	1.7%	BCG analysis
		2.3		5.0	

Third-party reports/ estimates[1]
BCG research
Extrapolation from industry trends/ previous estimates

15.6 Details for global abatement potential by sublever

Agriculture

Sublever	Abatement potential ($GtCO_2e$)	Addressable emissions ($GtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Livestock management	0.70	9.93	7%	Addressable emissions defined as livestock-related[1] with the saving potential based on the fact that cattle grazing in well-managed pastures reduces CH4 emissions by 20 percent: assume 50% penetration in developed regions and 20% in developing, and 50:50 split between the two in livestock emissions[2]	1. EDGAR database 2. BSR "Wireless and the Environment"
Smart farming	0.25	12.4	2%	Addressable emissions defined as all agricultural emissions.[1] Savings potential is based on estimates of the global increase in agricultural productivity (10% from 2012-2020) assuming that ICT is responsible for 20% of impact.[2]	1. EDGAR database 2. "Total Factor productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000"
Smart water	0.03	0.13	25%	Addressable emissions set to those from agricultural activities (US ratio applied globally).[1] Saving potential assumes 50% reduction in energy use from case studies[2] and 50% penetration rate[3]	1. River Network, "Carbon Footprint of Water" & IEA. 2. BSR "Wireless and the Environment" 3. Expert interviews
Soil monitoring/ Weather forecasting	0.62	12.4	5%	Addressable emissions defined as all agricultural emissions.[1] Savings potential is based on case studies and expert interviews[2]	1. EDGAR database 2. BSR "Wireless and the Environment"

Buildings

Sublever	Abatement potential ($GtCO_2e$)	Addressable emissions ($GtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Building design	0.45	N/A	N/A	40% reduction in retail buildings and 30% in others. Implementation: 60% of all new builds and 15% of retrofits (except 0% for residential)	SMART 2020
Building management system	0.39	N/A	N/A	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	SMART 2020
Integration of renewables in commercial and residential buildings	0.50	16.52	3.0%	Addressable emissions defined as commercial and residential building energy use.[1] Savings potential based on BCG estimates.[2]	1. River Network, "Carbon Footprint of Water" & IEA 2. BSR "Wireless and the Environment" 3. Expert interviews
Voltage optimization	0.24	N/A	N/A	10% reduction in heating/cooling and appliance consumption. Implementation: 80% of new builds, 30% of commercial retrofits and 20% of residential retrofits	SMART 2020

Customer and service

Sublever	Abatement potential ($GtCO_2e$)	Addressable emissions ($GtCO_2e$)	Savings potential (%)	Sub-model details	Sources
E-commerce	0.09	1.14	7.5%	Addressable emissions updated with more recent emissions data[1] and using the assumption that 20% of all private transport is for shopping[2]. Saving potential assumes penetration rate of 15% in developed world 3 and 0% in developing	1. IEA 2. SMART 2020 3. Wall Street Journal: http://blogs.wsj.com/digits/2011/02/27/e-commerce-will-keep-rolling-research-firm-says
E-paper	0.06	0.10	2%	Addressable emissions from 96.6 Mt of paper use with [1] tCO_2e per ton of paper[1] Savings potential determined estimated (61.5%)[2]	1. SMART 2020; Pira "The future of global printing" 2. www.tkearth.com/downloads/thoughts_ereaders.pdf
Minimization of packaging	0.22	N/A	N/A	5% reduction in packaging material, leading to a 5% reduction in all transports and in storage	SMART 2020
Online media	0.02	N/A	N/A	Assumes seven billion DVDs and 10 billion CDs globally sold per year. 1 Kg CO_2e per CD/DVD. Eliminates all CDs and DVDs	SMART 2020
Public safety/ Disaster managment	0.03	0.12	15/25%	Total addressable emissions estimated from average annual cost of natural disasters (based on last 5 years, split by developed and developing world, see additional details)[1] Savings potential estimated to be 15/25% for developed /developing world[2]	1. Munich Re 2. Expert interviews, triangulated with World Bank and the US Geological Survey data (www.dialog.lk/about/responsibility/outreach-cr/dewn)
Reduction in inventory	0.18	N/A	N/A	24% reduction in inventory levels, 100% of warehouses and 25% of retail are assumed to be used for storage	SMART 2020
Smart water	0.13	0.52	25%	Addressable emissions set to those from Public, domestic and wastewater treatment (US ratio applied globally).[1] Saving potential assumes 50% reduction in energy use from case studies[2] and 50% penetration rate[3]	1. River Network, "Carbon Footprint of Water" & IEA. 2. BSR "Wireless and the Environment" 3. Expert interviews

Manufacturing

Sublever	Abatement potential ($GtCO_2e$)	Addressable emissions ($GtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Automation of industrial processes	0.72	14.3	5.0%	Addressable emissions updated with total industrial energy use minus the motor energy use (covered in next sublever) and industrial heating and cooling (likely little opportunity for automation).[1] A 15% reduction in energy is assumed with a 33% penetration rate[2]	1. IEA 2. SMART 2020
Optimization of variable speed motor systems	0.53	2.92	18.0%	Addressable emissions updated with total motor systems emissions.[1] A 30% increase in efficiency with a 60% penetration rate is assumed[2]	1. IEA 2. SMART 2020

Power

Sublever	Abatement potential ($GtCO_2e$)	Addressable emissions ($GtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Demand management	0.01	0.25	4.0%	Addressable emissions based on total power capacity (6.9TW, 0.55 kg CO_2/kWh emissions factor used) and average ratio of energy savings as a result of DR (65 Wh/W)1 Savings potential based on penetration from case studies.[1]	1. IEA & EPRI: "The Green Grid"
Time-of-day pricing	0.21	21.48	1.0%	Sublever addresses all emissions related to electricity generation1 with a conservative total savings potential taken from report on smart grid[2]	1. IEA 2. PNNL: "The Smart Grid: An Estimation of the Energy and CO_2 Benefits"
Power-load balancing	0.38	0.64	60.0%	Addressable emissions equals non-base electricity generation (those associated with oil)1 – saving potential based on penetration of storage[2]	1. IEA 2. BCG Perspectives: "Revisiting Energy Storage"
Power grid optimization	0.33	1.10	30.0%	Addressable emissions based on those associated with T&D losses (7% of all electricity)[1] - 30% savings estimation from previous SMART 2020 report	1. The Energy and Resources Institute "T&D Losses" & IEA
Integration of renewables in power generation	0.85	3.40	25.0%	Addressable emissions based on change of emissions due to greening of power grid based on IEA [2] degree scenario1 – savings potential based on prior SMART 2020 estimation, represents contribution of ICT technology	1. IEA ETP
Virtual power plant	0.04	0.14	26.0%	Total addressable emissions is based on future VPP capacity (30GW)[1] with an estimate that a typical VPP incorporates 25% renewables and reduces energy demand by 1%[2]	1. Pike Research: "Virtual Power Plants" 2. Expert interviews
Integration of storage into off-grid applications	0.20	600 GW	400 hr/yr	BCG estimates there are 600 GW of installed fleet of diesel generators running ~400 hr/yr for island or off-grid applications	1. BCG Perspectives: "Revisiting Energy Storage" & Power Systems Research

Transportation

Sublever	Abatement potential ($GtCO_2e$)	Addressable emissions ($GtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Eco-driving	0.25	N/A	N/A	12% reduction in carbon intensity owing to improved driving style	SMART 2020
Real-time traffic alerts	0.07	9.56	0.7%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (in US, figured assume to be similar for world congestion) with a penetration rate depending on availability of communication technology[2]	1. IEA 2. US DOE: (www1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Apps for intermodal travel/public transportation	0.07	7.17	1.0%	Addressable emissions determined from emissions from passenger transportation.1 Savings potential from previous report.[2]	1. IEA 2. SMART 2020
Asset sharing/ Crowd sourcing	0.14	7.17	2.0%	Addressable emissions determined from passenger road transportation[1] with savings potential based on case study with the assumption that it applied to a global average[2]	1. IEA 2. RAND Corporation: "Energy Services Analysis"
Video-conferencing	0.08	N/A	N/A	30% of passenger air and rail travel is business travel; globally 30% of business travel can be avoided through videoconferencing	SMART 2020
Tele-commuting	0.26	N/A	N/A	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 2020
Optimization of truck route planning	0.19	3.88	5.0%	Addressable emissions updated with commercial road transportation[1] with the savings potential from prior report[2]	1. IEA 2. SMART 2020
Optimization of logistics network	0.57	3.88/2.2	14/1%	Addressable emissions updated with commercial road transportation/all other transportation emissions[1] with the savings potential taken from prior report[2]	1. IEA 2. SMART 2020
Integration of EVs	0.20	9.56	2.1%	Addressable emissions determined from all road transportation.[1] The savings potential is calculated from average reduction in emissions of 30% in the US, number assumed to be fairly constant world-wide (although there are some differences due to different generation mix)[2] and a 7% penetration[3]	1. IEA 2. New York Times: "How green are electric cars depends on where you plug in" 3. BCG Perspectives: "Batteries for Electric Cars"
Intelligent traffic management	0.03	9.56	0.4%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (in US, assume fuel use to be similar for world congestion) with a penetration rate depending on availability of communication technology[2]	1. IEA 2. US DOE: (1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Fleet management and telematics	0.08	3.88	2.0%	Addressable emissions determined by commercial road transportation.[1] savings potential determined by 10% of transportation that is "out-of-route" [2] with a 20% penetration rate.[3]	1. IEA 2. BSR "Wireless and the Environment" 3. Expert interviews

15.7 Details of abatement calculation by country

15.7.1 United Kingdom

Buildings

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Building design	9.8			Since US and UK have similar building characteristics: scaled previous SMART 2020 results in US addendum by ratio of UK/US building emissions (7.5%)	SMART 2020; EIA "Buildings"; UK Department of Energy and Climate Change
Building management system	3.6			Since US and UK have similar building characteristics: scaled previous SMART 2020 results in US addendum by ratio of UK/US building emissions (7.5%)	SMART 2020; EIA "Buildings"; UK Department of Energy and Climate Change
Integration of renewables in commercial and residential buildings	6.6	220	3.0%	Addressable emissions defined as commercial and residential building energy use.[1] Savings potential based on BCG estimates.[2]	1. UK Department of Energy and Climate Change 2. BCG Perspective, "What's Next for Alternative Energy?"
Voltage optimization	3.0			Since US and UK have similar building characteristics: scaled previous SMART 2020 results in US addendum by ratio of UK/US building emissions (7.5%)	SMART 2020; EIA "Buildings"; UK Department of Energy and Climate Change

Service and consumer

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
E-commerce	1.6	10.50	15.0%	Addressable emissions updated with more recent emissions data[1] and using the assumption that 20% of all private transport is for shopping[2]. Saving potential assumes penetration rate of 15% in developed world[3]	1. UK Department of Energy and Climate Change 2. SMART 2020 3. Wall Street Journal: http://blogs.wsj.com/digits/2011/02/27/e-commerce-will-keep-rolling-research-firm-says/
E-paper	3.0	4.80	61.5%	Addressable emissions from 4.8 Mt of paper use with 1 tCO_2e per ton of paper[1] Savings potential determined estimated (61.5%)[2]	1. SMART 2020; Pira "The future of global printing" 2. www.tkearth.com/downloads/thoughts_ereaders.pdf
Minimization of packaging	8.4			Based on calculation in previous report but scaled by percent of global GDP (~3.8%) to determine contribution in UK	SMART 2020
Online media	0.8			Based on calculation in previous report but scaled by percent of global GDP (~3.8%) to determine contribution in UK	SMART 2020
Public safety / Disaster management	0.2	1.12	15%	Total addressable emissions estimated from average annual cost of natural disasters (based on last 5 years, UK scaled from Europe emissions by GDP)[1] Savings potential estimated to be 15 percent.[2]	1. Munich Re 2. Expert interviews, triangulated with World Bank and the US Geological Survey data (www.dialog.lk/about/responsibility/outreach-cr/dewn/)
Reduction in inventory	6.8			Based on calculation in previous report but scaled by percent of global GDP (~3.8%) to determine contribution in UK	SMART 2020
Smart water	1.1	4.36	25%	Addressable emissions set to those from Public, domestic and wastewater treatment (US ratio of water emissions to total emissions applied to UK).[1] Saving potential assumes 50% reduction in energy use from case studies[2] and 50% penetration rate[3]	1. River Network, "Carbon Footprint of Water" & IEA. 2. BSR "Wireless and the Environment" 3. Expert interviews

15.7.2 China

Power

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Demand management	4.2	104	4.0%	Addressable emissions based on total power capacity in China in 2020 (2.0TW, 0.8 $kgCO_2$/kWh emission factor is used) and average ratio of energy savings as a result of DR (65 Wh/W)[1] Savings potential based on pentration from case studies.[2]	1. IEA 2. EPRI: "The Green Grid"
Time-of-day pricing	79.2	7917	1.0%	Sublever addresses all emissions related to electricity generation[1] with a conservative total savings potential taken from report on smart grid[2]	1. IEA 2. PNNL: "The Smart Grid: An Estimation of the Energy and CO_2 Benefits"
Power-load balancing	8.6	14.3	60.0%	Addressable emissions equals non-base electricity generation (those associated with oil)[1] – saving potential based on penetration of storage[2]	1. IEA 2. BCG Perspectives: "Revisiting Energy Storage"
Power grid optimization	142.5	475.0	30.0%	Addressable emissions based on those associated with T&D losses (6% of all electricity)[1] - 30% savings estimation from previous SMART 2020 report	1. The Energy and Resources Institute "T&D Losses" & IEA; SMART 2020
Integration of renewables in power generation	152.8	152.8	100%	Based on IEA projections for the integration of renewables	IEA
Virtual power plant	1.8	7.01	26.0%	Total addressable emissions is based on future VPP capacity (1GW)[1] with an estimate that a typical VPP incorporates 25% renewables and reduces energy demand by 1%[2]	1. Based on Pike Research: "Virtual Power Plants" 2. Expert interviews
Integration of storage into off-grid applications	0.5	0.55	100%	BCG estimates there are 78 MW of installed fleet of diesel generators are available for replacement with renewables/ storage for island or off-grid applications (please see report for additional details)[1]	1. BCG Perspectives: "Revisiting Energy Storage" & Power Systems Research

Manufacturing

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Automation of industrial processes	165.4	3308	5.0%	Addressable emissions updated with total industrial energy (estimated to be 33% of all CO_2 emissions – conversion to include all GHG required applying global ratio of GHG to CO_2) minus the motor energy use (from data in second lever).1 A 15% reduction in energy is assumed with a 33% penetration rate[2]	1. IEA; WorldBank Databank 2. SMART 2020
Optimization of variable speed motor systems	347.0	1928	18.0%	Addressable emissions is total motor systems emissions (calculated from estimated 2410TWh electricity use).[1] A 30% increase in efficiency with a a 60% penetration rate is assumed[2]	1. IEA; "Raising China's electric motor efficiency" 2. SMART 2020

15.7.3 Brazil

Transportation

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Eco-driving	3.0	N/A	N/A	Scaled from global SMART 2020 report based of ratio of Brazil transportation emissions to global total (1.2%)	SMART 2020
Real-time traffic alerts	1.2	166	0.7%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (based on US average, figure assumed to be similar a likely higher for world congestion, thus our estimation is conservative) with a penetration rate depending on availability of communication technology[2]	1. IEA 2. US DOE: (www1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Apps for intermodal travel/public transportation	1.2	118	1.0%	Addressable emissions determined from emissions from passenger transportation.[1] Savings potential from previous report.[2]	1. World Bank 2. SMART 2020
Asset sharing/ Crowd sourcing	2.4	118	2.0%	Addressable emissions determined from passenger road transportation[1] with savings potential based on case study with the assumption that it applied to a global average[2]	1. World Bank 2. RAND Corporation: "Energy Services Analysis"
Video-conferencing	2.3	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of Brazil transportation emissions to global total (2.9%)	SMART 2020; World Bank; IEA
Tele-commuting	7.5	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of Brazil transportation emissions to global total (2.9%)	SMART 2020; World Bank; IEA
Optimization of truck route planning	3.6	71	5.0%	Addressable emissions updated with commercial road transportation[1] with the savings potential from prior report[2]	1. World Bank 2. SMART 2020
Optimization of logistics network	11.2	71/128	14/1%	Addressable emissions updated with commercial road transportation/all other transportation emissions[1] with the savings potential taken from prior report[2]	1. World Bank 2. SMART 2020
Integration of EVs	3.5	166	2.1%	Addressable emissions determined from all road transportation.[1] The savings potential is calculated from average reduction in emissions of 30% in the US, number assumed to be fairly constant world-wide (although there are some differences due to different generation mix)[2] and a 7% penetration[3]	1. World Bank 2. New York Times: "How green are electric cars depends on where you plug in" 3. BCG Perspectives: "Batteries for Electric Cars"
Intelligent traffic management	0.6	166	0.4%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (in US, assume fuel use to be similar for world congestion, likely slightly higher in Brazil, thus we present a conservative estimate) with a penetration rate depending on availability of communication technology[2]	1. World Bank; 2. US DOE: (http://www1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Fleet management and telematics	1.4	71	2.0%	Addressable emissions determined by commercial road transportation.[1] savings potential determined by 10% of transportation that is "out-of-route" [2] with a 20% penetration rate.[3]	1. World Bank 2. BSR "Wireless and the Environment" 3. Expert interviews

Agriculture

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Livestock Management	17.9	256	7%	Addressable emissions defined as livestock-related[1] with the saving potential based on the fact that cattle grazing in well-managed pastures reduces CH4 emissions by 20 percent: assume 35% penetration rate	1. World Bank: http://sdwebx.worldbank.org/climateportalb/doc/ESMAP/FINAL_LCCGP_Brazil.pdf 2. BSR "Wireless and the Environment"
Smart farming	7.0	349	2%	Addressable emissions defined as all agricultural emissions.[1] Savings potential is based on estimates of the global increase in agricultural productivity (10% from 2012-2020) assuming that ICT is responsible for 20% of impact.[2]	1. World Bank: http://sdwebx.worldbank.org/climateportalb/doc/ESMAP/FINAL_LCCGP_Brazil.pdf 2. "Total Factor productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000"
Smart water	0.5	1.95	25%	Addressable emissions set to those from agricultural activities. Brazil estimated emissions taken from applying ratio of Brazil ag water use (1.15%) by total global water emissions[1] Saving potential assumes 50% reduction in energy use from case studies[2] and 50% penetration rate[3]	1. River Network, "Carbon Footprint of Water" & IEA. 2. BSR "Wireless and the Environment" 3. Expert interviews
Soil Monitoring/ Weather forecasting	17.5	349	5.00%	Addressable emissions defined as all agricultural emissions.[1] Savings potential is based on case studies and expert interviews[2]	1. World Bank: http://sdwebx.worldbank.org/climateportalb/doc/ESMAP/FINAL_LCCGP_Brazil.pdf 2. BSR "Wireless and the Environment"
Deforestation prevention	47.5	475.1	10.0%	Average Forest lost projected by taking 2008 deforestation levels[1] and assuming -1% CAGR (average decline in deforestation between 1990-2008). Assumes that savings potential is 10% because of limited number of IBAMA agents and difficulties posed by rural law enforcement [2,3]	1. National Institute of Space; 2. "Under pressure from rising deforestation, Brazil's IBAMA establishes 'Zero Deforestation Policy' in the Amazon " Imazon; 3. "ICT-Based

15.7.4 United States

Power

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Demand management	1.4	35.8	4.0%	Addressable emissions based on total power capacity in US in 2020 (1.0TW, 0.55 $kgCO_2$/kWh emission factor is used) and average ratio of energy savings as a result of DR (65 Wh/W)[1] Savings potential based on penetration from case studies.[1]	1. EIA & EPRI: "The Green Grid"
Time-of-day pricing	21.7	2165	1.0%	Sublever addresses all emissions related to electricity generation (3937 TWh. 0.55 $kgCO_2$/KWh emission factor)[1] with a conservative total savings potential taken from report on smart grid[2]	1. EIA 2. PNNL: "The Smart Grid: An Estimation of the Energy and CO_2 Benefits"
Power-load balancing	13.1	21.8	60.0%	Addressable emissions equals non-base electricity generation (those associated with oil)[1] – saving potential based on penetration of storage[2]	1. IEA 2. BCG Perspectives: "Revisiting Energy Storage"
Power grid optimization	45.5	151.6	30.0%	Addressable emissions based on those associated with T&D losses (7% of all electricity)[1] - 30% savings estimation from previous SMART 2020 report	1. The Energy and Resources Institute "T&D Losses" & IEA
Integration of renewables in power generation	84.7	84.7	100.0%	Based on EIA projections for the integration of renewables	EIA
Virtual power plant	6.3	24.1	26.0%	Total addressable emissions is based on future VPP capacity (5GW)[1] with an estimate that a typical VPP incorporates 25% renewables and reduces energy demand by 1%[2]	1. Pike Research: "Virtual Power Plants" 2. Expert interviews
Integration of storage into off-grid applications	0.0	0	0	Little opportunity for off-grid storage/renewables because of nearly 100% availability of modern grid	

Agriculture

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Building design	130			No update from previous US report	SMART 2020 – US addendum
Building management system	48			No update from previous US report	SMART 2020 – US addendum
Integration of renewables in commercial and residential buildings	87	2900	3.0%	Addressable emissions defined as commercial and residential building energy use.[1] Savings potential based on BCG estimates.[2]	1. EIA – "Buildings" 2. BCG Perspective, "What's Next for Alternative Energy?"
Voltage optimization	40			No update from previous US report	SMART 2020 – US addendum

15.7.5 Germany

Power

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Demand management	1.4	35.8	4.0%	Addressable emissions based on total power capacity in US in 2020 (1.0TW, 0.55 $kgCO_2$/kWh emission factor is used) and average ratio of energy savings as a result of DR (65 Wh/W)[1] Savings potential based on penetration from case studies.[1]	1. EIA & EPRI: "The Green Grid"
Time-of-day pricing	21.7	2165	1.0%	Sublever addresses all emissions related to electricity generation (3937 TWh. 0.55 $kgCO_2$/KWh emission factor)[1] with a conservative total savings potential taken from report on smart grid[2]	1. EIA 2. PNNL: "The Smart Grid: An Estimation of the Energy and CO_2 Benefits"
Power-load balancing	13.1	21.8	60.0%	Addressable emissions equals non-base electricity generation (those associated with oil)[1] – saving potential based on penetration of storage[2]	1. IEA 2. BCG Perspectives: "Revisiting Energy Storage"
Power grid optimization	45.5	151.6	30.0%	Addressable emissions based on those associated with T&D losses (7% of all electricity)[1] - 30% savings estimation from previous SMART 2020 report	1. The Energy and Resources Institute "T&D Losses" & IEA
Integration of renewables in power generation	84.7	84.7	100.0%	Based on EIA projections for the integration of renewables	EIA
Virtual power plant	6.3	24.1	26.0%	Total addressable emissions is based on future VPP capacity (5GW)[1] with an estimate that a typical VPP incorporates 25% renewables and reduces energy demand by 1%[2]	1. Pike Research: "Virtual Power Plants" 2. Expert interviews
Integration of storage into off-grid applications	0.0	0	0	Little opportunity for off-grid storage/renewables because of nearly 100% availability of modern grid	

Manufacturing

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Automation of industrial processes	6.0	119.2	5.0%	Addressable emissions updated with total industrial energy minus the motor energy use (from data in second lever).[1] A 15% reduction in energy is assumed with a 33% penetration rate[2]	1. SMART 2020 Germany 2. SMART 2020
Optimization of variable speed motor systems	27.1	150.8	18.0%	Addressable emissions is total motor systems emissions (calculated from estimated 260TWh electricity use).[1] A 30% increase in efficency witha a 60% penetration rate is assumed[2]	1. Dena 2. SMART 2020

15.7.6 Canada

Buildings

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Building design	10.9			Previous US results scaled by ratio of Canada/US building emissions (8.4%) based on similarities in housing market	SMART 2020 US Addendum; "CANADA'S EMISSIONS TRENDS" Canada Environment
Building management system	4.0			Previous US results scaled by ratio of Canada/US building emissions (8.4%) based on similarities in housing market	SMART 2020 US Addendum; "CANADA'S EMISSIONS TRENDS" Canada Environment
Integration of renewables in commercial and residential buildings	7.3	244	3.0%	Addressable emissions defined as commercial and residential building energy use.[1] Savings potential based on BCG estimates.[2]	1. Environment Canada 2. BCG Perspective, "What's Next for Alternative Energy?"
Voltage optimization	3.4			Previous US results scaled by ratio of Canada/US building emissions (8.4%) based on similarities in housing market	SMART 2020 US Addendum; "CANADA'S EMISSIONS TRENDS" Canada Environment

Transportation

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Eco-driving	11.3	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of Canada's transportation emissions to global total (4.5%)	SMART 2020 US Addendum; "CANADA'S EMISSIONS TRENDS" Canada Environment
Real-time traffic alerts	1.2	169	0.7%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (in US, assume to be similar for Canada congestion) with a penetration rate depending on availability of communication technology[2]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment; 2. US DOE: (www1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Apps for intermodal travel/public transportation	0.7	73	1.0%	Addressable emissions determined from emissions from passenger transportation.[1] Savings potential from previous report.[2]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment 2. SMART 2020
Asset sharing/ Crowd sourcing	1.5	73	2.0%	Addressable emissions determined from passenger road transportation[1] with savings potential based on case study[2]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment 2. RAND Corporation: "Energy Services Analysis"
Video-conferencing	3.6	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of Canada's transportation emissions to global total (4.5%)	SMART 2020 US Addendum; "CANADA'S EMISSIONS TRENDS" Canada Environment
Tele-commuting	11.7	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of Canada's transportation emissions to global total (4.5%)	SMART 2020 US Addendum; "CANADA'S EMISSIONS TRENDS" Canada Environment
Optimization of truck route planning	4.8	96	5.0%	Addressable emissions updated with commercial road transportation[1] with the savings potential from prior report[2]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment 2. SMART 2020
Optimization of logistics network	14.3	96/86	14/1%	Addressable emissions updated with commercial road transportation/all other transportation emissions[1] with the savings potential taken from prior report[2]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment 2. SMART 2020
Integration of EVs	3.5	169	2.1%	Addressable emissions determined from all road transportation.[1] The savings potential is calculated from average reduction in emissions of 30% in the US, number assumed to be fairly constant in Canada (although there are some differences due to different generation mix)[2] and a 7% penetration[3]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment 2. New York Times: "How green are electric cars depends on where you plug in" 3. BCG Perspectives: "Batteries for Electric Cars"
Intelligent traffic management	0.6	169	0.4%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (in US, assume fuel use to be similar for world congestion) with a penetration rate depending on availability of communication technology[2]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment 2. US DOE: (www1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Fleet management and telematics	1.9	96	2.0%	Addressable emissions determined by commercial road transportation.[1] savings potential determined by 10% of transportation that is "out-of-route"[2] with a 20% penetration rate.[3]	1. "CANADA'S EMISSIONS TRENDS" Canada Environment 2. BSR "Wireless and the Environment" 3. Expert interviews

15.7.7 India

Power

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Demand management	0.8	20.3	4.0%	Addressable emissions based on total power capacity in India in 2020 (0.39TW, 0.8 $kgCO_2$/kWh emission factor is used) and average ratio of energy savings as a result of DR (65 Wh/W)1 Savings potential based on pentration from case studies.[1]	1. IEA & EPRI: "The Green Grid"
Time-of-day pricing	13.8	1378	1.0%	Sublever addresses all emissions related to electricity generation[1] with a conservative total savings potential taken from report on smart grid[2]	1. IEA 2. PNNL: "The Smart Grid: An Estimation of the Energy and CO_2 Benefits"
Power-load balancing	9.6	16.0	60.0%	Addressable emissions equals non-base electricity generation (those associated with oil - 19TWh)[1] – saving potential based on penetration of storage[2]	1. IEA 2. BCG Perspectives: "Revisiting Energy Storage"
Power grid optimization	91.0	303	30.0%	Addressable emissions based on those associated with T&D losses (22% of all electricity)[1] - 30% savings estimation from previous SMART 2020 report	1. The Energy and Resources Institute "T&D Losses" & IEA
Integration of renewables in power generation	23.8	95.2	25.0%	Based on IEA projections for the integration of renewables	1. IEA
Virtual power plant	0.0	0.0	26.0%	Likely little technical potential for VPP in India	1. Expert interviews
Integration of storage into off-grid applications	2.0	2.0	100%	BCG estimates there are 290 MW market size of diesel generators are available for replacement with renewables/storage for island or off-grid applications (please see report for additional details)[1]	1. BCG Perspectives: "Revisiting Energy Storage" & Power Systems Research

Transportation

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Eco-driving	12.1	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of estimated India transportation emissions to estimated global total in 2020 (4.8%)	SMART 2020
Real-time traffic alerts	2.6	375.3	0.7%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (in US, figured assume to be similar for world congestion) with a penetration rate depending on availability of communication technology[2]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium; 2. US DOE: (http://www1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Apps for intermodal travel/public transportation	2.3	231	1.0%	Addressable emissions determined from emissions from passenger transportation.[1] Savings potential from previous report.[2]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium; 2. SMART 2020
Asset sharing/ Crowd sourcing	4.6	231	2.0%	Addressable emissions determined from passenger road transportation[1] with savings potential based on case study with the assumption that it applied to a global average[2]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium; 2. RAND Corporation: "Energy Services Analysis"
Video-conferencing	3.9	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of India transportation emissions to global total in 2020 (4.8%)	SMART 2020
Tele-commuting	12.5	N/A	N/A	Scaled from global SMART 2020 reported based of ratio of India transportation emissions to global total in 2020 (4.8%)	SMART 2020
Optimization of truck route planning	7.6	151	5.0%	Addressable emissions updated with commercial road transportation[1] with the savings potential from prior report[2]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium 2. SMART 2020
Optimization of logistics network	22.4	151/130	14/1%	Addressable emissions updated with commercial road transportation/all other transportation emissions[1] with the savings potential taken from prior report[2]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium 2. SMART 2020

Transportation continued

Sublever	Abatement potential ($MtCO_2e$)	Addressable emissions ($MtCO_2e$)	Savings potential (%)	Sub-model details	Sources
Integration of EVs	7.9	375	2.1%	Addressable emissions determined from all road transportation.[1] The savings potential is calculated from average reduction in emissions of 30% in the US, number assumed to be fairly constant worldwide (although there are some differences due to differenet generation mix)[2] and a 7% penetration[3]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium; 2. New York Times: "How green are electric cars depends on where you plug in". 3. BCG Perspectives: "Batteries for Electric Cars"
Intelligent traffic management	1.3	375	0.4%	Addressable emissions determined from the total emissions from road transportation[1] and the savings potential is based on the fact that about 1.6% of total fuel use is wasted due to congestion (in US, assume fuel use to be similar for world congestion) with a penetration rate depending on availability of communication technology[2]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium; 2. US DOE: (http://www1.eere.energy.gov/vehiclesandfuels/facts/2009_fotw581.html) & BCG "The Internet's New Billion: Digital Consumers in Brazil, Russia, India, China, and Indonesia "
Fleet management and telematics	3.0	151	2.0%	Addressable emissions determined by commercial road transportation.[1] savings potential determined by 10% of transportation that is "out-of-route" [2] with a 20% penetration rate.[3]	1. Energy & Emissions Outlook for the Transport Sector in India, Dr. Sarath Guttikunda; ICT's Contribution to India's National Action Plan on Climate Change, Digital Energy Solutions Consortium 2. BSR "Wireless and the Environment". 3. Expert interviews

15.8 Experts consulted and/or interviewed

Experts consulted

Name	Organization
David Carroll	AT&T
Cecil Lara	AT&T
John Schulz	AT&T
Gunar Hering	BCG
Andrew Mack	BCG
Holger Rubel	BCG
Pattabi Seshadri	BCG
Rory Wang	BCG
Dan Kilper	Bell Labs
Steve Korotky	Bell Labs
Marshall Chase	BSR
Peter Nestor	BSR
Dinesh Chand Sharma	Ericsson
Jens Malmodin	Ericsson
Manka Mishra	Ericsson
Alexandra Degher	HP
Carl Eckerseley	HP
David Fuqua	HP
Chuck Powers	National Renewable Energy Laboratory
Helena Castren	Nokia
Chen Min Alice	Nokia
Pranshu Singhal	Nokia
Marc Bettzüge	University of Cologne
Rod Tucker	University of Melbourne

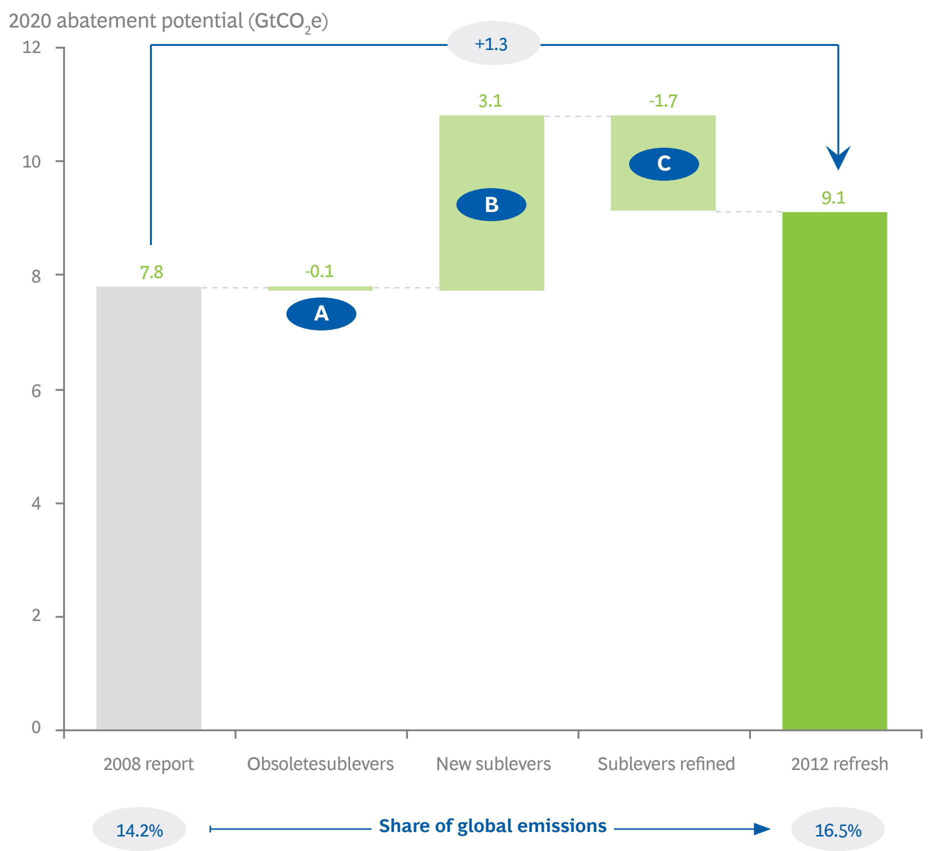
15.9 Comparison of abatement potential in this report with SMART 2020 report

In this appendix section we will describe in quantitative detail the differences in the sublevers used compared to the prior SMART 2020 report and the impact this had on the total calculated abatement potential.

The figure below illustrates that the total estimated abatement potential increased 1.3 $GtCO_2e$ from 7.8 $GtCO_2e$ in the previous report to 9.1 $GtCO_2e$ in the current version of the report. These difference was influenced by three main factors:

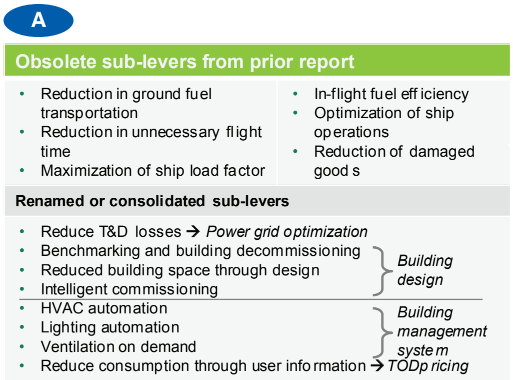
A Removing obsolete or repetitive sub- levers (-0.1 $GtCO_2e$)
B Adding new sublevers (+3.1 $GtCO_2e$)
C Refining estimations on previous sublevers (-1.7 $GtCO_2e$)

Figure
Revised estimate of abatement potential from previous report



A Obsolete (or renamed/combined) sublevers

These sublevers were already covered in a similar lever or renamed to better describe potential and thus removed. In other cases, it was found the impact from this sublever was very small or the abatement potential from the sublever was already realized.

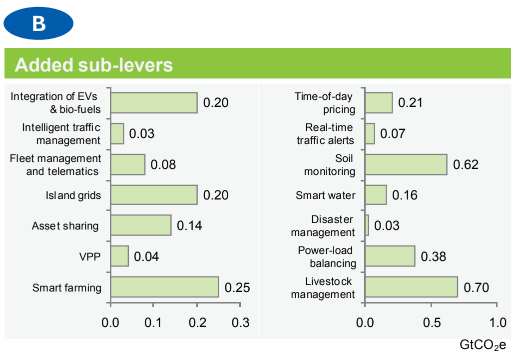


Total change: -0.1 $GtCO_2e$

Figure
Table illustrating the removed, consolidated, or renamed sublevers from the previous report

B Added sublevers

Several sublevers have been added to the new version of the report. Many of these are a result of innovation within the last few years. New solutions and technologies have increased the scope of possible sublevers, adding a total of 3.1 $GtCO_2e$ to the total abatement potential

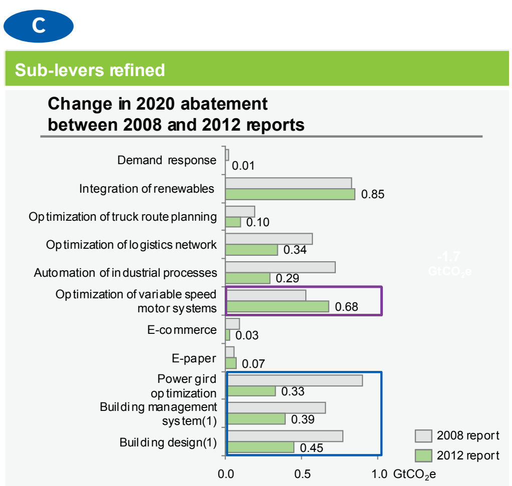


Total change: +3.1 $GtCO_2e$

Figure
Abatement potential of added sublevers

C Refinement to sublevers

Finally, there have been refinements to the sublevers than generally decreased the estimates from the previous report. These refinements are a result of more recent estimates by segment of global GHG emissions, recent trends in technological applications, generally more updated data, and an approach that takes a slightly more conservative estimate than those used in the previous report.



Total change: -1.7 $GtCO_2e$

Figure
Differences in refined sublevers from SMART 2020 report and SMARTer 2020

15.10 Glossary

A/V
Audio/video equipment

Bandwidth
Rate of data transfer, measured in bits per second

BAU
Business as usual

Biofuel
A fuel directly derived from living matter

Broadband
Wide band of frequencies used to transmit telecommunications information

BRT (bus rapid transit)
A bus system that utilizes many of the features of a metro system to increase efficiency and decrease transit time

Building Regulations 2010
Energy efficiency regulations for both residential and non-residential buildings in the U.K.

CAFÉ (Corporate Average Fuel Economy)
Regulations in the United States that require that the average fuel economy of a manufacturer's vehicles meet a certain fuel economy standard

CAGR
Compound annual growth rate

Carbon footprint
Impact of human activities on the environment measured in terms of GHG produced, measured in CO_2e

Carbon intensity
Quantity of CO_2e emitted per unit of energy produced by the burning of a fuel

Carbon sink
Natural entity that has the ability to absorb and hold carbon from the atmosphere, such as a forest or body of water. The destruction of such a carbon sink releases the carbon it holds as CO_2

CCC (Committee on Climate Change)
An advisory body in the U.K. that informs the government on the level of carbon budgets and areas in which cost-effective abatement can be realized

Center of Excellence
An international body that exists to help share best practices (e.g. sharing information and analysis) through effective communication and among various parties

Climate Change Act 2008
A 2008 law passed in the United Kingdom that sets clear targets for GHG emissions reductions and provides a carbon budgeting system that caps emissions over five-year periods, with three budgets set at a time

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

CO_2
Carbon dioxide

CO_2e
Carbon dioxide equivalent

Contained animal feeding operation (CAFO)
an institution that concentrates cattle in one area for feeding and raising, most typically found in developed nations. More commonly known as a feedlot

CRC Energy Efficiency Scheme
A mandatory cap and trade system in the United Kingdom; still in its earliest phases of development

DEC (Display Energy Certificate)
A certificate prominently displayed on buildings to give more underlying information to consumers about the building's energy usage

Decarbonization
Removing fuel sources from the fuel mix that lead to the release of CO_2 and other GHGs

Dematerialization
The substitution of high carbon activities or products with low carbon alternatives

E-commerce (electronic commerce)
Buying and selling of products and services over the internet and other computer networks

EV (electric vehicle)
a vehicle that operates using electricity

EERS (energy efficiency resource standards)
establish specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs

Emissions factor
Carbon footprint of any energy source, expressed for example as $kgCO_2/kWh$

Emissions intensity
CO_2 produced in kilograms per U.S. dollar of GDP generated

Energy Act 2011
UK law that seeks to bring about a step change in the provision of energy efficiency measures to homes and businesses

Externality
Something that is generated during the production of a good or provision of a service that bears a cost on society but is not borne directly by an individual; most frequently in this report, the externality of GHG emissions

Feed-in tariff
An amount of money given to a producer of renewable energy based on the amount of production in kWh; this amount is dependent on the type of power generated

Flex fuel
A vehicle that can run off gasoline, ethanol, or a blend of the two

Fracking
A process that results in the creation of fractures in rocks, the goal of which is to increase the output of a natural gas well

FYP (Five-Year Plan)
Centralized economic planning conducted by the Chinese government to set the direction of the economy over the coming five years

GDP
Gross domestic product

GHG
Greenhouse gas

GIB (Green Investment Bank)
The UK-based financial organization that has a mission to provide financial solutions to accelerate private sector investment in the green economy

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

HVAC
Heating, ventilation and air conditioning

Green Deal
A new UK framework to enable financing of energy efficiency improvements in domestic and non-domestic properties

HMI (human machine interface)
The user interface where interaction between the human and the machine occurs

Hydroelectric power
Electricity that is generated using the gravitational force of moving water fed through a turbine

IBAMA
Brazilian Institute of Environment and Renewable Natural Resources, the federal Brazilian agency charged with the protection of the environment

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 organization 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 procedures equipment or software associated with the electronic storage processing or transmission of data."

IEA
International Energy Agency.

IP (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

IRR
Internal rate of return, the discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. A higher IRR indicates more desirability

IT
Information technology

ITU
International Telecommunications Union

kWh
Kilowatt hour

Kyoto Protocol
Legally binding agreement of the UNFCCC in which industrialized 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

LCA (life cycle assessment)
Investigation and evaluation of the environmental impacts of a given product or service caused or necessitated by its existence

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

LEED (Leadership in Energy and Environmental Design)
Green building rating system established by the US Green Building Council

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

FOA (Food and Agriculture Organization of the UN)
UN agency that works on international efforts to defeat hunger by helping developing countries modernize and improve agriculture, forestry and fishery practices

Gt (gigaton)
A billion (10^9) tons

HVAC (heating, ventilation, and air conditioning)
Systems in a building that control interior environmental conditions; these systems are a major contributor to a building's emissions

IP (intellectual property)

IPCC (Intergovernmental Panel on Climate Change)
International organization charged with coordinating a global response to climate change

ITC (investment tax credit)
A sum deducted from the total amount a taxpayer owes to the state for investment for technology

Mt
Megaton (1 million tons).

NDVI (normalized difference vegetation index)
A graphical indicator that uses remote sensing measurements to determine changes in vegetation

NGO
Non-governmental organization

NPV
The difference between the present value of cash inflows and the present value of cash outflows

OECD
Organization for Economic Co-operation and Development

Payback period
The length of time required for an investment to recover its initial outlay in terms of profits or savings

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

Peak power plant
Power plants that are only brought online when demand for electricity is the highest; these plants tend to be the dirtiest and emit large quantities of GHG emissions

Prosumer
People that both produce and consume electricity

PTC (production tax credit)
A sum deduced from the total amount a taxpayer owes to the state for producing a certain quantity of a good

PUC (power usage effectiveness)
A measure of how efficiently a computer data center uses its power; specifically, how much of the power is actually used by the computing equipment (in contrast to cooling and other overhead)

PV (photovoltaic)
Solar cells that generate electricity from light from the sun

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

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

RPS (renewable portfolio standard)
A requirement set by the state that utilities must generate a certain percentage of their energy from renewable sources

Smart building
Group of embodied ICT systems that maximize energy efficiency in buildings

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

Slash and burn agriculture
When forests are cut down using rudimentary methods and the field remains burned to clear the field for crop production or the raising livestock

SME
Small and medium enterprises

Soil erosion
The washing away of soil by the flow of water

Split incentives
A situation that results because of the principal-agent problem, which arises through the difficulties in one party (agent) motivating another party (principal) to act on their behalf. A classic example is the landlord-tenant relationship, in which the tenant is often paying for the energy costs, but does not have the control to install energy efficient upgrades

T&D
Transmission and distribution

Tar sands
A mixture of clay, water and sand that is saturated with petroleum

Tax credit
An amount of money that can be offset against a tax liability

Telematics
Information technology that deals with the long-distance transmission of computerized information

THC (thermohaline circulation)
A large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes

Tilling (or tillage)
Using machinery to churn the soil to draw more nutrients to the surface

UNFCCC (United Nations Framework Convention on Climate Change)
International environmental treaty negotiated at the United Nations Conference on Environment and Development; the objective of the treaty is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system

WCI (Western Climate Initiative)
A regional cap and trade market for emissions being developed in western North America; includes California, Montana, New Mexico, Oregon, Utah, and Washington as well as the Canadian provinces of British Columbia, Manitoba, Ontario, and Quebec

4G LTE (4th generation long term evolution)
Most advanced high-speed mobile networks to date