June 2014

Report in Focus

ENABLING SUSTAINABILITY IN AN INTERCONNECTED WORLD

Canada is witnessing an unprecedented convergence of information and communication technologies (ICT) with the physical world. This convergence is evident in all aspects of day-to-day life, transforming how individuals live, work, and play. Today, ICT operate not only within those devices traditionally thought of as technology, such as computers and smartphones, but also connect vehicles, buildings, and appliances. Ubiquitous in all facets of life, ICT are enabling people and institutions to connect, learn, share, and innovate as never before. The impacts of ICT on social interactions and the economy are profound, so too may be their effects on environmental stewardship and sustainability. Many ICT-enabled solutions are already moving Canada toward sustainability through, for example, innovations that reduce energy consumption in buildings, monitor the environment, and empower decision-making. The opportunities for ICT to support sustainability are endless; the challenge lies in identifying and implementing those that have the greatest potential to benefit Canada.

CHARGE TO THE EXPERT PANEL

Environment Canada asked the Council of Canadian Academies (the Council) to conduct an in-depth, independent assessment to answer the following question:

> What existing or potential opportunities exist to use information and communication technologies (ICT) to create a greener Canada?

The Council assembled a 13-member expert panel (the Panel) of Canadian and international experts to complete this unique, forward-looking charge. With members from academia, government, and the private sector, Panel members drew on backgrounds in sustainability, environmental science, computer science, economics, engineering, and policy to complete the assessment.

The Panel's Approach

The Panel chose to interpret the term greening as encompassing the three well-accepted dimensions of sustainability: the environment, the economy, and social well-being. The Panel found many environmental data and other indicators lacking and therefore often used the reduction of greenhouse gas (GHG) emissions to demonstrate the impact of ICT opportunities for sustainability.

> **Defining Sustainability:** 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." For the purpose of this assessment, the Panel adopted an approach to sustainability that encompassed improvements in **environmental, economic,** and **social** well-being.

With the speed at which ICT are evolving, predicting the future of technology is difficult, if not impossible. Therefore, the Panel decided to highlight areas in which technological opportunities appear to hold promise for achieving clear sustainability benefits for Canada. The Panel chose to feature a range of opportunities from Canada and around the world, but did not seek to be comprehensive or prescriptive.

To conduct this assessment, the Panel considered four key categories of information — the technical components of ICT, possible ICT opportunities, challenges of ICT, and solutions

to overcome the challenges. The Panel developed a roadmap for the report that assisted them in answering the charge (Figure 1). At the base are the five technical components of the *ICT platform* that are central to many opportunities: (i) end-user devices; (ii) data; (iii) applications/data analytics; (iv) telecommunications, storage, and computing infrastructure; and (v) sensors and controls (all discussed in Chapter 3). Resting on this platform is the set of six thematic areas in which *interconnected ICT opportunities* were explored by the Panel in detail (discussed in Chapter 4). At the top are common *challenges* in realizing these opportunities and options for *solutions* (discussed in Chapter 5).

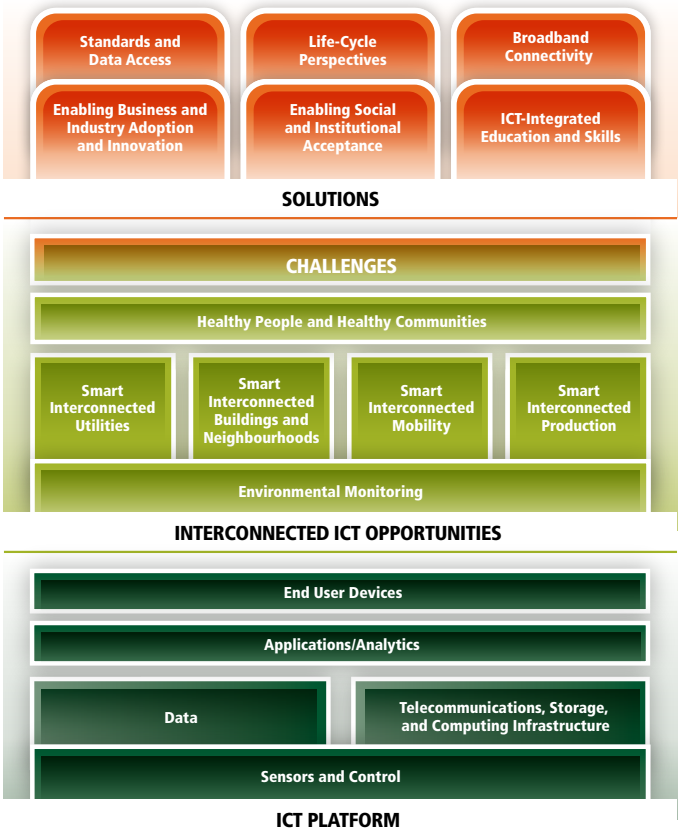


Figure 1
Towards an ICT-Enabled Sustainable Canada

Key Findings

The Panel determined that there are substantial opportunities to promote and support sustainability through ICT by building on existing Canadian strengths and capacities, in areas like technology adoption and physical and research infrastructure. These opportunities range from small-scale changes, such as household water conservation through applications that inform consumers of their water use, to large-scale changes, such as more reliable and efficient electricity systems when aging utility networks are replaced with smart grid technologies.

CANADA'S CAPACITY IN ICT

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

Technology Adoption: In general, Canada has a well-connected society with individuals and businesses embracing personal ICT devices such as smartphones and tablets. Compared to other similar countries, however, Canada is not highly ranked in terms of ICT penetration and diffusion among individuals, and in 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 its leadership in the development of specific infrastructure 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 take advantage of ICT opportunities is difficult to assess. An important asset is Canada's strength in ICT research. Not unique to Canada, however, is a possible mismatch between the skills needed to fully take advantage of ICT opportunities and those currently possessed by the workforce.

"Smart grids hold great promise for reducing greenhouse gas emissions, but no single technological opportunity will achieve sustainability for Canada on its own. A targeted, integrated approach to sustainability is required."

– David Miller, Chair, Expert Panel

The Panel explored ICT-enabled opportunities within six thematic areas. These areas are discussed below and one or two examples are provided. For additional examples, see Chapter 4 of the report.

(i) Environmental monitoring: Reliable sensor networks can 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 for additional uses.

(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 such as building control systems have already improved the electrical efficiency of buildings and reduced their GHG emissions. Further advances in ICT could reduce the environmental impact of buildings from design through to operation. 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. For example, ICT applications can help make public transit vehicles move more quickly through cities or enable smart logistics for more efficient transport of goods.

(v) Smart interconnected production: ICT applications such as 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 help address social challenges, help communities adapt to a changing climate, and enable new forms of participatory decision-making. For example, ICT could enhance the connectedness of a community through access to information, online education and e-health.

Beyond these six thematic areas, the Panel also observed that Canada is well positioned to be a global leader in green data centres due to its stable supply of emissions-free electricity, which can power energy-intensive data warehouses, and its cold climate, which can reduce energy needs for cooling equipment. Green data centres are one of many efforts to reduce the environmental impacts of ICT themselves as they enable centralization of processes such as server and network virtualization.

EXAMPLES OF ICT-ENABLED OPPORTUNITIES

Some of the ICT-enabled opportunities discussed in Chapter 4 are:

- Environmental monitoring systems
- Humans as sensors
- Advanced metering infrastructure
- Demand response management
- Microgrids
- Building management systems
- Traffic management applications
- Journey-planning applications
- Smart interconnected logistics
- Smart motors
- Precision irrigation
- Advanced weather monitoring and forecasting
- Data integration (e.g., health and environment)

Common Challenges

Having considered the evidence, the Panel found that the potential of ICT to drive sustainability is currently not being fully realized in Canada. Across the range of themes considered by the Panel, and the opportunities examined within them, the Panel identified some common challenges. These challenges range from a lack of data access and interoperability to inadequate broadband connectivity in rural areas to privacy and security issues.

A closer examination of these challenges revealed some related and more specific concerns. For example, there are difficulties moving from use of ICT on a small scale by a limited number of users to adoption on a much larger scale. There are also issues that arise from limited data access caused by fragmented ownership of datasets. Additionally, since ICT have their own environmental footprint associated with their production, transport, use, and disposal, the environmental impact of ICT is an important consideration.

Addressing the Challenges

The Panel identified a range of approaches to help realize the full potential of ICT-enabled opportunities. These include:

- **Demonstration-scale facilities:** to 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 manage applications more flexibly and ensure data are open and accessible for wider use;
- **Improved ICT design and privacy protection approaches:** to ensure 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 (unexpected) 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 Panel also noted that focusing on individual challenges and solutions in isolation will limit the transformative potential of ICT-enabled opportunities to support sustainability. The Panel concluded an **integrated approach** that identifies strategies to address multiple challenges and implement more than one solution should be considered. Taking into account a wide variety of stakeholders and the contexts in which decisions are made is also important.

EXAMPLES OF PROMISING PRACTICES

Privacy by Design Principles: These principles ensure privacy and personal control over personal information in the personal data ecosystem, while at the same time encouraging the socioeconomic benefits of big data and smart technologies.

Broadband Policies in Germany and Australia: The Australian government has established the goal of becoming one of the world's leading digital economies by 2020. Germany set national targets for the elimination of gaps in broadband penetration and capable broadband access by the end of 2010. Both countries have targeted speeds that are, at a minimum, 5 to 10 times faster than those projected by the CRTC.

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

Geobase: This initiative sees federal, provincial, territorial, and municipal agencies working 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.

The U.S. Energy Data Initiative: This initiative, by the U.S. government, through the Department of Energy and other government agencies, makes new and untapped data available to entrepreneurs to spur the development of new products and services with the intention of saving money and energy.

A PATH FORWARD

The Panel concluded that future work and research on ICT opportunities for sustainability could be grouped into five key areas:

Rethink ICT: The greatest impact of the application of the five components in the ICT platform (recall Figure 1) will be achieved through ICT-enabled solutions that integrate their separate functions and take advantage of their attributes together. 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: In Canada there is a gap in the degree of digital connectivity provided through the internet services available to rural communities as compared to urban centres. While almost all Canadians can access broadband internet, speed varies. Rural areas may not possess the speeds necessary to take full advantage of many ICT applications. While connectivity, in the context of technology, traditionally refers to internet access, there are other important links such as roads, water pipes, and electricity lines that could be improved through ICT applications.

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 its use in new ways that yield further unidentified benefits. Many orders of government 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 manage resources more effectively.

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, sustainable communities. Smart, interconnected buildings can communicate with one another, and with other smart objects, such as electric cars (allowing vehicle owners to charge their cars by way of their homes and also potentially put energy either back into their household or into the grid). Smart buildings that incorporate solar or wind generation into their design could also become integrated with the smart grid. Furthermore, ICT-enabled applications could improve building security, reduce building operating costs, and make conditions more comfortable for occupants.

Overcome Legislative, Behavioural, Technological, and Financial Challenges: Using ICT to achieve environmental and socio-economic goals will require decision-makers to consider policy, behavioural, and business challenges as well as those related to technology. Improving data access for wider use and considering life-cycle perspectives to mitigate second order effects are two examples. An integrated approach to addressing challenges and developing solutions is important in fully realizing the transformative potential of ICT.

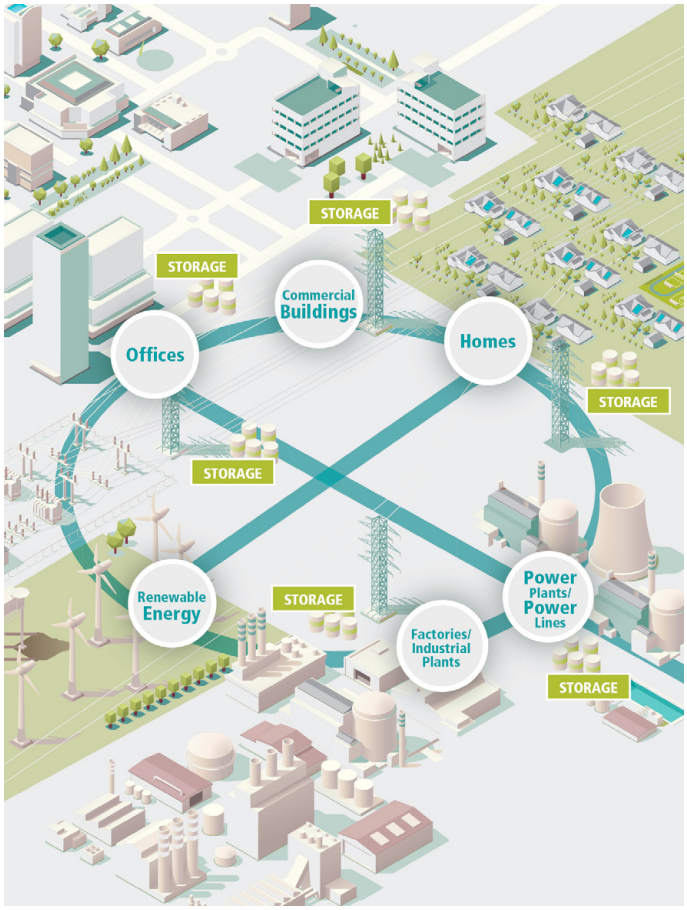


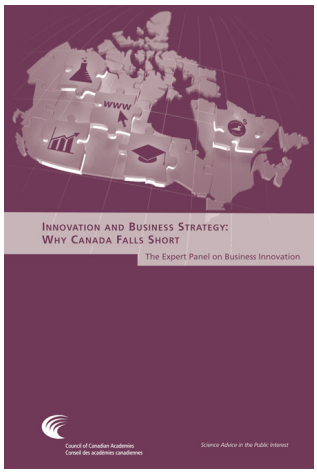
Figure 2
Integrated Energy Storage and Generation Systems at the Neighbourhood Level

CONCLUSION

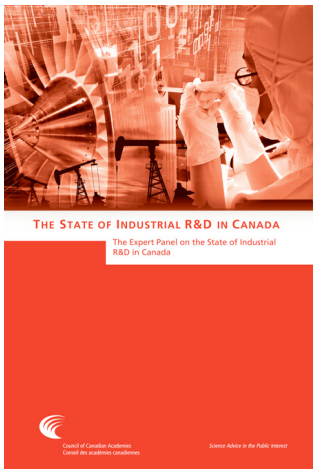
ICT are more than just gadgets meant to entertain. They are devices, systems, and platforms that are transforming how people live, work, and communicate with one another. In addition to the technical capabilities they provide, it is important to note that through enhanced capabilities, like timely access to information, ICT can enable changes in traditional governance, management, and decision-making. Understanding the potential of these technologies and how they can best operate in an interconnected manner is key to the success of building a sustainable future for Canada.

OTHER COUNCIL REPORTS THAT MAY BE OF INTEREST:

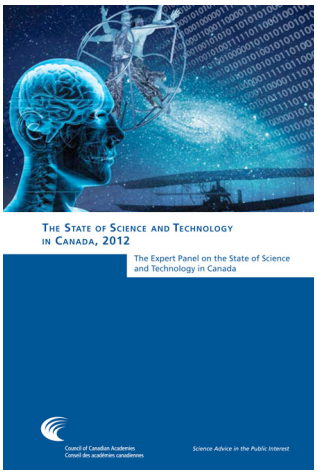
Innovation and Business Strategy: Why Canada Falls Short



The State of Industrial R&D in Canada



The State of Science and Technology in Canada, 2012



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This *Report in Focus* was prepared by the Council based on the Report of the Expert Panel on the Potential for New and Innovative Uses of Information and Communications Technologies (ICT) for Greening Canada.