ENABLING SUSTAINABILITY IN AN INTERCONNECTED WORLD

Executive Summary

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

THE COUNCIL OF CANADIAN ACADEMIES
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Science Advice in the Public Interest

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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.

Edowdeswell

Elizabeth Dowdeswell, **O.C.**, President and CEO
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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.

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

SOLUTIONS

CHALLENGES

Healthy People and Healthy Communities

Smart Interconnected Utilities	**Smart Interconnected Buildings and Neighbourhoods**	**Smart Interconnected Mobility**	**Smart Interconnected Production**

Environmental Monitoring

INTERCONNECTED ICT OPPORTUNITIES

End User Devices

Applications/Analytics

Data	**Telecommunications, Storage, and Computing Infrastructure**

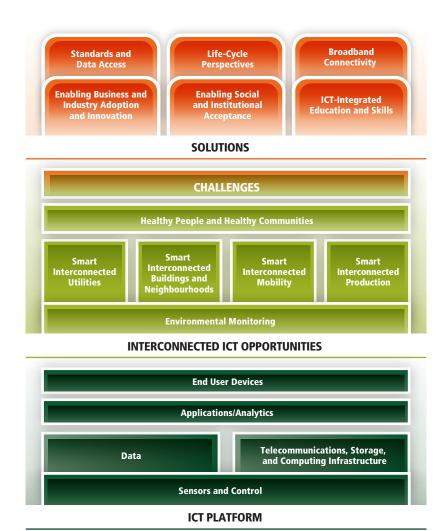**Sensors and Control**

ICT PLATFORM

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.