Enabling Sustainability in an Interconnected World

The Expert Panel on the Potential for New and Innovative Uses of Information and Communications Technologies (ICT) for Greening Canada

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

ENABLING SUSTAINABILITY IN AN INTERCONNECTED WORLD

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THE COUNCIL OF CANADIAN ACADEMIES
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This report was prepared for the Government of Canada in response to a request from the Minister of Environment. Any opinions, findings, or conclusions expressed in this publication are those of the authors, the Expert Panel on the Potential for New and Innovative Uses of Information and Communications Technologies (ICT) for Greening Canada, and do not necessarily represent the views of their organizations of affiliation or employment.

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Expert Panel on the Potential for New and Innovative Uses of Information and Communications Technologies (ICT) for Greening Canada

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The Council also recognizes the important contribution to this assessment of Mark Surman, Excutive Director, Mozilla Foundation.

Message from the Chair

We are today on the threshold of fundamental, transformative change driven by a powerful convergence of information technologies with our physical world. Meanwhile, increasing challenges to our environment, our economy and to social inclusion drive the need for innovative solutions to ensure environmental, economic, and social well-being: the triple bottom line of true sustainability.

The Expert Panel on the Potential for New and Innovative Uses of Information and Communications Technologies for Greening Canada was established in response to a request from Environment Canada who asked the Council to examine the issue of what existing or potential opportunities exist to use information and communication technologies (ICT) to create a greener Canada.

The following report reflects the efforts and contributions of 12 experts drawn from diverse fields in Canada and abroad, and me — as the Chair. I am deeply grateful for my colleagues on the Panel who contributed their time and effort to ensure the depth and quality of this report.

Over the course of its deliberations, the Panel sought assistance from many individuals and organizations that provided valuable information for consideration. Special thanks go to the following: Helen Gurfel, Greenprint Center; Darryl Neat, Oxford Properties; Ian Philp, Jesika Briones and Lynda O'Malley, MaRS; and Molly O'Neill, CGI. In addition, I would like to express my appreciation to CISCO for hosting the Expert Panel's 3rd Meeting via telepresence.

Finally, the Panel is grateful for the support it received from the staff members of the Council of Canadian Academies who were assigned to this assessment.

David Miller, Chair
Expert Panel on the Potential for New and Innovative Uses of Information and Communications Technologies for Greening Canada

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Report Review

This report was reviewed in draft form by the individuals listed below — a group of reviewers selected by the Council of Canadian Academies for their diverse perspectives, areas of expertise, and broad representation of academic, industrial, policy, and non-governmental organizations.

The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered in full by the Panel, and many of their suggestions were incorporated into the report. They were not asked to endorse the conclusions, nor did they see the final draft of the report before its release. Responsibility for the final content of this report rests entirely with the authoring Panel and the Council.

The Council wishes to thank the following individuals for their review of this report:

Peter Corbyn, Chief of Green, Green Nexxus (Fredericton, NB)

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The report review procedure was monitored on behalf of the Council's Board of Governors and Scientific Advisory Committee by **Lorne Babiuk, O.C., FRSC, FCAHS,** Vice President (Research), University of Alberta (Edmonton, AB). The role of the Report Review Monitor is to ensure that the panel gives full and fair consideration to the submissions of the report reviewers. The Board of the Council authorizes public release of an expert panel report only after the Report Review Monitor confirms that the Council's report review requirements have been satisfied. The Council thanks Dr. Babiuk for his diligent contribution as Report Review Monitor.

Elizabeth Dowdeswell, **O.C.**, President and CEO
Council of Canadian Academies

Executive Summary

The future will be shaped by greater and greater levels of connectivity — connectivity among people, as well as connectivity among objects. Now, everything that can be connected to high-speed broadband has the potential to be smart, and such smart devices are woven together in complex systems that can change how Canadians live, work, and play. The world is on the threshold of fundamental, transformative change — a powerful convergence of digital computing power and information technologies with the physical infrastructures and institutions that deliver energy, water, food, transport, and communication services. This convergence of information and communication technologies (ICT) with the physical world can potentially drive Canada towards significantly better environmental performance, economic productivity, and health and social well-being. In other words, ICT together with physical infrastructure and institutional design can help Canada on the path to sustainability. Citizen empowerment — both as consumers and social decision-makers — is a key part of this vision.

PANEL'S APPROACH TO THE CHARGE

In 2011, the Minister of the Environment, on behalf of Environment Canada (the Sponsor), asked the Council of Canadian Academies (the Council) to respond to the following charge:

> *What existing or potential opportunities exist to use Information and Communication Technologies (ICT) to create a greener Canada?*

To address the charge, and its four sub-questions, the Council drew from academia, government, and the private sector to assemble a 13-member panel of national and international experts (the Panel) with backgrounds in sustainability, environmental science, computer science, economics, engineering, and policy. This report is based on the consensus reached by Panel members through its evidence-gathering, deliberations, and collective experience.

Discussions of ICT can often become bogged down in narrow technical details that are not widely understood and that may become rapidly obsolete. The Panel instead focused on how ICT could benefit the day-to-day lives of Canadians and what tools could help to overcome the challenges to achieving the benefits. The Sponsor agreed to the Panel's interpretation that the assessment focus on opportunities with potential economic, social, and environmental benefits, encompassing the three-pillared concept of sustainability.

> **Defining Sustainability:** The *Federal Sustainable Development Act* defines *sustainability* as follows: "The Government of Canada accepts the basic principle that sustainable development is based on an ecologically efficient use of natural, social and economic resources and acknowledges the need to integrate environmental, economic and social factors in the making of all decisions by government" (Minister of Justice, 2013a). For the purpose of this assessment, the Panel adopted an approach to sustainability that encompassed improvements in environmental, economic, and social well-being.

The Panel's approach involved first identifying selected dimensions of Canada's capacity to develop, implement, and use ICT-enabled opportunities; and key components, and characteristics, of technologies that can be used to promote environmental, economic, and social sustainability. It then developed a catalogue of these opportunities and their potential benefits, and highlighted some Canadian and international promising practices. Finally, the Panel identified some common challenges to realizing these opportunities, and explored the options for solutions to mitigate or overcome the challenges (see Figure 1). The Panel did not intend the opportunities and solutions to be comprehensive or prescriptive. Instead, it chose to feature a range of options from Canada and around the world that could help enable the adoption of ICT-enabled sustainable opportunities.

KEY FINDINGS: USING ICT TO DRIVE SUSTAINABILITY IN CANADA

Canada's Capacity

Of the many relevant dimensions of Canada's capacity to develop, implement, and use ICT-enabled opportunities, the Panel focused on the following three in the particular context of this assessment:

Technology adoption: In general, Canada has a well-connected society with individuals and businesses embracing personal ICT devices such as smartphones and tablets. However, there is room for improvement; when compared to other similar countries, Canada is not highly ranked in terms of ICT penetration and diffusion among individuals, and the ability of firms to adopt technologies. Additionally, evidence shows that Canadian business in general lags behind other peer countries in ICT investment.

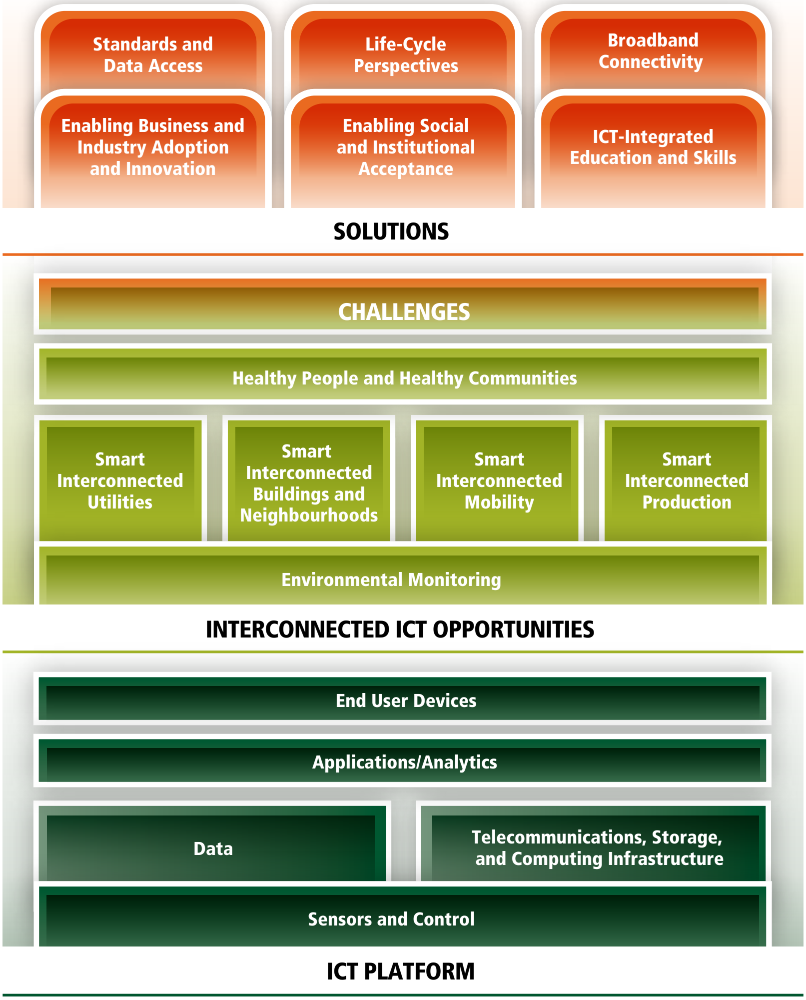

Figure 1

Report Roadmap: Towards an ICT-Enabled Sustainable Canada

The report begins with a discussion of the ICT platform that serves as a base to using ICT to help achieve sustainability. The greatest benefits can be achieved when the components of the ICT platform are integrated in a complementary system. Sitting on the base are the interconnected ICT opportunities that use the ICT platform to achieve environmental, economic, and social benefits. The Panel has chosen to present these opportunities in six key thematic areas: environmental monitoring; smart interconnected utilities; smart interconnected buildings and neighbourhoods; smart interconnected mobility; smart interconnected production; and healthy people and healthy communities. The top of the roadmap represents the targeted solutions to help overcome the challenges to successfully applying interconnected ICT opportunities.

Physical and research infrastructure: Canada has demonstrated its leadership in the development of specific infrastructures that take advantage of ICT for research and knowledge generation, including the NEPTUNE ocean sensor network and the CANARIE research and innovation network. Canada also benefits from higher education institutions that are leaders in ICT research and an ICT sector that has been identified as an area of industrial research and development strength. Despite this, while almost all Canadians have access to broadband internet, the quality of this access varies significantly across the country.

Skills: Canada's capacity in the human skills needed to develop, adopt, and fully take advantage of ICT opportunities is difficult to assess. An important asset is Canada's strength in terms of ICT research. Not unique to Canada, however, is a possible mismatch between the skills needed to fully take advantage of the ICT opportunities discussed in this report and those currently possessed by the workforce.

Opportunities

Overall, the Panel concluded that there are substantial opportunities to promote and support sustainability using ICT by building on existing Canadian strengths and capacities. These opportunities range from small-scale changes, such as applications that inform consumers of their water use, to large-scale changes, like those that replace aging utility networks with smart grid technologies. New and emerging ICT applications can be used to influence how decisions are made. For example, sensor networks produce environmental information that can inform decision-making by governments and individuals.

The Panel identified five interdependent technical components — the ICT platform — that are emerging as central to many ICT opportunities: (i) end-user devices; (ii) data; (iii) applications/data analytics; (iv) telecommunications, storage, and computing infrastructure; and (v) sensors and controls.

The Panel focused on six thematic areas that were chosen because they encompass ICT-enabled opportunities that would yield environmental, economic, and social benefits; facilitate thinking across sectors; and directly relate to the daily lives of Canadians:

(i) *Environmental monitoring:* Reliable sensor networks that connect Canadians to the environment provide access to timely and accurate information on both environmental health and how it changes over time. Anywhere, anytime smart sensing, monitoring, and analytics could transform evidence-based decision-making; and address social, environmental, and natural resource issues. For example, improved air and water quality data support regulatory enforcement, enable early detection of problems, and can be combined with other data to yield additional insight.

(ii) *Smart interconnected utilities:* ICT can help modernize electricity and water grids; promote sustainable utility management; and empower end-user choice. Smart grids could transform how utilities are produced and delivered across Canada — minimizing environmental impacts, such as electricity and water losses in distribution, reducing costs for operators and consumers, and ensuring reliability of service.

(iii) *Smart interconnected buildings and neighbourhoods:* ICT applications like building control systems have already improved buildings' electrical efficiency, reducing their greenhouse gas (GHG) emissions. Further potential advances could reduce the environmental impact of the built environment, from design through to operation. The shift to integrated and interconnected services and functions — neighbourhood-scale networks for buildings and infrastructure — is an important development. Local, integrated systems like on-site renewable energy could deliver more environmentally and economically efficient services.

(iv) *Smart interconnected mobility:* Available ICT applications can strengthen connections between individuals and businesses, and between Canadians and the goods and services they use. ICT applications can, for example, make public transit vehicles move more quickly through cities or enable smart logistics for more efficient transport of goods. These smart interconnected systems would improve productivity while minimizing costs and harmful air emissions, including GHGs.

(v) *Smart interconnected production:* ICT, through applications like smart motors, can make manufacturing equipment and processes more efficient, reducing GHG emissions and decreasing operating costs. Agricultural production and processes — particularly irrigation — can also benefit from ICT applications to improve water efficiency and change how food is moved from farm to table.

(vi) *Healthy people and healthy communities:* ICT can address social challenges and enable new forms of participatory decision-making and governance. In turn, these changes could enhance and accelerate the improvements described for environmental monitoring, utilities, buildings, mobility, and production. In addition, ICT applications can improve access to education services and enhance the quality of health care.

Finally, Canada is well positioned to be a global leader in green data centres. The manufacture and operation of ICT in and of themselves give rise to negative environmental impacts. Green data centres are one of many efforts to reduce these impacts as they enable centralization of processes such as server and network virtualization. Canada has a stable supply of emissions-free electricity that can power energy-intensive data warehouses, as well as a cold climate that would reduce energy needs for cooling equipment. Powering these centres in regions that have these attributes, and taking advantage of the concentrated nature of these facilities to supply heat to district energy systems would have a positive impact on the environment, in addition to contributing to economic and social benefits for Canada.

Common Challenges

Canada is a long way from realizing the full potential of ICT to support better environmental performance and decision-making, economic opportunities, and social benefits. Unlocking Canada's potential will require rapid and successful design, selection, and implementation of context-specific ICT-enabled applications. In analyzing its catalogue of ICT opportunities, the Panel identified some common challenges:

- costs, or fear of costs, related to implementation of the technology and corresponding infrastructure;
- lack of data access and interoperability;
- lack of the needed ICT skills;
- privacy and security issues;
- behavioural factors;
- second-order effects; and
- inadequate broadband connectivity in rural areas.

A closer examination of these challenges teased out some related and more specific challenges. For example, there may be asymmetry in the Canadian job market between the skill set desired by employers and the qualifications of job seekers, difficulties moving from use on a small scale by a limited number of users to implementation on a much larger scale, and limitations caused by fragmented data systems.

The Panel also noted that an integrated approach to identifying and addressing challenges, and developing solutions, would be valuable. Focusing on individual challenges and solutions in isolation would limit the transformative potential of ICT-enabled opportunities.

Overcoming the Challenges: Options for Solutions

While there is no one-size-fits-all solution for all ICT applications and jurisdictions, the Panel identified the following options to help overcome the challenges listed above:

- *Demonstration-scale facilities:* to potentially mitigate the risk and uncertainty in untested or high-risk solutions (e.g., living labs);

- *Policy instruments:* to increase demand and address market failures (e.g., green procurement);
- *Improved standards:* to enable interoperability;
- *Data accessibility:* to more flexibly manage applications and ensure data are open and accessible for wider use;
- *Improved ICT design and privacy protection approaches:* to ensure adoption, privacy, security, and personal control over personal information while allowing for the socio-economic benefits of big data and smart technologies to be achieved (e.g., privacy by design);
- *Improved digital and computer literacy:* to position Canada as competitive in a rapidly evolving digital environment;
- *Life-cycle or social life-cycle perspective:* to help identify second-order effects arising from implementation of ICT opportunities; and
- *Reduced connectivity gaps:* to maintain Canada's international competitiveness in broadband access and availability.

Promising Practices

The Panel identified many examples of international and Canadian promising practices, which are discussed throughout the report. These included targeted practices to take advantage of ICT for specific goals, such as design standards and aids that promote energy efficiency in buildings. They also featured broader policies or approaches that could potentially help Canada overcome the more significant challenges to ICT opportunities. Examples highlighted include the following: Sustainable Development Technology Canada, an organization that can help bridge research and commercialization; the principles of privacy by design, a type of policy that deals with privacy concerns; and the broadband policies of Germany and Australia, national programs to address connectivity gaps.

THE PATH FORWARD

Based on its evidence gathering, deliberations, and collective experience, the Panel landed on five elements that could enable Canada to strategically use ICT to help achieve sustainability.

Rethink ICT

The greatest impact of the application of the five components in the ICT platform will be achieved through integrated ICT-enabled solutions that take advantage of all of them. In addition, the implementation of an ICT application is more likely to succeed if planning is based on an integrated view of its social, political, and institutional dimensions, as well as the local context.

Connect Canadians

Canada has a digital connectivity gap between the internet service provided to rural communities and that is available in urban centres. While almost all Canadians can access broadband internet, the speed varies significantly. Rural regions may not possess the speeds necessary to fully take advantage of many ICT applications. While connectivity, in the context of technology, traditionally refers to internet access, there are other important links in Canada that could be improved through ICT applications. For instance, connections to electricity and water through a move to smart interconnected utilities; connections to the natural environment through reliable sensor networks for environmental monitoring; and connections among individuals and businesses through smart interconnected mobility.

Empower Individuals, Governments, and Businesses

Technology on its own cannot move Canada towards sustainability. The potential benefits of ICT-enabled opportunities will arise when users adopt and discover innovative ways to apply technologies. Ensuring data are accessible will empower their use in new ways that yield further, unintended benefits. Many governments are recognizing the importance of open data and are increasingly making their data public.

In many cases, important benefits also stem from user empowerment through ICT. Connective technologies can empower people to play a more active role in managing their lives, and provide the information needed by individuals, governments and businesses to more effectively manage resources.

Create New Forms of Social Organization

By establishing smart buildings, connecting them with one another and to the smart grid, and engaging in informed community planning, ICT can help build connected communities that are sustainable. Smart interconnected buildings can communicate with each other and with other smart objects, such as electric cars, and potentially become integrated with the smart grid through solar or wind technologies.

Overcome Legislative, Behavioural, Technological, and Financial Challenges

Important challenges hinder the implementation and adoption of promising ICT applications. Using ICT to achieve environmental and socio-economic goals will require decision-makers to consider social and economic factors as well as those related to technology. An integrated approach to addressing challenges and developing solutions will be required to fully realize the transformative potential of ICT.

FINAL REFLECTIONS

ICT are more than just gadgets meant to entertain. They are devices, systems, and platforms that are transforming how people live, work, and communicate with one another. Interconnected ICT applications have the potential to facilitate both small steps and great leaps towards sustainability. Small changes that can be implemented in the short term can have a significant cumulative impact on Canada's environmental performance: they may even start Canada on the path to transformative change. To exploit opportunities that create substantial economic opportunities and address pressing environmental and social issues, Canada must leverage its strengths and capacities related to ICT. The sustainability benefits that could be provided by ICT are achievable if Canada can successfully *rethink* ICT, *connect* and *empower* Canadians, *create* new forms of social organization, and *overcome* challenges.

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1 Introduction

A Day in the Life

It is 5:20 am (PST) in Vancouver, B.C. on a Wednesday morning in 2025. In three minutes, Deena will wake up and begin her day. Throughout the night, computers in Deena's home and across the city have been monitoring resource use and helping maximize efficiency. When she wakes up, Deena will interact with these systems much more directly than most people. As a smart grid manager, it's her job.

Powering a city like Vancouver isn't easy. A growing population and diminishing natural resources have created significant challenges. Many of the solutions required to maintain the viability of city life come from the sector of green information technologies.

Deena at home

5:23 am (PST)

Deena's alarm wakes her up when sensors in her mattress detect that she is at the most advantageous point in her sleep cycle. Based on the data from her movement and body temperature, the lights in the room have begun gradually getting brighter. By the time her alarm sounds, she is already nearly awake. She brushes her teeth using a paste that requires no water or rinsing — a now near-universal practice. As she does, a display integrated into the mirror shows data on real-time traffic information and several suggested routes to work by car and transit. Transit is nearly always faster, but due to unusual congestion the computer recommends catching a ride with her co-worker Ray.

When Deena is notified that Ray's vehicle is drawing near, Deena walks to the curb and is picked up 15 seconds later. Ray wants to arrive at work early because the price of energy is lower at this time of day, allowing him to charge his vehicle more cheaply. Deena wants to arrive early because she has a videoconference for which she will need access to the building's secure connection; for many routine tasks, she can work from home.

Deena at work

6:25 am (PST)

Deena enters her office, by now at her preferred temperature, humidity, and lighting level. The screen on her company computer displays graphs of aggregate energy efficiency, productivity, and workplace satisfaction. All have been trending upward for some time. Before preparing materials for her videoconference, Deena views her personal profile and notes that she nearly qualifies for an additional tax rebate based on her household's low energy use for the past quarter. Being an expert in energy has its perks; the incentives for efficiency are numerous and often quite large.

10:00 am (PST)

Later, Deena reviews statistics from a mobile app she recently commissioned. The app monitors an increasingly common activity: the use of devices to charge one another. While mostly benign, the practice circumvents the programs that monitor how much current is drawn by the various mobile devices in a normal home. Deena's app is an effort to restore much-needed precision to the monitoring system.

Unfortunately, the app has not been widely adopted so far. To remedy this, Deena asks her analytics department to organize a meeting with some experts on human behaviour. Experience has shown that researching the attitudes and habits of power consumers leads to more effective design strategies. Reflecting once more on her own day, she realizes that her son Quinn is between lectures and checks to see if he is online. She sends him a message to arrange a videoconference.

Videoconference at lunch

12:30 pm (PST) — Vancouver/2:30 pm (CST) — Regina

Deena has booked an unused conference room during lunch. She logs into the videoconference system and waits for her son Quinn, who is in his third year at the University of Regina, to do the same on the other end.

Quinn connects; the crisp image and glasses-free 3D rendering make him feel almost as if he's in the room with Deena. Although the same features are available to Quinn on his end, he opts for a 2D image, as he finds the added realism distracting. They discuss work, school, and (begrudgingly) Quinn's romantic life.

Hoping to change the subject, Quinn enthuses about the presentation he attended and raises the prospect of adjusting his degree track to include a certificate in the health sector. Happy as she has been to see her son following in her footsteps, Deena realizes she takes more pride in seeing him search for a path of his own. She casually mentions that Simon Fraser University has an extremely prestigious graduate program in sustainability and health.

1.1 ABOUT THIS ASSESSMENT

Canadians are at a threshold of fundamental, transformative change: a powerful convergence of information science and technologies (digital computing power) and the material world. This change offers the potential to drive Canada towards sustainability, helping to achieve improvements in environmental health, economic prosperity, and social well-being.

Society continues to move towards ever increasing connectedness. Everything that can be connected to high-speed broadband has the potential to be smart and smart objects are no longer just those traditionally thought of as technology. Rather than seeing technologies as isolated sets of physical artifacts, it is more useful to think of them as interconnected technical, political, social, and economic systems.

Information and communication technologies (ICT) play a critical role in the integration of systems, enhancing the ability to adapt and flexibly respond to the uncertainty associated with environmental challenges, social structures, and human-technology interactions. ICT can potentially improve the delivery of services of all kinds and the efficiency with which Canadians use energy, water, and materials, thereby reducing environmental impacts.

Empowerment of people, both as consumers and social decision-makers, is key to realizing the sustainability benefits of ICT. Unlocking their potential requires rapid and successful design, selection, and implementation of context-specific ICT-enabled applications across Canadian regions and sectors.

1.2 UNDERSTANDING AND ADDRESSING THE CHARGE TO THE PANEL

In 2011 the Minister of Environment, on behalf of Environment Canada (the Sponsor), asked the Council of Canadian Academies (the Council) to appoint an expert panel to conduct an assessment on the following question:

> *What existing or potential opportunities exist to use Information and Communication Technologies (ICT) to create a greener Canada?*

In addition, the Sponsor posed the following sub-questions:

- *What is Canada's capacity in ICT-enabled green technology and what are the existing areas of Canadians' strength and weakness in the most relevant segments of the economy?*
- *What opportunities, barriers and challenges exist within Canada and internationally related to the use of current and emerging scientific and technological advances to enable greening?*

- *What international best practices exist, including policy frameworks, on the use of ICT-enabled S&T to "green" the delivery of goods and services and related infrastructures required by society?*
- *What are the knowledge and best practice gaps in the development and application of ICT-enabled green technologies in Canada?*

To address the charge, the Council appointed a panel of national and international experts (the Panel) with backgrounds in sustainability, environmental science, computer science, economics, engineering, and policy. Panel members come from academia, government, and the private sector. Over the course of 16 months, the Panel held five meetings (four in person and one via telepresence) in addition to several teleconferences.

1.2.1 Defining Sustainability

At the beginning of the assessment process, the Panel met with representatives from Environment Canada to confirm its full understanding of the charge. At that time, the Sponsor clarified that the term *greening* could constitute all dimensions of sustainability. Use of the term sustainability to describe human progress gained widespread acceptance after the Brundtland Commission introduced the concept of sustainable development in 1987 (WCED, 1987). Its definition has since evolved. It is now accepted that sustainability is based on three dimensions of equal significance often referred to as the pillars of sustainability: the environment, economy, and social well-being. For the purpose of this report, *sustainability* is defined as improvements in environmental, economic, and social well-being. Therefore, the Panel considers opportunities that may yield social benefits, such as improved health or quality of life, to be relevant to its charge.

1.2.2 Defining ICT

ICT, or *ICT systems*, cover a wide range of devices, infrastructure, and applications that have drastically transformed the daily lives of Canadians in recent decades. UNESCO (2007) defines ICT as "forms of technology that are used to transmit, process, store, create, display, share or exchange information by electronic means." This definition not only includes physical technologies such as computers, sensors, and network hardware, but also the devices' software and the services and equipment needed to support them.

1.3 THE PANEL'S APPROACH: SCOPE, EVIDENCE, AND FRAMEWORK

The Panel sought evidence of examples of ICT being used effectively to help achieve sustainability goals in Canada and abroad. In an effort to make the report accessible to a wide audience, the Panel used a jargon-free style and demonstrated how ICT can have a positive impact on their daily lives rather than providing detailed technical information on specific ICT. The Panel selected six key thematic areas in which to illustrate the potential benefits associated with applying interconnected ICT applications:

- environmental monitoring;
- smart interconnected utilities;
- smart interconnected buildings and neighbourhoods;
- smart interconnected mobility;
- smart interconnected production; and
- healthy people and healthy communities.

These thematic areas were chosen as they directly relate to the daily activities in which Canadians engage, and they encompass substantial opportunities for ICT to benefit all three pillars of sustainability. The Panel noted the existence of many other positive ICT opportunities that can potentially enhance sustainability, but that are beyond the scope of this assessment.

To further widen the accessibility of the report, the Panel chose to include brief fictional stories that illustrate how ICT could benefit the daily lives of Canadians in the near future. These stories appear in green boxes throughout the report. The focus on people is important and deliberate because ICT opportunities cannot be realized if people do not choose to develop, implement, and use ICT.

Many of the technologies discussed throughout the report come from industry or are so new that little peer-reviewed literature exists. In some cases, the Panel examined non-peer reviewed grey literature from credible industry associations, non-profits, and international organizations (e.g., Organisation for Economic Co-operation and Development (OECD); Global e-Sustainability Initiative (GeSI)). In other cases, material was from peer-reviewed publications.

The Panel felt that, in addition to a discussion of promising ICT opportunities, it was important to consider the relevant aspects of the Canadian environmental, economic, and social contexts, including those related to the ICT industry, ICT education, and how Canadians are adopting and using technology. The Panel also introduces the key technical components for sustainability applications, and discusses opportunities to improve the environmental performance of the technologies themselves.

In their analysis of ICT opportunities, the Panel identifies several common challenges that may hinder the development, adoption, and success of these opportunities. These challenges are examined in depth and several different solutions that may help to overcome them are discussed. Furthermore, the Panel highlights several promising practices from Canada and abroad that may help ensure the full benefits of ICT opportunities are achieved.

Many of the opportunities identified by the Panel can be driven on the tangible, short-term benefits they provide to individuals, firms, or governments. Where short-term benefits are less immediately apparent, specific policies or programs to encourage adoption may be required. The differences in short- and long-term costs and benefits can be important because costs are specific and concentrated, while social returns are diffuse. In some cases, the funders of a technology may not reap the rewards.

1.4 ORGANIZATION OF THE REPORT

The Panel's approach to responding to the charge is illustrated in the report roadmap (see Figure 1.1). At the base of the roadmap are the various technical components of the *ICT platform*, which collectively form the foundation for the opportunities discussed in the report. Sitting on this platform are the *interconnected ICT applications* from the six key thematic areas selected to demonstrate how these applications can have a positive impact on Canada's sustainability. Above these six key thematic areas are *challenges*, factors that can hinder the successful adoption of ICT opportunities. The roadmap is capped by *solutions*, which represents targeted approaches to help overcome these challenges.

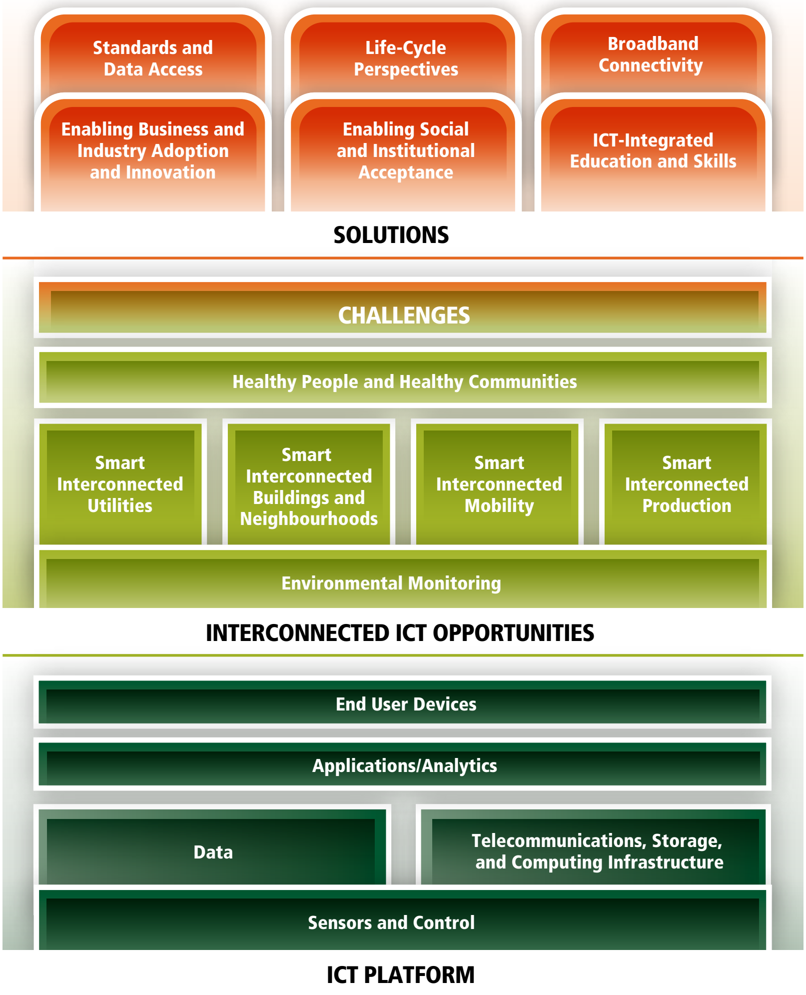


Figure 1.1

Report Roadmap: Towards an ICT-Enabled Sustainable Canada

The report begins with a discussion of the ICT platform that serves as a base to using ICT to help achieve sustainability. The greatest benefits can be achieved when the components of the ICT platform are integrated in a complementary system. Sitting on the base are the interconnected ICT opportunities that use the ICT platform to achieve environmental, economic, and social benefits. The Panel has chosen to present these opportunities in six key thematic areas: environmental monitoring; smart interconnected utilities; smart interconnected buildings and neighbourhoods; smart interconnected mobility; smart interconnected production; and healthy people and healthy communities. The top of the roadmap represents the targeted solutions to help overcome the challenges to successfully applying interconnected ICT opportunities.

The body of the report is divided into the following sections:

- **Background and Context:** Chapter 2 provides background information on sustainability and ICT in Canada, and provides a snapshot of the current capacity of the Canadian ICT sector.
- **ICT Platform:** Chapter 3 introduces the ICT platform for a sustainable Canada, identifies its key technical components, and discusses their environmental impact. The chapter then discusses ways to help mitigate this impact.
- **Interconnected ICT Applications:** Chapter 4 introduces a range of interconnected ICT applications that can be leveraged to move Canada towards sustainability. The chapter presents these opportunities through the lenses of the six thematic areas selected by the Panel. Importantly, some opportunities are discussed under multiple themes, illustrating that many ICT can provide multiple benefits when applied in different ways. The chapter also identifies some common challenges to realizing the opportunities described.
- **Challenges and Solutions:** Chapter 5 explores in more detail the challenges to development, adoption, and use of interconnected ICT applications in Canada, and then proposes some solutions that may help overcome these challenges. Solutions are organized into six categories: enabling business and industry adoption and innovation of ICT opportunities, standards and data access, ICT-integrated education and skills, enabling social and institutional acceptance, life-cycle perspectives, and broadband connectivity. For each category, the Panel outlines possible options for Canada and examples of existing and emerging promising practices in Canada and abroad.
- **Conclusions:** Chapter 6 synthesizes the findings in previous chapters and summarizes the Panel's responses to the questions in the charge. In addition, it includes a discussion of steps that could form the path forward to achieving the full benefits of ICT opportunities.

The report uses three types of boxes to support the main text:

- **Green boxes** contain *fictional stories* about different people across Canada to illustrate how ICT applications could have a positive impact on sustainability in Canada in the near future. In many cases the stories feature technologies that are already available.
- **Gray boxes** include *information* or *examples* to complement the text.
- **Orange boxes** present *promising practices* from Canada and around the world.

The Panel's report provides a snapshot in time of the ICT opportunities that can be leveraged today to help move Canada towards sustainability. But, more importantly, it discusses what is needed for successful implementation of ICT-enabled solutions for sustainability, and includes general criteria to identify potential ICT opportunities that would most benefit Canada. ICT can help Canada address the many environmental, economic, and social challenges it is facing, and secure a sustainable future for the country.

2

Background and Canadian Context

- The Three Dimensions of Sustainability
- The Connection Between ICT and Sustainability
- Canada's Capacity to Support ICT Development and Use for Sustainability
- How ICT Affect the Lives of Canadians
- Conclusion

2 Background and Canadian Context

This chapter provides an overview of the background and contextual factors needed to understand the Panel's approach to identifying ICT-enabled opportunities to achieve sustainability, and the challenges and solutions related to these opportunities. Topics covered include the three dimensions of sustainability (and Canada's current environmental performance); how ICT can enable sustainability; Canada's capacity to develop, adopt, and use ICT applications; and some of the ways ICT are affecting the lives of Canadians.

2.1 THE THREE DIMENSIONS OF SUSTAINABILITY

Canada's sustainability performance is based on environmental, economic, and social considerations. This section briefly introduces elements of the three dimensions, and additional information on Canada's current environmental performance. The economic and social dimensions have been combined in the following discussion as a detailed analysis of Canada's current economic and social performance would be beyond the scope of the assessment.

2.1.1 Environmental Considerations in Canada

Since the health of the environment is central to Canada's future, addressing the environmental issues is a priority. Climate change is particularly important because its impact is both great and unpredictable. A clear majority of Canadians are concerned about the effects of climate change (The Environics Institute, 2012). Other environmental issues also require attention if Canada is to enhance or maintain a healthy environment. Air and water quality, freshwater quantity, waste reduction, and biodiversity are areas in which ICT applications can make a positive impact (see Chapter 4). The discussion below, however, focuses on greenhouse gas (GHG) emissions because of its importance to all three dimensions of Canada's sustainability, and the many opportunities that ICT could provide for mitigating these emissions.

Canada's environmental performance leaves room for improvement on a number of fronts. In its most recent annual benchmarking of Canada against 16 peer countries, the Conference Board of Canada gave Canada low grades on several important environmental indicators, including energy intensity, total GHG emissions, municipal waste generation, and water withdrawals, among others (Conference Board of Canada, 2013b). This performance is consistent with rankings by other sources. For instance, Canada is one of the world's largest per capita emitters of GHGs according to GeSI, an industry organization representing more than 30 of the world's biggest ICT service providers and vendors (GeSI, 2012). Canada's total GHG emissions in 2011 were 702 million tonnes carbon dioxide (CO_2) equivalent ($MtCO_2e$) (20.1 tonnes CO_2 equivalent emissions per capita). This accounts for almost 2 per cent of worldwide emissions despite only having roughly 0.5 per cent of the world's population (Environment Canada, 2013c; World Bank, 2013c). Taking into account existing measures implemented by federal, provincial, or municipal governments, Canada's total GHG emissions are estimated to reach 734 $MtCO_2e$ by 2020 (Environment Canada, 2013c). This estimate is still significantly higher than Canada's goal of lowering emissions to 607 $MtCO_2e$ by 2020, as stated in the Copenhagen Accord (Environment Canada, 2010, 2012).

By sector, transportation contributes the most GHG emissions, followed by oil and gas (production, transmission, processing/refining, and distribution), electricity, and buildings[1] (Environment Canada, 2013c) (see Figure 2.1). Electricity is the only sector in which emissions have declined significantly between 2005 and 2011, with reductions the result of the integration of cleaner energy sources (e.g., replacement of coal) (Environment Canada, 2013c). Although vehicle and building efficiencies have improved over the same period, increases in the overall size of these sectors (i.e., total number of vehicles and buildings) have resulted in no large-scale net reductions in their GHG emissions.

The effects of climate change are serious challenges for Canada and are already being felt. To address these challenges, Canadian communities will need to adapt to the uncertainty linked to climate change. Adaptation is therefore an important component of sustainability. Proactive adaptation to climate change is defined by Aboriginal Affairs and Northern Development Canada as involving "long-term decision making which improves our ability to cope with future climate change. Periodic assessment and risk management strategies help make this response the most effective" (AANDC, 2010).

2.1.2 Economic and Social Considerations

It is increasingly being recognized that the environment and the economy are closely linked (e.g., Stern, 2006; Runnalls, 2011; UNEP, 2011). There have been attempts to quantify the economic costs of environmental degradation, although it should be noted that it is very challenging to establish exact monetary values. The *Stern Review*, prepared for the U.K. government by economist Nicholas Stern, discussed the potential economic impact of climate change:

1 During the publication of this report, Environment Canada released the executive summary to the *National Inventory Report 1990-2012: Greenhouse Gas Sources and Sinks in Canada* in which it was revealed that the oil and gas sector now narrowly edges out the transportation sector in terms of GHG emissions.

> Using the results from formal economic models, the Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5 per cent of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20 per cent of GDP or more.
>
> (Stern, 2006)

The *Stern Review* noted that dealing with climate change would require increasing resilience while minimizing expenses to protect both society and the economy. Further, Stern (2006) stated that "the costs of stabilising the climate are significant but manageable" and "delay would be dangerous and much more costly."

Economic benefits may be achieved through environmental initiatives. The United Nations Environment Programme (UNEP) suggests that economic and social benefits can be achieved by moving towards a *green economy* where

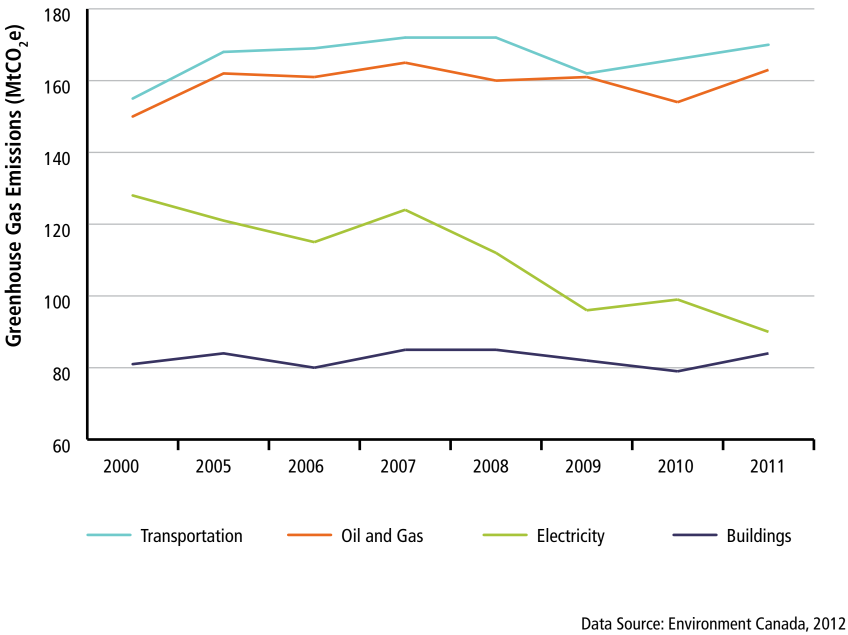


Figure 2.1

Greenhouse Gas Emissions for Canada's Top Emitting Sectors, 2000–2011

Greenhouse gas emissions for transportation, oil and gas, electricity, and buildings sectors in Canada from 2000 to 2011. Only emissions in the electricity sector have changed significantly over the period, decreasing by approximately 30 $MtCO_2e$.

higher incomes and job growth are driven by investments made to reduce GHG emissions and pollution (UNEP, 2011). UNEP (2010) describes the green economy as one that leads to "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities." Some Canadian industries are already realizing the economic potential of developing technologies to address environmental changes. For instance, in 2011 Canada was sixth in the world in number of patents filed for technologies related to climate change mitigation (including, but not exclusively, ICT-based applications) (OECD, n.d.).

Other important social and economic indicators reflect Canada's record of sustainability. Although some overlap exists between these dimensions, examples of economic indicators include gross domestic product (GDP), productivity, debt, and employment rate; social indicators include incidence of poverty, life expectancy, happiness, and civic participation.

2.2 THE CONNECTION BETWEEN ICT AND SUSTAINABILITY

2.2.1 What Does Sustainability Mean?

Although maintaining and enhancing the health of the environment is one of the key challenges facing Canada today, economic prosperity and social well-being are equally important to a sustainable future. These three dimensions cannot be considered in isolation because sustainability depends on a balanced integration of the three.

The federal government's definition of sustainability embraces this holistic approach. According to the *Federal Sustainable Development Act*, "The Government of Canada accepts the basic principle that sustainable development is based on an ecologically efficient use of natural, social and economic resources and acknowledges the need to integrate environmental, economic and social factors in the making of all decisions by government" (Minister of Justice, 2013a). In short, economic stability cannot be achieved without a healthy environment and a population with a good quality of life, just as environmental decisions taken to ensure sustainability must consider economic and social elements. Therefore, decisions about one dimension of sustainability must consider the other two.

2.2.2 How ICT Can Move Canada Towards Sustainability

Opportunities based on ICT have great potential to help Canada move towards sustainability. ICT are rapidly weaving their way into all aspects of day-to-day life, operating not only within those devices traditionally thought of as technology (e.g., computers, phones, tablets), but all objects with which people interact (e.g., cars, buildings, electrical appliances). The ICT sector has the capacity to foster innovation, where major changes can occur. Most homes, businesses, and public-sector agencies are adding ICT to their operations and activities, opening the door for these technologies to be used to yield environmental, economic, or social benefits. ICT provide opportunities for communication between people, between people and objects, and between objects themselves. In this emerging world of complex socio-technical systems, ICT can facilitate and enhance sustainability.

Many ICT-enabled solutions have already improved Canada's environmental performance through, for example, innovations that reduce energy consumption, monitor the environment, or increase the efficiency of vehicles (see Chapter 4). ICT have also contributed to large-scale improvements in the energy efficiency of buildings, which have led to a decrease in their overall per capita GHG emissions in Canada (GeSI, 2012; Environment Canada, 2013c). ICT have changed how water and electricity are delivered to consumers, enabling the use of mapping to develop and monitor new conservation programs, smart meters to educate consumers on their electricity or water use, and sensors to monitor delivery systems and ensure optimal efficiency.

Importantly, ICT can facilitate incremental changes and great leaps towards sustainability. Large changes can transform the behaviour of governments, industry, and individuals. Small changes implemented in the short term can cumulatively have a significant impact on Canada's environmental performance in the longer term, and often set the path that leads to transformative changes.

Direct Environmental Benefits: Greening of ICT

ICT themselves have their own environmental footprint: GHG emissions are associated with their production, transport, use, and disposal; material waste is associated with their production; and electronic waste is produced when they are discarded.

The environmental performance of ICT, however, has improved over the years as devices have become smaller and more energy efficient (GeSI, 2012). There is also potential to further improve the design, production, distribution, maintenance, and disposal of ICT-related goods and services (greening *of* ICT) (OECD, 2009b). These are often referred to as direct opportunities because the environmental benefits come from improving the technology itself.

Indirect Environmental Benefits: Greening through ICT

The indirect opportunities resulting from the application and use of ICT are more important than direct opportunities for achieving sustainability. The potential benefits for the environment, economy, and society of greening *through* ICT far outweigh the environmental impact of ICT themselves (e.g., Ahola *et al.*, 2010; OECD, 2010a; GeSI, 2012). These can be either enabling opportunities where the benefits arise from the use of ICT applications, or systemic opportunities where the benefits arise from changes in social structure or behaviour as a result of the availability, accessibility, application, and use of ICT.

In its *SMARTer2020* report, for example, GeSI predicts that greening through ICT solutions in the transportation, agriculture and land use, building, manufacturing, power, consumer, and service sectors can be leveraged to abate seven times the total emissions of ICT (GeSI, 2012). WWF (World Wildlife Fund in Canada and the United States, and World Wide Fund for Nature elsewhere), a non-governmental environmental conservation organization, also sees ICT as a means to abate GHG emissions in Canada and around the world (WWF Sweden, 2008; WWF Canada, n.d.). WWF Canada, for instance, predicts that Canada's GHG emissions could be reduced by about 20 $MtCO_2e$ per year in the near term by applying selected ICT products that would reduce the need for car and air travel, digitize materials, and improve building and commercial transport efficiency (WWF Canada, n.d.). Further, it predicts that wider application of these products could eventually lead to a 36 $MtCO_2e$ reduction per year by 2020.

In addition to providing solutions that address environmental challenges, ICT also have the potential to improve social well-being through, for example, increased access to knowledge and education opportunities, improved healthcare delivery and personalized health monitoring, new opportunities for democratic participation and governance, and increased comfort (see Section 4.6).

Several ICT opportunities also have economic benefits, including the potential to reduce costs for individuals and businesses through improved efficiency and lowered energy consumption. In its *Innovating Toward A Low-Carbon Canada* report, WWF Canada (n.d.) predicts that using ICT to achieve the near-term goals outlined would lead to an estimated annual savings of more than $7 billion for Canadian businesses, governments, and individuals.

The ability to push Canada towards all three dimensions of sustainability— environmental, economic, and social — is one of the advantages of ICT-based solutions. Furthermore, ICT opportunities often take advantage of the technology, infrastructure, data, and knowledge that already exist. The unique capabilities that ICT already provide (for example to easily collect, store, and transmit large amounts of data) can be leveraged to move Canada towards positive sustainability outcomes.

Risks

The introduction of ICT applications for sustainability should take into account their interaction with, and impact on, sustainability's three pillars. There are risks associated with implementing solutions in the wrong order, at the wrong time, or without proper support. Socio-technical systems interact in complex ways. Failure to consider drivers such as local context or unexpected (second-order) effects can result in costly failures. All these risks should be weighed against the potential negative impacts of doing nothing.

2.2.3 Geography, Demographics, and Other Considerations

An understanding of the Canadian context is important for determining what new and innovative ICT opportunities are most likely to foster sustainability. Canada faces particular challenges but also has numerous strengths to build upon. Canada covers almost 10 million square kilometres, with varying climate, terrain, and population density. Despite its low population overall, Canada is home to many large and vibrant cities. According to the 2011 Census, 69 per cent of Canadians currently reside in communities with populations over 100,000 and 35 per cent reside in one of Canada's three largest cities: Toronto, Montréal, or Vancouver (Statistics Canada, 2013e). Many Canadians, however, choose to make their home in rural areas, away from large population centres. Urban and rural perspectives are both important to discussions about Canadian sustainability.

Canada's geography, relatively small population, and low-GHG electricity sources (e.g., hydroelectric) are examples of factors that would inform the most promising types of ICT solutions in the Canadian context.

2.3 CANADA'S CAPACITY TO SUPPORT ICT DEVELOPMENT AND USE FOR SUSTAINABILITY

A variety of factors have an impact on Canada's ability to develop and adopt new ICT applications, including factors related to the state of the ICT sector itself, the role of higher education institutions, networked readiness, as well as other contextual factors. These issues are discussed briefly below.

2.3.1 ICT Sector

A snapshot of Canada's ICT sector today offers a glimpse of its importance to Canada's economy, and its capacity to support future ICT development for sustainability. Canada has traditional strength in telecommunications, and currently is home to a strong ICT sector that is research intensive and an important employer (see Box 2.1). More generally, since ICT are of growing importance to all industries and firms across Canada, the size of the ICT sector itself encompasses only a fraction of the total ICT-related activity in Canadian society.

Box 2.1
Employment, Size, and Research Activity of Canada's ICT Sector

- In 2011 Canada's ICT sector generated $62.7 billion in GDP and employed over 555,000 people (over three per cent of all jobs in Canada) (Industry Canada, 2012).
- Communications equipment manufacturing and computer systems design and related services account for over 18 per cent of all industrial research and development (IR&D) expenditures (CCA, 2013a).
- Canada is currently home to over 30,000 ICT firms, of which the majority are small (about 85 per cent have 10 or fewer employees). Only around 75 firms (less than 1 per cent) employ over 500 people (Industry Canada, 2013).
- In 2011 Canada's top 250 ICT firms increased their revenues by 12 per cent over 2010 to $82.62 billion (Branham Group Inc., 2012). This was a new record for revenues.
- The geographic composition of Canada's top 250 ICT firms is relatively static. In 2011, 95 per cent of them were headquartered in Ontario, Quebec, British Columbia, or Alberta. However, some of Canada's leading-edge firms are located in Fredericton, Halifax, and Winnipeg (Branham Group Inc., 2012).
- Canada benefits from a strong clean technology* sector of about 700 small or medium enterprises across the country, generating over 44,000 direct jobs (Analytica Advisors, 2012).

* *According to Analytica Advisors (2012), "a clean technology company is defined as predominantly engaged in developing and marketing and/or use of its proprietary technology to deliver products or services that reduce negative environmental impacts, while delivering competitive performance, and/or using fewer resources than conventional technologies."*

Both the ICT sector and green industries have strong footholds in Canada in terms of employment, with the potential for additional growth. Compared with the general workforce, ICT workers are more highly paid and more likely to have a university degree (Industry Canada, 2013). Green jobs are not isolated to one sector and are therefore more difficult to directly track, but there is evidence that green jobs are an area of potential growth. For instance, it has been estimated that for every $1 million invested in the green energy sector, 12 to 16 direct or indirect jobs are created, compared with 5 jobs in the fossil fuel economy (Pollin *et al.*, 2008; Pollin & Garrett-Peltier, 2009). In particular, growth in the intersection of the ICT sector and green industries could benefit Canada through the creation of a significant number of jobs, many of high quality.

Canada has traditionally been a leader in telecommunications. Firms such as Nortel and Blackberry made Canada a world leader in the technology sector in the late 20th century, creating thousands of jobs and many spinoff business opportunities. More recently, this leadership position has eroded. Despite this decline, Canada had the third fastest growth in global mobile-related patents between 2001 and 2012 (Diamond & Roberts, 2012). In 2011 overall telecommunication revenues reached $42.7 billion (CRTC, 2012).

ICT was recently identified as one of four key industries of IR&D strength in Canada (CCA, 2013a). Furthermore, communications equipment manufacturing and computer system design and related services were responsible for almost 29 per cent of all industry patents filed in Canada between 2003 and 2010. Canadian patents in the ICT industry are also highly cited, with an average relative citation[2] (ARC) score of 2.03 for communications equipment manufacturing and 1.69 for computer systems design and related services. The world average is 1.0 for all patents (CCA, 2013a).

IR&D expenditures (as a percentage of total GDP) have not remained static over recent years, increasing by almost five per cent in computer systems design and related services between 2001 and 2012, while decreasing by an approximately equal percentage in communications equipment manufacturing (CCA, 2013a). Exports followed the same trend, increasing in computer systems design and related services by over 6 per cent between 1997 and 2008, and decreasing by 0.85 per cent in communications equipment manufacturing over the same period (CCA, 2013a).

2.3.2 Higher Education Institutions

Research universities are important sources of fundamental knowledge contributing to the formation, development, and distribution of innovations (Mowery & Sampat, 2006). These knowledge-generating centres underpin the development of novel products, processes, and ideas that can revolutionize society

2 See CCA (2013a) for more information on ARC scores and how they are measured.

(Stokes, 1997). In preparation for the digital economy, research universities may play an important role in conducting research, creating and maintaining research infrastructure, and developing the next generation of talent (AUCC, 2010).

Canada's universities have demonstrated a strong research capacity in ICT. The Council's *State of Science and Technology in Canada, 2012* report identified ICT as one of six academic research fields where Canada excels, accounting for over 10 per cent of Canada's output of scientific papers from 2005 to 2010, second only to clinical medicine (CCA, 2012). Particularly strong sub-fields included medical informatics, information systems, computer hardware and architecture, and networking and telecommunications. Canada ranks among the top four countries in the world by ARC for all of these sub-fields. Several rapidly emerging research clusters were also identified, including networking and wireless technologies, information processing and computerization, and advanced data analytics.

Universities and colleges generate highly qualified and skilled personnel. The share of enrolment in Canadian post-secondary institutions in mathematics, computer, and information sciences peaked in 2001–2002 at over 83,000 students, but then fell off dramatically (Statistics Canada, 2013f). As of 2011–2012, enrolment was at just over 60,000, almost 30 per cent lower than at its peak. Enrolments in undergraduate engineering programs have increased significantly, however, reaching 190,000 students in 2011–2012, a 40 per cent increase over 2001–2002. In terms of post-graduate degrees, Canadian universities are internationally competitive in the production of doctorate holders in ICT-related fields. In 2010, 6.9 per cent of Canada's doctorate degrees were granted in mathematics, statistics, and computing (Statistics Canada, 2013c). Further, over the period 2005–2010, Canada exhibited a steady increase in the number of doctoral graduates in ICT-related fields.

Canada also benefits from colleges and universities that are actively involved in developing strategic partnerships with industry. These partnerships can assist in identifying Canada's sustainability challenges, assessing the existing and potential opportunities associated with ICT in addressing those challenges, and evaluating the potential impact of these technologies on human behaviour (AUCC, 2010). Several of these partnerships emphasize the development and promotion of innovative uses of ICT. These include several Natural Sciences and Engineering Research Council (NSERC) strategic networks: Smart Microgrid Network, Smart Net-zero Energy Buildings Strategic Research Network, and Strategic Network for Smart Applications on Virtual Infrastructure. In the college sector, one partnership of note is the Seneca Centre for Development of Open Technology (2013). This centre is a partnership between Seneca and various firms (e.g., Mozilla), focused on developing open-source products.

2.3.3 Networked Readiness

While the strength of Canada's ICT industry and ICT education system is an asset in developing new ICT opportunities, other economic and policy factors will also have an impact on these opportunities. In its recent report, *The Global Information Technology Report 2013*, the World Economic Forum ranked the current state of ICT networked readiness of 144 advanced and emerging economies (Bilbao-Osorio *et al.*, 2013). The rankings assess the state of business and regulatory support; the level of access and use of ICT by the main social agents (individuals, business, and government); and the broad social and economic impacts accrued from these transformative technologies. Canada ranked highly, placing 12th overall for networked readiness (the top three countries are Finland, Singapore, and Sweden). Canada offers a strong enabling environment for ICT development, ranking 10th in the world, with high marks for its business and innovation environment (availability of financing, access to talent, and availability of, and demand for, technology); and its regulatory and political environment (property rights protection and efficiency of the law-making process). Canada ranked ahead of several advanced economies including the United States, Germany, France, Japan, and Korea (Bilbao-Osorio *et al.*, 2013).

Canada is also one of the countries most prepared to leverage ICT, ranking fifth behind Finland, Iceland, Sweden, and the United States (Bilbao-Osorio *et al.*, 2013). Importantly, however, Canada ranked poorly on the cost of accessing ICT (43rd in the world). While Canada is one of the strongest countries for its state of ICT readiness and has an enabling business and regulatory environment, it is challenged in the area of increasing the use of ICT among actors (24th). In particular, Canada ranked 27th in ICT penetration and diffusion among individuals, 24th in the ability of firms to adopt technologies or be innovative, and 22nd in the level of importance the government places on ICT policies for improved well-being (Bilbao-Osorio *et al.*, 2013).

2.3.4 Other Factors

Additional contextual factors will have an impact on which ICT opportunities will have the greatest positive impact on Canada's sustainability. For example, Canada's large size and low population density are drivers, creating incentives to improve transportation and communication systems in rural and remote areas, as well as in urban environments. Using ICT to enhance urban planning, improve office and residential efficiency, and reduce transportation and other resource use will achieve significant benefits. Canada has an opportunity to extend access to these technologies to benefit rural and remote populations, generating tremendous economic, social, and environmental benefits.

2.4 HOW ICT AFFECT THE LIVES OF CANADIANS

As technology continues to evolve at a staggering rate, so too does consumer adoption of it. For example, as the penetration of personal mobile devices grows, many Canadians are now constantly connected, changing how they communicate, interact with their environment, educate themselves, conduct business, and spend their leisure time.

Other ICT developments have dramatically changed activities of businesses and governments, and the lives of individuals. For instance, cloud computing has drastically altered how Canadians and Canadian firms store and analyze data, and sensors have opened the door to many possibilities for more accurately monitoring the environment, as well as water and energy consumption. Furthermore, objects that were not traditionally considered technologies are now being made smart. Canadians are moving towards the *Internet of Things*, or the *Internet of Everything* (introduced by Cisco), where all objects are connected to each other in an internet-like network that changes how people see, use, and interact with their environment (Evans, 2012; Smith *et al.*, 2012).

The proliferation of ICT devices and increasing connectivity of those devices is leading to an explosion of data. For example:

- Cisco estimates that global mobile data traffic alone is expected to grow 13-fold between 2012 and 2017 (Cisco, 2013).
- Image and imaging data have greatly increased the data being collected and stored in the medical field and this is projected to continue. In 2012, there were 500 petabytes (one petabyte is equal to one million gigabytes) of health data worldwide, enough to fill 10 billion four-drawer cabinets. Some experts and groups estimate this will grow 50 times (to 25,000 petabytes) by 2020 (Andrews, 2011; Xerox, 2012).

Technology is continually evolving, and it is difficult, if not impossible, to predict which new developments will be game-changers and which will be largely ignored.

Enhanced communication is a fundamental goal of numerous ICT, and many applications have successfully changed the approach to communication. Social networking sites like Facebook, Twitter, and Pinterest are redefining community relationships by bringing together a broad coalition of previously unconnected people. These new connections can have a positive social impact on individuals, and also facilitate collaborations between groups working towards beneficial individual and mutual goals. At its best, social networking facilitates rapid mobilization of optimism and action among people globally. On the other hand, some have pointed to the tendency for such technologies to increase individual isolation from human interaction, undermine authoritative knowledge, or reinforce people's ability to cocoon themselves in self-referential world views (Fachbereich Wirtschaftsinformatik und Neue Medien, 2010).

Networked end-user devices now let people access and use information quickly and easily at home, work, or on the move. This access and engagement can have benefits in terms of sustainability. Citizens with greater access to information and analysis, for instance related to a company's environmental or social performance, can make more informed choices. Improved labelling systems for consumer products can potentially have a positive effect on consumer decision-making as well as industry standards. ICT-based labelling is one way to enhance the traceability of food products and thereby encourage sustainability in the food chain (Wognum *et al.*, 2011). See Box 2.2 for an example.

Box 2.2
An Example of ICT-Based Labelling: ThisFish

ThisFish is a consumer-focused seafood traceability system set up by Ecotrust Canada in collaboration with seafood harvesters and suppliers to provide more information about the authenticity, quality, and sustainability of Canadian seafood (Ecotrust Canada, 2013). Fish harvesters tag fish with a unique code at the time of harvest and then upload information on where and how that fish was caught. Other seafood businesses upload additional information corresponding to this code tag about how the fish is handled and processed as the fish travels through the supply chain. Consumers, retailers, and restaurateurs can use the unique code to retrieve details about the seafood at ThisFish.info. Ultimately, the program allows customers to make a more informed choice about their purchases while improving the transparency and accountability of fishing practices throughout the industry (Ecotrust Canada, 2013).

Governments are also increasingly engaging citizens online and promoting awareness for decision-making processes through e-government initiatives. Additionally, in the past few years, examples of ICT-enabled citizen engagement worldwide, range from the spontaneous citizen movements associated with the Arab Spring, to forms of participatory processes and community engagement activities (Allagui & Kuebler, 2011) (see Section 4.6).

In the context of promoting sustainable behaviour, engagement empowers stakeholders to define their own future in ways that will be personally and collectively beneficial. Full public engagement requires dynamic, participative communication between actors in addition to access to information. It is clear from this explosion of activities that ICT have provided a platform that allows people to engage in decision-making in new ways. Increased engagement of all segments of society in the decision-making process could enhance public trust in governments and promote social stability. Vancouver's the Greenest City Conversations Project takes this approach in facilitating participation through different channels and activities to promote growing behavioural awareness about sustainability issues (Tanenbaum *et al.*, 2011; Bendor *et al.*, 2012).

Another example of how ICT are changing daily life is the capability they provide to change consumption patterns by tracking and assessing information, changing prices accordingly, and implementing measures that will support sustainable use of resources. One application that demonstrates this is the concept of dynamic pricing, where the price of a service is based on the time at which the service is provided. Time-of-use rates for electricity, for example, allow a utility to charge different rates for electricity consumption at different times of the day, with peak time being more expensive. This could provide benefits for both the service provider and the consumer: the consumer gets cheaper electricity at off-peak times, and the service provider can potentially reduce overall loads.

ICT can also directly provide consumers with information that enables decisions that help them reach sustainability goals. Providing information through ICT in a user-accepted manner can provide the awareness needed to inform decisions about resource consumption or waste generation, for example. Changing people's behaviour can be as simple as providing them with the type of data that may persuade them to act in a more sustainable manner. For example, Kuznetsov & Paulos (2010) found that their deployment of water use monitoring displays effectively motivated water reduction in all private homes tested and led to greater behavioural awareness among participants for sustainability and environmental issues beyond water usage.

2.5 CONCLUSION

This chapter has briefly summarized some of the important contextual factors that need to be understood to identify which ICT and ICT applications can potentially yield the greatest environmental, social, and economic benefits for Canadians. By taking advantage of its strengths, Canada can improve its environmental performance, while at the same time, achieving economic and social benefits. Canada has a well-connected society and has an ICT industry and post-secondary institutions that are strong in terms of ICT research. There is room for improvement, however, as Canada does not rank highly in terms of ICT penetration and diffusion among individuals and the ability of firms to adopt technologies.

The following chapters discuss the ICT platform on which opportunities for sustainability can be built (Chapter 3) and explore how this ICT platform can be used to achieve sustainability benefits in Canada, through the lenses of six key thematic areas that relate to daily life (Chapter 4).

3

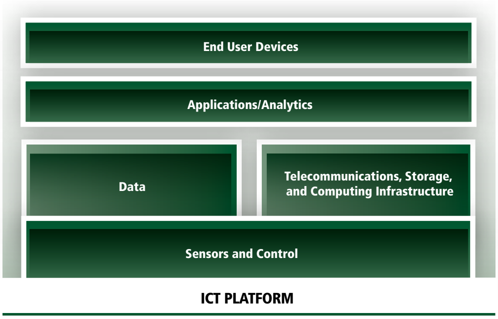
An Enabling Platform for a Sustainable and Interconnected Canada

- End-User Devices
- Data
- Applications and Data Analytics
- Telecommunications, Storage, and Computing Infrastructure
- Sensors and Control Systems
- The Environmental Cost of ICT
- Building on Canadian Strengths
- Conclusion

3 An Enabling Platform for a Sustainable and Interconnected Canada

Key Findings

- All elements of the complex ICT system are essential, including end-user devices; data; applications and data analytics; telecommunications, storage, and computing infrastructure; and sensors and control systems. These technologies are elements of interconnected nodes in complex socio-technical systems.
- Seamless integration of these elements into a smart, interconnected system provides unprecedented information and knowledge access, enabling sustainable reductions in environmental impact, enhanced quality of life, and significant value creation.
- The proliferation of these devices and systems will create environmental and social challenges.
- With many low-GHG electricity sources available, Canada has the potential to become a leader in hosting green data centres, which are a part of the technological infrastructure necessary to enable GHG emission reduction.



People are now connected in an unprecedented way to the world of information and the human-made world of things. This has profound implications for the economy, society, and human interaction with the natural environment. Access to, and analysis of, vast data sets in real time offers new opportunities to evaluate changes in the environment, and to collaborate, make decisions, and change behaviour to support sustainability objectives. With their accelerating rate of penetration and expanding functionality, ICT can reduce human impact on global ecosystems of all kinds, achieving economic and social benefits as well as environmental gains.

While the components that make up ICT are varied and continue to evolve, the Panel identified five ICT technical components that have significant potential to influence or promote sustainability (the ICT platform in Figure 1.1):

(i) *End-user devices* (such as smartphones, tablets, and laptops) provide the interface between the digital world (information and automation) and human users (consumers, business people, researchers, utility managers, ICT programmers, and more).

(ii) *Data* are the information points that people collect, analyze, and exchange. Data are harvested at an exponential rate from the countless ICT devices that are now in use around the world, as well as from more traditional information sources.

(iii) *Applications and data analytics* provide the tools to examine the data tsunami for patterns and correlations that can yield new insights.

(iv) *Telecommunications, storage, and computing infrastructure* provide the information systems (increasingly within the cloud), advanced computing power, and network infrastructures to transfer, archive, and manipulate information and increasingly large amounts of data.

(v) *Sensors and control systems* provide the interface between the digital and physical worlds. Sensors collect and transmit information about their physical environment such as energy consumption, changes in air quality, or rising water levels. Control systems use information to act on the environment directly or to control other ICT devices.

The five technical components are interdependent, and can have the greatest impact when implemented and used together. Together these technologies can be applied to make a wide range of tasks faster, more exacting, and more efficient. Indeed, it is the combined functionality of ICT that sets this group of technologies apart from others that might be used to achieve sustainability goals. Moreover, this functionality continues to broaden. Today's ICT can be used to adeptly monitor human-made or natural environments, predict the evolution of complex systems and interactions, manage large amounts of data, carry out diagnosis and instruction, and much more. The possibilities for the future spark the imagination.

3.1 END-USER DEVICES

Canada is a highly connected society. This is due in part to the recent evolution of mobile end-user devices, such as laptops, smartphones, and tablets, which can receive, store, and display information. Canadians have embraced these technologies, for both personal and professional use. The following properties best describe these technologies (list adapted from Diamond & Roberts, 2012):

Mobility and Ubiquity: The ever increasing functionality of mobile devices is leading more Canadians to adopt these devices for a variety of purposes. Although tablets in their current form were introduced to the market in 2010 by Apple, they were not immediately part of the daily lives of many Canadians. Just three years later, 21 per cent of Canadians reported using a tablet device, an increase of 11 per cent over the year before (Ipsos, 2013). About half of Canadians now report using a smartphone. More and more people are carrying around small devices that act as the interface between the digital and real world.

Connectivity and Interconnectivity: End-user devices are increasingly connected to wireless networks, allowing people to share information and collaborate with other connected people from any location.

Context Sensitivity: An average smartphone contains many different types of sensors, from Global Positioning System (GPS) to ambient light sensors, accelerometers, and magnetometers. With this range of equipment on board, people can use their smartphones and other devices to share information about their location or environmental data (see Box 3.1).

This move towards devices that facilitate information mobility signals a major shift in how individuals access and share information. This opens a new world of opportunities for individuals and communities to have a positive impact on sustainability issues: from learning about or reporting on the state of the environment, remotely controlling living spaces, accessing traffic information in real time, or simply sharing ideas. The rise of social media and crowdsourcing of information are just a few of the novel ways people are putting this new phenomenon to use. In addition to potential applications for sustainability, the adoption of mobile technology may have a positive impact on the economy. For example, 50 per cent of Canadian businesses report that they have reduced their operating costs by adopting mobile technologies (ICTC, 2013). However, as mentioned in Chapter 2, such technologies may isolate individuals from human interaction.

The Panel recognizes that the value of these devices to sustainability strategies lies in the breadth of the potential applications that can run on them and the ways people choose to use them. The evolution of end-user devices opens up a new world of opportunities for individuals and communities, from drivers accessing traffic information to utility managers tracking, modelling, and making decisions about energy or water consumption in real time. Those opportunities are discussed further in this chapter and in Chapter 4.

Box 3.1
Humans as Sensors and Agents of Change

End-user devices, packed with sensors, provide the opportunity for people to collect and provide valuable information on the changing state of the environment, making them a useful addition to sustainability strategies. This is the philosophy that underlies the concept of crowdsourcing, a participatory sensing activity that allows anyone, through the use of ICT, to make valuable contributions to scientific research that can inform public policy decisions. For example, many new smartphones have built-in barometers or temperature sensors that can be used to gather data to predict weather (Marks, 2013; Overeem *et al*., 2013).

The simple act of participation may lead citizens to feel more connected to sustainability issues. The information gathered can also be used to educate others and to encourage positive behavioural change.

3.2 DATA

"Ninety per cent of the data in the world today was created in the last two years."

(Cavoukian & Jonas, 2012)

By 2020, the amount of data generated worldwide is expected to increase by almost 5,000 per cent, from 1.8 to 90 zettabytes[3] (Wallis, 2012). Two main factors are spurring this growth: the increasing global capacity to generate information, and the arrival of new ways to store and manage the data (the cloud) (MaRS Commons, 2013). For example, Cisco predicts that by 2020 about 50 billion devices, most of them producing data, will be connected to the internet (Evans, 2012). Social media and crowdsourcing activities also generate their share of data: one billion posts to blogs and social networks appear daily (World Economic Forum, 2012). Data streams relevant to ICT applications that improve environmental performance can be related to a variety of issues, including environmental monitoring, energy and water distribution, and waste generation. For example, environmental monitoring produces petabytes of raw information from sensors, often in real time. This information can relate to environmental components as varied as air and atmosphere, water, climate, or soil. Data streams produced by ICT-enabled applications may be volunteered (e.g., crowdsourcing), observed (e.g., location, utility smart meters, building automation), or inferred (e.g., weather forecast, modelization, predictive analytics) (World Economic Forum, 2011).

3 1 zettabyte equals 1 billion terabytes.

Not only is the amount of data increasing, so is the speed at which they need to be analyzed. Real-time decision-making requires simultaneous data analysis if it is to be effective in cases where a rapid response is required (such as severe weather events, flood control, and structural monitoring). This trend has been termed *big data*, defined as "datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze" (Manyika *et al.*, 2011). The full potential of big data is currently under used. For example, a recent survey conducted by Forbes indicates that many executives struggle to define big data and their potential benefits (Forbes Insights, 2013).

The Panel recognizes that accessing, combining, and extracting information from this mountain of data are critical to meeting many sustainability challenges. One example of the complexities of this challenge specific to Canada is fragmentation across jurisdictions. Data from metering may be owned by one or more orders of government, the private sector, or individuals, depending on the jurisdiction. This can make it difficult to track who is responsible for measuring household electricity or water consumption for sustainability purposes. In Ontario distribution and metering are the responsibility of local companies, while in Quebec they are managed by the provincial utility, Hydro-Québec. Although the tracking of water consumption is primarily the responsibility of municipalities, metering lacks normalization, and there is a significant divide between urban and rural areas. In 2009, 72.1 per cent of single-family residential homes served by municipal water systems in Canada were metered (less than 50 per cent in communities with fewer than 2,000 people) (Environment Canada, 2009). Rural properties are on wells and generally are not covered by a centralized metering system. Privacy and security are two overarching challenges when it comes to dealing with big data (see Chapter 5).

3.3 APPLICATIONS AND DATA ANALYTICS

Applications are at the heart of technologies that can enable and run systems of smart grids, buildings, transit, sensor technologies, and other opportunities. Whether discussing decision support and data automation interfaces, analytics and discovery, or data organization and management, applications and data analytics are part of sustainable opportunities. In particular, data analysis is becoming an increasingly important component of sustainability. The data transmitted by the growing number of connected devices provide an opportunity for analysis to make the data even more useful. For example, Canada's Climate Research Branch incorporates modelling systems for climate and atmospheric research, contributing valuable information to Canadians and the international community on earth system dynamics, tracking severe weather, and studying the many causes and effects of climate change that affect all aspects of daily life (Environment Canada, 2013a). However, data indicate that the private sector in Canada lags its global counterparts in approaching big data technologies. For example, an International Data Corporation (IDC) survey carried out in 2012 found that only 48 per cent of responding Canadian companies had started to work with big data prior to 2011 compared to 76 per cent of companies worldwide (Wallis, 2012).

The rise of big data has led to the development of new tools and processes to make sense of the information generated and draw out useful information. Data analytics combines techniques from various scientific fields such as statistics, mathematics, or computer science with large computing power to infer conclusions about large data sets or discover new features in the data. The opportunities described in Chapter 4 produce immense amounts of data that could lead to unforeseen opportunities if they are properly analyzed. Table 3.1 shows examples of such applications in the building and smart grid sectors.

Table 3.1

Examples of Existing or Emerging Data Analytics in the Building and Smart Grid Sectors

Buildings	Smart Grids
• **Dashboards** display information in various ways about utility consumption, for example, but leave the analysis to users. • **Alerts** to users are based on data analysis. • **Scorecards** and benchmarks provide comparative analysis of performances. • **Trends and behaviour patterns** can be predicted to optimize performance.	• **Advanced metering infrastructure** provides the ability to predict load by delivering granular consumption data. • **Voltage data:** with smart meters, voltage readings can be retrieved and matched with other readings from the distribution network to optimize voltage regulation. • **Electric vehicle:** analysis of charging trends.

Data Source: Hogan & Nicholson, 2011; GTM Research, 2012

In the Panel's view, the application of data analytics to sustainability issues can lead to significant sustainability gains in areas of importance to Canada, including the following:

- Data analytics are at the heart of technologies and applications that enable and run systems of smart grids, buildings, transit, sensor technologies, and other opportunities (for example, see GTM Research, 2012 for smart grid data analytics).
- Data analytics can advance research and decision-making in countless areas of environmental importance: from understanding climate change and weather patterns to tracking air and water pollutants, modelling changes in species

counts and movements, and tracking the progress of harmful pathogens. Data analytics can improve the operational efficiency of businesses and support new business creation and innovation (Cebr, 2012).

- Data analytics can create jobs. Gartner (2012) predicts that big data will generate as many as 4.4 million ICT jobs globally by 2015, as specific skills are required to properly use large data sets.

Moreover, much of the potential of data analytics is yet untapped. While massive amounts of data are generated, most are currently not put to use. As data are increasingly transmitted by the growing number of connected devices coming online, the potential to glean information to support sustainability objectives will grow exponentially.

3.4 TELECOMMUNICATIONS, STORAGE, AND COMPUTING INFRASTRUCTURE

3.4.1 Data Pipelines: Telecommunication Networks

Telecommunication networks are the backbone of ICT applications, and are a critical element of the successful application of ICT in promoting sustainability in Canada. From environmental monitoring to smart transportation, successful ICT applications depend on the capacity to reliably transmit and receive data at a reasonable speed. The need for telecommunication networks in promoting sustainability is demonstrated in many sectors. For instance, the U.S. Department of Energy (2010) recognizes one of the critical components of smart grids as the "sufficient access to communications facilities." Industrial applications of sensor networks also rely on the data rate of connectivity (Buratti *et al.*, 2009). Additionally, an increasing load is put on networks worldwide as more and more processes are being virtualized and data storage is moving to the cloud.

Network usage is evolving at a fast pace. A wide range of digital devices are increasingly connected to networks of all kinds, including cellular networks and the internet. At the same time, a growing proportion of data is exchanged through wireless networks (GeSI, 2012). This trend is likely to continue and Cisco (2013) predicts a 13-fold growth in mobile data between 2012 and 2017, along with a 7-fold increase in speed.

Canadians overall have access to broadband internet, but there is huge variation in the speeds available across the country. By the end of 2013, 99 per cent of Canadian households were expected to have broadband internet with download speeds greater than 1.5 megabits per second (Mbps) or higher (CRTC, 2011b). Still, the coverage is not uniform; for example, in 2011 only 29 per cent of the population of Nunavut had access to these speeds. For higher speeds, the digital

Promising Practice
CANARIE — Leveraging Research and Education Networks in Canada

A program of particular importance for Canada's ICT infrastructure is Canada's Advanced Research and Innovation Network (CANARIE). CANARIE links researchers from Canada and around the world via a dedicated network of over 19,000 kilometres of high-speed fibre optic cable (CANARIE, 2012c). CANARIE allows about one million researchers, scientists, and students to share and analyze large amounts of data. It offers download speeds of 10 billion bits per second across its core network and 100 billion bits per second in main corridors. Between 2007 and 2012, traffic over CANARIE increased by 587 per cent (CANARIE, 2012b, n.d.). CANARIE funds programs that promote the evolution of digital infrastructure for Canadian researchers and innovators. In the 2012 federal budget, CANARIE received $40 million in new funding over two years (CANARIE, 2012a).

divide is greater. As of 2011, about 95 per cent of large population centres, but only about 20 per cent of rural areas, had access to download speeds between 30 and 49.9 Mbps. Furthermore, no households had access to broadband speeds over 25 Mbps in Nunavut, while access in Yukon, the Northwest Territories, Saskatchewan, and Prince Edward Island was 60 per cent or less (CRTC, 2012).

3.4.2 Storage and Computing Infrastructure

Data storage and analytics are increasingly occurring on remote infrastructures that are either shared or privately owned. These offer organizations and individuals an external computing resource that provides hardware and software for various applications including storage, data analysis, and virtualization of processes. The hardware is usually located in dedicated buildings, with environmental controls such as air conditioning and associated components such as telecommunication networks. As the quantity of data to be stored and computed grows, so does the size of data centres; therefore, the market size is expected to reach about $220 billion worldwide by 2020 (Belady, 2011). Cloud computing is recognized for its ability to improve reliability, security, and opportunities for collaboration (OECD, 2009a). It also offers several efficiency incentives that can align with sustainability objectives, including:

- potential CO_2 abatement;
- potential energy savings in the United States of US$12.3 billion per year by 2020;

- fewer front-end expenditures, as users do not need to own advanced processing and storage infrastructure;
- flexibility, as services are virtualized and can be rapidly scaled to suit demand; and
- independence of location, as servers are virtualized and accessed through networks, which means the physical location of users is less important.

(list adapted from Carbon Disclosure Project, 2011; European Commission, 2012)

Canada is home to various supercomputers owned by academia, governments, or industry. Of Canadian supercomputer sites, as of November 2013, 10 were ranked among the 500 fastest supercomputers in the world and 10 among the 500 most energy-efficient (The Green500, 2013; Top500 Supercomputer Sites, 2013). Table 3.2 shows the most energy-efficient supercomputer sites in Canada.

Table 3.2

Most Energy-Efficient Canadian Supercomputers Sites

Rank	Year	Manufacturer	Site	Type of structure
34	2012	IBM	Southern Ontario Smart Computing Innovation Consortium/University of Toronto	Academic
93	2013	IBM	Bombardier Aerospace	Industry
94	2013	IBM	CLUMEQ – McGill University	Academic
187	2011	IBM	Environment Canada	Research
188	2011	IBM	Environment Canada	Research
196	2011	SGI	Calcul Canada/Calcul Québec/ Université de Sherbrooke	Academic
204	2010	IBM	CLUMEQ – McGill University	Academic
259	2009	IBM	SciNet/University of Toronto/ Compute Canada	Research
260	2013	Hewlett-Packard	IT Service Provider (C)	Industry
474	2012	Hewlett-Packard	Government	Government

Data Source: The Green500, 2013

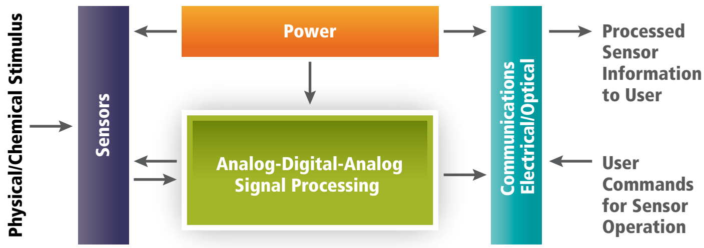
500 supercomputers in the world have been ranked by energy efficiency with 1 being the most efficient.

Reducing the number of data centres can also yield environmental benefits, provided these larger centres are energy efficient and run on clean energy. At the federal level, Shared Services Canada is adopting a centralized model by consolidating its 485 data centres into 7 data centres (Government of Canada, 2013b).

3.5 SENSORS AND CONTROL SYSTEMS

3.5.1 Sensors

Sensors carry out a wide range of tasks, from geospatial mapping to monitoring complex interactions in manufacturing processes, and play an important role in meeting many of Canada's sustainability challenges. Sensors can be organized into a network and act co-operatively to sense and exchange information about their environment in real time with other sensors and data control centres. Networks of sensors can add to the robustness of the information they gather by verifying data with other sensors. This built-in redundancy can improve the flexibility and resilience of the monitoring system (Culler *et al.*, 2004; Buratti *et al.*, 2009). The key trait of sensor systems that allows them to be leveraged for applications contributing to sustainability is their ability to deliver accurate real-time information about a variety of activities within a network that is strong and resilient (as shown in Table 3.3).



Reproduced with permission from The Electrochemical Society
Hunter *et al.*, 2010

Figure 3.1

Smart Sensor System

A sensor system has three main components: the sensor itself captures the external stimulus, a microprocessor processes the signal (represented by the analog-digital-analog signal processing box), and a communication system (represented by the communications electrical/optical box) transmits the information. All three of these components require a power source to function.

Table 3.3
Types of Sensor Network Applications

Monitoring Space	Environmental monitoring
	Precision agriculture
	Indoor climate control
Monitoring Things	Structural monitoring
	Condition-based equipment maintenance
	Urban terrain mapping
Monitoring Complex Interactions	Wildlife habitat
	Ubiquitous computing environment
	Manufacturing process flow

Culler *et al.*, 2004

In addition to environmental benefits, sensors can be applied to activities that provide social benefits. For example, sensors used in weather forecasting help meteorologists to predict severe weather events that can lead to flooding, high winds, drought, or forest fires. Smart sensors can be used to support remote surgery, improving access for Canadians living in rural or remote locations. (For an example of smart sensors using robotic surgeries, see SSIM, n.d.)

Promising Practice
NEPTUNE — Expanding Knowledge of the Ocean System

NEPTUNE Canada is a subsea cabled ocean observatory that collects data to expand knowledge about the ocean system in the Northeast Pacific. It spans a 450,000-square-kilometre region in the northeast Pacific Ocean, off the shore of British Columbia and Washington. A 812-kilometre-long fibre optic cable links five instrumented nodes located in various geological and ecological locations and collects data on earthquakes and plate tectonics, fluid flow, marine processes, climate change, and deep-sea ecosystem dynamics, as well as engineering and computational research (NEPTUNE Canada, 2012). NEPTUNE also promotes education by enabling students to remotely participate in ocean observation (NEPTUNE Canada, 2014).

3.5.2 Control Systems

Control systems are devices that analyze and process data (from sensors for example), and use the resulting information to control other devices or systems. Control systems are used in many ICT-enabled sustainable solutions.

Box 3.2

The Internet of Things and the Emergence of the Internet of Everything

The Internet of Things refers to the networked connections of physical objects. In a world with the Internet of Things, most objects in people's daily lives will be interconnected (European Research Cluster on the Internet of Things, 2011). By 2020, 50 billion things may be connected in this way (Evans, 2012). "Things" range from smart-home applications (e.g., remote control of lighting, heat, water, and more); home appliances (e.g., smart refrigerators); databases; controllers; data centres; end-user devices; and even vehicles. Many predict an explosion of machine-to-machine (M2M) connections in the coming years. This concept has been extended by Cisco to the "Internet of Everything," where connected things, people, processes, and data are taken as a whole (Evans, 2012). Things organized in a network add context awareness and provide augmented processing power. M2M technologies are projected to become a US$948 billion business and could save 9,100 $MtCO_2e$ through efficiency gains in total by 2020 (Cullinen, 2013). A recent report by the Carbon War Room and AT&T identified potential in CO_2e abatement in the following key sectors: energy, transportation, the built environment, and agriculture (Cullinen, 2013). Cisco predicts that the Internet of Everything may create over US$14 billion in value for firms and industries from 2013 to 2022 when both increased revenues and reduced costs are considered (Bradley *et al.*, 2013).

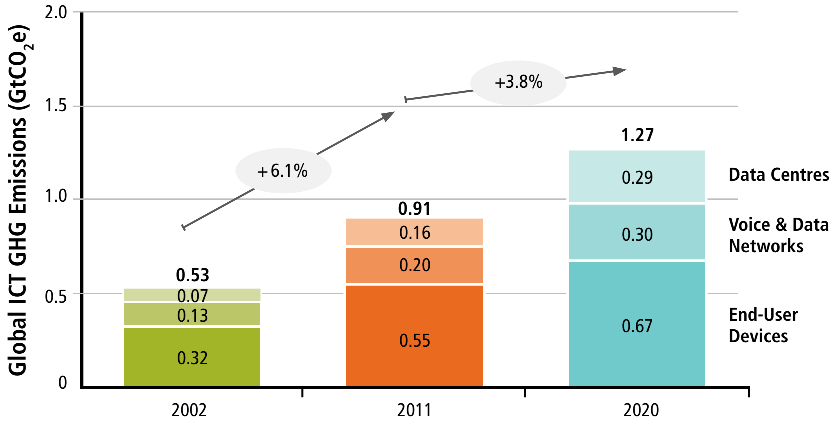
The Internet of Things may ultimately lead to novel approaches to economic and social organization, giving rise to new forms of employment, changes in social interaction, and even greater concern about privacy issues.

A Day in the Life

Camille, Montréal

11:00 am (EST)

Camille has recently taken over a project. She is developing an application that can be installed on almost any smart device. By communicating with numerous other smart devices around it, as well as with a central disaster-mitigation server, the program will maintain a constantly updated handbook of information to be used in an emergency event.



	2002	2011	2020
ICT as percentage of global emissions	1.3	1.9	2.3
Global GHG emissions ($GtCO_2e$)	40	48	55

Reproduced with permission from GeSI, 2012

Figure 3.2

Global Greenhouse Gas Emissions (in Gigatonne Carbon Dioxide Equivalents) from Global ICT, as Calculated by GeSI

Global ICT emissions broken down by end-user devices, voice and data networks, and data centres. Although emissions from ICT are expected to continue to grow, the rate of this growth is expected to decrease. While emissions increased by 6.1 per cent between 2002 and 2011, the rate is expected to drop to 3.8 per cent from 2011 to 2020.

For example, HVAC (healing, ventilation, and air conditioning) systems can be managed by control systems to improve overall efficiency. A simple example of a control system is the electronic device that controls the cooling system of a refrigerator when the temperature is above a certain threshold. A controller may also directly act on the environment through an actuator. An actuator is a mechanism used by a control system to convert a signal in a physical action. Controllers, in combination with sensors, are going to play an increasingly important role in applications for sustainability. As described in Box 3.2, in the near future 50 billion things may be connected to the internet. These things, ranging from home appliances to manufacturing devices, will have the capacity to be managed by controllers but also, depending on the device, act themselves as controllers or sensors.

3.6 THE ENVIRONMENTAL COST OF ICT

As discussed in Chapter 2, ICT and ICT-enabled applications can potentially improve Canada's environmental performance, but they have a significant environmental impact. GeSI estimates that global GHG emissions for all ICT reached 910 $MtCO_2e$ in 2010 (GeSI, 2012). This value is approximately equal to the emissions produced by about 178.5 million cars per year.[4] Each of the five technical components of the ICT platform has its own environmental costs (see Figure 3.2); however, these could be mitigated through technological advances that minimize their impact on the use of energy and materials. As the International Institute for Sustainable Development has noted, the ICT industry could adopt a zero-carbon strategy by combining new technologies (e.g., clouds and grids using Web 2.0 technologies) with zero-carbon data centres that are powered by renewable energy sources and linked by optical networks (MacLean & St. Arnaud, 2008). Some of these strategies are discussed below.

3.6.1 End-User Devices

The increased use of tablets, smartphones, and other personal devices raises complex environmental issues. The energy used to produce and operate these end-user devices is responsible for an important share of GHG emissions (GeSI, 2012). The high market penetration of these devices, combined with their short lifespans, is also the primary cause of increasing amounts of e-waste (discarded electronic appliances). In 2010 the United States alone disposed of 1.79 million short tons of e-waste, representing 310 million individual units. Recycling of e-waste is still limited, as it is often considered too expensive to be feasible on a larger scale. It is estimated that, in 2009, only 25 per cent of total electronic products in the United States were collected for recycling, with the rest ending up in landfills and incinerators (EPA, 2011b). Furthermore, many electronic devices contain toxic elements, such as transition metals in cell phones (e.g., lead and cadmium), which can contaminate land and water when not disposed of properly. As a result, e-waste already accounts for more than two-thirds of the heavy metals and 40 per cent of the lead found in U.S. landfills (Grossman, 2007). Finally, end-user devices contribute, directly or indirectly, to a large and growing use of electricity, to power the devices, but, more importantly, to provide the interconnectivity and information required to use them. Life-cycle analysis and social life-cycle analysis are tools that can be used to assess environmental and social impacts of technologies. These tools are discussed in more detail in Chapter 5.

4 Based on the fact that a passenger vehicle emits 5.1 metric tons of CO_2 per year (EPA, 2011a).

3.6.2 Data

Data have their own environmental footprint. The explosion of data from both wireless and wired networks is driving rising energy use, as telecommunication networks strive to transmit more and more data. Network emissions accounted for 22 per cent of all global ICT emissions in 2011 (GeSI, 2012).

3.6.3 Telecommunications, Storage, and Computing Infrastructure

The backbone of the ICT platform — telecommunication networks, cloud storage, and computing infrastructure — is responsible for a variety of environmental challenges. Although relatively invisible to many users, wireless networks consume a significant amount of energy. For example, Long Term Evolution (LTE) base stations consume 3.7 kilowatts (in comparison, a furnace consumes about 0.75 kilowatts) (Vereecken *et al.*, 2011; U.S. Department of Energy, 2013). Several options are available to improve the energy efficiency and lower operation expenditures of telecommunication networks: green photonics, adaptive control, efficient power adaptive processing, and moving storage and processing to the cloud. The environmental footprint of data centres is similarly significant, offsetting some of the environmental benefits achieved by centralizing data storage and computing in the cloud. Large amounts of electricity are needed to operate the computer processors housed in these centres, as well as to power air conditioning to cool the servers and other equipment. Worldwide, data centres were estimated to consume about one per cent of total electricity usage in 2005 (Koomey, 2008). GeSI predicts that as more data and applications move to the cloud, data centres' footprint will increase by 7.1 per cent per year, reaching 290 $MtCO_2e$ in 2020 (GeSI, 2012). Despite this, data centres still present a real opportunity to drastically reduce the global environmental impact of ICT. Some data centres have been built to specific economic and environmental requirements, such as Telus's Kamloops Internet Data Centre, which is expected to have an annual power usage effectiveness rating of 1.15, using 80 per cent less energy than a centre of similar size (TELUS, 2012).

3.6.4 Sensors

Like end-user devices, sensors have an environmental impact through the materials they are made of and the energy that they consume in operation. The communication range of a sensor is usually measured in tens of metres, with information moving hop-by-hop through a network of sensor nodes to cover long distances. Wireless sensors consume about 20 milliwatts (this is less than a typical end-user device). At present, batteries (either rechargeable or non-rechargeable) are the most common power supply for wireless sensor nodes. There are also other, more environmentally benign, methods that can power sensors. Solar cells, for example, can generate about 10 milliwatts per square centimetre when placed outdoors; mechanical sources of energy (e.g., vibration of windows) can generate about 100 microwatts (Culler *et al.*, 2004). As semi-conductors inside sensors become smaller, they consume less energy, fit on smaller surfaces, and can require fewer materials to produce.

3.7 BUILDING ON CANADIAN STRENGTHS

3.7.1 Green Data Centres

Canada has a unique opportunity to lead in hosting green data centres, which will be the core of the future internet, and, more broadly, an important enabling platform for sustainability in a connected world. Green data centres are a key component of efforts to achieve the lowest possible environmental impact for ICT. The cloud provides the opportunity to centralize processes through server virtualization, cloud printing, or network virtualization, and to make those processes more efficient (see Box 3.3). However, for the cloud to become a sustainable opportunity, particular attention needs to be paid to the type of energy that powers data centres. This can be solved in part by locating data centres in areas that benefit from a cool climate and low-GHG energy sources; Canada has a competitive edge in both these areas.

Canada's Abundant Low-GHG Energy

Data centres can greatly reduce their environmental footprint if they are located where electricity is supplied by non-GHG-emitting sources. Canada has many regions that have access to electricity from sources that are low in GHG emissions. The majority of Canada's electricity needs are met by hydro generation (about 54 per cent of total production), with this source making up 87 per cent or more of the electricity generated in British Columbia, Yukon, Manitoba, Quebec, and Newfoundland and Labrador (Baker *et al.*, 2011). Furthermore, renewable energy sources, specifically wind power, are increasingly being incorporated into the electricity supply (Baker *et al.*, 2011). Several regions of the country have the potential to provide the energy needed to operate low-emission data centres.

The Cool Climate Advantage

Canada is also an ideal location for data centres because of the moderate and cool climate in many parts of the country. The opportunity for free cooling can reduce the need for costly and energy-intensive air conditioning within data centres. For example, service providers such as Facebook and Microsoft are building data centres in countries with cold climates to cut on cooling costs (Network Computing, 2013). There is also the opportunity to use the waste heat from concentrated data centres as a heat resource. For example,

> ***Box 3.3***
> **Network Virtualization and Green Data Centres**
>
> Network virtualization is the implementation of a network function (software that can run on a server instead of running directly on hardware-based appliances). These servers can be located in data centres, at network nodes, or on the end user's premises (Chiosi *et al.*, 2012). One benefit of virtualization is the ability to choose where virtual processes run. For example, users in a region that depends on coal for electricity can choose to run a virtualized network function on servers where clean energy is available rather than on their personal computers. There are also economic benefits to virtualization. It can reduce equipment costs and time to market, and increase competitiveness in the marketplace by opening "the virtual appliance market to pure software entrants, small players and academia" (Chiosi *et al.*, 2012).
>
> A virtualization approach that takes advantage of data centres in regions that use low- (or no-) emission electricity is Canada's GreenStar Network (Lemay *et al.*, 2012). This pilot project is funded by CANARIE and involves participants from academia, the private sector, and government. A related green ICT project, Equation, multi-partner public-private collaboration, is developing cloud-based network technologies that offer the same robustness and quality of service as a traditional telecommunication network (Prompt Inc., 2013). This includes the hardware and software required by telecommunication operators and data centres to manage the network through the cloud, while reducing energy consumption. By leveraging the GreenStar concept, data centres can assess their energy use and capitalize on renewable energy sources (solar, wind, and hydro) to operate the network.

the Seattle Office of Sustainability & Environment is working on a project to reuse waste heat from data centres close to the city to power a district heating system (Network Computing, 2013).

Economic and Social Benefits

By seizing the market opportunity in green data centres, Canadian companies can generate important economic and social benefits. The construction, operation, and maintenance of the centres will create jobs and pump money into local economies. For example, the 25,000-square-foot IBM Canada Leadership Data Centre, which opened in 2012, brought a $90 million investment to the community of Barrie, Ontario (IBM, 2012). In addition to construction jobs, the new data centre created 20 skilled jobs in the region (Techvibes, 2012). In June 2013 Ericsson announced that it will spend an estimated $1.2 billion to build and equip a new 40,000-square-metre R&D data centre in Vaudreuil-Dorion, Quebec. Sixty new jobs will be created with the investment (Van Praet, 2013). Although data centres have a relatively modest direct impact on employment, their indirect socio-economic benefits can be significant when coupled with a comprehensive digital economy strategy involving ubiquitous broadband access.

3.8 CONCLUSION

In this chapter, the Panel investigated five technical components that make up the ICT platform in the Panel's report roadmap (recall Figure 1.1). These five technical components are: end-user devices; data; applications and data analytics; telecommunications, storage, and computing infrastructure; and sensors and control systems. This chapter also discussed the increasing impact of ICT themselves on the environment and suggested an opportunity for Canada to mitigate some of those effects through green data centres.

The next chapter profiles selected ICT-enabled opportunities for sustainability through the lenses of the six key thematic areas identified by the Panel (see Section 1.3). All of the opportunities are based on the components of the ICT platform described in this chapter. Chapter 4 exemplifies the transformative power of the five components in promoting sustainability when they are implemented intelligently. The Panel stresses that, although these components can be taken as distinct entities with the potential to promote sustainability, their real transformative power comes when implemented and used together.

4

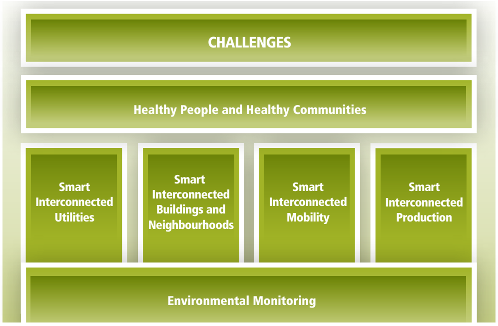
Interconnected ICT-Enabled Opportunities for Sustainability

- Environmental Monitoring
- Smart Interconnected Utilities
- Smart Interconnected Buildings and Neighbourhoods
- Smart Interconnected Mobility
- Smart Interconnected Production
- Healthy People and Healthy Communities
- Conclusion

4 Interconnected ICT-Enabled Opportunities for Sustainability

Key Findings

- Smart environmental monitoring can transform Canada's ability to conduct evidence-based decision-making; and address social, environmental, and natural resource issues.
- Smart interconnected utilities are already getting more out of aging infrastructure, enabling new technologies, and empowering end-user choice. Taking advantage of all of the benefits provided by smart grids could be transformative, changing how utilities are produced and delivered across Canada — minimizing environmental impacts, such as electricity and water losses in distribution, reducing costs for operators and consumers, and ensuring reliability of service.
- Buildings consume much of Canada's energy, and a number of them are well equipped with ICT. Smart building control systems could generate significant and quick economic and environmental gains.
- Connecting neighbourhoods with integrated and interconnected networks of functions (e.g., neighbourhood-scale integrated energy, water, or waste systems) could deliver services in a more efficient and socially and environmentally beneficial manner.
- Opportunities for smart interconnected mobility could enhance Canada's capability for more environmentally and economically efficient transportation and logistics.
- Integrated monitoring, control, and process planning through ICT could enable improvements in environmental performance and productivity in agriculture and manufacturing, shifting optimization from the individual unit level to that of the system.
- ICT can be used to address social challenges, and enable new forms of participatory decision-making and governance. These changes could enhance and accelerate the improvements described for environmental monitoring, utilities, buildings, mobility, and production, and contribute directly to enhanced human well-being in terms of, for example, access to and delivery of health and education services.



INTERCONNECTED ICT OPPORTUNITIES

ICT have already revolutionized how people communicate with one another, make decisions, and carry out activities in their daily lives. By effectively applying the technical components discussed in Chapter 3, ICT can have a positive, transformative impact on different aspects of life and help drive Canada towards sustainability. ICT-enabled opportunities generate excitement because their potential is limited only by human imagination. The potential of ICT comes also from the staggering speed at which they can be incorporated into various aspects of life. Technologies that were brand new just a few years ago, such as tablets and smartphones, are now commonplace.

The Panel's charge was to identify existing and potential opportunities to use ICT to create a sustainable Canada. With the speed at which ICT are evolving, predicting the future of technology is challenging. The Panel therefore chose to highlight some areas where ICT have already demonstrated potential to bring about substantial positive change. The Panel also embraced the definition of sustainability introduced in Chapter 1: to have the greatest impact, opportunities must be environmentally, economically, and socially beneficial. The criteria listed in Box 4.1 (in no particular order) were used to help identify which opportunities to explore.

Box 4.1
Selection Criteria for Potential ICT-Enabled Opportunities for Sustainability

Environmental Impact
- Pollution reduction
- Effect on energy consumption
- Effect on resources (water, energy, land use, etc.)
- Effect on biodiversity and ecosystem services

Socio-Economic Impact
- Impact on employment
- Economic development
- Opportunities in the global market
- Reduced costs for individuals, businesses, and government
- Opportunities for community engagement and political participation
- Improved health
- Increased access to more social and economic opportunities
- Enhanced access to information

The Panel did not seek to rank opportunities against these criteria, but instead selected opportunities that could achieve clear environmental, economic, and social benefits for Canada. As ICT opportunities are not limited to a single, traditional sector of the economy, an approach focusing on rigidly defined sectors would be too limiting. Instead, the Panel profiled opportunities within overarching thematic areas that reflect and encompass the multidisciplinary nature of the subject and also relate to the needs, functions, and activities of society. The Panel considered that a thematic approach would be appropriate to expose the potential for integrating the opportunities put forward.

Thematic Approach

The Panel chose six key thematic areas that can be, at least partially, enabled through the effective use of ICT and ICT-based applications: environmental monitoring, smart interconnected utilities, smart interconnected buildings and neighbourhoods, smart interconnected mobility, smart interconnected production, and healthy people and healthy communities. These thematic areas were chosen because they:

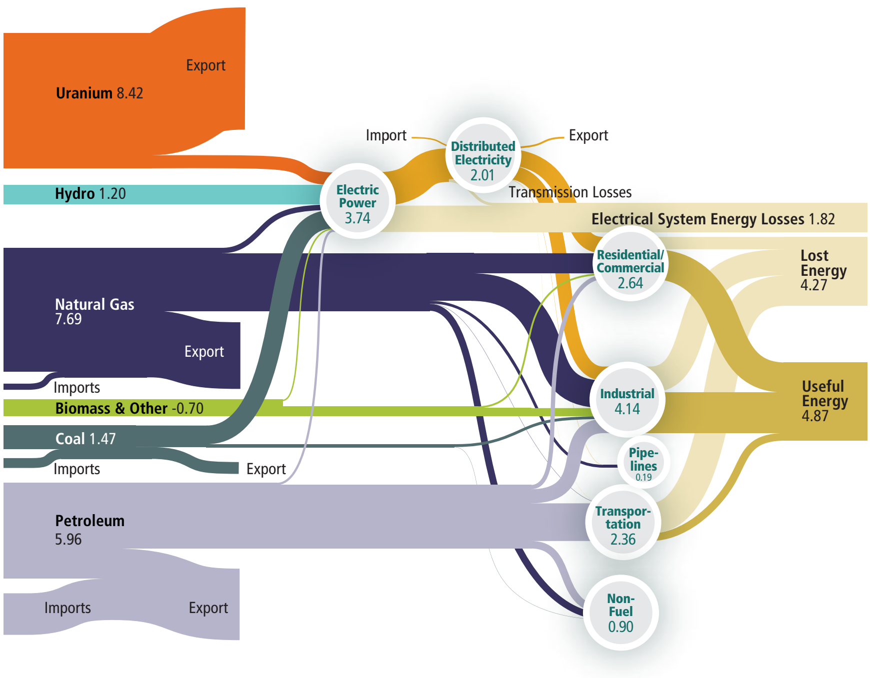
- directly relate to the daily activities in which Canadians engage;
- encompass substantial opportunities for ICT to benefit all three pillars of sustainability;
- facilitate thinking across sectors and demonstrate the links between sectors;
- make it possible to look at the potential benefits of ICT through different lenses because ICT can integrate solutions across a wide range of sectors; and
- can be illustrated by innovative practices developed in Canada and/or abroad.

Improving efficiency is a common thread in the thematic areas. Many of the ICT-based opportunities discussed achieve their benefits through eliminating losses, such as wasted electricity in buildings, gasoline in transport, and water in distribution pipes. An example of the losses that can occur from generation to use is illustrated in Figure 4.1, which shows the cycle of energy sources in Canada from primary extraction to end use. This figure shows not only where energy ends up being used, but also that a significant amount of energy is lost along the way. While much of this lost energy is inherent in the energy conversion process and cannot be prevented, some is lost through inefficiencies that could be reduced (National Advisory Panel on Sustainable Energy Science and Technology, 2006).

The importance of systemic and behavioural changes is also highlighted in the discussion of each thematic area, as these changes may prove to have the greatest long-term impact.

For each thematic area, the Panel discusses the impetus for implementing ICT solutions in that area: the sustainability drivers (e.g., GHG emissions); some opportunities where ICT may have positive impacts in terms of sustainability, including examples of Canadian and/or international promising practices; and, briefly, some of the challenges that could hinder the adoption of the ICT opportunities for sustainability. The list of challenges is not meant to be comprehensive for each thematic area, but rather serves to highlight some of the most important challenges for the ICT opportunities discussed. When available, quantitative data, such as the amount of GHG emissions or quantity of water use, are provided. The lack of data in many cases highlights the need for targeted environmental monitoring.

In most industries or sectors, the maturation of technology usually includes five stages (see Box 4.2). Although these were not explicitly used in the analysis of opportunities, the Panel recognizes these stages could prove a useful tool for identifying the future developments expected for technology in a given field.



Adapted from a figure published in the Report of the National Advisory Panel on Sustainable Energy Science and Technology 2006, with permission from the Office of Energy Research and Development, Natural Resources Canada

Figure 4.1

Canadian Energy Flows, 2003

Energy is produced in Canada through a variety of sources and is used in several different ways. Much of this energy is lost, however, and while some loses are inherent in the energy conversion processes, others are the result of inefficiencies and are preventable. Energy values listed are in exajoules.

Box 4.2
Journey of Maturation of Technologies

The journey of maturation of technologies typically includes five stages. The ICT-enabled opportunities discussed under each thematic area are at different stages in this maturation process. These stages are:

- instrumentation and field data capture;
- data management and integration;
- intelligent alerts and event management;
- advanced analysis and forecasting; and
- asset optimization.

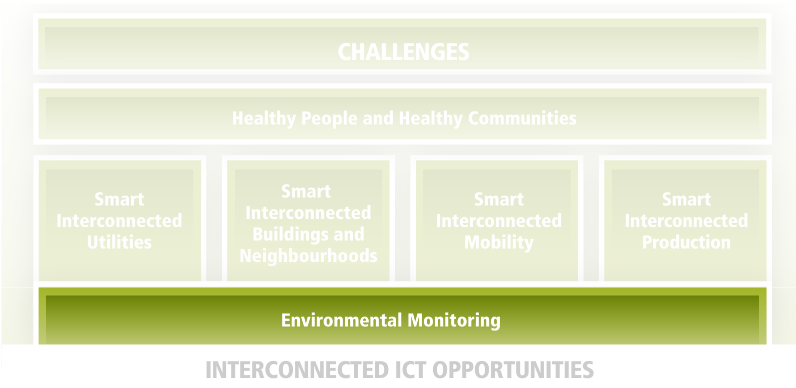
(IBM, 2011)

There are clear connections that link the six thematic areas:

- The targeted use of ICT in environmental monitoring can lead to greater understanding of the natural environment, providing the baseline information needed to monitor the effectiveness of any new environmental initiatives or to extract natural resources in a less environmentally damaging way.
- The infrastructure that delivers the services provided by these natural resources (e.g., electricity from hydropower or water for drinking) can be revolutionized by ICT, leading to smart interconnected utilities.
- These utilities, notably electricity, water, and gas, are used by people in the buildings where they live, work, and play. ICT applications can help achieve smart interconnected buildings and communities by giving buildings the intelligence needed to enhance the comfort of occupants while using utilities in more efficient ways, and by providing tools to increase efficiency and effectiveness by viewing these different buildings as part of a single network.
- Smart interconnected mobility supported by ICT allow people and goods to move around these neighbourhoods more economically and environmentally efficiently, whether they are moving across a city, between provinces, or from one coast to another.
- The goods moved on the mobility web can be made (or grown) more efficiently using smart interconnected production.
- And finally, the ICT applications that are most significant for sustainability, regardless of what they target (e.g., transport, energy, or buildings), also have clear social benefits that help support healthy people and healthy communities.

The Panel believes its focus on selected thematic areas is an informative, compelling, and relatable approach to identifying and discussing ICT-enabled opportunities. However, it recognizes there are other valid ways to present these kinds of opportunities. Although some sectors are not included explicitly in the discussion, this does not mean that there are no opportunities in these sectors.

4.1 ENVIRONMENTAL MONITORING



Environmental monitoring is defined by the United Nations (2003) as "an activity undertaken to provide specific information on the characteristics and functions of environmental and social variables in space and time." Modern-day environmental monitoring programs often use data collected from monitoring to develop (and improve) effective modelling and forecasting capabilities. Effective monitoring protects the safety of Canadians (by ensuring drinking water is safe, for example); provides baseline data on the current state of Canada's environment; and measures how the health of the environment is changing with time.

The Panel chose to discuss environmental monitoring first because it is fundamental to all subsequent opportunities. It is impossible to properly understand and measure the impact (good or bad) of human activity on the environment if there are no baseline data on its current state. Baseline data are needed to monitor how the environment changes over time, the impact of specific activities on different dimensions of the environment, and the effectiveness of applications intended to improve the health of the environment. Environmental monitoring data can also be used in many applications that have additional benefits. Notably, a more complete understanding of the natural environment can help improve the efficiency of resource extraction and minimize environmental impacts. Monitoring in the field of health and social indicators is equally important and relevant; however, the focus here is environmental monitoring.

A Day in the Life

Jurgen, Whitehorse

10:00 am (PST)

In Whitehorse, Jurgen surveys a 3D map of the power grid surrounding his factory. He has reviewed the materials sent to him by Deena, a smart grid manager in Vancouver, and prepared his own remarks for her visit in two days. Upgrading an environmental monitoring array to government specifications is neither cheap nor easy. The process cannot be executed in phases, and having the array offline is expensive. But the benefits of having sensors that can communicate directly with the government's own networks are important. Additionally, the fiscal advantages of having more current and precise environmental readings are significant. Although Jurgen's factory follows established best practices when it comes to the environment, no two ecosystems are identical and priorities shift over time.

Once the system is online, the government will have direct access to all data it collects. In return, Jurgen's firm will have access to information from the entire network in real time. As well as the tax benefits of being part of the network, the government and other manufacturers seem to agree that expanding interoperability is the main incentive. The penalties for environmental infractions are extreme, and are exacted both by the government and by consumers.

The five technical components introduced in Chapter 3 play an important role in environmental monitoring. Sensors provide the backbone of many ecosystem monitoring systems or can improve their efficiency. Telecommunication networks then allow these data to travel from the sensor to the location where they will be analyzed and shared widely. The data are often stored in the cloud, and processed there using virtualized programs. As one of the benefits of sensors is the potential to collect vast amounts of data, the cloud is especially needed to allow the data to be stored indefinitely. Applications and data analytics also ensure that all data collected are used to maximum benefit. Finally, in the context of environmental monitoring, end-user devices are needed to analyze data and can also act as sensors themselves, through crowdsourcing.

ICT can greatly improve environmental monitoring systems because they allow for collection of large quantities of data in a reasonable amount of time and at a reasonable cost. ICT currently play an important role in environmental monitoring in applications as varied as detection of contamination in water or air; tracking the movement of birds and wildlife; and monitoring climate (e.g., air pressure and wind).

4.1.1 Drivers for Environmental Monitoring in Canada

The Panel's difficulty in obtaining quantitative information on the environment for this report highlights gaps in the existence, or availability, of environmental data in Canada (these gaps have been noted by others, for instance see Hyde *et al.*, 2010). Accurate baseline information on the current health of the environment over time, as well as on emissions and use of utilities such as electricity and water, can have a variety of benefits. For instance, environmental monitoring can facilitate a variety of government responsibilities, including design of effective environmental programs, efficient allocation of resources, assessment of compliance with environmental regulations, and early identification of problems (Office of the Auditor General of Canada, 2011). Environmental data can also complement or aid scientific research and city planning, and be used by public health officials. Many of these functions can also be beneficial for individuals and businesses.

Environmental monitoring data can be used by actors other than the group (e.g., government) that collected them. Weather is an example. Although collected by the federal government, the data are widely used by individuals and businesses. The data are collected by one of Canada's weather-monitoring networks and, in combination with modelling, are used by numerous outside organizations for the daily weather forecast. Climate data are also used by all three orders of government for long-term planning, by providing information on the potential environmental risks in a region. For instance, historical data on rainfall, in combination with modelling, are essential for establishing regulations on flood protection (Environment Canada, 2013b). ICT also play an important role in high-precision weather forecasting, which can be used in predicting weather patterns, and therefore help in planning and mitigation of the impact of extreme weather events (e.g., above average rainfall) (Mauree, 2011). The importance of ICT in weather forecasting is demonstrated by their use in the World Weather Watch system, as described in Box 4.3.

Monitoring data can also be used in applications that help protect human health. For instance, air quality sensors can collect the information needed to declare smog advisories. The Ontario Ministry of Environment uses its Air Quality Index Network of 40 monitoring sites to collect hourly data on the concentration of several air pollutants (Ministry of the Environment, 2011). When these concentrations exceed a certain level in a given city, the local government issues a smog advisory to alert citizens to the poor air quality (City of Toronto, n.d.). Air quality data can also be combined with health data to detect trends and develop effective programs (see Box 4.11).

Box 4.3

Core System Components of The World Meteorological Organization's World Weather Watch*

- **Global Observing System:** provides observations on the atmosphere and ocean surface from all over the globe.
- **Global Telecommunication System:** allows for the exchange of meteorological data between national services in real time.
- **Global Data Processing and Forecasting System:** provides meteorological analyses, forecasts, and warnings that are generated by a network of World Meteorological Centres and Regional Meteorological Centres.

(Mauree, 2011)

** For more information, see World Meteorological Organization, n.d.*

Another important driver for obtaining better data on the environment through monitoring is the value of natural ecosystems themselves. This is especially true in Canada as it is home to many natural ecosystems (e.g., freshwater lakes, boreal forest), and natural resources play an important role in its economy. In fact, natural resource industries were responsible for 11.5 per cent of the country's GDP in 2010, and they directly employed over 760,000 people (Natural Resources Canada, 2011). The concept of ecosystem services can be used to represent the value given by the different ecosystems in a concrete and relatable way. Ecosystem services are defined by the Millennium Ecosystem Assessment (2005) as "the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling" (Millennium Ecosystem Assessment, 2005).

Although it is difficult to put a dollar value on many ecosystem services (e.g., aesthetic, cultural) estimates of the values that can be quantified are powerful illustrations of the value obtained from the different ecosystems. For instance, the Pembina Institute and the Canadian Boreal Initiative have calculated the total non-market ecological services of Canada's boreal forest at over $700 billion, most of which is the value of carbon storage in wetlands (Anielski & Wilson, 2009). Ecosystem services are also a useful reminder that the environment can often provide a service more cheaply (i.e., free) than if people were to carry out the task. For instance, maintaining or even restoring wetlands is often much cheaper than building a new water treatment plant, as wetlands provide natural water filtration (Anielski & Wilson, 2009).

Governments have recognized the importance and utility of valuing ecosystem services through the creation of the Economics of Ecosystems and Biodiversity (TEEB) initiative. The TEEB initiative evolved from a meeting of the environment ministers for the G8+5 countries in 2007, where the importance of understanding the negative economic impact of biodiversity loss and ecosystem degradation was recognized (TEEB, n.d.).

According to the Office of the Auditor General of Canada (2011), the federal government spends more than $500 million each year on environmental monitoring activities carried out by 2,500 people across Canada. The study identified 94 monitoring systems in total (individual systems or clusters of systems). Of these, 32 were related to plants and animals, 20 to air and atmosphere, and 19 to water.

In 2009 the National Round Table on the Environment and the Economy (NRTEE) noted a reduction in meteorological and ecosystem monitoring efforts in Canada over the last 15 years (NRTEE, 2009). Canada's North has been particularly affected, as the number of monitoring stations dropped markedly between 1994 and 2008. In addition, NRTEE noted that the region was already affected by inconsistent data collection methods and limited monitoring coverage in time and space before the reduction in monitoring stations (NRTEE, 2009).

The private sector also undertakes some environmental monitoring in Canada. For example, the Ecological Monitoring Committee for the Lower Athabasca (EMCLA) has supervised the implementation and operation of certain monitoring programs in the Lower Athabasca Planning Region since 2010 (EMCLA, n.d.). The EMCLA includes members from Environment Canada, Alberta Environment and Sustainable Resource Development, and private firms that are active in the Lower Athabasca oil sands. The organization seeks to improve monitoring quality to meet the requirements of selected biodiversity and wildlife sections of the *Environmental Protection and Enhancement Act* for development in the oil sands (EMCLA, n.d.).

Private-sector efforts cannot replace all public monitoring. Transparency in monitoring creates public trust of the data collected. The Alberta government has recognized this and has announced plans to establish a provincial, but arms-length, environmental monitoring agency that is open and transparent (Government of Alberta, 2013).

4.1.2 Opportunities

The Panel chose monitoring of natural ecosystems as the focus for its discussion of ICT-based opportunities. Due to space constraints, the report does not include the wide range of ICT-based opportunities associated with environmental monitoring, such as those that can increase the efficiency and accuracy via self-reports from private-sector firms. The links between monitoring and sustainability are clear:

- Many of the applications discussed in this chapter require a knowledge of the current state of the environment, which can only be obtained through baseline environmental monitoring.
- The environmental impact (positive or negative) of an application cannot be assessed without a baseline knowledge of the current state of the environment.
- An understanding of how the environment is changing with time will allow for better planning to both deal with and mitigate any changes.

Monitoring of Natural Ecosystems

Monitoring of natural ecosystems can establish baseline data and determine how the environment is changing with time (positively or negatively). It can be divided into four environmental components: air, land, biodiversity, and water. ICT have the potential to improve monitoring in each component: for example, monitoring the level of air pollutants such as sulphur oxides (SOx) and nitrogen oxides (NOx), detecting pollutants in soil, tracking the movement and numbers of animal species in a region, and detecting pathogens or nutrient contamination in surface-water sources.

According to the Office of the Auditor General of Canada (2011), all successful monitoring systems, independently of what is being monitored, share certain features that represent good practices: design, implementation, data collection, quality control, synthesis and analysis of the data, internal and external reporting and communication, and audit and review of the system. Many types of ICT play a role in each of these features: mapping tools used to design a program, sensors that collect the data, the cloud where the data are stored, the analytics that analyze the data, and the applications for quality control. The credibility of a monitoring system, and the decisions made based on the data it produces, is enhanced by the transparency that ICT can provide.

ICT can facilitate sharing of environmental monitoring data between organizations (e.g., government departments) and make them widely available online to the public. Data sharing can have multiple benefits:

- allows others to use the data in new and innovative ways to achieve additional benefits;
- allows the data to be combined with other data sets to elucidate other information and trends; and

- aids the credibility and reputation of monitoring by allowing anyone to access the data collected.

The Alberta Environmental Monitoring Working Group identified credibility as especially important given the role of resource development in the provincial economy and the rapid growth that has occurred in many communities (AEMWG, 2012). The importance of sharing data was recognized in a recent collaboration between the federal and Alberta governments to develop a world-class monitoring system for the oil sands region. The system will include monitoring of air quality, water quality, water quantity, aquatic ecosystems, terrestrial biodiversity, and habitat, and will also address cumulative effects (The Standing Senate Committee on Energy, 2012). All data collected will be made public and peer-reviewed periodically.

Effective monitoring systems also have distinct economic benefits. For instance, they can reduce environmental management costs through early detection of problems, help governments effectively allocate their resources to the areas that need them most, and aid in the enforcement of government environmental regulations by quickly detecting instances of non-compliance (Office of the Auditor General of Canada, 2011). Additionally, with applications such as major weather event forecasting, sensors can provide increased security and resilience to individuals and communities. For example, they can track the structural integrity of flood protection structures such as levees and dams to predict imminent disaster (Stuijt, 2003) and provide real-time information during an extreme weather event (Mauree, 2011). Scientists have stated that groundwater data from National Aeronautics and Space Administration (NASA) satellites could have been used to predict the large-scale flooding that occurred in Alberta in 2013, which would have given governments more time to prepare for the disaster (Semeniuk, 2013).

A Day in the Life

Quinn, Regina

3:00 pm (CST)

Quinn rushes to the washroom between lectures at the University of Regina. On his way out, Quinn notices that one of the taps is leaking. He opens the university maintenance app on his phone and waves the device near the broken sink. His phone reads the near-field communication (NFC) ID of the sink and automatically composes a message to the school’s custodial staff. Later, Quinn realizes that the citizen science initiative he was learning about earlier might benefit from NFC-based hardware IDs like the ones used by his school.

Economic possibilities can be derived directly from the data produced by remote sensors collecting environmental data. For example, the U.S. Geological Survey concluded that the value of information on groundwater quality in northeastern Iowa produced by remote sensing was approximately US$858 million in 2010 (Forney *et al.*, 2012).

Box 4.4
Monitoring in Natural Resource Extraction

ICT can improve the environmental performance of resource extraction and monitor its impact on the environment through applications that provide baseline data. Baseline data must be collected before resource extraction begins so as to measure its future impacts and ensure that firms comply with environmental protection regulations. They are also needed to fully understand the resource so as to extract it as efficiently as possible.

One example comes from the oil and gas industry, where adopting carbon dioxide-enhanced oil-recovery (or CO_2-EOR) technology can potentially mitigate GHG emissions. The technology has been implemented in the IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project, which has been active since 2000 in Saskatchewan. Flooding the oil reservoir with CO_2 is expected to extend the life of the field by some 25 years, while, at the same time, storing the CO_2 underground will significantly reduce the amount of CO_2 in the atmosphere. For example, the projected CO_2 stored by the end of the life of the Weyburn oil field is about 30-plus million tonnes, equivalent to removing over six million cars from the road for a year (PTRC, 2013). In terms of its relationship to ICT, the IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project has provided an extended research and monitoring data set that is unique in the world, and can provide the basis for future research into the CO_2-EOR technology (Hitchon, 2012). An analysis by the Pembina Institute found that if oil extracted through this technology were to displace all other types of crude oil, there would be a net benefit for GHG emissions (Wong *et al.*, 2013). The study also found, however, that the technology's impact on GHG emissions varied greatly by project and the ratio of CO_2 injected per barrel of crude oil produced.

Opportunities also exist for people to become sensors themselves by using ICT to provide information on the environment around them. For example, the SEMA (Sensors, Empowerment, and Accountability) Human Sensor Web in Tanzania combines geographic and web applications (like Google Maps), new media, and people, who with their mobile phones become the human sensors

(NWO, 2013). Using their phones, citizens identify when water service (i.e., quality or quantity) is below standard. These complaints are then publicly visible on the application until the problem has been solved. The information can be used by communities to spread information about water quality, advocate for improvements, and, in some cases, identify the source of problems (by comparing the data to the time of power failures, for example) (NWO, 2013).

The program developers found regional hurdles to adoption of the application. For instance, the initial answer module for the application did not match the communication style of the region. Users preferred to write long answers rather than select one-word answers, such as yes or no. The developers identified an understanding of "which aspects of communication are crucial and why, between humans and the application, between the web and the supplier" as a key contextual feature in an application's success (NWO, 2013).

As mentioned above, ICT-enabled opportunities in environmental monitoring extend beyond monitoring of natural ecosystems. Box 4.4 highlights an example of how ICT could reduce the environmental impact of resource extraction through environmental monitoring.

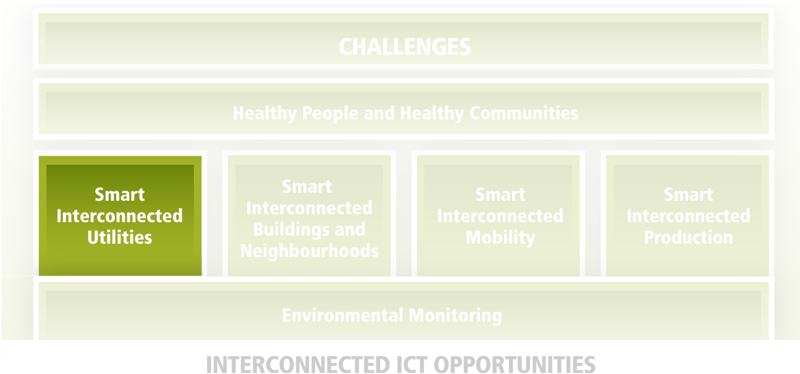
4.1.3 Challenges

To achieve effective environmental monitoring in Canada, several hurdles need to be overcome. The most important challenges relate to achieving maximum benefit from the data collected. Closed data sets and data that cannot be read or understood by others because of a lack of standards limit the potential benefits of the information collected. Other challenges are associated with the implementation of the necessary sensor networks and corresponding infrastructure, such as the costs involved and who pays for the infrastructure; and the availability of workers with the appropriate skills to deal with the large amount of data produced (e.g., analytics).

4.1.4 Summary

Effective monitoring protects the safety of Canadians, measures how the health of the environment is changing, and provides baseline data on the current state of Canada's environment. ICT can greatly improve environmental monitoring systems because they allow for collection of large quantities of data in a reasonable amount of time and at a reasonable cost. They are also important in applications as varied as detection of contamination in water or air, tracking the movement of birds and wildlife, and monitoring climate. ICT-enabled opportunities can enhance monitoring of natural ecosystems and improve the environmental performance of resource extraction. Anywhere-anytime smart sensing, monitoring, and analytics can transform the ability to make decisions on the basis of high-quality data and evidence, allowing Canadians to confront crises arising from extreme natural and social events and address the resulting environmental and natural resource issues. Accurate monitoring data, such as baseline data, electricity use in a building, or number of vehicles on a highway, and the sensors that collect these data, provide the basis for many of the opportunities discussed in the following sections.

4.2 SMART INTERCONNECTED UTILITIES



Electricity and water are delivered to end users through a network of unique physical assets, known as a grid. The grid includes generation plants, transmission and distribution lines, pipelines and pumping stations, towers and wires, and control equipment specific to each service. The grid is part of society's hard critical infrastructure, and ICT can play a role in making this infrastructure more reliable and efficient.

The Panel chose to focus on the delivery of these services, as opposed to their generation. ICT have great potential to improve the infrastructure that delivers and, in some cases, disposes of electricity, drinking water, wastewater, sewage, and natural gas. In addition, the Panel focused on components of electricity because of its importance for Canada's environmental performance and the smart grid's potential to fundamentally change how electricity is delivered. Smart grid applications can be employed for other utility flows, and examples are highlighted in the next section.

Historically, the *soft* infrastructure, which uses ICT, has played a supporting role in each utility network. However, low-cost and widely deployed ICT, combined with the power of data analytics, allows ICT to be an integral part of sustainable management and operations of important utilities through informing better decisions by individuals, businesses, utility providers and regulators, and governments. A smart grid uses ICT to empower utility users and providers based on instantaneous, two-way, and interactive communication across supply and demand networks. ICT can offer an affordable solution to modernizing utilities, promoting sustainable management, and delivering economic value and environmental performance for individual well-being through safe, reliable, and efficient services.

4.2.1 Drivers for Smart Interconnected Utilities in Canada

Many factors are simultaneously driving the need to improve the delivery capabilities of utilities in Canada. These include growing usage demands, and infrastructure, resource, and budget concerns, along with the complementary desire of various actors in terms of sustainability.

Traditional grids in Canada are under pressure with aging infrastructure that is, in some cases, deteriorating and inefficient. Additionally, Canada still uses coal, which has more than 20 times the GHG intensity of the average of all other electricity sources, to generate electricity (approximately 12 per cent of electricity generation in 2011) (Weis *et al.*, 2012; IEA, 2013). Pollutants found in coal emissions, such as nitrogen dioxide (NO_2) and harmful particulate matter, are also observed to have direct health impacts on human respiratory, cardiovascular, and nervous systems (Lockwood *et al.*, 2009). With emerging pollution awareness, monitoring capabilities, and sustainability demands, emissions from electricity generation are expected to decrease from 90 $MtCO_2e$ per year in 2011 to 82 $MtCO_2e$ per year in 2020. However, electricity generation itself is forecasted to increase from 545 terawatt hours in 2011 to 609 terawatt hours in 2020 (Environment Canada, 2013c).

Canadian water grids deal with more withdrawals than in many other industrialized nations (Conference Board of Canada, 2013b). However, water infrastructure development and maintenance have not been a priority since the 1970s, leaving much of the infrastructure nearing the end of its useful life (Keizer *et al.*, 2011). A significant amount of that water (an estimated 13 per cent) withdrawn by Canadian municipalities is lost before it reaches final users (e.g., through leakage), and is typically only discovered after damage has occurred (Renzetti & Dupont, 2013).

With growing resource supply concerns, emerging environmental policies, and public demands for efficient, sustainable sources, the appeal of renewable electricity and sustainable use of water is growing in Canada and around the world (for example, see Box 4.5). Canada is the world's third-largest hydropower producer and in 2011 Canada produced 342 terawatt hours of its electricity through hydropower (63 per cent of total generation) (Environment Canada, 2013c; Natural Resources Canada, 2013). Canada also holds significant non-hydro capacity, and is the ninth-largest producer of wind energy in the world (The Canadian Chamber of Commerce, 2013). In 2011 alone over 1,200 megawatts of wind energy capacity was added to grids across Canada and it is expected that projects built across Canada from 2013 to 2018 will generate over 6,000 megawatts from wind energy (The Canadian Chamber of Commerce, 2013). Biomass, solar, and geothermal capacity is also expected to increase, with 5,400 megawatts projected to be added by 2035, which would lead to those sources accounting for six per cent of generation (NEB, 2011).

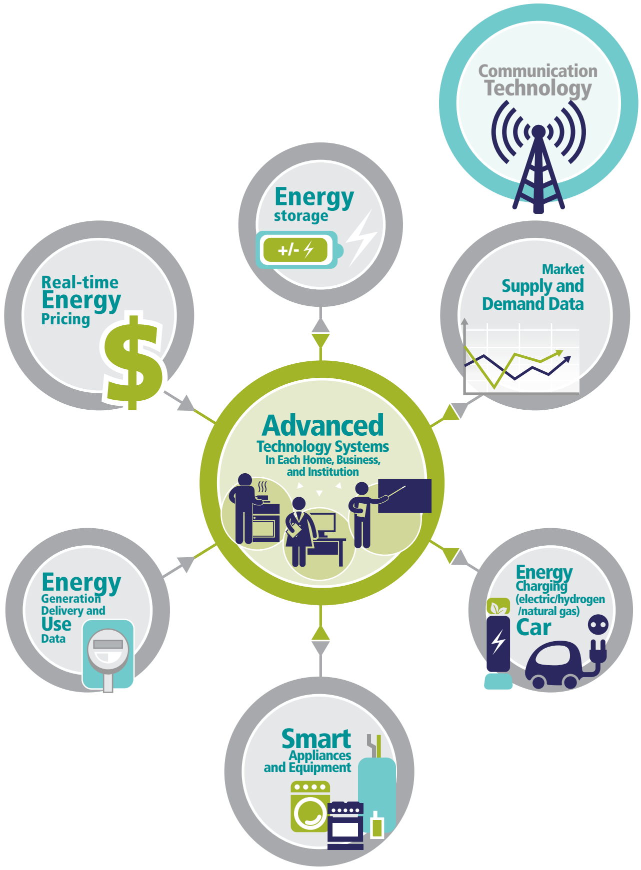
Box 4.5
Wastewater is a Resource

It is generally accepted that wastewater contains more than 10 times the energy required to treat it (e.g., Sizas & Bagley, 2004). Therefore, this value can be harvested rather than disposed of, and Canadian firms are responding to leverage that value. For example, Lystek International Inc., Ostara Nutrient Recovery Technologies Inc., Anaergia Inc., and Plasco Energy Group Inc. are developing enhanced methods to treat and reuse waste and wastewater for commercial services. The City of Guelph's Wastewater Treatment Plant has installed upgrades that will allow the city to produce approximately four gigawatt hours annually (enough energy to power over 450 homes) using co-generation. This will save $300,000 in electrical costs while also offsetting 3,500 tonnes of GHG emissions per year (FLOW *et al.*, 2008).

Meeting the demand for safety, reliability, and efficiency using old infrastructure poses capital, maintenance, and human resource constraints. According to Conference Board of Canada estimates, the Canadian electricity sector is expected to invest an average of about $15 billion per year from 2010 to 2030 to deal with growth and maintain existing infrastructure (Baker *et al.*, 2011). This size of investment is greater than past levels. The Conference Board also notes that in recent years two-thirds of capital investments have been used to either replace or repower electricity generating stations (Baker *et al.*, 2011). The Federation of Canadian Municipalities estimates that $31 billion is needed to eliminate the existing municipal water and wastewater infrastructure deficit (Mirza, 2007), noting that many First Nations communities are the most vulnerable to water insecurity (FLOW *et al.*, 2008).

4.2.2 Opportunities

Traditional grids, initially developed at a time when one-way communication was the norm, can hold valuable data that are currently inaccessible because they are stored locally and were not collected and stored in an organized fashion.



Reproduced with permission from the Waterloo Institute for Sustainable Energy, 2012

Figure 4.2

Components of Smart Energy Networks

In smart energy networks, ICT provide the means to gather diverse information from a variety of sources that were previously not linked, such as data from vehicles and appliances, and real-time information on energy pricing. Linking these data can promote better decision-making to manage energy usage as efficiently as possible.

ICT can enable two-way communication monitoring and demand management, asset optimization, and the integration of new, cleaner forms of generation and storage to serve the grid. Additionally, information sharing through ICT provides the ability to empower utility providers and users by bridging the gap between them. While much of the literature around smart grid technologies focuses on electricity infrastructure, many of these technologies can also be applied in varying capacities to other sectors, including water.

The deployment of ICT systems and applications outlined in Chapter 3, such as placing sensors across pipelines, using cloud-based networks, and applying data analytics tools, promotes smart energy networks (see Figure 4.2). Sensors and data analysis applications sharing information through two-way data-communication networks can facilitate smart monitoring across utilities, commonly known as advanced metering infrastructure. These tools also allow for demand response management, data analysis to inform control applications so as to best manage resource loads (e.g., through dynamic pricing models). Applications can enhance utility distribution systems by allowing them to monitor and control the distribution network in real time, improving service reliability and quality. Additionally, the ubiquitous deployment of ICT can permit the integration of distributed generation and storage, reducing the need for extended transmission lines; better connect local generation to local load requirements; facilitate the integration of renewable generation sources; and enable energy trading between utility companies.

Advanced Metering Infrastructure

Advanced metering infrastructure uses the data communicated through analytics software between providers, users, and numerous places along the utility supply chain to establish more effective flow management. For instance, smart meters can record and display flow consumption over defined intervals and communicate this information back to the utility company and end consumer. They also provide reliable information to grid monitors for detection of leakage or theft. BC Hydro has used theft detection as part of its business case for smart meters, pointing out that the yearly cost of electricity theft in that province amounts to approximately $100 million and is enough power to supply 77,000 homes (BC Hydro, n.d.). Information shared via smart meters allows utility providers to detect electricity theft and tampering more accurately and quickly, which delivers tangible financial benefits to the utility while reducing the cost burden on legitimate utility customers (BC Hydro, n.d.). Smart meters, along with other sensors across flow lines, carry numerous benefits for utility managers and users in understanding and adequately forecasting resource usage.

Demand Response Management

Sensors deployed across resource infrastructure networks feed information to utility providers and consumers. Utility providers can use this information to develop stronger models for forecasting flow usage, which can help systems to better manage user demand. This process is known as demand side management or demand response management (DRM). Utility providers can use DRM to develop incentives for consumers to reduce or shift their usage to alleviate peak load periods, promoting supply security and saving resources (The Canadian Chamber of Commerce, 2013). For example, the Canada Electricity Association estimates that DRM could save 17,000 megawatts of electricity usage across Canada by 2025 (CEA, 2008). On the user end, evidence shows that time-of-use rates enabled by frequent and accessible data communication through smart meters can reduce electricity and water utility demands and nudge users towards more sustainable behaviour (Power, 2008; SmartGrid Canada, 2012).

Large commercial and industrial consumers take even greater advantage of DRM programs. For example, some U.S. states place large industry and commercial consumers on dynamic rates by default, as they typically have the resources to shift power use to off-peak periods (Barbose *et al.*, 2005; Chopra, 2011). As a result of these dynamic rates, over 80 per cent of all peak reductions in 2009 came from commercial and industrial consumers (Chopra, 2011; Federal Energy Regulatory Commission, 2011).

Dynamic pricing of resources and access to information through ICT tools like smart meters help users move from passive payers to active participants in their utility use. Load forecasting allows utilities to understand the realities of user demand rather than remaining in an inefficient state of maximum load expectations. Understanding demand realities can give utility providers a better view of how to sustainably manage their infrastructure in a way that increases reliability for consumers.

Benefits of Two-Way Communication

Two-way communication through smart metering infrastructure not only enables consumer participation in the resource management chain, but may also, through transparency and DRM programs, provide the stimulus to induce behavioural changes in consumption patterns. Smart meters are an important element of the modern smart grid and enablers of DRM programs, which can further allow consumers to use ICT applications to develop cost-effective solutions that match their lifestyles (Chopra, 2011). Furthermore, ICT deployment across the grid provides major benefits by helping utility providers better understand users. Providing operators with situational awareness about the grid promotes workforce efficiency and safety, particularly in fault isolation, which can serve to more effectively reduce outage times and other reliability concerns.

The flow of information related to electricity use can extend outside the utilities sectors to fuel sustainable development in other sectors, through energy mapping for example. Accessing this information can expand its linkages to numerous other sectors that use electricity to develop nuanced solutions for effective and sustainable use of resources.

Promising Practice

Knowledge Sharing in Smart Grid Projects

The European Commission Joint Research Centre for Energy and Transportation hosts a smart grid, and the Energy Security Division is involved in data analytics, mapping, and simulation of various load and supply technologies. With these tools, they were able to analyze 400 EU smart grid projects and gather data to compare all countries on investment and performance in smart grid technology from 2005 onward. They are now modelling the European power distribution system, starting with Austria, and have a detailed geological and electrical map. The model will be used to determine if storage technology is better positioned on the distribution or transmission grid, when, and for what type of cycle.

(T. Rand, personal communication, 2013)

Enhancing Grid Reliability

ICT applications use real-time sensor data to inform decisions and improve service reliability and quality. Sensors along the grid communicating back and forth with utility managers serve as a tool for mobile incident detection. Operators can analyze the continually polled sensors to discover damage along distribution lines, such as electrical issues or fluid leaks, and dispatch repair services more efficiently. This also enables the utility to effectively communicate outage information to its consumers through automatic messaging using cell phones. Consumers are made aware of the outage, the fact that restoration is being pursued, and estimated restoration times (Ontario Smart Grid Forum, 2010).

Incident and interruption awareness delivered through sensors and analytic applications can yield workforce and economic benefits. For example, the American Public Power Association reports about 1,000 deaths and 7,000 burns every year among workers in the electricity utility industry (NETL, 2010). Through the use of mobile communications and GPS, service crews can better understand an incident, receive up-to-the minute updates, and therefore more effectively and safely resolve an issue (Ontario Smart Grid Forum, 2010). Interruptions also carry financial impacts, due to lost productivity, damaged goods or data, and customer reimbursements. For example, a 1998 report prepared for the U.S. Department of Energy estimates that the economic loss by industrial sector in the United States due to electrical interruptions is US$150 billion per year (Swaminathan & Sen, 1998). The Perfect Power Institute estimates that these interruptions cost each household US$400 per year, and that smart grid investments that improve reliability and power quality would provide $75 billion in indirect savings to consumers (Kelly *et al.*, 2012). Major incidents such as the Northeast Blackout of 2003, which forced the shutdown of 508 generating units at 256 power plants and affected 55 million people in the United States and Canada, are increasingly rare because advances in grid automation at the transmission and distribution levels help increase reliability and reduce losses (U.S.–Canada Power System Outage Task Force, 2004; CEA, 2011).

Other ICT-enabled innovations can help improve grid reliability, a trait that will become more important in the face of climate change and increasingly unpredictable weather. Events like Hurricane Sandy demonstrate the risks associated with electricity infrastructure having too many single points of failure (Magill, 2013). Reliability can be enhanced through the use of ICT to loosely couple many independent microgrids through the existing grid (Ragaini & Oudalov, 2012). While microgrids are typically connected to a larger electricity system from which they can buy or sell electricity (Ontario Smart Grid Forum, 2010), they are designed to be self-sufficient even if disconnected from the larger system (Hiscock & Beauvais, 2012). Thus, even in cases where the traditional grid is down, electricity will remain on for those buildings linked to a microgrid (e.g., essential services such as hospitals). Microgrids could help cities adapt to the effects of climate change by preventing widespread blackouts during extreme weather events. There are currently over 260 microgrid projects planned or operational in the United States (Magill, 2013).

Established in 2010 with $4.6 million, the NSERC Smart Microgrid Network is a major five-year project consisting of academic, government, and industry partners aiming to develop, test, and verify the technologies and regulations required to harness the smart microgrid (Hiscock & Beauvais, 2012).

Distributed Generation and Storage

The transmission of data, facilitated by ICT, is one of the keys to the practical integration of small-scale or alternative utility-generation networks, such as renewable electricity and water treatment plants. By leveraging the combined potential of numerous small sources together, local generation can be better connected to local load requirements. For example, the smart grid can help stabilize the incorporation of intermittent renewable electricity sources into the current transmission system by monitoring and analyzing relevant interconnectivity data (The Canadian Chamber of Commerce, 2013).

A Day in the Life

Deena & Ray, Vancouver

3:00 pm (PST)

The computers in Deena and Ray's office building monitor the ambient light and the rate at which the solar panels are collecting energy. As predicted, it is overcast late in the day, and although the panels rotate to face the sun and continue to produce some electricity, it is not sufficient to meet the needs of the building. To offset this, the electrical grid begins to draw energy from car batteries parked in nearby structures, using it to make up for the temporary deficit. The amount of energy drawn from each vehicle is determined by the owner's itinerary for the week. The owner is automatically reimbursed at the current rate per watt-hour, and is notified in case they want to limit the amount of energy drawn.

This technology has enabled the Ontario Feed-in Tariff (FIT) program, which allows for individuals and businesses to generate and sell renewable energy to the province at a guaranteed price for a fixed term (Ontario Ministry of Energy, 2012a). According to the Ontario Ministry of Energy, in two years (from 2009 to 2011), FIT had attracted over $27 billion in investments from the private sector and created more than 20,000 jobs; it is projected to create a total of 50,000 jobs (Ontario Ministry of Energy, 2012b).

In addition to integrating renewables, ICT can also enable the electricity sector to more effectively store energy resources and for longer periods. This could have a profound impact, by allowing for electricity that is generated in non-peak periods to be stored days, weeks, or even months, until it is needed (Belanger & Rowlands, 2013). Energy storage is a particular concern in the emerging electric vehicle market (see Box 4.6). Given the intermittent flow of renewable electricity generation sources, effective storage methods are a major part of more effectively realizing the full potential of these vehicles. For example, flow batteries could provide power flexibility and efficiency features to meet different grid functions (Nathwani & Blackstock, 2012). Hydrogenics Corporation of Mississauga, Ontario, which won a three-year, $92 million contract in November 2012 (Government of Ontario, 2012), developed a Power-to-Gas system that converts surplus energy production from wind, solar, and nuclear sources to hydrogen for storage and transport through the existing natural gas infrastructure (Hydrogenics, 2012). While historically the price of energy storage technology was very high, the emerging renewable-driven market is decreasing these costs (Nathwani & Blackstock, 2012).

Box 4.6
Electrified Clean Transport in British Columbia

Residents of British Columbia are adopting electric vehicles at twice the rate of the Canadian average (Tsang, 2009). As areas of high adoption are predicted to have rates of adoption of 5 per cent in 2015 and 50 per cent in 2030, unconstrained electric vehicle charging could have dramatic effects on the aging grid by adding to the peak loads of already stressed infrastructure, increasing the risk of failures, and requiring mitigation planning (Tsang, 2009). However, local B.C. governments have adopted policies and practices that enable the inclusion of more electric vehicles, including by-laws for installation of charging stations in new single-family detached homes (since 2008) and 20 per cent of parking stalls in multi-unit residential buildings (since 2009) (City of Vancouver, 2012).

Advanced loading and pricing schemes enabled by smart grid advance metering infrastructure technology supports electric vehicles by allowing customers to charge at off-peak hours based on dynamic pricing and car use patterns, thus reducing the overall costs of the lifetime of an electric vehicle (CEA, 2008). Furthermore, bi-directional metering could allow electric car users to sell back stored power during peak hours. This concept, known as vehicle-to-grid, is currently being researched by Canadian institutions like British Columbia Institute of Technology (Moorhouse & Laufenberg, 2010). This bi-directional transmission can also allow energy to be put back into an individual's household (vehicle-to-home).

A Day in the Life

Deena, Vancouver

7:00 pm (PST)

Deena sits down to eat her dinner and examines the notifications displayed in the window in front of her. The house recommends that she improve her monthly energy efficiency by increasing the cooling set point slightly and reducing the water temperature. She accepts the first option, rejects the second, and dismisses the rest of her notifications. As she exits the interface, the window becomes transparent once more.

Other Utilities

Many of the ICT-enabled applications discussed throughout this section are also relevant to other types of utilities. For instance, ICT have an important role to play in moving towards a smarter water delivery system through multiple applications including those that help reduce water losses along the distribution network and in homes (e.g., Mauree, 2011; Smith *et al.*, 2012). Sensors throughout the water distribution network (e.g., in water pipes) allow utility providers to identify leaks and carry out repairs in near real time. Smart pipeline systems, where self-healing is triggered by sensors in pipes, have also been postulated (Mauree, 2011). This could lead to significant water savings; the World Bank estimates over 32 billion cubic metres of water are lost per year in water distribution networks worldwide (Kingdom *et al.*, 2006). Through more consistent monitoring of water networks using sensors, leaks can be detected and their locations identified more easily.

Smart meters can also alert consumers to anomalous water usage more quickly, which can lead to significant water reductions. Approximately 5 to 10 per cent of U.S. homes have water leaks that drip 90 gallons (~340 litres) a day or more (Oracle, 2010). Smart meters that allow consumers to see how much water they are using can reduce consumption by up to 10 per cent (Power, 2008). Additionally, the collection of accurate data on water usage through real-time monitoring opens the door for variable pricing and provides decision-makers with more accurate data on which to make decisions (e.g., through water mapping) (Canadian Urban Institute, n.d.). This data can also be used for water mapping, allowing water usage data to be linked to other sectors. Water mapping can, for example, be used to inform policies that targeted those people or industries that use the most water.

ICT can also be used to improve the environmental performance of oil pipelines by preventing leaks (see Box 4.7).

Box 4.7
ICT Applications to Other Types of Utilities: Oil Pipeline Leak Detection

Pipelines are a common method used to transport oil and gas from extraction sites to refineries and from refineries to market, as they can handle large volumes continuously without the use of trucks or trains. In Canada more than 100,000 kilometres of pipeline currently moves liquid petroleum or natural gas (Canadian Energy Pipeline Association, 2013). There are risks associated with pipelines as leaks can cause significant damage to natural ecosystems.

ICT have the potential to reduce the impact and frequency of pipeline leaks by detecting them immediately, or even before they occur. For instance, sensors placed at consistent intervals along a pipeline can wirelessly transmit information about its physical condition, detecting areas of fatigue before leaks occur (Canadian Energy Pipeline Association, 2013). A smart membrane wrapped outside the pipe can also detect leaking fluid and accurately determine its location. These tools would allow for monitoring the structural health of a pipeline remotely and continuously, and providing maintenance crews with information to help them more effectively target their work.

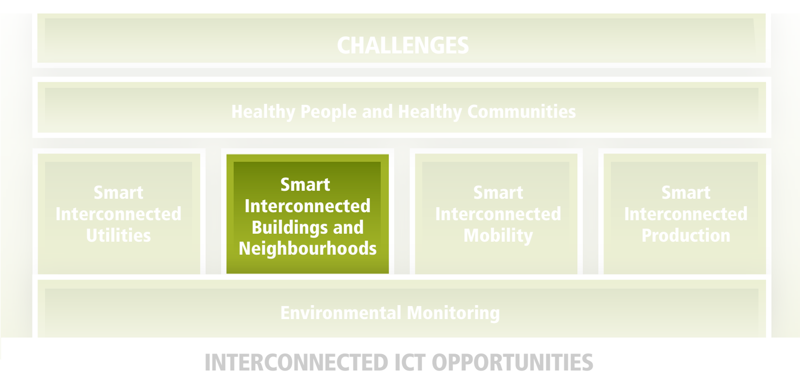
4.2.3 Challenges

There are several key technological challenges to achieving maximum benefit from smart interconnected utilities. These include technical challenges related to a lack of interoperability because of an absence of standardization or those related to gaining access to data. Privacy and security are also important issues of concern both for consumers and utility companies. Privacy concerns may prevent users from adopting smart grid applications, for example. Implementation costs will also be a challenge given the high cost of many smart utility applications. Aging infrastructure is certainly a driver for updating Canada's electricity, gas, and water delivery systems. However, in some cases, large investments that have already been made to keep these infrastructures operational could impede adoption of new technologies. Past investments that cannot be recovered, known as *sunk costs*, may prevent operators from making further investments, despite the benefits they would achieve. A further obstacle may be technological path dependency because it is difficult to implement an ICT application if it is a deviation from what is already known and understood. Additionally, there are serious risks associated with locking into an ineffective, or less effective, technology early on.

4.2.4 Summary

The delivery of utilities (e.g., electricity, water, and gas) is an essential part of Canadian life. The infrastructure that delivers these utilities, however, is often in need of repair and the sustainability benefits of updating the system would be significant. ICT can offer an affordable solution to modernizing grids through a wide variety of opportunities, including advanced metering infrastructure, DRM, distributed generation, and storage. Through these and other applications, ICT can enable sustainable utility management, empowering end-user choice, and delivering economic value and environmental performance for individual well-being through safe, reliable, and efficient services.

4.3 SMART INTERCONNECTED BUILDINGS AND NEIGHBOURHOODS



Buildings are an integral component of the physical framework of life. They provide places of shelter, centres for commercial activity, and, at times, platforms for artistic expression. With such wide use, it is not surprising that buildings account for a large share of total energy use. Whether individual homes, office buildings, or skyscrapers, buildings are where people use electricity and water every day. Buildings do not exist in isolation, and together they form neighbourhoods and communities. Understanding options to improve the environmental performance of buildings, and by extension neighbourhoods and communities, is one step towards sustainability.

4.3.1 Drivers for Smart Interconnected Buildings and Neighbourhoods in Canada

Buildings are the second-largest secondary energy [5] user in the Canadian economy when the consumption of buildings from the residential and commercial/institutional sectors are combined. Buildings in these sectors consumed 31 per cent of secondary energy in 2009, with residential and commercial/institutional accounting for 17 per cent and 14 per cent, respectively (Natural Resources Canada, 2012). Residential and commercial/institutional buildings also experienced high rates of growth in secondary energy use, increasing by 11 per cent and 37 per cent respectively between 1990 and 2009. The growth in the use of energy by commercial/institutional buildings was driven primarily by an increase of approximately 170 per cent in the energy use of auxiliary equipment. Auxiliary equipment includes devices that are plugged directly into electrical outlets, such as the ICT products that are now standard in most homes and businesses (e.g., computers). Given the large amount of energy used, it is no surprise that the commercial/institutional sector spends a large amount on energy for buildings ($24 billion in 2009) (Natural Resources Canada, 2012). The importance of ICT in the electricity consumption of buildings highlights the environmental and economic benefits that could be incurred through improving the environmental performance of ICT, as discussed in Chapter 3.

Population growth and a change in Canadian residential living contributed to an increase in residential energy use. Between 1990 and 2009, the number of Canadian households increased by 3.5 million (Natural Resources Canada, 2012). This increase, as well as increases in the square footage of living spaces, the penetration of appliances, and the number of people cooling their homes in the summer months, resulted in the 11 per cent increase in residential energy use.

5 NRCan (2012) defines secondary energy use as “the energy used by final consumers in various sectors of the economy.”

Buildings are the fourth-largest producer of GHG emissions in the economy (Environment Canada, 2013c). Over the period from 1990 to 2005, emissions from buildings in Canada rose from 70 to 84 $MtCO_2e$. However, from 2005 to 2011, emissions from buildings have remained stable. The lack of increase, despite the increase in total number of buildings, can be attributed to reductions in emissions from commercial/institutional buildings as a result of improved energy efficiency. It is estimated that 40 per cent of all floor space in Canada underwent some sort of energy retrofit between 2005 and 2009 (Environment Canada, 2013c).

Environment Canada estimates for Canada's GHG emissions from buildings in both the residential and commercial/institutional sectors are listed in Table 4.1. In the residential sector, it is anticipated that building emissions will rise slightly between 2005 and 2020, from 44 $MtCO_2e$ to 47 $MtCO_2e$ (Environment Canada, 2013c). The increase is small despite an anticipated increase of about three million homes over the same period. The increase in GHG emissions from buildings in the commercial sector is expected to be greater, from 39 $MtCO_2e$ in 2011 to 48 $MtCO_2e$ in 2020. The increase is expected as a result of expansion of commercial floor space in the coming years. The projected estimates to 2020 consider existing measures by governments, building code regulations, and incentives and rebates for energy-efficiency improvements (Environment Canada, 2013c).

Table 4.1

Greenhouse Gas Emissions from Buildings

	2005	2011	2020 (projected)
Residential			
Emissions ($MtCO_2e$)	44	45	47
Households (Millions)	12.7	13.9	15.6
Commercial			
Emissions ($MtCO_2e$)	39	39	48
Floor Space (Millions m^2)	654	727	884

Data Source: Environment Canada, 2013c

Even with the provision of government measures, these projections demonstrate that there is still a need, and an opportunity, to further decrease GHG emissions by 2020. Further, the electricity sector currently produces about 6 $MtCO_2e$ more than buildings (Environment Canada, 2013c). Yet, by 2020, the electricity sector is projected to produce 7 $MtCO_2e$ less. These statistics signal that alternative solutions are needed to reduce GHG emissions of buildings. ICT can play an important role in reducing GHG emissions from buildings; for instance, GeSI (2012) estimates that application of ICT in buildings could reduce GHG emissions by 26 $MtCO_2e$ annually by 2020, approximately one-third of total building emissions in 2010. The Institute for Prospective Technological Studies, an institute of the European Commission's Joint Research Centre, found the use of ICT in facility management alone could reduce CO_2 emissions from buildings by 3.5 to 6.3 per cent (Erdmann *et al.*, 2004).

Improvements in the energy efficiency of buildings have clear economic benefits in addition to environmental ones. For instance, improvements in the residential sector since 1990 resulted in energy savings worth $8.9 billion in 2009 (Natural Resources Canada, 2012). Over the period (1990 to 2009), the commercial sector also saved a significant amount of money ($3 billion) because of energy savings. Advances in both sectors included improvements to the thermal envelope and improved efficiency of energy-consuming items such as furnaces, appliances, lighting, and air conditioning (Natural Resources Canada, 2012). While these advances are not directly related to ICT, they demonstrate the large savings that can be obtained through improved energy efficiency.

Building improvements can also have social benefits for occupants. An intelligent building can assist organizations in fulfilling their mandates through management of resources, thereby contributing to organizational productivity and efficiency (Derek & Clements-Croome, 1997). These buildings can also adapt to human need and respond to both social and technological change.

4.3.2 Opportunities

Building life can be divided into four distinct phases: design, construction, operation, and renovation and/or demolition. The Panel chose to focus primarily on opportunities relating to the operation stage, with a brief discussion of the design and construction phases.

More Efficient Buildings: Design and Construction

The design of a building can have significant implications for its energy performance and emissions output. The Intergovernmental Panel on Climate Change (IPCC) estimates that sustainable building designs can reduce annual energy costs by 35 to 50 per cent, while GeSI predicts they can reduce total building emissions in Canada by 43 per cent (approximately 11.2 $MtCO_2e$ per year) (Levine *et al.*, 2007; GeSI, 2012). Creating a sustainable building design requires consideration of a host of factors including orientation, envelope, glazing area, and mechanical and electrical systems (Levine *et al.*, 2007). By using ICT such as simulation and modelling software, building designers can estimate the potential energy savings and emission reductions offered by different design models

(European Commission, 2009a). Further, these software and measurement tools can be used to determine the energy consumption patterns of existing structures, thereby identifying areas of inefficiency. If common areas of inefficiency are identified, best practice guidelines can be developed so as to improve building performance (GeSI, 2012).

In addition to designing individual building structures, ICT applications have been employed to inspire the design of complex urban systems. The increased use of these technologies is in response to rising demands for efficiency, reduced costs, and improvement in service delivery within the built environment (Larsen, 2003). Communications, analysis, and modelling tools that are currently used by local governments, for example, include geographic information systems (GIS), businesses intelligence systems, data warehouses, and electronic document interchanges (Andersen *et al.*, 1999 as referenced in Larsen, 2003).

Building information modelling applications could address challenges of data integration and interoperability by facilitating communication between software applications and collaboration of industry stakeholders. They allow for the capture of information across the entire life-cycle of the building (Isikdag *et al.*, 2007). Autodesk Revit is an example of a leading building information modelling software.

Promising Practice

Passive House Institute (Passivhaus Institut), Darmstadt, Germany

Currently, 30,000 homes around the world (without regular heating or cooling) conform to the Passivhaus design concepts and standards (Mead & Brylewski, 2013). Using a variety of planning aids, software, and tools, Passivhaus has developed a design standard that requires a building's annual specific heat demand load to be less than 15 kilowatt hours per square metre with particular detail paid to insulating to reduce heat loss and sealing leaks. The first Passivhaus residences were built in Darmstadt, Germany in 1991 and the standard has been promoted in Europe by the Passivhaus Institute (Mead & Brylewski, 2013).

Sustainable Building Operation

A variety of tools may enable sustainable operation of buildings. Notably, building management systems are technological systems that can control and monitor building services (Levermore, 2002). With the assistance of sensors, an energy manager can, although centrally located, remotely control a wide variety of building components, including temperature and lighting (Katipamula *et al.*, 1999). These systems can be operated either manually or automatically, and have the potential to conserve resources, reduce energy consumption, and monitor building occupancy (GeSI, 2012). Although there is evidence that building management systems reduce energy consumption overall, the estimates of exactly how much vary significantly. A review of the literature by the IPCC, for example, found that energy savings estimates range from 5 to 40 per cent (Levine *et al.*, 2007).

A Day in the Life

Jamal, Toronto

8:00 am (EST)

Jamal's phone sends a signal to his office when his car is approximately 15 minutes away. This is roughly when they pass the traffic light near Union Station (a historical sight; traffic hasn't been controlled by lights in years). When his office receives the location data, the climate control system (which shuts off to save energy when the room is vacant) activates so that the room will be at its occupant's preferred setting once they arrive.

Another important technology for building management is voltage reduction/optimization systems that control the voltage supplied to an appliance or installed equipment at an optimal level (GeSI, 2012). The technologies are designed to reduce energy demand and loss, in addition to offering electricity cost savings. GeSI estimates that voltage optimization can result in an emission reduction of 3.4 $MtCO_2e$ per year (GeSI, 2012).

User awareness tools can also reduce the environmental impact of buildings. Devices that provide end users with real-time information on their energy (or water) consumption can influence user behaviour and thereby improve building efficiency. The European Commission estimates that such devices could lower energy consumption by 5 to 15 per cent (European Commission, 2009a).

Furthermore, a smart building can accomplish things that are limited in a conventional building. On the supply side, a smart building can produce electricity for its own consumption (for example via photovoltaics), with any excess energy being fed into the grid, making the building a *prosumer* (i.e., both a provider and consumer) (European Commission, 2009a). Intelligent energy storage technologies can also be used to balance the energy supply from the smart grid. On the demand side, ICT can alert consumers of the current rate of energy use, giving them the opportunity to respond to price signals from the grid and to change their behaviour to reduce their energy costs.

A Day in the Life

Natasha, Calgary

9:00 am (MST)

As Natasha enters the lobby of the skyscraper where she works, she glances at the large display covering the rear wall. At the moment it is showing energy efficiency statistics for each department. The numbers are weighted to account for different energy needs and number of employees. She is pleased to see that her department is currently in the lead within the company — and that the company is a national leader in the industry. Although the scores are affected by many factors beyond anyone's individual control, Natasha has a competitive streak and monitors efficiency scores very closely.

Community Engagement Processes

Processes that facilitate the active inclusion and collaboration of individuals and groups towards a specific goal can also be used to achieve sustainability goals. In the smart built environment, ICT can be exploited in three distinct ways. First, they can be used as a mode of communication between a building and its occupants. Second, ICT can serve as a forum for participation in specific activities. Finally, ICT applications can be used to celebrate and incentivize positive sustainable behaviour among occupants. These ICT-enabled attributes of the built environment contribute to the creation and preservation of sustainable living communities.

Connected Neighbourhoods

A smarter building does not stop at the walls that surround it. Rather, built structures interact with, and are affected by, their surroundings. Buildings exist as components of complex infrastructural systems that interact at different scales. The built environment takes into consideration the web within which buildings exist. Hence, sub-optimizing sustainability at the building scale is a limiting endeavour.

Sustainability within the built environment can be better accomplished at the neighbourhood level (see Box 4.8). For instance, local energy generation and storage units can integrate various forms of renewable energy that are locally available. Excess energy generated can be returned to the grid and exchanged

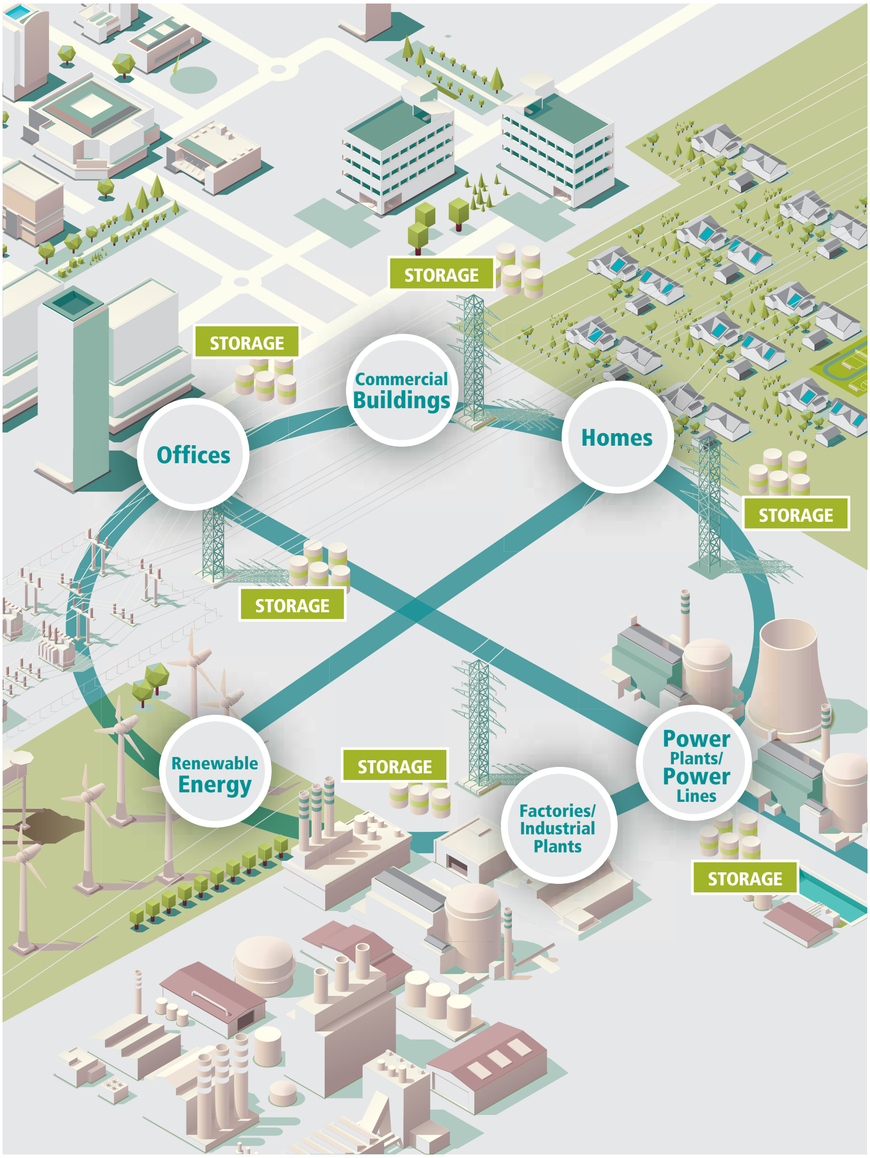


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Figure 4.3

Integrated Energy Storage and Generation Systems at the Neighbourhood Level

All the buildings in a neighbourhood can be linked through ICT. Furthermore, these buildings can be connected to integrated energy systems that allow electricity to be generated and stored locally.

with other buildings in the neighbourhood (European Commission, 2009a) (see Figure 4.3). Further, ICT applications can optimize the energy efficiency of buildings. These technologies include intelligent systems that can manage the energy demand of temperature-controlling devices as well as lighting and auxiliary equipment. ICT are not limited to individual buildings. Applications such as open interfaces to external utility services facilitate the trading of energy at the neighbourhood level (European Commission, 2009a).

A neighbourhood can consist of buildings, homes, commercial facilities, and factories, all of which have energy needs. In an integrated energy system, these structures are linked to one another as well as to the energy generation and storage systems. These links demonstrate that with ICT, buildings are no longer isolated, but rather serve as connection points within the flow of data and resources. The flow between buildings can be in the form of energy, data, water, resources, people, or goods. This interconnectivity can address key sustainability indicators such as better resource management, energy efficiency, and human well-being. There are many opportunities for buildings to play a bigger part in a smarter community: a system of systems that informs people of what they can do better, both inside the building and out.

Box 4.8
The City of Toronto's Tower Renewal Program

Between the 1950s and 1980s over 1,000 multi-unit residential buildings were constructed in the City of Toronto (City of Toronto, 2011). At the time, the buildings were constructed using concrete frames, a popular design concept for that period with little consideration for energy efficiency. With a collection of aging, overcrowded, and energy-inefficient buildings, the City launched the Tower Renewal Project. The aim was to transform Toronto's older apartment buildings to achieve a greener city, as well as social and economic benefits. After monitoring the success of initiatives at pilot sites in different locations around Toronto, a city-wide roll-out strategy was developed to be implemented from 2011 to 2030. The program consist of projects varying in size, some of which were based on ICT, including those that reduced electricity consumption (e.g., light sensors), as well as those that improved tenant safety (e.g., installing a digital key system for building entry). The results from pilot sites demonstrated that the initiatives with the best range of benefits were those that were the most comprehensive (City of Toronto, 2011).

Promising Practice
Smart Building Dimension of Sustainable Cities, Morgenstadt, Germany

Fraunhofer in Germany, Europe's largest organization focused on applied research, has undertaken a research initiative centred on the future city of Morgenstadt. The project focuses on what is needed to make a city carbon-neutral and climate-adapted and "people's needs in the fields of health, safety and security, communication, mobility, energy, and the environment" (Fraunhofer, 2012). Currently, 15 institutes are collaborating on interdisciplinary research projects on issues related to energy, logistics, mobility, buildings, and urban processes, among others.

A key approach to modernizing buildings is to use local energy sources like solar power to achieve maximum energy efficiency and, when possible, self-sufficiency in power. One element of the research program was the construction of the "efficiency house plus" in Berlin, which opened in December 2011 (Fraunhofer, 2012). The house features several innovations related to energy efficiency, including photovoltaic panels on the roof and walls. The energy produced is used in the house, with excess energy stored in batteries that are used to power electric vehicles. In March 2012 a family of four moved into the house, which has three bedrooms and two bathrooms (Detail Das Architekturportal, 2012).

Preliminary results on the energy consumption and generation from the house between March 2012 and February 2013 have been released (Erhorn *et al.*, 2013). Despite lower than average solar power yield during the year, the energy the house produced exceeded the energy needs of its occupants. The surplus produced was used to cover about 25 per cent of the energy needed for the family's electric cars. The energy consumption of the house was significantly higher (75 per cent) than anticipated, a discrepancy attributed to inefficiency in the heating system, higher than expected electricity consumption by appliances, and uncontrolled air from the outside in the ventilation system (Erhorn *et al.*, 2013).

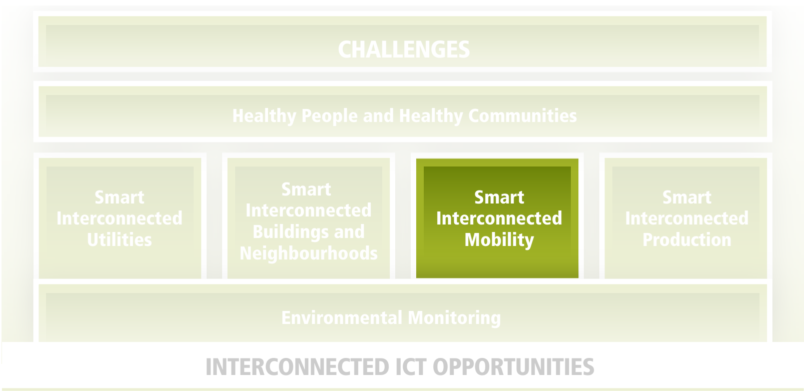
4.3.3 Challenges

Despite the potential benefits of a more intelligent built environment, a number of challenges hinder the realization of these opportunities. The disconnect between owner and occupant is specific to rented residential or commercial buildings. In some cases, although the owner makes the financial investment in an ICT application, the tenant reaps the rewards (e.g., lower bills because of reduced electricity consumption). Thus neither party has an incentive to adopt a given technology. Additionally, as with the utilities sectors, the sunk costs associated with buildings can be an obstacle to the implementation of new ICT applications, even though they may be economically beneficial.

4.3.4 Summary

Buildings are an integral component of the physical framework of the lives of Canadians, serving as centres for personal and commercial activities. In Canada, as in many parts of the developed world, living standards and daily activities are oriented towards a stock of buildings that are high consumers of energy and producers of GHG emissions. ICT can play an important role in improving the environmental performance of buildings and neighbourhoods. Opportunities exist to design a more efficient built environment and facilitate the sustainable operation of buildings. The interconnectivity of the built environment offers opportunities to address key sustainability indicators such as better resource management, energy efficiency, and human well-being both at the individual and community level.

4.4 SMART INTERCONNECTED MOBILITY



Whether by foot, bike, car, or bus, transport is essential to move people between their homes and places of work and play, and to move goods from where they are produced to where they will be used or consumed. Improving the efficiency of the mobility web and the links between its components can have a profound positive impact on Canada's sustainability.

> Transportation facilities consume resources that can be put to alternative uses (housing, recreation, etc.), and cars consume resources that can be put to alternative uses (chemicals, food, heating, etc.). Does anyone believe that anything more than small percentages of the resources committed in the name of the car are being put to their highest and best use?
>
> (Wellar, 1975)

Canada's large size, and varied terrain and climate, make moving and deploying people and goods a challenge. It has long been recognized that changes are needed if Canada is going to benefit from a transportation system that is truly environmentally, economically, and socially sustainable (e.g., Wellar, 1975). Since the transportation and logistics sectors are part of the same mobility system, they should be considered together in any examination of the opportunities provided by ICT.

4.4.1 Drivers for Smart Interconnected Mobility in Canada

Different forms of transportation, such as private road vehicles, public transit, rail, air, boat, bikes, and feet, are often considered separately. Smart interconnected mobility, however, considers all modes of transportation as part of the same mobility web regardless of what they are moving (i.e., people or goods). Integration of the components of the overall mobility web is one of the transformative opportunities of ICT.

Canada's vast, coast-to-coast transport web consists of paved and unpaved roads, rail, air, and water; as well as numerous logistics networks comprising distribution centres, warehouses, ports, multimodal fleets, handling and storage systems, and information and decision systems. These mobility networks are needed to allow people to move between their homes and other locations (e.g., for work or shopping) and to provide access to the goods they need and want. More than one million kilometres of two-lane equivalent roads across the country are shared by about 20 million light vehicles and 750,000 medium and heavy trucks (Transport Canada, 2012b). Many people in Canada also travel by air, with almost 80 million passengers passing through Canadian airports in 2011, and on rail, using more than 46,000 kilometres of Canadian rail tracks. Additionally, transportation-related infrastructure (including public transit, road and bridge construction and maintenance) is a significant expenditure for all orders of government (Transport Canada, 2012b).

Transport is an important part of the Canadian economy, with transportation services directly contributing 4.2 per cent of Canada's GDP (Transport Canada, 2012b). Transport is also significant for trade. The trucking industry transported 507 million tonnes of freight domestically and 85.1 million tonnes internationally in 2008, and 353.3 million tonnes of freight were moved on Canadian railways in 2007 (Transport Canada, 2012b, 2012a). Freight is responsible for 95 per cent of the roughly $10 billion generated by the rail sector yearly. Air is similarly important for moving goods, with 739 million tonnes of revenue cargo moved in 2010 (Transport Canada, 2012b).

Given the geography and distance between major urban cities in Canada, it is no surprise that the sector's environmental footprint is large. Emissions from transportation accounted for 170 $MtCO_2e$ in 2011, 24 per cent of Canada's total GHG emissions (higher than any other sector) (Environment Canada, 2013c). Of the 170 $MtCO_2e$, 56 per cent was from passenger transport (mostly personal vehicles), 36 per cent was from moving freight, and the remainder was from other vehicles (e.g., recreation). There are other environmental impacts, as well: for instance, transport is responsible for emitting several other air pollutants. Notably, mobile sources are responsible for over 50 per cent of all NOx emissions and, excluding natural sources, over 20 per cent of all volatile organic compounds (VOCs) (Environment Canada Pollutant Inventories and Reporting Division, 2014). The health impacts of transport-related emissions are large: Toronto's Medical Office of Health estimates that air pollution due to traffic causes 440 premature deaths and 1,700 hospitalizations per year in that city alone (McKeown, 2007).

Congestion on the roads is an important problem that can have significant negative social and economic impacts, in addition to environmental impacts. The OECD (2010b) estimates that traffic jams cost commuters in the City of Toronto $3.3 billion each year and the Texas A&M Transportation Institute has calculated that in the United States, road congestion resulted in people living in urban centres traveling an extra 5.5 billion hours, corresponding to the purchase of 2.9 billion gallons of gasoline and a total cost of $121 billion (Schrank *et al.*, 2012). Another economic driver may be the recent increases in the price of gasoline as individuals, businesses, and governments look to reduce their fuel-related costs. Canadians currently spend more on transportation energy than on energy from any other sector: $63 billion in 2009 (Natural Resources Canada, 2012).

4.4.2 Opportunities

Many of the significant applications for ICT in mobility can be grouped into five categories:

- changing vehicle operation;
- changing driver behaviour;
- improving travel networks;
- using smart interconnected logistics; and
- reducing the need for travel.

(extended list inspired by Kay *et al.*, 2010)

The five categories cover several dimensions of transport and logistics, and opportunities overlap in many cases. Although the impact of some of the opportunities discussed below may seem small, collectively the impact could be much greater. For instance, GeSI estimates that implementation of several smart transportation technologies could lead to a 55 $MtCO_2e$ reduction in GHG emissions from the transportation sector by 2020 (GeSI, 2012), which would be a more than 30 per cent reduction over 2011 transport emissions (Environment Canada, 2013c). Furthermore, as discussed above, the greatest potential of ICT may be in breaking down the artificial barriers that exist between transport and logistics, between the different types of transport, and between the transport of goods and people.

While no single technology is used for all ICT opportunities related to mobility, most of the applications in the five categories use the technical components discussed in Chapter 3. Many of these opportunities depend on fast and reliable networks to transmit the data collected by sensors, while virtualization allows for data to be stored and manipulated in the cloud. Finally, in many cases, the data collected are used more effectively through personal and professional applications that allow them to be presented in a clear and targeted way.

Changing Vehicle Operation

ICT can be used in a variety of ways to reduce the environmental impact of various types of vehicles, by improving their overall efficiency and ensuring that they run at maximum efficiency at all times. The impact of even simple features such as tire pressure monitors that send a message to a smartphone application when pressure is low can be significant. A U.K. survey found that 95 per cent of vehicles in that country had at least one tire that was underinflated (totallymotor.co.uk, 2008). Maintaining tires in optimal condition can reduce vehicle GHG emissions by up to three per cent (WWF Sweden, 2008).

A Day in the Life

Ray, Vancouver

4:00 pm (PST)

Most days, Deena's co-worker Ray shares his car with other people and makes his daily route to work available to his coworkers' trip-planning programs. Although cars are generally slower than transit, and are less energy efficient, some people still prefer them. Due to advances in battery technology, Ray is able to have his own vehicle without having to rely on fossil fuels.

From 1990 to 2009, significant improvements were made in fuel efficiency, with decreases of 19 per cent and 29 per cent for cars and buses/urban transit, respectively, in passenger transportation energy intensity (i.e., the energy needed to move one person over one kilometre) (Natural Resources Canada, 2012). While these improvements were not exclusively the result of ICT, applications such as semiconductor-based sensors and actuators in engines are responsible for some of the improvements (Laitner *et al.*, 2010). Current and proposed regulations will further improve overall fuel efficiency (Public Works and Government Services Canada, 2010; Environment Canada, 2012; Minister of Justice, 2013b). Improvements will come from making engine refinements in traditional gasoline-based vehicles, and also from increased offerings of alternative energy vehicles such as hybrids and fully electric vehicles. As mentioned in Section 4.2, ICT will be needed to fully integrate electric and hybrid-electric vehicles into the grid and take advantage of these vehicles for energy storage.

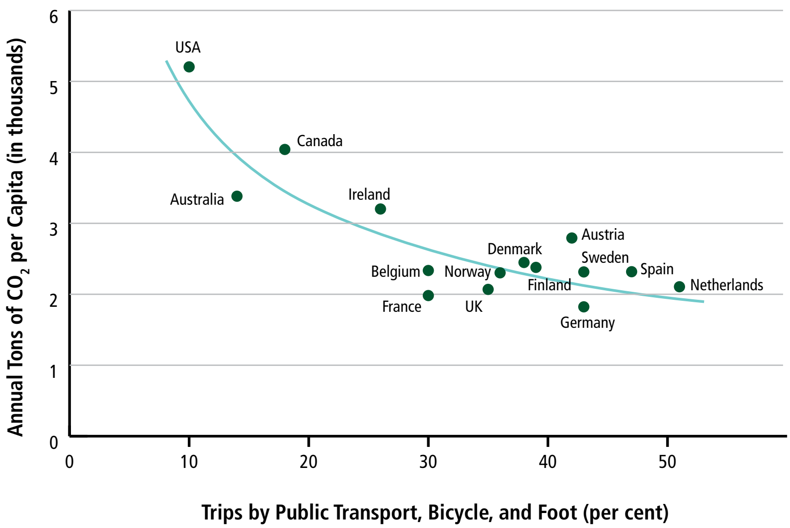
Changing Driver Behaviour

The concept of changing driver behaviour has several dimensions including encouraging drivers to drive more efficiently, providing them with information needed for eco-driving, and influencing choice of travel mode. ICT have the potential to enable individuals, businesses, and governments to make sustainable transportation choices and change how they view transportation.

Some simple ICT have long been used to influence driver behaviour, for instance the enforcement of speed limits through speed guns and the use of truck weight checks at roadside checkpoints. Reduced speeds have social benefits in the form of improved road safety, but also environmental advantages, as lower vehicle speeds reduce CO_2 emissions (Committee on Climate Change, 2009). Other dimensions of eco-driving include driving with windows closed, moderating air conditioner and heater use, and reducing excess weight. ICT applications on smartphones incorporated into vehicles could be used to inform drivers of both the environmental and economic benefits of eco-driving practices.

The greatest potential for ICT-based applications to change driver behaviour lies in influencing people's choice of travel mode. The number of vehicles on the road is increasing: between 1990 and 2009, the number of vehicles on Canadian roads increased by 35 per cent, to 19.2 million (Natural Resources Canada, 2012). This increase is not only the result of population growth; during the same period, the number of cars per person aged 18 years or older increased from 0.68 to 0.71 (Natural Resources Canada, 2012). Figure 4.4 illustrates the relationship between transportation mode and CO_2 emissions per capita, showing that those countries where a greater percentage of urban trips are made using public transit, bicycle, or foot have lower per capita emissions (Buehler & Pucher, 2011). It is important to note that since many of these leading countries are smaller and more densely populated than Canada, the United States, and Australia, they would therefore have lower per capita CO_2 emissions as a result of road and rail transport. Furthermore, Canada's geography does make multimodal transportation essential in some cases. However, there is significant room for improvement in urban transport by public transit, bicycle, and foot in Canada.

Simple tools such as journey-planning applications, which incorporate environmental, health, and cost indicators in addition to time, can encourage people to bike or walk instead of driving. This can be done, for instance, by listing the CO_2 emissions that will be prevented and the calories burned if a person chooses to walk a short distance rather than drive. This is the concept of the WalkIt website in the United Kingdom, which has had some success: surveys demonstrate that almost 80 per cent of users have chosen walking over a motorized mode of transportation at least once (Forum for the Future, 2009).



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Data Source: Buehler & Pucher, 2011

Figure 4.4

Association Between Percentage of Trips by Public Transport, Bike, and Foot and the GHG Emissions per Capita from Rail and Road Transport in Selected Countries

The annual CO_2 emissions from road and rail per capita in a country are inversely related to the percentage of trips that people take on public transit, bicycles or foot.

Promising Practice
Public Transit in Vienna, Austria

Vienna, Austria has been cited as a top city in terms of its public transit system (Siemens AG, 2009; Textor, 2010). The city has good coverage, with just under 99 per cent of all schools, and 96 per cent of residential and office buildings, located within 300 metres of a bus or tram stop and 500 metres of a metro stop (Siemens AG, 2009). The service is also well used; for example, from Monday to Friday, more journeys are made by public transit than by private vehicles (35 per cent versus 32 per cent) (Siemens AG, 2009).

There are many dimensions to the success of Vienna's public transport system, with ICT playing a role. Public transit is run by the city-owned Wiener Linien and consists of metro trains, buses, and trams. Recently, the city has been taking advantage of existing tram infrastructure to power new electric buses, and now has a full fleet of these buses in the city centre. The current collectors are automatically turned on at charging stations (at the final stop on the line) using the tram overhead power lines and at night they are fully recharged in their garage (Wien.at, n.d.). Vienna city officials predict that these new buses will reduce the city's carbon dioxide emission by about 300 tons annually (MacDonald, 2013).

Wiener Linien takes advantage of ICT for user engagement and direct marketing to different groups. It has a separate website dedicated to younger riders (www.rideontime.at) in addition to its main website (Siemens AG, 2009). This site now directs to its Facebook page, which has regular transit updates as well as other features such as historical photos and short trip ideas (Wiener Linien, 2013). For instance, after a large snowfall in 2013 a map of the best tobogganing locations in the city was posted, along with information on how to get to these locations using public transit.

Wiener Linien has also been a partner in developing a platform to provide comprehensive multimodal information on how to get from one place to another. The SMILE application seeks to simplify travel planning and demonstrate the benefits of public transit by allowing users to consider all types of transport, compare different itineraries for travel (e.g., car + train, versus bus + train) as well as book and pay for tickets (Gara, 2012).

The greatest area of impact for ICT to change passenger behaviour may be in encouraging people to switch from private to public transportation. This is very important in the Canadian context, as currently the vast majority of consumer spending on transportation goes to private transportation options (90 per cent) (Transport Canada, 2012b). According to a worldwide tracking survey done by National Geographic and GlobeScan Incorporated (2012), 36 per cent of Canadians never use public transportation, while 16 per cent use it once a year or less.

In addition to the benefits associated with simply having fewer vehicles on the road, public transit has other social and economic benefits. For instance, a University of Leeds study found that the Great Britain public transportation system supported the "modern urban economy" in a wide variety of ways, including "facilitating better matching between people and jobs and increasing labour market participation," "improving the accessibility to education and training, especially for people from deprived areas," and "support[ing] the vitality of urban centres" (Mackie *et al.*, 2012). Many applications can improve public transportation, including applications that provide real-time information on public transit routes and waiting times, either on smartphones or on screens in stations.

Improving Travel Networks

In addition to improving the efficiency of drivers, transporters, and vehicles, ICT have the potential to improve the efficiency of the overall transportation network in ways that lead to more sustainable travel. A stronger emphasis on urban and regional planning that includes traffic planning and traffic development prediction can lead to a more efficient travel network, and will also reduce the need for more road infrastructure, saving resources and money.

Applications in this category can be classified as those that make all road traffic flow more freely or those that make public transit more efficient (and subsequently more appealing than private vehicle travel) (Kay *et al.*, 2010). Opportunities related to the former include parking management tools; congestion pricing using cameras (with the potential to link the rate to factors such as fuel efficiency of vehicles and time of day, for example); and active traffic management, in which ICT are used to monitor congestion and travel speeds, with alternate routes provided to motorists via electronic signs (Kay *et al.*, 2010). Additionally, smart traffic light systems could be used to minimize the number of cars forced to stop while there is no traffic in the crossing lanes, and to synchronize flows in traffic intense areas. Examples of ICT that can be applied to improve the efficiency of public transit include applications that give signal priority to transit vehicles, allowing buses to move more quickly through cities, and computerized signaling systems that allow subway cars to run more closely together and therefore more frequently.

Using Smart Interconnected Logistics

GeSI identified logistical network optimization (smart logistics) as the category under smart transportation that had the greatest potential for GHG reduction. The organization estimated that transport-related GHG emissions could be reduced by 14.3 MtCO_2e per year by 2020 using ICT applications (GeSI, 2012). Smart logistics does not apply solely to road transportation, but many of the potential opportunities are related to, or can be applied to, that mode.

A Day in the Life

Ray, Vancouver

5:00 pm (PST)

On his way home from work, Ray stops at an urban hub located near his office and picks up three modular containers containing locally produced jams. These modular containers are destined for another urban hub that is located next to Ray's condo building and he can drop them off easily without going out of his way. Ray moves containers between these two urban hubs once a week and gets paid a set amount for each container he transports as he is contributing to freight mobility and reducing the need for trucks on the road.

The potential benefits of smart interconnected logistics are not just environmental. Improving logistics also has distinct economic advantages for Canadian businesses. As of 2008, the logistical and supply chain management costs for Canadian firms were significantly higher than those of U.S. firms: 30 per cent higher for retailers, 18 per cent higher for wholesalers, and 12 per cent higher for manufacturers (Industry Canada, 2008). A recent study estimated that if 25 per cent of the U.S. supply chain were to adopt the Physical Internet principles of interconnected freight mobility (see Box 4.9), it would result in annual gains of US$100 billion in yearly profits, and U.S. consumers paying less at the counter for their goods, in addition to a 32 per cent reduction in logistics GHG emissions (Meller & Ellis, 2013).

The transportation of goods across the country and internationally is an important industry in Canada, with the trucking sector alone consisting of over 56,000 firms employing over 200,000 people (Transport Canada, 2012b). Goods logistics consists of multiple steps, notably packaging, movement (transport and handling), and storage, and this logistical network can often be very inefficient. For instance, 20 per cent of the total truck-kilometres travelled in the United States in 2009 was with an empty trailer (McKinnon, 2009). The current nature of logistics for many businesses requires them to store large amounts of products in warehouses and distribution centres. As is the case for water and electricity infrastructure, these warehouses are often built based on the capacity needed at peak times and, because of the seasonal nature of most products, are underused for most of the year (Montreuil, 2011).

Marchet *et al.* (2009) have classified the types of applications available for logistics into four categories:

- transportation management;
- supply chain execution;
- field force automation; and
- fleet and freight management.

Definitions and examples of the opportunities within each category are described briefly in Table 4.2.

Table 4.2

ICT Applications for Logistics

Type of Applications	Definition	Functionalities
Transportation Management	Support tools for planning, optimizing, and executing logistical tasks	Routing and scheduling, shipment tracking
Supply Chain Execution	Management and automation tools for the flow of production during the different stages of the transportation process	Information exchange (e.g., order processing and digitalization of freight documents)
Field Force Automation	Mobile tools to support the integration of a firm's remote workforce and corporate processes	Access to office information or forms by front-line workers, onsite order processing
Fleet and Freight Management	Reporting tools that measure fleet traits	Access to real-time data allowing for dynamic management (e.g., vehicle travel times, load temperatures)

Lambert *et al*., 1998; Gilmore & Tompkins, 2000; Mason *et al*., 2003; Rodina *et al*., 2003; Zeimpekis & Giaglis, 2006; Marchet *et al*., 2009; Perego *et al*., 2011

Reducing the Need for Travel

Reducing the need for travel is another area where ICT can improve quality of life while also generating positive environmental outcomes. Applications such as telework, facilitated by virtual connectivity to a place of business, can reduce GHG emissions due to reduced travel, but can also be socially

Box 4.9
The Physical Internet

The Physical Internet (PI) is a concept that seeks to improve the way physical objects are moved, stored, realized, supplied, and used across the world. The PI works similarly to the digital internet, but with the movement of physical packages rather than digital packages of information. By viewing the interconnected logistical networks as an entity like the digital internet, different packages can be seen as standard units regardless of their size, mass, or distance they need to travel. Overall the PI would lead to more efficient logistics, and therefore reduce the GHG (and other air) emissions, as well as the costs and delays, resulting from transport and storage of goods (Montreuil, 2011; Montreuil *et al.*, 2013).

One component of the PI concept is having standardized modular containers designed for easing logistics (Montreuil, 2011). They would be made of environmentally friendly materials, and come in varying sizes ranging from cartons and pallets to cargo containers. To maximize the benefits of these containers, they need to be smart; ICT are therefore essential. By attaching smart tags to containers, they become smart objects that can communicate. This would make all stages of transport, including identification, routing, and maintenance, easier and allow for the standardization of the logistics process. In addition, the use of these smart containers for different types of goods would allow firms to share resources more easily. For instance, a truck could be fully laden with containerized goods from different firms without worry about confusing loads.

The PI would allow for the movement of goods to evolve towards interconnected transport where the traditional point-to-point and hub-and-spoke transport systems are replaced by a more efficient open system exploiting multi-segment multimodal transport between openly distributed hubs (Montreuil, 2011). In short, while it would take approximately 120 hours for a single driver to make a delivery from Los Angeles to Québec, a total of 17 drivers could deliver the object in only 60 hours by transferring it between trucks at designated hubs, or using trains to perform key segments.

Another dimension of the PI is interconnected distribution, which moves away from each firm building and operating its own distribution network, limiting the storage of its products only to the distribution centres (DCs) it owns or leases (Montreuil, 2011). Instead, it would enable firms to deploy their products dynamically near points of use through a web of open DCs spread across their markets. These open hubs are designed to deal with standardized PI modular containers. Firms would pay for their use only as needed.

and economically beneficial to employees (e.g., less time lost in commuting and reduced transportation costs) and potentially increase their productivity (Lister & Harnish, 2011). A 2010 report commissioned by the Carbon Disclosure Project compiled case studies from 15 Global 500 companies and concluded that teleconferencing delivers a rapid 15-month return on investment, avoiding the generation of millions of metric tons of CO_2 in a span of a decade (Verdantix, 2010). It also found that businesses with annual revenues of more than US$1 billion could realize profits of almost US$19 billion by 2020 (Verdantix, 2010). According to the OECD (2010a), there are a variety of factors that will influence telework uptake, including commuting distances, education, and other socioeconomic factors. Second-order effects play an important role in the overall environmental impact of initiatives that reduce the need to travel (e.g., telework), as in some cases these programs may actually lead to more travel overall. For instance, in the case of telework uptake, commuting distances, education, and corporate culture will need to be considered if the environmental and social benefits are to be achieved (Fuchs, 2008; OECD, 2010a).

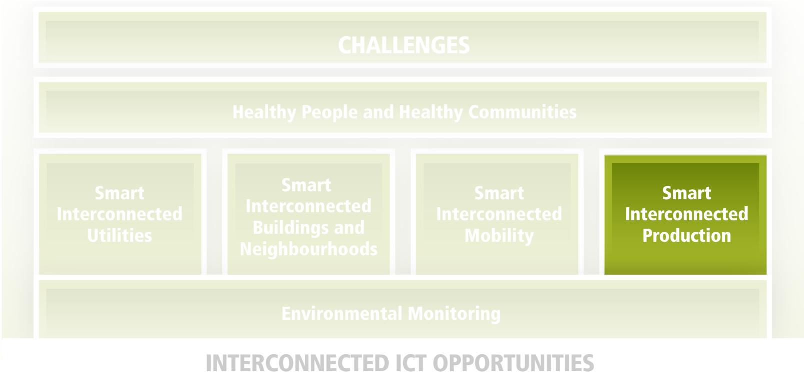
4.4.3 Challenges

In addition to the importance of second-order effects, other challenges may hinder the development of a smart interconnected mobility. The transportation web is complex, and the challenges associated with successfully implementing ICT-enabled opportunities will vary depending on which aspect of the web the opportunity effects. In cases where it relates to consumer decision-making (e.g., choosing which transport method to use), challenges related to human behaviour (and second-order effects) will be notable, as will implementation costs in some cases. Updating public transit networks or large-scale logistical systems, in particular, will require large investments that may be seen as prohibitive by governments or businesses, despite the eventual economic benefits. Similarly, transportation sunk costs may also be a challenge for governments in terms of implementing large-scale ICT initiatives.

4.4.4 Summary

Interconnected transportation and logistics through ICT-enabled opportunities will radically enhance Canada's capability for (i) efficient, sustainable, synchronized, and multimodal transportation; and (ii) dynamic distributed deployment of goods and people. Opportunities exist to change vehicle operation, change driver and transporter behaviour, improve travel networks, use smart interconnected logistics, and reduce the need for travel. By acting quickly, Canada has the potential to be a world leader in this transformation.

4.5 SMART INTERCONNECTED PRODUCTION



Reducing the need for travel can also be achieved by reducing the distance travelled by goods to reach their destination and manufacturing products or growing food near where it will be used or consumed. This forms part of the concept of smart interconnected production, which also includes improving the efficiency of manufacturing and agricultural processes (e.g., energy and water use). Given the importance of manufacturing and agriculture to Canada, in terms of their environmental and economic impacts, efficiency improvements in these sectors will have a significant impact on sustainability.

4.5.1 Drivers for Smart Interconnected Production in Canada

Manufacturing is one of the largest sectors in Canada, responsible for about 11 per cent of the country's GDP in 2012, a percentage that had been relatively constant over the previous four years (Statistics Canada, 2013b). In 2013 the sector employed 1.74 million people, a decrease over previous years (Statistics Canada, 2013a). Construction and durable goods manufacturing are responsible for about 60 per cent of these jobs with the remaining in non-durable goods manufacturing. Historically, Ontario (particularly southern Ontario) and Quebec have been the manufacturing centres of Canada (Balakrishnan *et al.*, 2007). Currently about 73 per cent of Canadian manufacturing jobs are in one of these two provinces (Statistics Canada, 2013a).

Although the manufacturing sector produces less GHGs than the buildings or transportation sector, its emissions are still significant. Light manufacturing (with construction and forestry resources) emits 3.3 per cent of Canadian GHGs (23 $MtCO_2e$), production of chemicals and fertilizers emit 3.4 per cent (24 $MtCO_2e$), and pulp and paper production emits just over 1 per cent (6 $MtCO_2e$) (Environment Canada, 2013c). Reducing energy use would reduce GHGs and also be economically beneficial due to lower production costs.

Manufacturing is also responsible for emitting several other air pollutants (notably VOCs, SOx, and NOx) (Environment Canada Pollutant Inventories and Reporting Division, 2014).

Agriculture also plays an important role in the Canadian economy with almost 300,000 farm operators and over 200,000 farms on 160 million acres (Statistics Canada, 2012). Primary agriculture had $51.1 billion in gross farm receipts in 2010 (Statistics Canada, 2012). Agriculture is also a central part of Canada's history and continues to play an important role in Canadian culture. As consumers become more concerned about where their food comes from, there is a greater desire to eat food that is grown locally.

The agricultural sector is the largest consumer of freshwater in Canada (66 per cent), with the majority being consumed as a result of irrigation (NRTEE, 2010). Other water consumption activities on farms include livestock watering and cleaning of farm equipment. Agriculture can also negatively affect water quality, as a result of runoff that may include nutrients from fertilizers (nitrogen and phosphorus), pathogens, and endocrine-disrupting substances from animal waste or pesticides (Corkal & Adkins, 2008). Contaminated water may have a negative impact on drinking water quality and on wider ecosystem health.

While irrigation is important to Canadian agriculture, the vast majority of farms are precipitation-fed (rain and snow) (Statistics Canada, 2012, 2013d). Irrigation may become more important in the future because it can potentially protect farmers against the uncertainty associated with climate change. As such, efficient irrigation and other methods that provide water protection (e.g., smaller-scale water harvesting, targeted watering) in times of drought and heat waves may help to strengthen Canada's agriculture sector. ICT can potentially improve these methods, notably irrigation, to ensure the most efficient use of water.

While the agriculture sector does emit just under 10 per cent of Canada's GHG emissions (68 $MtCO_2e$), the potential abatement using ICT is minimal, as almost half of the sectors emissions is the result of animal production (Environment Canada, 2013c).

4.5.2 Opportunities

Manufacturing

Manufacturing is often a complex process involving multiple technologies, machines, people, stages, suppliers, and clients. As described by Porter (1985), the value chain of an organization is made up of many different activities that can be linked to the organization's competitive strength. Activities within the value chain can be categorized as either primary or supporting activities. Primary activities include operation, inbound and outbound logistics, marketing and sales, and service, while supporting activities include procurement, infrastructure, and technological development. The success of the value chain depends on all of these activities and effective links between them. ICT have the potential to improve the efficiencies at multiple stages of the manufacturing process. Collectively, these improvements can lead to significant reductions in energy use, leading to lower manufacturing costs for firms. Park *et al.* (2009) calculated that a one per cent reduction in the electricity consumption of manufacturing worldwide would result in total savings of US$4.7 billion.

While there are ICT opportunities throughout the manufacturing process, the Panel chose to focus on those related to the primary activity of operation. ICT can improve the environmental performance of manufacturing through:
- direct improvement of equipment efficiency;
- process planning improvements; and
- improvements to the organization and deployment of the overall manufacturing system.

Examples of ICT applications for each of these opportunities are briefly described below and a discussion of how 3D printing may change manufacturing is included in Box 4.10.

Equipment Efficiency

An example of direct improvement of equipment efficiency is the use of smart motors. Motors are an important component in many industrial processes, but traditionally they operate at full capacity at all times, regardless of the needed output. Making motors smart, with components such as variable speed devices and intelligent motor control, allows them to adjust their output based on load and therefore increase their efficiency (GeSI, 2008). According to GeSI (2008), optimization of motor systems is expected to increase their energy efficiency by up to 30 per cent. In addition, making different components of the manufacturing process smart allows for communication between machines and systems, enabling further adaptation to changing load and processing demands.

Process Planning

ICT can be used to improve the effectiveness of process planning through a variety of applications. For instance, energy mapping with ICT can be used to detect the most energy-intensive operations in a manufacturing process, allowing firms to target these operations in retrofits. Simulation scenarios can compare different processes to determine which will be most energy and cost-efficient while still serving the needs of customers. Similarly, simulation approaches can be applied to improve water use or material good efficiency (European Commission, 2009b).

Organization and Deployment of the Overall Manufacturing System

ICT can improve the organization of the manufacturing system in several ways. Notably, they can help select the location of plants themselves more strategically, which minimizes overall transport and logistics needed. This can help move manufacturing away from unique centralized plants that serve huge territories and require inbound and outbound flows, and lead to long delivery times to clients and from suppliers.

Box 4.10
3D Printing

Three-dimensional (3D) printing is a technique that allows people to design and print objects with the help of a computer and a 3D printer. Unlike the traditional manufacturing process, which includes removing material by cutting, drilling, or machining, 3D printing works by adding layers of material, and is therefore called additive manufacturing. The process starts by designing the product with a drafting software, which then goes through a program that translates it into two-dimensional layers, which are materialized to reality through the 3D printer (CSC, 2012). While 3D printing has been around since the 1980s, technological advances and a substantial decrease in price have led to a rapid evolution of technology and application in many fields, including departments of defense, aerospace, automotive, and biomedical industries (CSC, 2012; Ehrenberg, 2013; Royte, 2013).

Although 3D printing has thus far been applied mainly to small-scale and low-volume production, Computer Sciences Corporation (a large global company that provides IT) claims that products can also be far superior, lighter, stronger, and more customized than with traditional modes of production (CSC, 2012). 3D printing can also make impossible-to-manufacture products with delicate parts, movable and strange curving components already assembled, made right where they are needed and cost less than if created with traditional manufacturing processes (Ehrenberg, 2013). The most common materials used in the 3D printing process are plastic polymers; however, more expensive machines can handle feedstock consisting of metals, ceramics, and other custom materials, including organic compounds (Ehrenberg, 2013).

continued on next page

According to the Computer Sciences Corporation, one of the main benefits of 3D printing is the ability to make items locally where they are needed, without having to rely on limited spares and extensive supply chains that may be very far away or require bulk production (CSC, 2012). 3D printing can also eliminate the time and expense of creating complicated and intricate objects, and remove the mass from mass manufacturing by making limited products more affordable (Ehrenberg, 2013).

Similarly, large inventories and storage facilities can be scaled down, minimizing the need for transportation, handling, and storage, including emissions of the embodied energy within each of the steps (Royte, 2013). A recent study from Michigan Tech University found that overall, "distributed manufacturing using open-source 3D printers has the potential to have a lower environmental impact than conventional manufacturing for a variety of products" (Kreiger & Pearce, 2013).

Just as the rise of networked computers brought down the costs of communication and services associated with distributed computing, 3D printing can do the same for the cost, complexity, and energy associated with manufacturing and transport of many products and their parts (Ehrenberg, 2013). Another promising component of 3D printing for sustainability involves the versatility of 3D printer feedstock, which can include recovered and recycled plastics to make a variety of products. In the future, it may be feasible to synthesize printer feedstock out of many materials, including agricultural or other industrial waste, which can be recovered to make building blocks for new products and thus help close the loop on production and disposal of material, as well as minimize the amount of waste going to landfills.

While the optimism about the benefits of 3D printing is warranted, it is also important to be aware of potential negative consequences and second-order effects of frivolous 3D printing and production of objects that have no real added value (Ehrenberg, 2013; Royte, 2013). The continued responsible development of 3D printing and its effects on society, technology, and the environment should be closely monitored.

Agriculture

ICT can also play an important role in precision farming, a management system that takes advantage of ICT to help enable environmental monitoring and control of agricultural practices (Roblin & Barrow, 2000). The objectives of precision farming are to (i) describe the spatial distribution of factors affecting crop growth; (ii) manage this spatial variability by applying variable-rate treatments of the needed input (e.g., water, agrochemicals, and fertilizers) depending on location specific requirements; (iii) maximize profitability; and (iv) minimize environmental impacts (Roblin & Barrow, 2000). The improved yields provided by precision farming can help negate the need for intensive, mono-cropping that reduces biodiversity and can more quickly degrade farm conditions (e.g., soil health) (Hall & Dorai, 2010). Wireless environmental sensor networks for real-time decision-making are part of the technologies available to farmers for precision farming. Crop and soil water status can also be determined through remote sensing methods that include aerial, satellite, and hand-held remote sensing technologies (Zerger *et al.*, 2010; Díaz *et al.*, 2011).

Precision irrigation, for instance, allows for more efficient use of water, by providing information on exactly how much water is needed for a given crop, in a given area, and at a given time. This can have a significant impact on water consumption as irrigation efficiencies are typically only in the range of 30 to 50 per cent (Hillel & Vlek, 2005). The average water savings by precision irrigation are 10 to 15 per cent compared with conventional irrigation practices, and could be as high as 50 per cent, depending on the efficiency of the previous irrigation management regime (Sadler *et al.*, 2005).

Connecting Consumers to Farmers

ICT also help connect people with local farmers in their area, allowing them to purchase food directly. Enabling users to purchase locally grown food has clear environmental benefits, as it would reduce the GHG emissions associated with transportation. There are also important benefits for both the farmer and the consumer, allowing smaller-scale operations to sell their goods without an intermediary and providing consumers access to fresher local food.

Promising Practice

Lufa Farms, Montréal, QC

Lufa Farms is a greenhouse business in downtown Montréal, on the roof of a commercial building. The operation is much more than a rooftop garden, at just under 3,000 square metres and producing over 450 kilograms of vegetables every day (Immen, 2013). The farm grows 40 types of herbs and vegetables and, since it is located in a greenhouse, can operate all year (Immen, 2013).

Lufa Farms uses its website to connect with consumers, who make weekly orders that are then delivered to one of dozens of local pickup points across the city (Lufa Farms, 2013). Those who subscribe decide which vegetables they will receive in a given week and which day they would like to pick up their order. The website also contains a blog of recipes, as well as descriptions of the green practices carried out at the farm (e.g., rain harvesting, using biological controls).

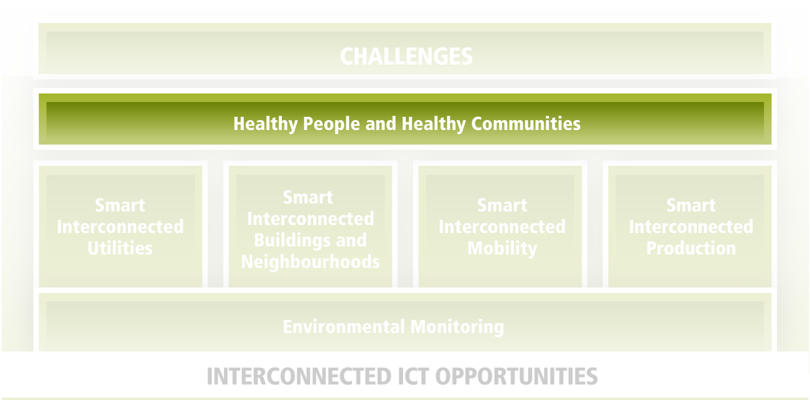
4.5.3 Challenges

As with the other thematic area, costs may hinder the adoption of ICT opportunities in manufacturing and agriculture. Firms may not have the capital needed to make the necessary investments in the new technologies, or may not perceive the large initial investments as worthwhile, despite the eventual economic payoff. Additionally, there may be challenges related to behaviour as the inclusion of new ICT in production processes may, in some cases, require fundamental changes for individuals or businesses involved in the agricultural or manufacturing process.

4.5.4 Summary

Smart interconnected production, in which ICT is used to improve the efficiency of manufacturing and agricultural processes in terms of energy and water use, would have a significant impact on sustainability. Additional sustainability benefits could be achieved by using ICT to help carry out production near where manufactured goods or food will be consumed.

4.6 HEALTHY PEOPLE AND HEALTHY COMMUNITIES



The Panel felt it was important to re-examine all of the above opportunities through a social lens because the social benefits of ICT opportunities are equally as important as the economic and environmental benefits, despite being harder to quantify. The most effective ICT applications for sustainability will meet the triple-bottom line: helping ensure Canada's environmental, social, and economic sustainability. The Panel chose to briefly highlight some of the positive benefits of selected ICT applications for health, education, and resilient communities, as these are essential components of the health of individuals and the population as a whole. Healthy communities are integral components, as well as co-creators, of sustainability.

A Day in the Life

Dorsey, St. John's/Quinn, Regina

7:30pm (NST)/5:00pm (CST)

Video chatting with a friend at Memorial University (MUN), Quinn is impressed with how quickly their campus has recovered from recent flooding. Dorsey explains that Newfoundland's climate data collection and modelling are among the most accurate in the world. In addition, a growing population has led to highly efficient social media notification and organizing services. She makes sure to point out that MUN's online courses in first aid and disaster recovery — distributed over the most recent iteration of the original CANARIE network — are popular nationwide.

Quinn is, of course, especially interested in the rapid recovery of the power grid. Dorsey explains that MUN's grid is one of several in Canada to be built with a much higher-resolution sensor network. This network is coupled with a federally managed cloud service, which allows working systems to draw on resources throughout the country to compensate for reduced capabilities. These resources are then used to diagnose the grid and distribute information and instructions to those in the affected area. Quinn is familiar with the service. Every province subscribes, and British Columbia maintains the highest ratio of resources shared to resources accessed.

ICT ultimately have the potential to positively affect the health of people and their communities. According to the World Health Organization (WHO), health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" and "the extent to which an individual or a group is able, on the one hand, to realize aspirations and to satisfy needs, and on the other, to change or cope with the environment" (WHO, 1946; WHO, 2009). Health is a broader concept than simply physiological well-being and is influenced by a wide variety of determinants that range from education and access to healthcare, to social support networks and other political, economic, and environmental factors. Many of these determinants also relate to overall community health, which in turn affects the health of the individuals within a community.

4.6.1 Drivers for Healthy People and Healthy Communities in Canada

This section focuses on how ICT can have an impact on individual and community health by improving access to health services, and making communities more resilient, more engaged in decision-making processes, better educated, and better equipped to face environmental challenges and act to address them. Table 4.3 shows how the opportunities presented in this chapter can improve the quality of life of Canadians in addition to the health benefits that would be achieved through reduced pollution. The discussion of opportunities identifies additional ICT applications that can achieve benefits in education, health, and community resiliency.

Table 4.3

ICT-Related Opportunities for Healthy People and Healthy Communities

Thematic Area	Examples of Social Benefits
Environmental Monitoring	• Better community awareness of surroundings and environmental problems • Resiliency to natural disasters • Integration of environmental data with other data (e.g., health)
Smart Interconnected Utilities	• Enhanced user capability to transform from passive ratepayers to active, engaged participants • Resiliency to disturbances, attacks, natural disasters, etc.
Smart Interconnected Buildings and Neighbourhoods	• Increased productivity • Increased comfort
Smart Interconnected Mobility	• Less congestion therefore less time lost in transport, which means less stress
Smart Interconnected Production	• Reduced manufacturing costs • Access to local food • Customized production

4.6.2 Opportunities

Access to Knowledge

ICT are without a doubt changing the way people throughout the world communicate and acquire information. Canada has some of the largest internet penetration rates in the world, with 8 out of 10 Canadians online (CIRA, 2013). Canada also leads the world in file-sharing and hours spent online (45 hours per month), with social networking and entertainment websites (e.g., Facebook and YouTube) the most popular among Canadians (CIRA, 2013). ICT platforms such as social media websites and other networking platforms therefore have the potential to provide solutions and information that can increase awareness, education, and engagement.

One of the key advantages of ICT is the ease and speed with which information is disseminated, developed, and stored. ICT can create greater environmental and community awareness by providing access to various information and data (e.g., government, media), in various formats and despite geographical location, and the capability to trace, cross-reference, and verify that information. Together, the increased use of social media and greater access to environmental and social information can provide communities and individuals with the necessary tools to better understand issues and the opportunity to share, collaborate, link up, and act. Despite the benefits of data access for sustainable solutions, some have raised concerns about possible negative health impacts of such an overwhelming amount of information (Shenk, 2009).

Combined with sensor-based monitoring technologies, ICT can improve terrestrial, atmospheric, and remote monitoring and assessment of environmental changes by providing information and tools that help inform people about the state of affairs and identify areas that need protection (see for example Ling *et al.*, 2007). ICT can provide numerous data sets on the state of the surrounding environment and community; generate or improve modelling and system analysis, often in real time; and inform decision-making that affects the environment and other aspects of life.

However, to achieve positive social benefits, environmental information must be made available and accessible to the general public. According to the group European ICT Environmental Sustainability Research, for example, environmental capacity-building with public participation is one of the key parameters for successful incorporation of ICT into environmental issues. This includes "improving environmental conditions with efforts to increase public awareness on environmental issues and integration of the environmental content into formal education" (Pillman *et al.*, 2009). Similarly, many ICT-based initiatives intended to provide people with information about their community, and the services available to them, have emerged. Federal, provincial, and municipal governments, organizations, and firms throughout Canada are increasing their online presence, opening their data, and connecting with the general public (see for example Government of Ontario, 2013).

An example of community engagement and information dissemination through ICT comes from the City of Vancouver, which has been very active in promoting the Greenest City 2020 Action Plan through social media and web platforms. The city posts reports, project criteria, and implementation updates; solicits public feedback and ideas; and provides know-how, tips, event details, funding opportunities for community greening projects, and other opportunities for involvement (City of Vancouver, 2013).

Social media and ICT can also help coordinate and integrate voices of the community into policy planning by providing opportunities for increased involvement through web forums and groups, which can all influence decision-makers to push for more sustainable regulations and processes (Ling *et al.*, 2007).

Education

ICT can provide opportunities for education about the environment and science. These includes self-schooling and learning outside of the classroom to supplement formally acquired knowledge, as well as enhancing existing learning environments through visualization, multimedia, and hands-on applications. With the rise in smartphones and portable technologies that can connect to the internet at any time, knowledge exchange, collaboration, and learning though the internet are increasingly common. With open education tools, open-access journals, and access to e-books, e-lectures, and numerous how-to and do-it-yourself forums, individuals now have the opportunity to learn or study regardless of their location, and often for free, provided they have a reliable internet connection. The rise in open-access digital content under sharing-friendly licenses, like Creative Commons, is helping to build free, accessible, quality content and drive innovative projects like Wikipedia, Public Library of Science, Human Genome Project, Open Energy Information Initiative, and Science for Humanity. The possibilities for more efficient research and technological development, and the significance of ICT for education and collaboration, may increase as more applications, commerce, and social life migrates to internet platforms (Bollier, 2007), although others have argued that the positive effects of these developments have been overstated (see for example White, 2010; Morozov, 2011).

If widespread access to education content through ICT reduced the need for travel, it would result in a positive impact on the environment. The growth of open online courses, together with the rise of open-access publication, peer-to-peer sharing, and new information intermediaries, may be part of a major transformation of the global educational culture that can change how knowledge is acquired and shared (Brousseau & Curien, 2007; Walsh, 2011). Some open universities, like Coursera, provide online lectures very typical to traditional classrooms, while others, like Udacity, offer interactive lessons, activities, and quizzes between videos and lectures. According to the Canadian Urban Institute (2008), e-learning opportunities "[provide] an opportunity for new research tools and learning related to energy and the environment" and should be incorporated into strategies for engagement with communities at large.

As with access to information, open education and increased collaboration can save both resources and time in the face of growing environmental and sustainable development challenges. However, the social and economic implications of these changing paradigms can potentially reach even further (Zelenika & Pearce, 2013).

Health

The concept of e-health includes a broad range of activities within a healthcare system, in which ICT are a central component (Holmner *et al.*, 2012). Examples include electronic medical records; telemedicine such as remote assessment, diagnosis, or surgery; and e-health surveillance. In addition, ICT can help combine health data with other data sets (e.g., environmental) to yield additional information (see Box 4.11). The social, environmental, and economic impacts of ICT applications in the health field are well documented. Advantages include direct and indirect benefits related to the decreased need for travel (Merrell, 2009). It is estimated that increased efficiency through health information technology could provide overall financial savings of over US$77 billion per year in the United States (Rand Corporation, 2005). Telemedicine and self-assessment procedures can significantly reduce the need for in-person visits, which can be inconvenient, time-consuming, painful, and expensive, especially for those who are very sick, elderly, or living in rural areas (Rintels, 2008). Additionally, telemedicine applications can help with the treatment of chronic conditions, such as diabetes, congestive heart failure, hypertension, and depression, and therefore prevent the admission to long-term institutional care (Darkins *et al.*, 2008).

Promising Practice
e-Health in Croatia

By implementing Ericsson's e-Health system, Croatia has connected 2,400 primary healthcare teams under one system. The system updates patient files, provides electronic patient reporting and booking, and creates digital copies of prescriptions and referrals, so they can be sent to other healthcare centres (e.g., pharmacies) without the need for printouts (Ericsson, 2009). Ericsson estimates that e-referral services alone can reduce patient visits in Croatia by 50 per cent. It also estimates that e-referral and e-prescription services combined have the potential to reduce CO_2 emissions by up to 15,000 tonnes per year, while adding only 330 tonnes per year from their manufacture and operation (Ericsson, 2009).

Electronic patient and medication records, e-prescriptions, and decision-support systems could be important components of renewal and updating of the healthcare system (Prada & Santaguida, 2007; Conference Board of Canada, 2013a; U.S. Department of Health and Human Services, n.d.). Governments across Canada have made significant commitments to e-health applications: for instance, the federal government has announced funding of $2.1 billion to support Canada Health Infoway to develop e-health records and e-health technologies (Canada Newswire, 2013). While Canada has made progress towards interoperability, standardization, and information sharing between clinicians and across administrative boundaries, there are still areas for improvement. For example, Canada severely lags many OECD countries in implementing electronic medical records at the family practice level (Anderson *et al.*, 2006; Protti, 2007; Prism Economics and Analysis, 2009).

In addition to improving the technical component of e-health information systems, broadening and improving the IT skills of medical professionals (Prism Economics and Analysis, 2009), and creating a deeper understanding of people's needs and quality assurance, need to be emphasized. While improvements in e-health carry many benefits, there are concerns about the increased energy consumption and electronic waste related to some ICT-based health activities. The environmental impact of these technologies needs to be tracked and minimized whenever possible (Kolbasuk McGee, 2011). Privacy and security of patient health records and other sensitive information is another challenge that will need to be addressed (Prism Economics and Analysis, 2009), with special care given to protecting patient-doctor confidentiality and safeguarding against cyber-attacks or other unlawful access to records.

Box 4.11
Integration of Environmental Data with Health Data

A Health Canada report, *Strengthening Environmental and Occupational Health Surveillance in Canada,* concluded that environmental and occupational health surveillance in Canada should be strengthened (Health Canada, 2001 as cited in Health Canada, 2004). Further work highlighted the benefits of integrating environmental and health surveillance data to better understand the links between environmental risks and human health (Health Canada, 2004). Such integration would bring the opportunity to leverage data supplied by environmental monitoring activities and the healthcare system. However, to achieve such integration, serious hurdles relating to security, privacy, and data interoperability and access would need to be addressed (Ali *et al.*, 2007).

Resilient and Integrated Communities

Resilience can be defined as "the ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth" (USAID, 2012). The approach of community resilience is that of pro-activity, as opposed to reactivity, that is based on strong social networks and utilization of social capital (Murphy, 2007; Resilient Communities Canada, n.d.). Effective deployment of ICT for community resilience can increase adaptation capacity in a world where the effects of climate destabilization and rising energy prices are expected to increase.

Some of the parameters that apply to resilient and integrated communities have already been mentioned earlier in this chapter. These include access to information, public participation, education, and health. Benefits of ICT in the context of resiliency can include a mix of technical capabilities as well as the social dimensions of knowledge and resource sharing, better understanding of environmental and earth systems, support, assistance, capacity-building, and disaster relief. Given Canada's large geographic area, interconnectedness through ICT can play an important role in bringing communities together in times of need, especially for isolated rural regions. However, to fully capitalize on the opportunities provided by ICT for community resilience, it will be important to address problems of the digital divide (such as access and cost), building awareness, supporting infrastructure (hard and soft technologies), promoting participation, and a multilayered approach to organization, governance and support (Simpson, 2005). A policy brief by the University of Westminster outlined a number of key factors for the success of sustainable community initiatives ("eco-city initiatives"), including:

- integration across scales, systems, and organizations for effective innovation;
- community engagement tailored to a wide spectrum of public life, with emphasis on transparency and participation;
- environmental-technological goals balanced with social sustainability; and
- accessibility and comparability of data for research, knowledge exchange, and shared learning.

(Joss, 2013)

Disaster management is an example of an area where ICT can enhance resilience. The World Bank estimates that meteorological disasters are responsible for about 75 per cent of losses due to adverse natural events worldwide. From 1980 to 2011, natural disasters around the world led to over 2.5 million deaths and caused about US$3.5 trillion in damages (World Bank, 2013a). Looking ahead, climate change is likely to continue to have major implications for global ecosystems, agriculture, water supplies, sea level rise, and storm surges.

Therefore, "effective climate risk adaptation strategies [can] help manage disaster risk in the medium term while reducing vulnerability over the longer term" (World Bank, 2013a). The power of ICT for disaster risk management has been widely recognized, and many opportunities for disaster prediction and management can provide better awareness, education, training, and preparation (World Bank, 2013b).

Applications for timely weather forecasting, better informed and enforced zoning and development requirements, and public preparedness are integral to Canada's community security and resilience. As mentioned, some scientists have stated that, in addition to precipitation information, groundwater data from U.S. NASA satellites were available and could have been used to predict the large-scale flooding that occurred in Alberta in 2013, which would have given governments more time to prepare for the disaster (Semeniuk, 2013). The power of digital communication technologies and crowdsourcing was very evident as Calgary dealt with the flooding (Montgomery, 2013). Residents used Twitter and Facebook to share information about businesses or people providing free help and resources, pumps, water vacuums, building materials, and recycling drop-off. Shared videos and round-the-clock news updates from neighbourhoods using YouTube and Vimeo also helped inform many individuals, working crews, and news outlets (Montgomery, 2013).

In light of this example, it is pertinent to note that ICT-enabled sustainability, in addition to the technical capabilities it may provide, can enable changes in traditional governance, management, and decision-making. An important component involves a shift away from the traditional control-based model of certainty and *predict and supply* style of management, which tend to view technologies as silver bullets, to alternative approaches that see social, political, and environmental issues as inherently complex and unpredictable (Meadows, 2008). This shift requires modes of analysis and governance based on adaptive approaches to alternative future conditions, leading to a more decentralized, but interconnected, model of resilient communities with ICT as the tools for building resilient, proactive, and adaptive management (Allenby & Sarewitz, 2011). Embedded in this approach is the growing idea of sustainability as an emergent property, created collectively, as is becoming more and more evident through the explosion of citizen-led and community-based initiatives (Robinson, 2004; Robinson *et al.*, 2011; Roseland, 2012). All of these factors could help lead to a deeper understanding of earth systems and a more integrated approach to sustainable development and the interconnected relationships between humans, nature, and technology. Simply adding more technologies will not get us there. Better strategies and systems of social inclusion and governance must be developed, along with methods to take advantage of the richness and diversity of systems that will provide resilience and adaptability.

4.6.3 Challenges

The challenges that hinder the adoption of the opportunities for healthy people and healthy communities are similar to those discussed for other thematic areas. Notably, behavioural challenges are important for ICT applications aimed at individuals, such as those related to education or accessing healthcare. If people are not comfortable with specific ICT applications, they may choose to avoid using them. Similarly, lack of ICT skills may be a challenge in some cases, preventing individuals from successfully adopting a particular ICT opportunity. Privacy and security issues are especially important for opportunities related to health because protection of the integrity of patient data is essential.

4.6.4 Summary

Health is a broad concept that is influenced by a wide variety of determinants that range from education and to social support networks. Indeed, healthy people and healthy communities are integral components, as well as co-creators, of sustainability. ICT ultimately have the potential to positively affect the health and resilience of people and their communities. In terms of demographics and participation in the democratic process, ICT can enable new forms of participatory decision-making and governance. ICT can also contribute directly to quality of life through better access to delivery of health and educational services.

4.7 CONCLUSION

There are an almost infinite number of applications based on the ICT platform introduced in Chapter 3 that could yield positive environmental and socio-economic benefits. Identifying which opportunities would be most beneficial for Canada required considering the contextual factors discussed in Chapter 2, and establishing the desired benefits for the environment, economy, and social well-being. The Panel looked at ICT-enabled opportunities in six key thematic areas with significant current or potential positive impacts in the daily lives of Canadians.

The opportunities identified in this chapter have a wide range of potential sustainability benefits. They also span many different sectors and target groups. Given the variety of sustainability opportunities, the Panel also identified some common challenges that act as obstacles to the successful implementation and adoption of ICT applications for sustainability in Canada but that can be mitigated given proper planning and appropriate actions:

- Costs, or fear of costs, related to implementation of the technology and corresponding infrastructure;
- lack of data access and interoperability;
- lack of the needed ICT skills;
- privacy and security issues and behavioural factors; and
- second-order effects.

Although inadequate broadband connectivity in Canada was not identified as a challenge within a specific thematic area, the Panel recognizes that fast and reliable access to broadband is fundamental to all opportunities put forward. Thus, it adds it as a sixth challenge.

In the next chapter, the Panel explores the six challenges in further detail and investigates some of the solutions that can help address these challenges so as to more fully realize the benefits of ICT-enabled opportunities.

5

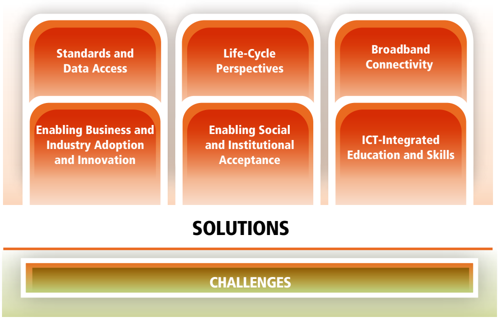
Addressing Challenges

- Enabling Business and Industry Adoption and Innovation
- Standards and Data Access
- ICT-Integrated Education and Skills
- Enabling Social and Institutional Acceptance
- Life-Cycle Perspectives
- Broadband Connectivity
- Conclusion: An Integrated Approach to Solutions

5 Addressing Challenges

Key Findings

- Living labs could help mitigate the risk and uncertainty associated with the use of untested or high-risk solutions.
- Enabling business adoption of ICT could require the use of policy instruments, for example procurement, to increase demand and address market failures.
- It is important to encourage collaboration by ensuring data is accessible. Opening data is one step, but standards are also needed to ensure interoperability, where datasets can be read, understood, and used by all users.
- Promoting digital and computer literacy and making ICT cognitive and technical proficiencies an educational priority for both citizens and ICT professionals would have social benefits and give Canada a competitive edge in a rapidly evolving digital environment.
- The implementation of practices such as privacy by design could protect privacy and give users personal control over their information while, at the same time, positioning Canada to reap the socio-economic benefits of big data and smart technologies.
- Adopting a life-cycle perspective could assist in the identification and mitigation of second-order effects that may arise from the implementation of ICT opportunities.
- Addressing broadband connectivity gaps may require a national commitment, but would give Canada the capabilities to remain competitive in the global economy.



A range of opportunities for ICT-enabled applications for sustainability in Canada were presented in Chapter 4 along with a brief discussion of the six most prominent challenges associated with realizing these opportunities. This chapter explores these challenges in more detail and identifies selected solutions for each. The Panel does not intend these solutions to be comprehensive or prescriptive. Instead, the Panel features a range of options, often illustrated by examples and promising practices from Canada and around the world, that could help enable the adoption of ICT-enabled sustainable technologies.

To simplify the discussion, the Panel grouped the options into six key categories:

- Enabling Business and Industry Adoption and Innovation
- Standards and Data Access
- ICT-Integrated Education and Skills
- Enabling Social and Institutional Acceptance
- Life-Cycle Perspectives
- Broadband Connectivity

Finally, the Panel discusses the need for an integrated approach to addressing sustainability challenges through ICT — one that will continue to promote the three pillars of sustainability.

5.1 ENABLING BUSINESS AND INDUSTRY ADOPTION AND INNOVATION

ICT have significantly benefited the global economy over the last few decades (Draca *et al.*, 2006). The invention of technologies, such as computer and communication equipment, gave an initial boost to the performance of firms. Then, and perhaps even more importantly, managers and employees learned how to reorganize business processes to further improve and transform operations, drastically increasing productivity.

ICT-enabled opportunities for sustainability could be equally as potent, not only in further improving business performance but also in lessening the environmental impact of businesses and households (Popp, 2012). This effect will be critical as future economic growth will increasingly have to come about with limited environmental impact. However, this can only be realized if a number of challenges are overcome. In a nutshell, the rate of developing and adopting new technologies is generally too slow, and the incentive to improve the environment is too weak (Hall *et al.*, 2010).

5.1.1 Exploring the Challenges

The Panel identified costs, or fear of costs, related to implementing new technology as a major challenge to the development and implementation of ICT-enabled opportunities. This challenge is particularly relevant in the context of businesses. Although securing appropriate financing is vital for firms, other challenges include slow adoption rates, insufficient incentives for sustainable technology creation, path dependence, and Canada's historically poor innovation performance.

Since major financial penalties are not imposed on business for negative environmental impacts in the absence of significant reaction by consumers and governments, excessive damage is imposed on the environment. For example, businesses often do not pay for pollution. This is an example of what economists call a *market failure*, that is when goods and services are not allocated efficiently in the free market. To overcome this market failure, the government can use a range of policy instruments such as regulations and fees to help prevent environmental damage. Indeed, municipal, provincial, and federal governments in Canada have an established track record of implementing policies to protect the environment. Although demand may be created through government policies, adoption of sustainable ICT by businesses, like other technologies, may be insufficient because of the other market failures and challenges discussed in this chapter.

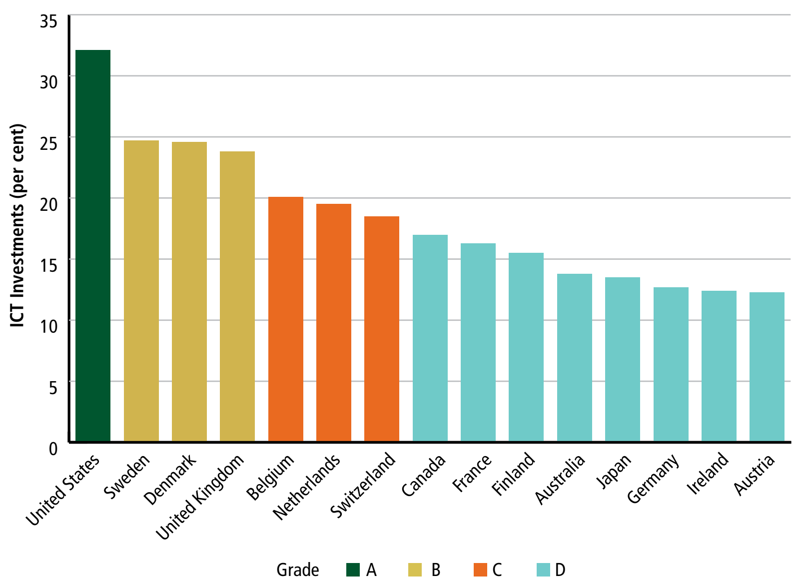
The market failures associated with the adoption of new technologies such as ICT are many (Stoneman & Diederen, 1994; Popp, 2010). Early adopters may face problems from glitches in early production, from struggling how best to optimize the new technology, and from high initial cost before economies of scale can be exploited. Early adopters that overcome these problems can share valuable information on best use of the new technology. However, there is no reward in creating this public good as late adopters can benefit from learning of those initial errors without cost. This reluctance to explore new technologies means that their adoption will be slowed, and may not even start if such hurdles are too large. These are not abstract problems, but instead are translated into practical challenges. Those selling new technologies face challenges in convincing customers of how well the product operates. But, this barrier may translate into making it difficult to raise financing. Inability to raise financing is therefore a symptom of a deeper problem that needs to be addressed directly.

With these forces at work, ICT-enabled opportunities for sustainability are not only hindered by insufficient demand for the end product if environmental impacts are inappropriately regulated, but there will also be insufficient incentives to adopt new technologies or even to develop them in the first place. Any failure along this chain will lead to incomplete adoption of ICT-enabled opportunities and nullify the incentives to develop them. Given that the evidence suggests that the Canadian economy is not as productive and innovative as it needs to be (CCA, 2009, 2013a), encouraging adoption of new ICT-enabled opportunities is likely to present a clear challenge.

Although in many cases, well-targeted government intervention is required, barriers to greater investment in sustainable ICT may also exist because of business practices that are more difficult to influence (de T'Serclaes & Jollands, 2007; Gillingham *et al.*, 2009). Some of these business practices may exist because of the challenges outlined above of insufficient information about new products. Insufficient information may make it difficult to secure financing as a lender may be unwilling to secure its loan on risky projects. Perceived risk could lead to businesses evaluating projects using a high hurdle rate so that only projects with immediate payoffs will be adopted. Projects that involve high initial costs may need greater scrutiny by additional levels of management.

Wider problems may also exist as firms interact with each other. Individual firms may develop their own types of technology, but which are then incompatible with those developed by others. Path dependence may be established when specific technologies or standards are adopted and can make it very difficult for new technologies and practices to become established later on. Failure to adopt common standards could inhibit costs from falling by preventing economies of scale from being exploited. Building owners face no incentive to invest in energy-efficient power and heating if the costs are borne by those leasing buildings.

On the business side, there is evidence that Canada under-invests in ICT compared with other advanced countries (Sharpe & Andrews, 2012; Conference Board of Canada, 2013c). Canada ranked in the bottom half (8^{th} out of 15 peer countries) in ICT investments as a percentage of non-residential gross fixed capital formation and received a D grade in the Conference Board of Canada report card on ICT investments (Conference Board of Canada, 2013c) (see Figure 5.1). The report



Reproduced with permission from the Conference Board of Canada, 2013c

Figure 5.1

ICT Investments of 15 Peer Countries

The Conference Board of Canada ranks 15 peer countries in ICT investments as a percentage of non-residential gross fixed capital formation. ICT investment has three components: software, IT equipment, and communications equipment.

also noted that Canada's investment in ICT was below the 15-country average. The rankings measure the collective investments in communication equipment, IT equipment, and software. Within these components, Canada ranked sixth, eighth, and ninth respectively, all slightly below the 15 country average.

5.1.2 Options for Solutions

"Failure is simply the opportunity to begin again, this time more intelligently."

- Henry Ford

The implementation of a new technology or ICT application is a complex endeavor and the costs, or fear of the costs, may be a challenge. For instance, a new ICT application may have high initial costs, a lack of demand, and limited incentives to adopt. While there are many possible approaches to address these challenges, the Panel has chosen to focus on two solutions: (i) living laboratories and (ii) scaling up ICT technologies. These activities help to mitigate the risks associated with market entry of a new product in addition to encouraging a competitive market for ICT products and services.

Living Laboratories

Living labs are real-world experimental settings in which users and producers co-create and validate innovations. People are at the centre of the innovation process in these dynamic environments, making processes "human driven" rather than "technology driven" (Molinari, 2012). The ability to integrate customers into innovation processes is proving to be a key advantage in today's business environment (Edvardsson *et al.*, 2010). Through these co-creation innovation processes, businesses can respond more effectively to consumer needs, reduce risks associated with the market entry of new products, and improve time to market (Niitamo *et al.*, 2012).

Promising Practice

Forschungszentrum Informatik (FZI) House of Living Labs, The FZI Research Centre for Information Technology, Karlsruhe Institute of Technology

The FZI House of Living Labs is a research institute that supports small or medium enterprises by providing a platform to develop, integrate, and test new applications in preparation for product launch and commercialization. The institute's research environment provides access to modern equipment such as mobile or stationary ICT, and building technologies. Participating firms may also receive support from more than 150 researchers specialized in computer science, electrical or mechanical engineering, and economics. The institute houses living labs devoted specifically to smart energy, home, mobility, automation, mobile IT, and service robotics (FZI, 2014).

Universities can serve as living laboratories because they are open innovation platforms capable of tolerating significantly more risk than individual firms. In assuming this role, universities turn their physical assets into test beds in which the institution and its partners in the private, public, and non-profit sectors "test, study, teach, apply, and share lessons learned, technologies created, and policies developed" (Robinson *et al.*, 2013a). Universities have not just a responsibility, but a significant academic and operational opportunity to practice sustainability; to do research on the technical, economic, social, and institutional challenges; and to train students.

Promising Practice
The Centre for Interactive Research on Sustainability

The Centre for Interactive Research on Sustainability (CIRS) at the University of British Columbia (UBC), completed in 2011, is designed to provide net positive benefits to its environment and its inhabitants. Both a demonstration project and research infrastructure, CIRS provides data and support for ongoing research projects on sustainable building performance and facilitates the interplay between the building, its subsystems, and its inhabitants.

ICT play an important role in CIRS research, building design, and operations. Examples include:

- a sensing, monitoring, and control system with 3,000 points integrated under a common building technology platform;
- a building information modelling program for building design, energy modelling, and generation of construction drawings; and
- video walls in the lobby that display real-time building performance data and information about building systems.

The environmental and human performance of CIRS is currently the subject of considerable research by a team of graduate students, postdoctoral fellows, and faculty, with involvement of private-sector partners. Preliminary indications suggest that the environmental performance goals are not yet being met, but strategies to achieve these goals are being developed. The lessons learned from CIRS have already begun to influence decision-making for other buildings and infrastructure development at UBC.

(Robinson *et al.*, 2013b)

Universities are not the sole examples of living labs; innovation may relate to a wide variety of issues resulting from the engagement of a broad range of stakeholders including industries, governments, or collectives. This is exemplified by the varied projects that have received Living Labs Global Awards. Created in 2009, these awards have since brought together solutions from over 1,500 providers to meet strategic challenges from 42 cities around the world (LLGA, 2013). Providers, from firms, research centres, or non-profit organizations, are invited to present technological innovations ready to be deployed.

Strategy to Scale Up ICT

Many existing approaches can encourage a scaling up of technology, that is moving from use on a small scale by a limited number of users to implementation and use on a much larger scale. One such strategy is for governments to create a demand for ICT products with environmental benefits (ITAC, 2009). Government departments in Canada are leading users of ICT. The federal government spends approximately $2.5 billion per year on the procurement of ICT goods and services (Government of Canada, 2010). This means that through its procurement policies and buying decisions, the government is capable of encouraging, or even creating, a national market for specific ICT products and services (IISD, 2011). Through Public Works and Government Services Canada, the government has a specific policy on green procurement to ensure that procurement of goods, services, and construction integrates environmental considerations, thereby expanding the market for environmentally sound goods and services (Government of Canada, 2014b). Additionally, the federal government procures pre-commercialized innovations from Canadian firms through its Build in Canada Innovation Program. The program helps to bridge the pre-commercialization gap, support Canadian businesses, and stimulate the market for new innovations (Government of Canada, 2014a).

Promising Practice
European Commission Strategy for Key Enabling Technologies

In 2011 the European Commission adopted a strategy for furthering the development and commercial deployment of key enabling technologies. The strategy's two goals are to spur economic development and address societal challenges. It was significantly informed by the findings of the High-Level Expert Group on Key Enabling Technologies (European Commission, 2011). This expert group recognized the difficulties that Europe has faced in translating knowledge into commercialized products, and outlined a three-pillar approach to help ICT firms cross the "valley of death" with their products and services. The approach is designed to reduce the risk of viable technological opportunities not being brought to scale, and to provide support throughout the innovation chain:

- The first pillar focuses on advancing technological research.
- The second pillar focuses on product development, including the provision for pilot scale and prototyping facilities.
- The third pillar focuses on providing an enabling environment for globally competitive manufacturing.

(European Commission, 2011)

While the strategy focuses on the production and deployment of key enabling technologies, the framework could also be applied more broadly to ICT-enabled sustainable technologies. The Panel suggests that Canada could seize the opportunity to adopt this type of strategy and be one of the first nations to take action to further the adoption and uptake of ICT sustainable opportunities.

Promising Practice
SDTC and MaRS, Supporting Technology Development, Demonstration and Adoption

SDTC positions itself as the bridge between research and commercialization, where funding is necessary to prove that a new sustainable technology works. It does this by supporting the development and demonstration of clean technologies in preparation for commercialization. Through its signature funds, SD Tech Fund and NextGen Biofuels Fund, SDTC has approved funding of $598 million for 246 projects in a variety of sectors including energy exploration and production, power generation, energy utilization, transportation, agriculture, and waste management.

In addition to its traditional support of late-stage development and pre-commercial demonstration of clean technologies, SDTC has engaged in pre-funding activities to help improve the management capacity and value proposition of firms with early-stage and promising technologies. It has signed memoranda of understanding with Export Development Canada to open up new avenues to commercial financing and export markets for the firms they support (SDTC, 2012).

MaRS provides resources — expert advice, market research, and education, as well as connections to talent, customers, and capital — to ensure that high-potential companies can launch and grow in Canada, and scale in international markets.

MaRS (2012a, 2013) has created over 4,000 jobs and, in the last three years, raised a total of over $750 million in capital and earned over $375 million in revenue. In 2012 alone, MaRS ventures raised over $350 million in capital from a combination of angel investors, venture capitalists, government programs, and debt financing (MaRS, 2012a).

MaRS supports the growth of technology firms based in Ontario through management of the Investment Accelerator Fund. This program, funded by the Ontario government and delivered through the Ontario Network of Entrepreneurs, invests up to $500,000 in early-stage technology-based companies (MaRS, 2012b). MaRS also partners with the MaRS Cleantech Fund — a $30-million privately backed fund that focuses on early-stage clean technology firms with high potential. The Fund typically invests up to $1 million in MaRS Cleantech companies as an initial investment, with the possibility for follow-up funding. In addition, MaRS operates JOLT, a technology accelerator program that supports the most promising web and mobile start-ups by providing space in the MaRS Commons, seed financing of $50,000, and mentorship, as well as access to partners and investors (MaRS, 2012b; JOLT, 2014).

5.2 STANDARDS AND DATA ACCESS

Anything that prevents cooperative activities of actors is a challenge to achieving the full benefits of ICT-enabled opportunities for sustainability. In Chapter 4, the Panel identified lack of data access and interoperability as a particular challenge. In this section, the impacts of two ineffective practices, fragmented data systems and lack of data standardization and accessibility, are examined in more detail.

5.2.1 Exploring the Challenges

Fragmented Data Systems

Fragmented systems can make it difficult to implement ICT opportunities for sustainability or to apply (or expand) these solutions across multiple jurisdictions. Fragmentation often stems from a lack of cooperation between key actors and institutions, or from an absence of a unified policy framework. In some cases, fragmented structures or jurisdictional control may make it more difficult to obtain the capital needed to implement a solution. A notable example of fragmented jurisdictional control in Canada is utility data ownership (see Section 3.2).

Complex jurisdictional control may also make implementation of ICT-enabled opportunities more challenging. For instance, in Canada ownership of transportation infrastructure is shared between three orders of government. Furthermore, municipal governments, which operate most public transit systems, may not have the capital for large-scale investments. Complex jurisdictional relationships do create barriers to data sharing, suggesting a need for increased collaboration and cooperation.

Fragmented data structures are not unique to the public sector. Business structures, relationships, and practices can also create obstacles to collaboration and data sharing. Smart building construction and operation is one example. The construction industry is information- and process-centred (Eastman *et al.*, 2011), and the design and construction of a building is a complex endeavour requiring multidisciplinary perspectives (Isikdag *et al.*, 2007). The most common form of communication between multidisciplinary team members is through paper documentation (Isikdag *et al.*, 2007). The reliance on non-digital documentation prevents effective communication of concepts and ideas among stakeholders, and subsequently hampers the efficiency and performance of the industry. The drive for innovation and adoption of technology in the construction industry related to building information modelling may with time address some of these challenges, although in practice it is a complicated endeavour requiring a coordinated effort (Staub-French & Khanzode, 2007).

Lack of Data Standardization and Accessibility

As ICT devices have become more powerful, more ubiquitous, and more varied in their functions, the total amount of data being produced is increasing rapidly. Furthermore, ICT are producing different types of data that may or may not be compatible. There are potential benefits associated with this proliferation of data (recall the discussion on big data in Section 3.2), but accessibility and compatibility are essential. Users (governments, businesses, and individuals) can only take advantage of a dataset if it is accessible and in a usable format.

A Day in the Life

Jonas, Halifax

2:00 pm (AST)

Jonas turns to page 180 of the proposal the government has sent him. It is an offer to purchase the rights to his hobby and creation, a distributed computing system that he calls Pivot. Collecting data from hundreds of millions of sources, it allows users to model potential strategies for adaptation. Pivot then rates each strategy in a variety of ways, all centring on quantifiable risks, costs, and benefits. The system has created excellent results for those with access to it, and has prompted many attempts at imitation. But the increasing complexity of user queries has begun to test the limits of the program, and similar programs have, in some cases, been implicated in disastrous decisions. Worse, the program only runs on the original system and has almost no interoperability with other networks and tools. The proposal includes a plan for transferring the entire system over to government servers.

Although Jonas is loath to give up control of the project, he is not a software engineer, and the demands of his system are beginning to exceed the freely accessible infrastructure available to him. The proposal includes provisions for making code available to other programmers at no cost, and a requirement that derivative works be similarly licensed. Jonas insisted on this much. Pleasingly, it also presents its data in a form designed to be entered into Pivot itself.

The increasing variety of data sources, both structured (computer readable) and unstructured, may hinder the capacity of software to process, manage, analyze, and combine data sets. For example, regionally collected climate-related data may be in formats that are not useful for decision-makers or end-users (NRTEE, 2009).

Given the large amount of data now being produced, finding the right type of data may also prove challenging, especially in cases where users want to browse data, unsure of what they are looking for. In short, the fragmentation and lack of standardization and accessibility of data are important hurdles that need to be overcome to achieve data integration and open the door to new opportunities for sustainability.

5.2.2 Options for Solutions

A clear benefit of ICT is their potential to break down silos and drive the convergence of traditional infrastructures. Convergence — in electrical, building, transportation, or other key infrastructures — can move Canada towards sustainability. The electricity grid is a good example: grid infrastructure would be much more efficient if the system could access and precisely anticipate energy consumption, weather changes, and even driving patterns.

Promising Practice

The Adoption and Use of Interoperability Standards with Smart Grid Technologies

Efficient smart grids need to be able to exchange information and work together in holistic systems (Ontario Smart Grid Forum, 2010). This requires the development and implementation of interoperability standards for grid-management systems. In Canada, the Smart Grid Technology and Standards Task Force has recommended a series of priority standards for the smart grid. In particular, the task force highlighted standards for energy market communications, energy management systems, distribution management systems, supervisory control and data acquisition, substation automation, distribution automation, and distributed energy resources and security (SCC, 2012). The adoption of such standards is critical to realizing the smart grid system (Gungor *et al.*, 2011b). There have been a number of activities in smart grid standardization that include interoperability standards. Two examples are the European Union Technology Platform's Smart Grid Strategic Deployment Plan (SmartGrids, 2010) and the Ontario Energy Board's commitment to providing the regulatory framework for a smart meeting initiative (OEB, 2007). Information security and enhanced interoperability are some of the goals that can be attained through smart grid standardization (Gungor *et al.*, 2011a as referenced in Gungor *et al.*, 2011b).

A Day in the Life

Quinn, Regina

6:40 pm (CST)

Quinn sees a notification that a city planner from Quebec is about to give a statement over a streaming service accessible to listeners with certain engineering or city planning credentials. The topic is loosely tagged as "adaptability," with the scope described as covering the coming month.

As the planner begins his speech, listeners begin to discuss the content with one another. Some choose to converse with those nearby, while others focus on those who share their interests. Noting that the talk focuses on flooding, Quinn looks for listeners who live in coastal areas. Within minutes, Quinn is at the centre of an animated discussion. The group isolates one problem presented in the planner's speech — that of preserving delicate information infrastructure in harsh conditions — and suggests software improvements that could dramatically reduce the damage caused by severe flooding. In particular, they suggest greater integration of warning systems so that human users can be more quickly and effectively informed as a situation develops.

As complex systems mature, safeguarding the development of efficient and effective solutions will increasingly require tools that support the interoperability of different technologies and datasets. The tools would also provide stakeholders with a common language to develop a technology and promote its adoption. This requires the introduction of technical specifications to support collaboration between private-sector players, orders of government, not-for-profit organizations, and citizens.

Standards and data may be addressed at two levels of openness (see Liang, 2012):

- **Technical openness:** Using normalization and standardization so that different systems can talk to each other allows for more flexibility. This is also known as *open standards*.
- **Policy and institutional openness:** The development of processes that support data accessibility and usability leads to greater flexibility in managing applications and reducing costs. This is also known as *opening the data*.

Both of these options are examined here.

Open Standards (Technical Openness)

Open standards are applicable to both technical standards and data. Open standards allow interoperability, promote efficient sharing, and allow data to be compared (see Box 5.1).

The Canadian National Committee to the International Electrotechnical Commission task force on Smart Grid Technology and Standards has recommended that the Standards Council of Canada "should encourage Provincial [and] Territorial regulators and utilities, when developing business plans for Smart Grid initiatives, to ensure that systems migrate from proprietary technologies to open standards" (SCC, 2012). Germany has also seen benefits in promoting the development of open standards and supporting manufacturers in the early stages of standardization (BMWi, 2010). Open standards not only promote collaboration and cooperation between stakeholders, but, if controlled by credible standards organizations, they are also a prerequisite to supporting emerging privacy-enhancing platforms (Cavoukian, n.d.).

There is a need to develop open standards (BMWi, 2010; SCC, 2012; Liang, 2012). ICT opportunities involve many sectors of the economy, stakeholders, and types of technologies, and standardization work is often driven by different organizations depending on the type of infrastructure. For example, Natural Resources Canada and the Standards Council of Canada created the Task Force on Smart Grid Technology and Standards. The task force's mandate is to "promote efficient and effective standardization in Canada" (Bryans & Lojk, 2010). To date, no clear consensus has emerged on the existing standards and constantly evolving technologies (SCC, 2012). On the other hand, standards for sensors and sensor networks, which are mainly driven by industry, are particularly mature. For example, technical standards such as ZigBee (IEEE 802.15.4), 6loPAN, and Z-Wave are in place for wireless network protocols for devices and sensors. The World Wide Web Consortium (W3C), an organization that works to develop web standards, has a working group on sensors and sensors network, and has recently developed the Semantic Sensor Network (SSN) ontology.[6] The telecommunication industry was an early adopter of open standards: it was a necessary condition for the mass adoption of the telephone, cell phones, and the internet (Leiner *et al.*, 1997). In the area of environmental modelling, OGC Sensor Web Enablement is an example of a mature data model standard.

6 For more information see http://www.w3.org/community/ssn-cg/wiki/SSN_Applications

> ***Box 5.1***
> **Characteristics of Open Standards**
>
> The European Interoperability Framework for Pan-European eGovernment Services report defined the open standards and specification characteristics necessary to achieve interoperability of government services to citizens and enterprises (European Commission, 2004):
> - The standard should be adopted and maintained by a not-for-profit organization, and the decision-making should be transparent.
> - The standard should be published, available freely or at a nominal fee, and include permission to copy, distribute, and use.
> - The intellectual property of all standards should be available for use without the need to pay royalties or licence fees.

Opening the Data (Policy and Institutional Openness)

Opening data (in combination with proper data standards) from utilities, energy consumption, and traffic allows any person or application to use or combine datasets. If datasets are available, accessible, and usable, potential public benefits could include:

- increased citizen participation and monitoring;
- enhanced collaboration and innovation;
- improved efficiency; and
- support for new partnerships and opportunities.

The success of many open data projects and applications depends directly on the willingness of stakeholders to share their data, the appropriate licenses and tools to distribute and integrate the data, and shared common ontologies. Various orders of governments have started opening up government and public administration data to citizens, and the public and private sectors. In Canada initiatives are underway at the municipal, provincial, and federal level to share datasets with the public.

In 2010 the cities of Ottawa, Toronto, Edmonton, and Vancouver agreed to collaborate on a national open government initiative through an open data framework. The G4 Open Data Framework seeks to provide leadership in the open data movement, share technologies and resources, exchange notes on experiences, identify common problems, and work on common data standards while supporting additional jurisdictions looking to develop open data catalogues (Giggey, 2012). The G4 Open Data Framework is based on the Sunlight Foundation's 10 principles of openness and accessibility of government data to

Promising Practice
GeoBase

GeoBase is an initiative of federal, provincial, territorial, and municipal agencies in collaboration with the Canadian Council of Geomatics. Prompted by fiscal constraints and the challenges of collecting data on a large and varied landscape, Canadian geospatial organizations began to rethink how to gather, process, and distribute geospatial data. GeoBase was launched in 2001 to provide all Canadians with free and unrestricted access to quality and unique geospatial data. Canadians can access data for a wide variety of applications, including sustainable resource development, environmental protection, and public safety and protection (GeoBase, 2014).

the public: completeness, primacy, timeliness, ease of physical and electronic access, machine readability, non-discrimination, use of commonly owned standards, licensing, permanence, and usage costs (Sunlight Foundation, 2010).

Benefits of the G4 collaboration have been immediate. For example, Vancouver and Toronto have launched open data catalogues (data.vancouver.ca and DataTO.org) that provide the public with access to city data sets, and are accepting requests for additional data to be released (Giggey, 2012). Edmonton and Ottawa have hosted open data contests. Edmonton, first to launch its contest (Apps4Edmonton), shared lessons learned as well as its technical platform, so that Ottawa could reuse it with no additional capital investment (Giggey, 2012). To date, about 30 Canadian cities have launched their own open data sites (Government of Canada, 2013a).

Similarly, in recent years, most provincial governments have opened data portals to make a wide array of government data in machine-readable format available with open licenses to the public.[7]

In October 2012 the Canadian government launched the Open Data Portal managed by the Chief Information Officer Branch of the Treasury Board Secretariat. The portal provides over 273,000 datasets from 21 participating agencies and has generated around one million user sessions in about eight months (Treasury Board of Canada Secretariat, 2012). The data offering includes 171 data sets from Environment Canada and covers a wide range of subjects (e.g., emissions of toxic substances, indicators on household use of

7 For an updated list of open data portals, see http://data.gc.ca/eng/maps/open-data-canada

Promising Practice
The U.S. Energy Data Initiative

The U.S. government, through the Department of Energy and other government agencies, has launched the Energy Data Initiative to use government and non-government data to create opportunities to save money and energy (Connected World, 2013). The initiative makes new and untapped data available to entrepreneurs to spur the development of new products and services.

The Energy Data Initiative's objectives are to:

- "Work with data owners inside and outside of government to make energy-related data available, machine-readable, and accessible, while ensuring personal privacy is protected.
- "Collaborate with private-sector entrepreneurs and innovators to ensure they are aware of these existing and newly available digital assets, and encourage them to include these data as inputs in new products, services, and product features that improve energy productivity and catalyze the transition to a clean energy economy" (United States Government, n.d.).

chemical pesticides and fertilizers, phosphorous levels in the St. Lawrence River) (Environment Canada Pollutant Inventories and Reporting Division, 2013). Most recently, in 2014, the federal government proposed the creation of the Open Data Institute to take "a role in aggregating large datasets, informing the development of interoperability standards, and catalyzing the development and commercialization of new data-driven apps" (Government of Canada, 2014c).

5.3 ICT-INTEGRATED EDUCATION AND SKILLS

A strong knowledge base is an integral component, and indeed a foundational part, of a healthy innovation ecosystem (CCA, 2013b). As such, it is crucial to successful implementation of new and innovative ICT-enabled solutions for a sustainable Canada. A lack of ICT skills was identified in Chapter 4 as a potential challenge impeding the realization of several ICT opportunities in Canada. This section explores further the challenges involved in creating a digitally literate society and establishing access to a dynamic and ICT-savvy workforce, and highlights some options for solutions to overcome the challenges.

5.3.1 Exploring the Challenges

With ICT entering every domain of public life, strong ICT literacy skills are demanded in the daily lives of Canadians as well as in the labour market. Canada's education system may be challenged to equip generations of students with skills and knowledge required to meet the changing science and technology demands of the 21st century. The key objective of digital and computer literacy is "to build capacity in areas that promote a resilient society capable of effectively adapting to rapid change [...] with focus on competencies such as critical thinking, character, creativity, innovation, as well as digital and computer literacy" (Action Canada, 2013). Canadian-based not-for-profit advocacy organization C21 Canada also identifies digital and computer competence as one of the key core concepts for 21st century learning (C21 Canada, 2012).

While the mandates of provincial education systems have a strong focus on ICT education and digital literacy, Action Canada reports discrepancies between provincial policies on the integration of ICT in curricula with what is actually implemented in the classroom (Action Canada Task Force, 2013). Action Canada's Task Force report on education systems for the 21st century notes a positive association between teacher education and the facilitation of learning, with a strong relationship between the active use of ICT and other learning abilities. This suggests that technology is a key enabler of 21st century learning. The report recommends a more integrated and cohesive provincial strategy across Canada to address learning needs and the disparities between policies and their actual application in the classroom (Action Canada Task Force, 2013).

Given the increasing complexity of software applications and a growing demand for IT professionals and data analysis, students also need strong computer programming and high-end technology development skills (Wallis, 2012). Computational thinking and digital literacy competency go hand-in-hand with problem solving and creative, critical, and reflective thinking — core elements of modern education. According to the U.S.-based organization Partnership for 21st Century Skills education and professional development must incorporate a full spectrum of digital technologies as a tool for research, organization, and communication of information, as well as to access, manage, analyze, and create the new technologies and information required for today's ICT-enabled knowledge economy (Partnership for 21st Century Skills, 2012)

There is also a growing demand for skills and talent in the ICT sector due to rapid technological change and an aging workforce. The Information and Communications Technology Council (ICTC) estimates that Canadian employers will need to employ approximately 106,000 ICT workers between 2011 and 2016, (ICTC, 2011). Moreover, ICTC estimates that between 2013 and 2018, emerging ICT sectors such as cloud, mobile computing, and applications are expected to create an additional 78,000 jobs, with other sectors, such as data analytics, adding over 4,000 new positions annually (ICTC, 2014).

Potential future labour shortages within the ICT sector (Nordicity & Ticoll, 2012) may pose significant challenges for Canada's competitiveness and its shift towards a green economy. The ICTC projects critical shortages of skilled personnel for computer and information systems managers, telecommunication carrier managers, information systems analysts and consultants, and broadcast technicians (ICTC, 2011). The McKinsey Global Institute predicts a future shortage of expertise in data analytics. The United States alone could lack up to 190,000 individuals with specific analytical skills, and about 1.5 million managers and analysts that understand big data (Manyika *et al.*, 2011).

The projected shortages in ICT talent will be magnified by both supply and demand issues. On the demand side, there is a growing need for ICT professionals in the ICT sector as well as in other sectors such as finance, education, and manufacturing (Nordicity & Ticoll, 2012). On the supply side, universities (a key talent pool for the ICT sector) may not be producing sufficient graduates in ICT-related fields, such as computer science and engineering (ITAC, 2013). Undergraduate enrolments in these fields have declined since 2001, an after-effect of the 2000 dot-com bubble burst (Nordicity & Ticoll, 2012).

A Conference Board of Canada report suggested that younger generations are moving from ICT-related education and activities in part because of a perception that ICT jobs are difficult, complex, and not enjoyable (Conference Board of Canada, 2009). The report also identified a gender gap, with male students more favourably viewing a career in ICT than female students. Women are still currently under-represented in knowledge-intensive careers such as in the life sciences, ICT, aerospace, electricity, and defence sectors (Orser *et al.*, 2012). Specifically with respect to the underrepresentation in ICT careers, some of the rationales identified the lack of mentorship, role models, and access to informal networks of decision-makers (Foust-Cummings *et al.*, 2008). These factors, combined with the forecast of a tight labour market and a demographic crunch as baby boomers exit the workforce, may provide serious obstacles to addressing the projected skills shortage.

There may also be a mismatch between the skills sought by employers and those available in the labour pool (ICTC, 2011). Employers seek an eclectic mix of appropriate technical expertise; soft skills (business and communication expertise) (Cukier, 2003); and foresight to identify business needs and potential applications of ICT (ICTC, 2011). As a result, there may be asymmetry in the job market between the skill set desired by employers and the qualifications of job seekers, particularly among new graduates and internationally trained professionals (ICTC, 2011). Although not discussed in this report, the Panel recognizes the similar need of other education streams to include more ICT skills. Engineers, managers, social workers, biologists, and many other professions would benefit from adding some knowledge of ICT and sustainability to their main skills. In addition, jobs involving technical IT skills or data analysis for software and application development also increasingly require numerous social sciences skills to provide social insight into big datasets (LSE, 2012).

While many in the ICT sector project a skill shortage, others dispute this claim. Some preliminary research suggests that empirical evidence on ICT sector labour shortages is weak. One key argument for this theory is that wages in the sector have remained relatively constant despite the claim of increased demand (Veall, 2013). Further research may be needed to gain a better understanding of the issue.

5.3.2 Options for Solutions

Realizing the benefits of an ICT-enabled sustainable economy depends on the existence of a digitally literate society and access to an ICT talent pool with the right mix of technical and soft skills. Improving digital literacy education and addressing the skills mismatch requires a coordinated approach involving government, industry, academia, and individuals. This section briefly outlines some options that could help overcome these challenges.

Promotion of digital literacy skills at all levels: Education of the technical proficiencies necessary to adopt, use, and further develop ICT applications can begin in the elementary classroom, continue all the way to the post-graduate level, and include components outside the traditional classroom (ETS, 2002). By partnering with various levels of education institutions, public interest groups, learning centres, English as a Second Language (ESL) schools, adult training, and community outreach programmes, it is possible to ensure that citizens have the opportunity to gain the skills needed in a digitally enabled knowledge society, even if they are not directly employed in the ICT sector. The skills needed for ICT sector employment can also be strengthened by including partnerships between post-secondary institutions and industry (Edmondson *et al.*, 2012). An example is the Seneca Centre for Development of Open Technologies where students are exposed to, and work on open software technologies and have the possibility of an internship at Mozilla. Many students have benefited from this collaboration by acquiring advanced digital skills through hands on learning (Robles *et al.*, 2011).

Enhancing capacity by attracting immigrants and women to the labour pool: Some Canadian ICT firms surveyed said they had hired foreign-trained professionals to address shortages of skills that could not be found in Canada (Nordicity & Ticoll, 2012). This underscores the important role immigrants will play in the ICT labour pool going forward (ITAC, 2013). Additionally, there has been an increased presence of women in ICT careers. These trends may signal an opportunity to address these and other concerns about ICT skills capacity.

Capitalizing on the untapped opportunities in applications and analytics: As discussed throughout the report, applications and data analytics are critical to effective operation of smart grids, buildings, transit, and other ICT-enabled opportunities. This represents a significant and, as of yet, largely untapped opportunity for Canada. The unprecedented amounts of data generated by end-users and other devices must be analyzed to be useful. To meet the demand for data analytics products, applications, and a skilled workforce Canada must develop the know-how and promote associated careers and sectors. Whether decision support or system automation, data analytics and discovery, or data organization and management, Canada could benefit by leveraging its strengths to capture market opportunities for world-leading data analytics applications for sustainability.

5.4 ENABLING SOCIAL AND INSTITUTIONAL ACCEPTANCE

The success of new technologies and ICT-based applications depends on the willingness of individuals, businesses, or society to adopt and use them. In Chapter 4, the Panel identified several factors that influence the behaviour of potential end-users and thus can hinder the adoption and use of new technologies. This section examines several of these factors more closely: human behaviour, cultural characteristics and habits, as well as privacy and security concerns. Addressing these challenges requires a society that encourages interconnectivity of systems but, at the same time, develops and emphasizes strong privacy standards. The Panel highlights ways in which user-friendly technology design and a commitment to privacy and personal control over information in the personal data ecosystem can help realize the environmental and socio-economic benefits of ICT opportunities.

5.4.1 Exploring the Challenges

Human Behaviour

ICT have changed the way people learn: information-receivers and passive learners are being replaced by information-seekers and active learners. However, this change has affected different groups in different ways depending on age, background, and learning style (Mignone *et al.*, 2008; Tong & Yang, 2009). Prensky (2001) popularized the notion of divide in technological aptitude and learning behaviours between *digital natives* who are raised interacting with technology and *digital immigrants* who adopt technology later in life. These differences can, for example, influence who participates in crowdsourcing and online engagement activities. As Tom Watson explains in CauseWired, new generations of youth have always lived with the internet. The new technologies and the people's drive to communicate are creating the foundation for what Watson calls the "golden age of activism and involvement" (Watson, 2008). Understanding the learning style and needs of the target audience for an ICT application is thus crucial to properly design and implement ICT opportunities for sustainability.

Cultural Characteristics and Habits

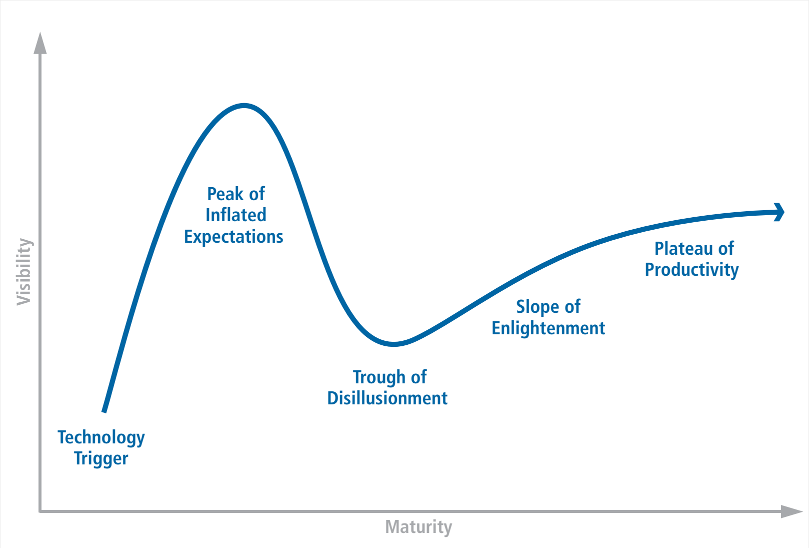
The cultural characteristics of end-users, both individually and collectively, may affect their adoption of ICT applications. Characteristics include social distribution of power, uncertainty avoidance or risk aversion, and individualism (Erumban & De Jong, 2006). Furthermore, the cultural divide between digital natives and digital immigrants may also affect how people relate to, or identify with, technology use and technology acceptance (Prensky, 2001). As with learning styles, consideration of these issues is important for ensuring uptake of an ICT application by those who could most benefit from its use. For instance, an application whose target audience is new immigrants to Canada needs to be developed and marketed differently from one whose target is current citizens or long-time residents.

Other human behaviours may also limit the effectiveness of an ICT application such as resistance to changing a routine (Oliver, 1997). Evidence shows that people are often creatures of habit, sticking to routines they are unlikely to change (Hupkes, 1982). For instance, in the transportation sector, individuals may have negative views of public transit such as inefficiency and unreliability of service. Although the adoption of smart mobility technologies would challenge many of these negative assumptions, certain individuals would still choose to take private forms of transportation. Examples can also be found in the service and consumer sectors; here, even though new digital technologies have provided alternatives, individuals may have a strong preference for physical media such as vinyl records or paper books (GeSI, 2012).

Behavioural challenges may also be associated with business norms. For instance, at the organizational level, common business customs and practices may hinder adoption of new ICT. An example is when businesses continue to use software even though it may be obsolete. Whether related to individuals, businesses, or other organizations, these types of challenges can result from customs, routines, values, and traditions.

Box 5.2

The Hype Cycle — Charting Human Attitudes Towards Technologies



Gartner, Hype Cycle Research Methodology,
http://www.gartner.com/it/products/research/methodologies/research_hype.jsp

Introduced in 1995, the Hype Cycle model illustrates the progression of an emerging technology, from a period of great interest and zeal, through a period of dissatisfaction, to an eventual understanding of its true relevance and importance to the market. The first part of the curve, the positive hype, is usually fuelled by media speculation and commentary, while the second part, after the negative hype, is influenced by improvements in performance and market adoption over time. The cycle illustrates the nature of human responses to emerging technologies, a model that can be used for most technologies, because the main fixed factor is people, rather than the technologies.

The model is used to caution firms not to make investment decisions on technology choices simply based on hype, or to rule out the adoption of technologies if they have failed initial expectations.

(Linden & Fenn, 2003)

Privacy and Security Concerns

Data privacy and security are an important consideration for many ICT users, and are often cited as a major concern impeding the adoption of certain types of ICT-related solutions (Chan & Perrig, 2003). Increasing amounts of data about people's lives are being collected and stored by ICT: from closed circuit television, smart meters, and building monitoring systems to internet banking, social networking websites, and cloud computing. Concern is growing over how the data will be used and who will have access to them (ICTC, 2012).

A Day in the Life

Guy, Trois-Rivières

3:45 pm (EST)

Guy checks his personal environmental index for the month — an unusually accurate rating due to the high density of sensors on campus. Seeing that it could be better, he adjusts his schedule to shift heavy computing tasks away from peak hours. As long as he lives on campus, he has decided to grant the networks greater access to his information than he would otherwise do. When he goes elsewhere, his privacy settings automatically become more restrictive.

Guy knows that many people have different feelings about how much access to grant and to whom. User security and privacy are integral parts of software design, but, even with certain rights protected by law, he believes it is foolish to have a carefree attitude about personal information.

Most Canadians feel they have less privacy than they did 10 years ago, and 65 per cent believe that personal information protection will be one of the most important issues in the next 10 years (Harrisdecima, 2011). They also feel that they do not have enough information to understand how technologies might affect their personal privacy. In addition, privacy policies that are perceived as unclear are rarely consulted by users (Ecotrust Canada, 2013).

The Office of the Privacy Commissioner of Canada oversees compliance with privacy legislation for both the public and private sectors; however, firms also self-regulate. A 2012 study found that 62 per cent of firms do have a privacy policy. Those without one cited reasons such as:

- a perceived lack of need (45 per cent);
- the firm is too small (17 per cent);
- the firm does not collect personal information on customers (14 per cent); or
- the firm has never thought about it (10 per cent).

(Phoenix Strategic Perspectives Inc., 2012)

The ICTC recently reported that, while Canada has one of the strongest digital infrastructures in the world, the country lacks both stringent cyber-security standards and appropriate policies and assessment tools (ICTC, 2012). As computer networks transmit an increasing amount of personal data, privacy and security matters associated with ICT use are especially important and need to be addressed with existing and emerging technologies. Recent revelations of the United States' use of the *Patriot Act* to surveil private telephone calls and internet traffic are one example (Gellman & Poitras, 2013).

Ensuring data security and protecting privacy is becoming increasingly difficult, "as information is multiplied and shared ever more widely around the world. Information regarding individuals' health, location, electricity use, and online activity is exposed to scrutiny, raising concerns about profiling discrimination, exclusion, and loss of control" (Omer & Polonetsky, 2012). Over 60,000 new malicious computer programs are identified daily in the United States. Some U.S. officials estimate that threats from cyber-attacks will surpass terrorism as the number one security risk in the country (Adams, 2012).

Cloud computing has been heralded as the next stage of the internet's evolution (see Chapter 3). However, it faces similar challenges to those of on-site computing, such as identity management and protection and ownership of information. In addition, there are questions about third-party access through the use of networks, servers, data warehouses, and software applications, and about distinguishing legitimate from illegitimate activities (ICTC, 2012). Increasing public and industry security concerns have already created a massive global cyber-security market between 80 and US$150 billion annually, which is likely to grow as more activities and information move online (ICTC, 2012).

Privacy and security issues need to be taken into account in any consideration of ICT opportunities for a sustainable Canada. Increased collection or availability of personal information rises with integrated networked systems, increased automation and functionality of ICT, and with increasing numbers of devices connecting to the network and acting as separate access points. This was especially evident in the public debates about the potential security and privacy issues associated with BC Hydro's smart meter installations. Consumers voiced a range of concerns about the type of data collected, their accessibility, and the vulnerability of the system to breach or attack. They also worried about security and privacy including the potential for third-party remote access and the possibility of tampering with hardware or the network to track when someone is home, change data points to increase a bill, or completely shut off power (CBC News, 2011, 2013).

In general, the level and type of concerns related to privacy vary by demographics. For instance, younger people who have grown up with technology are seen to be less sensitive to security threats, and are also better able to alleviate these concerns with due diligence (Levin *et al.*, 2008).

In addition to protecting personal data, security is important to protect the integrity of ICT-heavy infrastructure. Data can be compromised by a range of threats, including bugs, crashes, operator errors, misconfigurations, or malicious security breaches. According to Adams (2012), because of Canada's advanced economy, interconnected government, and proximity to the United States, sustained and coordinated collective action by the federal government, industry, academia, and private citizens will be needed to properly mitigate and address threats to privacy and security. Unaddressed vulnerabilities can jeopardize Canada's security and integrity and trigger a public and regulatory backlash that can dampen data expansion and stifle innovation (Cavoukian & Jonas, 2012; Omer & Polonetsky, 2012).

5.4.2 Options for Solutions

Social and institutional acceptance of ICT-enabled applications can be hampered by both behaviour and concerns associated with privacy and security. The Panel looks at overcoming these challenges through an emphasis on ICT design, and data security, and privacy protection.

A Day in the Life

Dorsey, St. John's

8:30 pm (NST)

Dorsey reads over the final revisions to his report. It chronicles the evolution and effects of several purely citizen-driven initiatives that arose in response to water scarcity. One of the most important initiatives stemmed from the commercial availability of lotions intended to reduce the need for water. Though the commercial product saw some success, it was unpopular in North America and Europe until open-source software for formulating similar products was distributed. The true potential of the initiative was reached when students in Canada modified the program, greatly enhancing its ability to factor in the environmental impact of potential ingredients. This capability has led to a model now being applied to other forms of manufacturing. A central server (usually owned by the government or a university) is tasked with rating resources for their present and predicted environmental effects and relaying these ratings in real time to programs that recommend changes to manufacturing procedures. While the sophisticated algorithms used in making and acting upon these predictions come from various places, Dorsey is pleased to report that their integration originated mostly from citizen efforts. And just as importantly, those efforts are ongoing and remain overwhelmingly decentralized and volunteer-run.

The Importance of Effective ICT Design

The ability of technologies to achieve sustainability goals, including improved quality of life, is dependent on their acceptance and proper use by individuals and groups. Successful technical design for sustainability, therefore, must take into account social and human elements as well as traditional technical, environmental, and economic factors. Technology design that considers human needs and behaviour can lead to applications that are more easily adopted and used by diverse groups of people who may benefit from their use.

As technologies become more advanced and are used by people of different backgrounds, ages, and skill levels, their ease of use and functionality strongly affect their adoption and potential benefits. Simple, straightforward, and convenient human-computer interactions can lead to positive experiences. These, in turn, result in continued use of technologies, with the potential for enhanced quality of life and improved environmental impact for users. For example, e-banking is convenient and easy to use. People around the world use e-banking daily to make electronic bill payments, which has a smaller environmental footprint than paper transactions (Türk *et al.*, 2003; Laitner *et al.*, 2012; CBA, 2013).

Box 5.3
The Nudge Effect

There are many indirect ways in which ICT can be used to encourage positive behavioural changes in people and frame choices to influence decision-making. One such example is online eco-labelling, which provides energy efficiency information on products available for purchase online (Cave & Cave, 2012). This example reflects the nudge approach, popularized in Thaler and Sunstein's book *Nudge: Improving Decisions about Health, Wealth, and Happiness*, which proposes a choice architecture for people through the concept of libertarian paternalism (Thaler & Sunstein, 2008). This approach indirectly facilitates desired actions by making certain desirable choices more convenient than others, but still allows the user to ultimately make their own choice. However, by understanding what influences people's choices, through concepts such as framing, anchoring, non-economic incentives, social relations, and human dimensions, this approach can allow people to be nudged in the direction of adopting behaviours that may improve their quality of life and achieve sustainability goals.

Groups like Design for All recognize the importance of usability in ICT design.[8] They advocate for a user-centred approach to products that addresses the range of abilities, skills, requirements, and preferences of the user population, including marginalized, disabled, and elderly people. In a report funded by the European Commission, Design for All found that new technologies needed to embed enough intelligence to enable emerging systems to be adapted to the needs of different users, or of the same users in different contexts (Emiliani *et al.*, 2008). It also concluded that technologies are often used in new ways that were not anticipated or part of their initial design; this can have a mix of positive and negative effects. Flexibility and user preferences in technology design are of great importance in allowing for reorganization and adaptability (Emiliani *et al.*, 2008).

Starting from the concept stage, a designer's methods should match people's needs with what is technologically possible and, through a workable business strategy, convert a product into customer value (Brown, 2008). This people-centred, creative, and reiterative approach, dubbed *design thinking*, works with users as co-creators and focuses on integrative, collaborative design as a continuous process of prototyping, testing, and refinement (Brown, 2008). This

8 For more information please see http://designforall.org/

new socio-cultural approach to technology design stands in stark contrast to a more traditional, linear approach where designers predict user preferences and product function through a predefined series of orderly steps.

The links between ICT design, human needs and usage, and sustainability outcomes are complex because technology can change social relationships (Franklin, 1996). There are still many gaps in the understanding of what contributes to successful ICT acceptance and use. More research is needed to understand key internal and external motivational factors that affect use and application of ICT in the private and public realm (Zhang, 2008). Human-computer interaction researchers argue that successful design in the future depends on studying how artifacts are now used and incorporated into current social practices (Brown, 2005).

Ensuring Data Security and Protecting Privacy

By 2020, estimates suggest there will be more than one trillion networked devices in operation. That is about a thousand wireless connections for every person on the planet (CWTA, 2010). With more data points transmitted, recorded, and stored through multiple nodes and stakeholders, a proliferation of different policies, security architectures, tools, and technologies can be expected.

The potential sustainability benefits of data and smart technologies will need to be balanced against rising security and privacy concerns. As is often the case, the technological and business developments on the ground have far outpaced existing legal frameworks and standards of cyber-security (Adams, 2012; Omer & Polonetsky, 2012).

More and more ICT infrastructure and functionality can now be accessed and controlled remotely. Ensuring the privacy and security of data and systems while taking advantage of opportunities that can be derived from permission-based, consensual use of personal information is important. Privacy policy experts such as Ontario's Information and Privacy Commissioner, Ann Cavoukian, indicate that privacy concerns must be an integral part of smart grid initiative system design from the start to safeguard against privacy challenges and to protect the consumer. Cavoukian and her colleagues have developed principles to safeguard against security and privacy threats while supporting development of big data and smart grid initiatives (Cavoukian, 2010, 2012). The objective of privacy by design is to ensure privacy and personal control over personal information in the personal data ecosystem, while at the same time encouraging the socio-economic benefits of big data and smart technologies. Privacy by design is only one example of the type of policy that can be used to protect data.

Promising Practice
Principles of Privacy by Design

(i) Proactive not Reactive, and Preventative not Remedial

- Anticipate and prevent privacy invasion before it happens.
- Analyze the risk of unintended consequences when establishing an ecosystem of multiple stakeholders, policies, and technologies.

(ii) Privacy as the Default Setting

- Ensure personal data are automatically protected in any given IT system or business practice.
- Minimize private data at every stage of the information life-cycle; if personal data are not required, they should not be collected.
- Employ embedded privacy settings, filter controls and analytics for anonymizing data.

(iii) Privacy Embedded into Design

- *Participant Primacy:* Users should retain control over their raw data and sub-sets of data.
- *Data Legibility:* System must provide high-level tools and guidance on implications of data collection, sharing, and retention.
- *Long-term Engagement:* System should encourage continued engagement of users about their sharing preferences.

(iv) Full Functionality — Positive-Sum, not Zero-Sum

- Accommodate all legitimate interests and objectives in a positive-sum or win-win manner.
- Avoid false dichotomies and unnecessary trade-offs of privacy versus security.

(v) End-to-End Security — Full Life-Cycle Protection

- Extend privacy safeguards throughout the entire life-cycle of the data involved.
- Protect metadata, secure back-end system infrastructure, and ensure destruction of personal data.

(vi) Visibility and Transparency — Keep It Open

- *Commitment:* Stakeholders within the personal data ecosystem should create sound policies to protect privacy and employ meaningful transparency that demonstrates the ability to uphold privacy.

continued on next page

- *Implementation:* Stakeholders should maintain robust internal standards and controls to integrate privacy into design and throughout implementation.
- *Assurance:* Stakeholders should conduct ongoing monitoring and evaluation, with real-time corrections if necessary.

(vii) Respect for User Privacy — Keep It User-Centric

- Put the interests, needs, and expectations of users ahead of those of organizations.
- Empower users to play more active roles in the management of their personal data.
- Improve user interface design to ensure effective, efficient, and satisfying experiences.

(Cavoukian, 2011)

5.5 LIFE-CYCLE PERSPECTIVES

While ICT often have many intended positive impacts, such as increased energy efficiency, enhanced convenience, data access, or facilitation of social interactions, their use may also lead to unexpected consequences or second-order effects. In this section, the Panel discusses the impact of these unintended effects and illustrates how the adoption of a life-cycle perspective could mitigate some of the challenges.

5.5.1 Exploring the Challenges

Much work is underway to understand and balance the potential sustainability benefits of ICT with an understanding of possible risks associated with their adoption and implementation. The impact of ICT can sometimes be overestimated. This is partly because the role of ICT in society is often evaluated as too positive and partly because second-order effects have a tendency to be ignored (Wagner *et al.*, 2003). Further, the increased efficiency induced by use of ICT can result in a rebound effect or Jevons' Paradox where efficiency gains increase consumption of a resource rather than decreasing it (Alcott, 2005). For example, when efficiencies reduce energy costs in an energy-intensive sector, much of the savings can then be used to increase production, which in turn uses more energy (Maxwell & McAndrew, 2011).

Two types of second-order effects are associated with the use of ICT:

- *direct effects*, such as increasing car use as a result of more efficient engines or reduced traffic jams; and
- *indirect effects*, such as people buying more goods that have environmental impact with the savings they achieved from technical improvements and behavioural changes.

(University of Sussex, 2014)

Second-order effects, as illustrated in the two examples below, show the importance of considering human preferences and behaviour in ICT planning, development, and application processes. However, second-order effects can also have positive unintended effects.

Mobility and Transportation: Although expected to result in reduced transportation services, the digitization of work, shopping, and leisure activities has placed further demand on different services. For example, when working at home is possible, teleconferencing and teleworking have reduced peak-hour travel, helped cut down work-home traffic kilometres, and improved work-family balance (Bomhof *et al.*, 2009). On the other hand, teleworking can cause an increase in demand for equipment and additional ICT for support, data storage facilities and servers, duplication of material, heating and cooling of homes for a single person, and other effects (Wagner *et al.*, 2003). Similarly, while online shopping can help lower the need for transport and cut down on congestion and emissions, the ease and convenience can also cause an increase in total shopping. A study from Newcastle University indicates that carbon savings from online shopping can only occur with the right conditions. For example, the study suggests that the "environmental savings can be achieved only if online shopping replaces 3.5 traditional trips, if 25 orders are delivered at the same time, or if the distance to where the purchase would otherwise be made is more than 50 kilometres" (Newcastle University, 2010).

Increased Consumption: A proposed benefit of the digital economy is to reduce the need for natural resources to make material goods. Interestingly, the availability of digital devices has been associated with increased consumption. For example, ICT systems were expected to replace the need for paper and lead to the paperless office. Evidence indicates that ICT use contributes to increased paper consumption due to increased functionality, speed, and capacity to print more at a reduced price (Maxwell & McAndrew, 2011). With the emergence of personal computing and the internet, printing and writing paper consumption per capita increased by 93.6 per cent between 1983 and 2003 in Canada (Sciadas, 2006).

Efficiency improvements on their own may not solve underlying environmental problems. Recognizing second-order effects, where they exist, can aid in understanding this reality (Maxwell & McAndrew, 2011). Second-order effects are sometimes difficult to measure because of the number of parameters that may be involved. However, failure to take them into account can impede progress towards energy and climate change targets (Maxwell & McAndrew, 2011). Although second-order effects should not prevent the implementation of ICT applications to support sustainability, they must be considered (and potentially expected) before implementation. Even after accounting for them, the best ICT opportunities will still have a net benefit in terms of sustainability, especially if positive second-order effects are encouraged appropriately.

5.5.2 Options for Solutions

Second-order effects may be mitigated by adopting a life-cycle perspective. Life-cycle is defined as the actions that go into making, consuming, transporting, and disposing of a product (Environment Canada, 1997). Environment Canada defines life-cycle management as “minimizing environmental burdens throughout the life-cycle of a product or service” (Industry Canada, 2011). In parallel with ICT proliferation, there is a growing need for both government and business to develop and enforce proper life-cycle assessment and responsible disposal management practices, guidelines, and policies for ICT.

Life-cycle management strategies are coming into practice at all orders of government across Canada. In February 2010 Public Works and Government Services Canada launched a Canadian e-waste strategy to ensure the environmentally sound and secure disposal of surplus federal electronic equipment. Provincial and municipal e-waste programs are also helping to promote strategies, policies, and partnerships to synchronize efforts, involving businesses and private enterprises (Public Works and Government Services Canada, 2013).

A sustainable framework for full life-cycle assessments and end-of-life management strategies should take in to account substances that go into product manufacturing and use, longevity of devices, reusability, and disposability. The International Telecommunication Union (ITU) also emphasizes the need to standardize many of the evaluation methods in the life-cycle assessment, including evaluating CO_2 reductions through the use of ICT (ITU, 2009). There is a need for ICT-enabled solutions to make life-cycle management of all pertinent products much more amenable, efficient, and proactive on a massive scale by myriads of people and organizations.

> ***Box 5.4***
> **Social and Socio-Economic Life-Cycle Assessment**
>
> Life-cycle assessment (LCA) can be used to understand the environmental impacts of a product or process. LCA tools guide firms on which aspects of production can be improved to reduce environmental impacts. Social and socio-economic life-cycle assessments add another level to the traditional LCA analysis by assessing the social and sociological aspects of a product (whether positive or negative) through its full life-cycle. This provides the information needed by businesses or individuals who wish to produce or purchase responsibly (UNEP, 2009; Life Cycle Initiative, 2013).

5.6 BROADBAND CONNECTIVITY

Access to broadband networks is essential to maximizing the transformational opportunities arising from ICT applications for sustainability — a key challenge identified in Chapter 4. Seamless connectivity to broadband networks enables the dematerialization of products, goods, and services while providing a platform for grass-roots sustainable innovation. In this section, the Panel first explores the major challenges associated with current broadband connectivity in Canada, followed by a discussion of a vision of a networked world, which describes how a broadband strategy can be used to address connectivity gaps.

The growth of connections between devices and people can improve innovation, productivity, and efficiency. Information and communication networks are being used in ways that stimulate sustainable development while reducing costs of operation or services. According to Cisco, over 99 per cent of devices that could potentially be linked to the network (basically anything with a chip processor) are not yet connected (Bradley *et al.*, 2013). These new opportunities not only open the door for environmental applications, but they have the potential to create up to US$14.4 trillion in value from increased revenues and lower costs between 2013 and 2022 (Bradley *et al.*, 2013).

Consider what is now unfolding in the energy sector with the network used to monitor, manage, and reduce electricity use in the grid, offices, and homes. Connecting buildings and electronic devices to the network allows office and utility managers and consumers to monitor, manage, and reduce energy use by creating the visibility essential to understand how and where, in real time, electricity is being consumed. Chapter 3 discusses how data centres are both fundamental to sustainable ICT and an essential component of opportunities for sustainability. However, such technology cannot be successfully implemented without a robust telecommunication network providing a fast and reliable way to transmit data.

5.6.1 Exploring the Challenges

The vision of a networked world, simply put, can be boiled down to the following: if it can be connected to high-speed broadband, it can be smart — and if it is smart, it can help drive humanity faster towards an interconnected world of sustainable development with positive economic, environmental, and social impacts.

The Canadian Urban Institute undertook a study to evaluate the potential of broadband technologies in stimulating sustainable communities and regions in Ontario. It concluded that “broadband networks play a role in the development of compact and complete communities, integrated transit systems, and the information networks needed to support employment in a knowledge-based and green economy" (Canadian Urban Institute, 2008). A networked society has an impact on everything from utility distribution and real-time pricing, to transportation data management, buildings, and ecosystem monitoring, to the communities themselves. Applied uses for telecommunications such as telework, and telehealth, along with e-commerce, education, and research, can help Ontario conserve energy and reduce GHG emissions while strengthening the knowledge economy (Canadian Urban Institute, 2008).

Access to network speeds on the low to medium end of broadband (defined as 1.5 megabits per second or higher (CRTC, 2011b)) is not sufficient for many commercial and public applications such as multipoint video conferencing, downloading high-definition videos, server backup (one terabyte capacity), and telecommuting (Columbia Telecommunications Corporation, 2010). Moreover, Canada still has a digital connectivity gap in the services provided to rural versus urban areas (see Chapter 3). A Canadian Radio-television Telecommunications Commission (CRTC) report notes that while about 95 per cent of large population centres had availability to download speeds of between 30 and 49.9 megabits per second, in rural areas the share dropped to about 20 per cent (CRTC, 2012).

Looking to 2020 and beyond, the growing list of online applications that can be foreseen will require a far higher data-transfer capacity rate (Columbia Telecommunications Corporation, 2010). If no action is taken to improve rural connectivity, the urban-rural digital divide may widen. The CRTC has established target speeds of 5 megabits per second for download and 1 megabits per second for uploads to be made available to all Canadians, through a variety of technologies, by the end of 2015 (CRTC, 2011b). However, to support all of the opportunities described in this report, the broadband network may need to scale to much higher requirements. For example, to support an exponential number of sensors and objects connected to the networks and still have short latency (1 millisecond) the network would need to support higher wireless communication speeds (over 10 gigabits per second) (Fettweis, 2012). In addition, the development of green clouds is directly dependent on the availability of fast, reliable broadband connections.

5.6.2 Options for Solutions

Countries similar to Canada in terms of population and landscape have begun implementing national broadband strategies. For example, the Australian government has implemented the National Broadband Network with the aim of becoming one of the world's leading digital economies by 2020. Its plan is to roll out an open network that can be leveraged by all citizens, service providers, and a host of applications. Despite a different landscape and population, the German government has developed a strategy to focus attention on improving the accessibility of a high-performance network.

Promising Practice
The Australian and German National Broadband Strategies

The Australian government has established the goal of becoming one of the world's leading digital economies by 2020 (Australian Government, 2013). A key action of the Australian National Digital Economy Strategy is the implementation of the National Broadband Network, which the governments states will be an "open access broadband network offering equivalent terms and conditions to all access seekers or service providers." This network will provide 100 per cent of Australian homes access to the network: 93 per cent through fibre (at speeds of 1 gigabit per second), and the rest through fixed wireless and satellite technology (at download speeds of up to 25 megabits per second). The Australian Communications and Media Authority recognizes that more efficient and effective spectrum allocation will be necessary to deal with the increasing demand for mobile wireless data. The digital dividend spectrum has been optimized for mobile broadband and will be open in January 2015 (Australian Government, 2013).

Working in unison with federal states, localities, and industry, the German federal government is planning a massive boost in its broadband network to provide reliable infrastructure for those broadband services they feel will have high economic returns, including eGovernment, ehealth, and eLearning. Germany established the end of 2010 as a target for the elimination of gaps in broadband penetration and access (BMWi, 2009). A sub-target is, for at least three-quarters of the population, to make networks available that provide access to transmission rates of at least 50 megabits per second by the end of 2014 (BMWi, 2010). Key steps identified to achieve these goals include capitalizing on synergies in infrastructure construction, formulating regulations that foster investment and growth, and ensuring adequate financial support.

Australia and Germany have targeted speeds that are, at a minimum, 5 to 10 times faster than those projected by the CRTC. Moving forward, Canada has to reflect on whether the target nationwide network speed of 5 megabits per second by 2015 will allow the country to remain competitive in the digital economy or be sufficient for realizing the benefits of ICT-enabled sustainable opportunities.

5.7 CONCLUSION: AN INTEGRATED APPROACH TO SOLUTIONS

The seamless integration and interconnectivity of people, data, and things enables unprecedented levels of information exchange and analysis, and facilitates the development of more wide-ranging and innovative response to the sustainability challenges faced by Canada. The Panel has highlighted many ICT-enabled opportunities that could help transform traditional sectors of Canada's economy such as energy, transportation, and buildings. It has focused on transformative technologies that are beneficial to the environment while improving productivity and competitiveness and improving the well-being of communities. However, to realize the sustainability benefits of these ICT-enabled opportunities, challenges in a number of areas must be understood: market failures and barriers; standards and data accessibility; digital and computer literacy; access to ICT skilled talent; cultural, social, and business norms; security and privacy concerns; second-order effects; and broadband network access. The Panel showcased a variety of options for solutions to address these challenges. These can be summarized as follows:

- supporting the establishment and/or continued operation of demonstration-scale facilities (living labs) to potentially mitigate the risk and uncertainty associated with the use of untested or high-risk solutions.
- enabling business and industry adoption of ICTs may require the use of policy instruments such as public procurement to increase demand and address market failures.
- improving standardization and data accessibility to enable interoperability;
- developing processes that support data accessibility and usability to provide greater flexibility in managing applications and reducing costs.
- implementing approaches like privacy by design to ensure privacy and personal control over personal information in the personal data ecosystem, while, at the same time, encouraging the socio-economic benefits of big data and smart technologies;
- promoting digital and computer literacy to position Canada as competitive in a rapidly evolving digital environment;
- adopting life-cycle or social life-cycle perspectives to assist in the identification of second-order effects that may arise from the implementation of ICT opportunities; and
- addressing connectivity gaps to maintain Canada's competitiveness with other advanced economies in broadband access and availability.

The Panel recognizes that identifying these challenges in isolation, and then responding to them with isolated tactical responses, could limit the transformative potential of ICT-enabled sustainable opportunities. Rather, an integrated approach should be considered. Such an approach is a first step in planning for a world in which people, data, and things will be connected in an unprecedented fashion. This interconnectivity offers opportunities to contribute to positive environmental impacts, promote sustainable economic growth, help create new jobs, and bring about social benefits for Canada. Such an approach would consider the various challenges discussed in this report in an integrated manner, as shown in Figure 5.2.

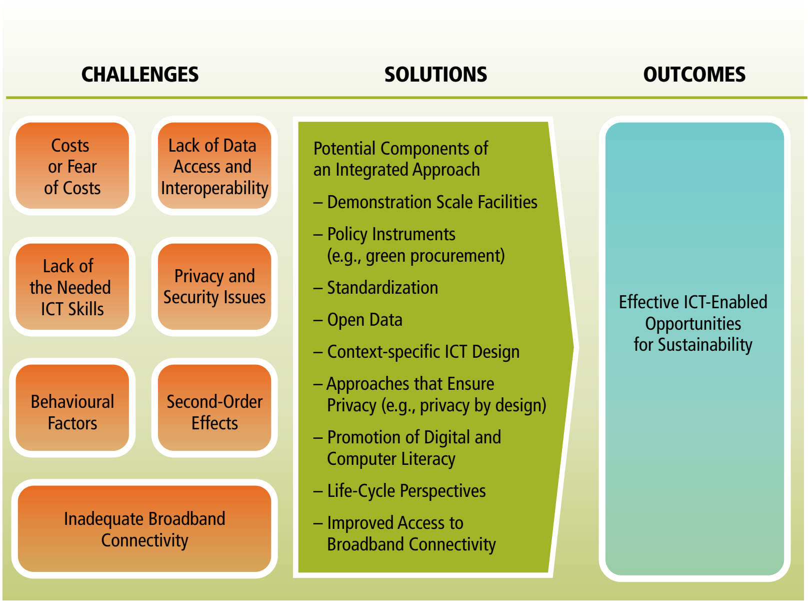


Figure 5.2

An Integrated Approach to Addressing Sustainability Challenges Through ICT

An integrated approach would consider that sustainable living and the move towards a green economy are multifaceted challenges that require a broad range of responses from a wide variety of stakeholders. It would consider coordinated but varied responses to sustainability issues. These could include incentives, regulations, shared decision-making, and stakeholder engagement that recognize both the unique and common linkages among all actors. The approach provides a platform for common solutions, which can achieve a more effective and sustainable impact. An understanding of all these factors further illuminates the interconnected relationships between nature, technology, and human society, and the need for an integrated approach to sustainable development.

6

Conclusions

- Responding to the Charge
- The Path Forward
- Final Reflections

6 Conclusions

ICT systems have had, and are continuing to have, powerful effects on people and their communities. They are ubiquitous in all facets of the lives of Canadians, transforming how they live, work and play, learn, share, and connect at a pace unprecedented in the historical context of technology developments. The promise and potential of ICT and ICT-enabled applications open new ways to expand access to information, generate economic benefits, and improve Canada's environmental performance.

This chapter synthesizes the evidence and findings of the previous chapters to summarize the Panel's answers to its charge. Looking forward, the Panel considers some key elements that could allow Canada to strategically use ICT to help achieve sustainability.

6.1 RESPONDING TO THE CHARGE

What existing or potential opportunities exist to use Information and Communication Technologies (ICT) to create a greener Canada?

- *What opportunities, barriers and challenges exist within Canada and internationally related to the use of current and emerging scientific and technological advances to enable greening?*
- *What are the knowledge and best practice gaps in the development and application of ICT-enabled green technologies in Canada?*

The main question in the charge, along with two of the four sub-questions (listed above), focuses on ICT-enabled opportunities in Canada and the challenges to reaping their benefits. The Panel chose to interpret "knowledge and best practice gaps" as challenges of this nature. The Sponsor agreed with the Panel's interpretation that the emphasis of the assessment is on ICT-enabled opportunities with potential environmental, economic, and social benefits — encompassing the three-pillared concept of sustainability. To tackle these particular questions, the Panel's approach involved first identifying key components, and characteristics, of technologies that can be used to promote environmental, economic, and social sustainability. It then developed a catalogue of relevant opportunities for Canada and their potential benefits, and identified some common challenges. Finally, the Panel explored the options for possible solutions to help mitigate or overcome these challenges.

To encourage accessibility to its report, the Panel's firm focus was on how ICT could have a positive impact on the day-to-day lives of Canadians. Thus it investigated six key thematic areas in which ICT had already demonstrated potential to yield environmental, economic, and social benefits; and to which individuals, governments, and the private sector could relate: *environmental monitoring, smart interconnected utilities, smart interconnected buildings and neighbourhoods, smart interconnected mobility, smart interconnected production,* and *healthy people and healthy communities.*

Overall, the Panel concluded that there are substantial opportunities to promote and support sustainability using ICT by building on existing Canadian strengths and capacities. These opportunities range from small-scale changes, such as applications that inform consumers of their water use, to large-scale changes, like those that replace aging utility networks with smart grid technologies. New and emerging ICT applications can be used to influence how decisions are made at the highest level, as when big data are used to generate electricity mapping to inform decision-making about energy use.

Due to the wealth and breadth of opportunities it catalogued (in Chapter 4), the Panel felt it would not be useful to develop any kind of definitive ranking. In any given situation, the selection of the most relevant ICT-enabled opportunities will be based on the local context and the desired goals. For example, if governments are seeking to better understand the current state of the environment so as to increase knowledge, enforce environmental regulations, or measure the effectiveness of initiatives aimed at improving environmental health, new sensor networks that reliably monitor the environment remotely over time would be needed. If the goal is improved electricity efficiency and better integrated renewable energy sources, smart grid technologies would be essential. Using ICT to achieve social goals, such as enabling active participation in public life, could perhaps be best accomplished by providing a way for citizens to connect with government leaders and access government data.

However, the Panel found that the vast potential of these technologies to drive sustainability is currently not being realized in Canada. In analyzing its catalogue of ICT opportunities, the Panel identified some common challenges:

- costs, or fear of costs, related to implementation of the technology and corresponding infrastructure;
- lack of data access and interoperability;
- lack of the needed ICT skills;
- privacy and security issues;
- behavioural factors;
- second-order effects; and
- inadequate broadband connectivity in rural areas.

A closer examination of these challenges teased out some related and more specific challenges. For example, there may be asymmetry in the Canadian job market between the skill set desired by employers and the qualifications of job seekers, difficulties moving from use on a small scale by a limited number of users to implementation on a much larger scale, and limitations caused by fragmented data systems.

The Panel also noted that an integrated approach to identifying and addressing challenges, and developing solutions, would be valuable. Focusing on individual challenges and solutions in isolation would limit the transformative potential of ICT-enabled sustainable technologies.

Unlocking the potential of ICT opportunities, understanding the array of challenges, and subsequently developing options for potential solutions was a difficult task. Possible solutions to aid sustainability will require rapid and successful design, selection, and implementation of effective, context-specific ICT-enabled applications. Using ICT to achieve these goals will require decision-makers to consider matters beyond those related to technology, such as social and economic factors. As such, the Panel showcased a series of options for solutions to help address the challenges and realize the potential of ICT-enabled opportunities. These can be summarized as follows:

- **Demonstration-scale facilities:** to potentially mitigate the risk and uncertainty in untested or high-risk solutions (e.g., living labs);
- **Policy instruments:** to increase demand and address market failures (e.g., incentives, public procurement);
- **Improved standards:** to enable interoperability;
- **Data accessibility:** to more flexibly manage applications and ensure data is open and accessible for wider use;
- **Improved ICT design and privacy protection approaches:** to ensure adoption, privacy, security and personal control over personal information while allowing for the socio-economic benefits of big data and smart technologies to be achieved (e.g., privacy by design);
- **Improved digital and computer literacy:** to position Canada as competitive in a rapidly evolving digital environment;
- **Life-cycle or social life-cycle perspective:** to help identify second-order effects arising from implementation of ICT opportunities; and
- **Reduced connectivity gaps:** to maintain Canada's international competitiveness in broadband, and to increase the quality of access and availability.

The transformative potential of ICT innovations depends on the interplay between business, regulatory and human determinants alongside technological development and deployment. The Panel noted that simply adding more technology, regulation, or money will not solve the sustainability issues that lie ahead. What is required are enhanced strategies that respect sustainability challenges and leverage key strengths in order to build a more resilient and adaptable society.

The charge to the Panel included two additional sub-questions, which were not directly related to the discussion and analysis of opportunities, challenges, and solutions. The answers to these sub-questions are summarized briefly below, and discussed throughout the report.

What is Canada's capacity in ICT-enabled green technology and what are the existing areas of Canadians' strength and weakness in the most relevant segments of the economy?

Of the many relevant dimensions of Canada's capacity to develop, implement, and use ICT-enabled opportunities, the Panel focused on the following three in the particular context of this assessment:

Technology adoption: In general, Canada has a well-connected society with individuals and businesses embracing personal ICT devices such as smartphones and tablets. However, there is room for improvement. When compared to other countries, Canada is not highly ranked in terms of ICT penetration and diffusion among individuals, and the ability of firms to adopt technologies. Additionally, evidence shows that Canadian business in general lags behind other peer countries in ICT investment.

Physical and research infrastructure: Canada has demonstrated leadership in development of specific infrastructures like the NEPTUNE ocean sensor network and the CANARIE research and innovation network, which successfully harness ICT for research and knowledge generation. Canada also benefits from higher education institutions that are leaders in ICT research and an ICT sector that has been identified as an area of industrial research and development strength. Despite these strengths, the quality of broadband access varies significantly across the country although almost all Canadians have access.

Skills: Canada's capacity in the human skills needed to develop, adopt, and fully take advantage of ICT opportunities is difficult to assess. An important asset is Canada's strength in terms of ICT research. Not unique to Canada, however, is a possible mismatch between the skills needed to fully take advantage of the ICT opportunities discussed in this report and those currently possessed by the workforce.

What international best practices exist, including policy frameworks, on the use of ICT-enabled S&T to "green" the delivery of goods and services and related infrastructures required by society?

The Panel identified many examples of international and Canadian promising practices, which were highlighted in the orange *Promising Practice* boxes throughout the report. These included targeted practices to take advantage of ICT for specific goals, such as design standards and aids that promote energy efficiency in buildings. They also featured broader policies or approaches that could potentially help Canada overcome the more significant challenges to ICT opportunities. Examples highlighted include the following: Sustainable Development Technology Canada, an organization that can help bridge research and commercialization; the principles of privacy by design, a type of policy that deals with privacy concerns; and the broadband policies of Germany and Australia, national programs to address connectivity gaps.

6.2 THE PATH FORWARD

Through its evidence gathering, deliberations, and collective experience, the Panel identified five key elements that could enable Canada to strategically use ICT for sustainability.

- Rethink ICT;
- Connect Canadians;
- Empower individuals, governments, and businesses;
- Create new forms of social organization; and
- Overcome legislative, behavioural, technological, and financial challenges.

6.2.1 Rethink ICT

Seamless integration of individual pieces of technology into smart interconnected systems is needed to achieve the full transformative capacity of ICT. The Panel identified five interdependent technical components that are emerging as central to the ICT applications described throughout this report: (i) end-user devices; (ii) data; (iii) applications/data analytics; (iv) telecommunications, storage, and computing infrastructure; and (v) sensors and control. Individually, application of these components can yield important environmental and socio-economic benefits. However, the greatest impact will be achieved through integrated ICT-enabled solutions that take advantage of all of these components. For instance, a fully capable monitoring sensor network will provide the most benefit if it is connected to a telecommunication network that can transmit environmental data to the cloud for storage and analytics. Moreover, its impact will be further amplified if the sensor network is part of a system that enables end-user devices equipped with relevant applications to access and use the data in real time.

ICT are elements of interconnected solutions that include social, political, and institutional dimensions. These factors are apparent in the way ICT are currently woven into all aspects of day-to-day life — affecting how people communicate; work and spend their leisure time; and how governments, businesses, and individuals make decisions. Managing such socio-technical systems challenges both the tendency to view technologies as artifacts in isolation from their context, and the traditional control-oriented approach to technology governance. The implementation of an ICT application is more likely to succeed and contribute to sustainability if planning takes an integrated view of all of these dimensions, in addition to the local context.

The manufacture and operation of ICT in and of themselves give rise to negative environmental impacts that need to be minimized. A prime opportunity for Canada lies in the greening of technology that includes a move towards a greater use of data centres. Canada has a stable supply of emissions-free electricity that can power energy-intensive data warehouses, as well as a cold climate that would reduce energy needs for cooling equipment. Powering these centres in regions that have these attributes, and taking advantage of the concentrated nature of these facilities to supply heat to district energy systems, would have a positive impact on the environment, in addition to contributing to economic and social benefits for Canada.

6.2.2 Connect Canadians

Canada still has a digital connectivity gap between the service provided to urban and rural communities. While almost all people living in Canada have access to broadband internet, the speed varies significantly. People that live in urban centres have access to reliable high-speed broadband, but those in more rural regions may not have the speeds necessary to fully take advantage of many ICT applications. Approaches taken in other countries, such as those in Australia and Germany, could provide a model to address the gap in Canada.

Canadians also rely on dependable connections to utilities like electricity, water, and gas. However, the infrastructure that delivers these utilities is, in many cases, in need of significant repair or upgrading. Smart grid ICT applications could provide a way to achieve smart interconnected utilities that improve efficiency, robustness, and resiliency of distribution. The arrival of smart grids would be transformative, changing how utilities are produced and delivered across Canada — minimizing environmental impacts, such as electricity and water losses in distribution, reducing costs for operators and consumers, and ensuring reliability of service.

Reliable sensor networks that connect Canadians to the environment are also important in terms of sustainability. These networks provide access to timely and accurate information on environmental health and on how it is changing with time. Environmental monitoring data are used in decision-making. Improving the accuracy and breadth of this information would allow governments and businesses to make more evidence-based decisions moving forward. Furthermore, environmental monitoring data support regulatory enforcement, enable early detection of problems, and can be combined with other data, such as those related to health, to yield additional insight.

Another powerful advantage of ICT is their ability to strengthen connections among individuals and businesses, and between Canadians and the goods and services they use. Through applications that improve the efficiency of Canada's transport and logistics systems, such as those that improve public transit systems or enable smart interconnected logistics, ICT can make it easier for goods and people to move around while concurrently minimizing costs, waste, and harmful air emissions, including GHGs.

6.2.3 Empower Individuals, Governments, and Businesses

Technology on its own cannot move Canada towards sustainability. The potential benefits of the ICT-enabled opportunities discussed in this report will arise when users adopt and use them. Users can discover innovative ways to apply technologies and use the data they produce, often producing additional, unintended benefits. Ensuring data are accessible is therefore essential. Open data can also provide prospects for collaboration that can lead to the development of transformative solutions. Many governments and organizations are recognizing the importance of open data and are increasingly making their data publically available.

In many cases, important sustainability benefits stem from the capabilities that ICT provide to users. Technologies can connect countless aspects of life, empowering people to play a more active role in managing their lives by giving them the information they need and a platform to react to this information. ICT can supply the information needed by individuals, governments, and businesses to more effectively manage resources — from managing electricity consumption in the home through smart grid applications, to using sensors that detect leaks in the water distribution system, leveraging entrepreneurial activities for new business opportunities, or minimizing the impacts associated with resource extraction through computer modelling. Additionally, ICT can allow individuals to access new education opportunities, as well as more effective and efficient health care.

6.2.4 Create New Forms of Social Organization

By establishing smart buildings, connecting them with one another and to a smart grid, and engaging in informed community planning, ICT can help build connected communities that are sustainable. Just as a community is not simply a series of individuals, businesses, and buildings co-existing in the same geographic area, a building is more than the materials that make up its structure. Buildings have a significant environmental impact, particularly in terms of electricity consumption and GHG emissions. ICT have already been used to improve the electrical efficiency of buildings and further advances are possible to reduce the environmental impact of the built environment — from design to operation. Smart interconnected buildings can communicate with each other and with other smart objects (such as electric cars). They also have the potential to become integrated with a smart grid through solar or wind technologies. Furthermore, ICT-enabled applications can improve the security of buildings, maximize the comfort of their occupants, and reduce the costs associated with operation.

The shift to integrated and interconnected services and functions — neighbourhood-scale networks for buildings and infrastructure — is an important development. Local, integrated energy, water, or waste systems could deliver more environmentally and economically efficient services. The manufacturing process, including the delivery of goods, is a similarly complex system that could make strategic use of ICT to improve its efficiency and bring about smart interconnected production. The application of ICT to improve the efficiency of manufacturing equipment (e.g., smart motors) and sharpen process planning would reduce GHG emissions from manufacturing processes while reducing operational costs. Additionally, ICT-enabled smart interconnected supply chain logistics would improve the efficiency of goods delivery, leading to reduced harmful air emissions (including GHGs) and business costs, while making it easier to get products to market. The same is true for production and delivery of agricultural goods, where ICT could improve water efficiency on farms, particularly in irrigation, and change how food is moved from farm to table. Finally, ICT can enable new forms of participatory decision-making and governance, as well as improve health care delivery, education, and resiliency of communities. These communities would also be better equipped to face and address environmental challenges.

6.2.5 Overcome Legislative, Behavioural, Technological, and Financial Challenges

The Panel identified several legislative, behavioural, technological, and financial factors that could hinder the implementation of innovative ICT applications, as well as tools and approaches that could be used to help overcome them. While there is no one-size-fits-all solution for all ICT applications and jurisdictions, some relevant options and considerations have been highlighted by the Panel:

- Encourage collaboration through open data and open standards and protocols. An absence of standards and inadequate cooperation between governments can inhibit implementation and development of new ICT opportunities, limit access to data, and make it challenging for governments to apply (or expand) successful solutions or learn from the past experiences of others. However, opening data is only one step. Even if data can be located, a lack of standardization across datasets may limit their usability because other users cannot interpret a given dataset.
- Ensure that private data are protected and applications are secure through user-friendly technology design and measures such as privacy by design. Communicating these protections is important: users with concerns about protection of personal data will be less likely to adopt a technology, even if privacy and security criteria have been met.
- Use long-term planning and a life-cycle or social life-cycle perspective to assist in the identification and mitigation of second-order effects that may arise from the implementation of ICT applications. This will be important to ensure anticipated benefits are realized, as unintended effects could negate some of the positive changes achieved (e.g., more people driving because of reduced gridlock).
- Investigate and use a range of policy instruments, including public procurement, to overcome economic challenges that can also act as a challenge to adoption or development of ICT applications by businesses, governments, or individuals. Additionally, demonstration-scale facilities, like living labs, can provide experimental settings in which users and producers co-create and validate innovations, allowing the benefits of new ICT-enabled applications to be accurately quantified and showcased.
- Promote digital and computer literacy in the education and training of citizens in the technical proficiencies necessary to adopt, use, and further develop ICT applications. This can begin in the elementary school classroom and continue all the way to the post-graduate level.

6.3 FINAL REFLECTIONS

ICT are more than just gadgets meant to entertain. They are devices, systems, and platforms that have transformed how people live, work, and communicate with one another. Interconnected ICT applications have the potential to be a key driver of sustainability. To exploit opportunities that create substantial economic opportunities and address pressing environmental and social issues, Canada must leverage its strengths and capacities. The sustainability benefits that could be provided by ICT are achievable if Canada can successfully *rethink* ICT, *connect* and *empower* Canadians, *create* new forms of social organization, and *overcome* challenges.

Glossary

Glossary

For the purposes of this report, the Panel was guided by the following definitions:

Big Data: The Panel relied on the following definition of big data: "datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze" (Manyika *et al.*, 2011).

Cloud Computing: As defined by the U.S. National Institute of Standards and Technology a cloud is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell & Grance, 2011). A *data centre* refers to the facility that hosts the computer systems and its associated components (e.g. air conditioning).

Information and Communication Technologies (ICT): The Panel adopted the UNESCO definition of ICT as "forms of technology that are used to transmit, process, store, create, display, share or exchange information by electronic means" (UNESCO, 2007).

Interconnected: Interconnected entities are *things* (e.g., buildings, trucks, sensors), individuals, and organizations (e.g., businesses and governments) that are connected to one another through telecommunication networks and possibly traditional infrastructures such as roads or utility pipelines.

Sensor: Sensors measure a physical quantity (e.g., temperature, pressure) and convert it to an electric signal. They carry out a wide range of tasks, from environmental monitoring to energy utility metering.

Smart: The Panel adapted the definition from the OECD's report *Building Blocks for Smart Networks:* a smart system is able to learn from previous situations and to communicate the results of these situations to other systems and users. These systems and users can then change their behaviour such as improving energy or time efficiency to best fit the situation and subsequently meet sustainability goals. This means that information about situations needs to be generated, transmitted, processed, correlated, interpreted, adapted, displayed in a meaningful manner and acted upon (adapted from OECD, 2013).

Sustainability: As defined by the *Federal Sustainable Development Act*, "The Government of Canada accepts the basic principle that sustainable development is based on an ecologically efficient use of natural, social and economic resources and acknowledges the need to integrate environmental, economic and social factors in the making of all decisions by government" (Minister of Justice, 2013a). For the purpose of this assessment, the Panel adopted an approach to sustainability that encompasses improvements in environmental, economic and social well-being.

Virtualization: In the context of ICT, virtualization is the abstraction of a device or resource such as an operating system or a computer network resource.

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