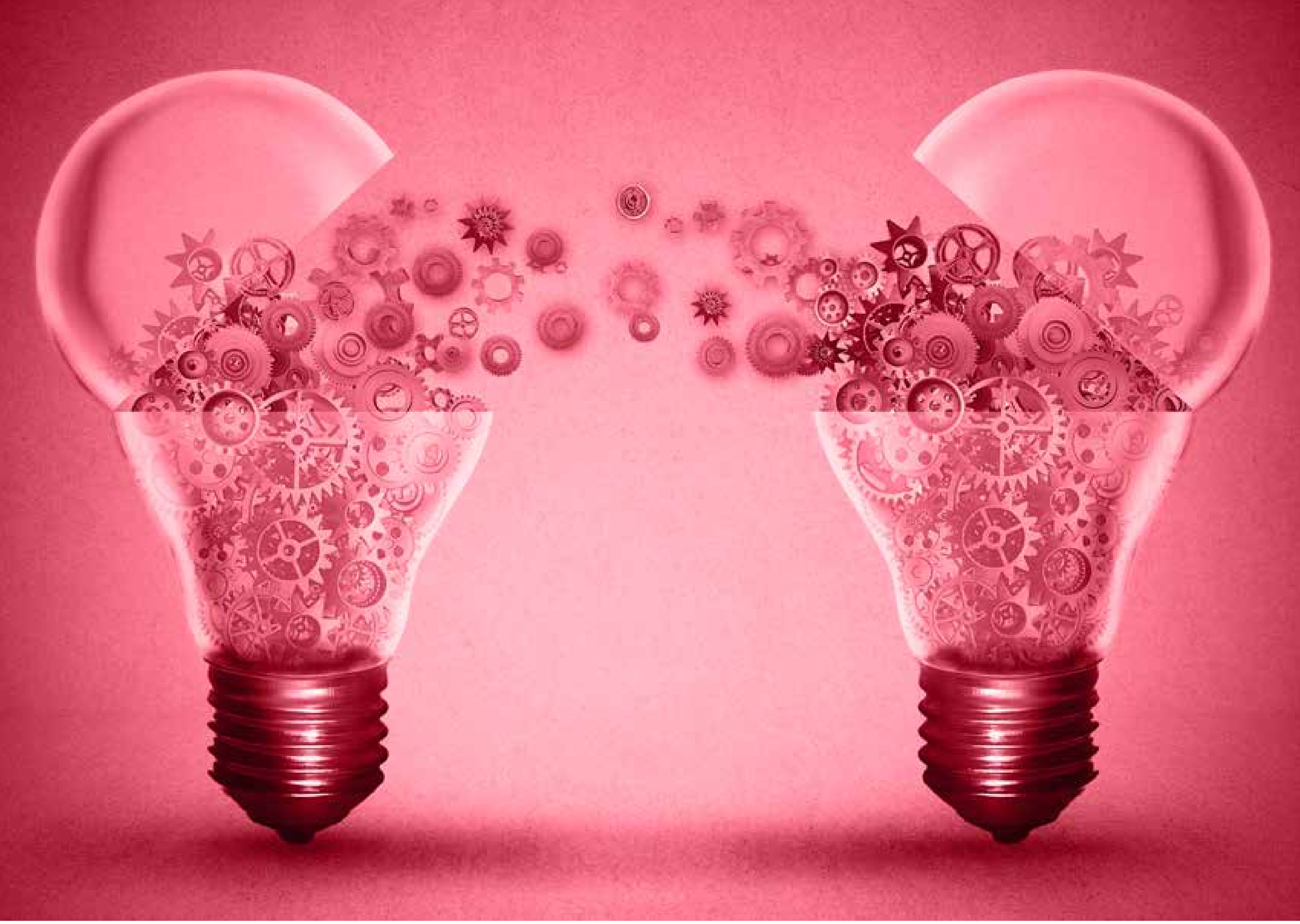

Science Policy: Considerations for Subnational Governments

A Workshop Steering Committee Report

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

SCIENCE POLICY: CONSIDERATIONS FOR SUBNATIONAL GOVERNMENTS

A Workshop Steering Committee Report

THE COUNCIL OF CANADIAN ACADEMIES
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Notice: The project that is the subject of this report was undertaken with the approval of the Board of Governors of the Council of Canadian Academies (CCA). Board members are drawn from the Royal Society of Canada (RSC), the Canadian Academy of Engineering (CAE), and the Canadian Academy of Health Sciences (CAHS), as well as from the general public. The Steering Committee and workshop participants responsible for the report were selected by the CCA for their special competencies and with regard for appropriate balance.

This workshop report was supported by a grant from the Government of Alberta. Any opinions, findings, or conclusions expressed in this publication are those of the authors, the Workshop Steering Committee on Subnational Science Policy and do not necessarily represent the views of their organizations of affiliation of employment or the Government of Alberta.

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Participants in the Workshop on Subnational Science Policy

Under the guidance of its Scientific Advisory Committee, Board of Governors, and Member Academies, the CCA assembled the Workshop Steering Committee to lead the design of the workshop, complete the necessary background research, and develop the workshop report. The Steering Committee directed the CCA in identifying the experts who participated in the workshop. Each expert was selected for his or her expertise, experience, and demonstrated leadership in fields relevant to this project.

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Message from the Chair

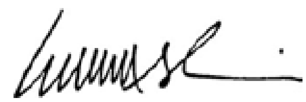
The Workshop Steering Committee is grateful to the Government of Alberta for supporting this project. In the course of the research, workshop discussions, and subsequent analysis, the Steering Committee observed that many science policy experts draw heavily from their tacit knowledge, and there is no formal "playbook" for developing science policies. The Steering Committee hopes that the elements of science policies and related considerations set out in this report will make this knowledge accessible to a wider audience and help advance the development of many science policies, particularly at the subnational level.

Joy Johnson, FCAHS
Chair, Steering Committee and Workshop on Subnational Science Policy

Message from the CCA President and CEO

Science has the ability to inform policy development, funding decisions, and the choices made by the public at large. This report, *Science Policy: Considerations for Subnational Governments*, is more than a set of workshop proceedings. It is an insightful, high-quality study that identifies key considerations for the development of science policies and is intended to be used as a roadmap to guide conversations and inform decision-making at the subnational level.

I would like to thank Dr. Johnson, FCAHS, and the members of the Steering Committee for their efforts in seeing this project through to completion. I would also like to thank the Government of Alberta for their support in undertaking this project.



Eric M. Meslin, PhD, FCAHS
President and CEO, Council of Canadian Academies

Report Review

This report was reviewed in draft form by the individuals listed below — a group of reviewers selected by the CCA 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 Steering Committee, 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 Steering Committee and the CCA.

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

David Castle, Vice-President Research, University of Victoria (Victoria, BC)

Timothy I. Meyer, Chief Operating Officer, Fermi National Accelerator Laboratory (Batavia, Il)

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P. Kim Sturgess, C.C., FCAE, CEO, WaterSMART Ltd. (Calgary, AB)

The report review procedure was monitored on behalf of the CCA's Board of Governors and Scientific Advisory Committee by **John Hepburn, FRSC,** Vice President, Research, CIFAR. The role of the peer review monitor is to ensure that the Steering Committee gives full and fair consideration to the submissions of the report reviewers. The Board of the CCA authorizes public release of a report only after the peer review monitor confirms that the CCA's report review requirements have been satisfied. The CCA thanks Dr. Hepburn for his diligent contribution as peer review monitor.

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Key Findings

Key Findings

The rationale for creating an explicit science policy at the subnational level is compelling.

Science is now central to government agendas at all levels, both as a means for addressing complex policy challenges and for stimulating innovation. All governments have *implicit* science policies in budget allocations and policy and program decisions in domains such as health, education, and the environment. Making science policy *explicit*, however, through formal, comprehensive, cross-cutting policies, has a number of advantages. Explicit science policies provide an opportunity to articulate the value and objectives of public support for science, and a platform for enhancing intra- and intergovernmental coordination. Such policies increase transparency, clarifying how resources are distributed in response to policy and research priorities. Making science policy explicit at the subnational level also aids in leveraging and complementing federal support for science.

Science and innovation policies are distinct, but inextricably linked, for all levels of government.

Governments may be tempted to justify public support for science because of its contributions to innovation and economic development. However, science policy is a distinct and complex area of policy with its own challenges and opportunities. Conflating science and innovation policy neglects the broader importance of science to achieving a wider range of public benefits, including its role in tackling major societal challenges at all scales — regional, national, and global. In the view of this project's Steering Committee and workshop participants, governments are well served in recognizing that science policy cannot be readily subsumed within innovation policy, but neither can it be isolated from it. There is value in having an explicit science policy, while recognizing its interfaces with social, economic, environmental, and cultural contexts.

Subnational governments play many of the same roles as national governments in supporting science.

Science is not an area of policy characterized by clearly delineated roles and responsibilities. In Canada, both federal and provincial governments are active in virtually all areas of policy and government action involved in supporting scientific research, ranging from the provision of R&D tax credits to the training of new researchers. Many of the issues and challenges faced by subnational governments in developing science policy are therefore similar to those faced by national governments. The lack of a clear division of responsibilities in relation to science is both a risk and an opportunity for provincial governments, and speaks to the importance of developing provincial science policies that capitalize on federal science policies and programs.

A comprehensive framework for a science policy can be built around five core elements: people, infrastructure, research, science culture, and knowledge mobilization.

Science systems vary in size, orientation, composition, culture, funding mechanisms, and many other factors. Thriving science systems, however, tend to benefit from effective support in five core areas: (i) they have deep and growing pools of scientific expertise; (ii) they have sustainably supported research infrastructure; (iii) they have research funding programs that meet multiple objectives; (iv) they have well-developed channels for public science outreach and engagement; and (v) they can mobilize research effectively to develop new technologies and inform public policy. Factors that need to be considered in each of these areas vary by domain, and in response to the characteristics of the science system and the local context. These core areas are necessary, but insufficient, for defining a comprehensive science policy. They are ideally embedded within a policy framework that includes a vision and principles, governance mechanisms, and a foundation for monitoring and evaluation.

Cross-sectoral and cross-governmental coordination and cooperation are central to an effective subnational science policy.

Subnational science policies can enhance cross-governmental coordination in several ways. A science policy can clarify the division of departmental responsibilities and accountabilities, create ownership for the policy and any specific commitments that it includes, and establish coordination mechanisms to maximize the contribution that science can make to addressing government priorities. Developing and implementing a science policy can facilitate coordination across stakeholders outside of government, helping subnational governments to create an environment for cooperation, networking, and strong relationships among researchers, institutions, sectors, and regions (i.e., with other provinces). In this respect, subnational governments often have more direct relationships than national governments with local firms, institutions, and research facilities.

A subnational science policy can bring clarity to provincial research priorities.

Explicit science policies create an opportunity to be more transparent about research priorities pursued by the government, and to be more strategic in the allocation of science resources. Subnational governments, in particular, can benefit from this by aligning public research investments with regional strengths, and by selectively supplementing national science investments. Targeting research funds at priority areas, however, should be counterbalanced by a recognition that the ultimate benefits associated with fundamental research are not readily foreseeable. There is value therefore in maintaining a broad base of research capacity alongside support for specific research or technological priorities.

Committing long term to a subnational science policy is important for maintaining and developing the science system.

Frequent changes in science policy, or in the priorities of governments and institutions supporting research, can be detrimental to the development of research capacity and success in the long term. Subnational governments can enhance the likelihood of achieving policy sustainability by considering a variety of factors, including the need for broad, cross-party political support; the resonance of the policy's goals and commitments with citizens; the extent to which the policy design allows it to demonstrate and build on early successes; the level of stakeholder involvement and engagement, particularly in the development of the policy; and the extent of sustained public engagement. Failure to attend to these factors may, conversely, result in a policy more likely to be abandoned due to changes in economic or political circumstances, thereby re-injecting uncertainty about the direction and structure of the government's support for science.

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Introduction

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1 Introduction

All levels of government face complex challenges, and subnational governments — like their national counterparts — now rely heavily on science in the search for solutions. Science has the potential to inform policy development and enhance public welfare in diverse domains such as national security, health, environment, education, and social policy. Investments in science can also create new economic opportunities and help develop the knowledge and social capital upon which societies depend. Technological advances and scientific breakthroughs are often mutually supportive, leading to innovations that bolster productivity and create new products and services. Science, along with technology and innovation, features centrally in government agendas at all levels as a result.

Some governments take a deliberate approach to harnessing science to achieve their objectives, and are strategic in how they seek to support the science system. Analyzing their strengths and weaknesses, they focus on fostering research capacity that will sustain important global linkages, leveraging other sources of research funding, or creating a research environment that addresses known gaps or deficiencies. Other governments, however, continue to support science and research on an ad hoc and largely uncoordinated basis, through individual programs and policies scattered across departments, with little consideration of purpose, alignment, and coherence. The result can be a collection of support mechanisms at odds with one another, potentially interfering with or undercutting the development of the scientific capacity that they seek to support.

In Canada, successive federal governments have been grappling with developing coherent cross-cutting science policy for many decades. Provinces, for their part, have ample justification for developing explicit, comprehensive science policy because the policy problems that they face are often as complex as those at the federal level. The federal government has recently reaffirmed its commitment to science and evidence-based decision-making, and its support for innovation and fundamental science. As a result, there is a particularly strong rationale for subnational governments to develop their own science policy to align with federal policies, address gaps, and build on existing science strengths.

Developing comprehensive, subnational science policy is a substantial undertaking. Achieving policy and program alignment for supporting science can be difficult given the diversity of objectives, departments, and institutions involved. Clear jurisdictional demarcations are often lacking, leaving multiple levels of government active in many of the domains involved in supporting science. A wide range of issues must be considered, including design of funding mechanisms, support for research training and recruitment, public understanding and engagement with science, governmental capacity to access scientific advances and insights, and the adequacy of mechanisms for inter- and intra-governmental alignment. Successfully navigating these issues requires a science policy that is tailored to the local context and not simply imported, unaltered, from another jurisdiction.

1.1 ABOUT THIS REPORT

To inform ongoing work in the area of science policy, the Alberta Government supported the Council of Canadian Academies (CCA) with a grant to undertake a project that identifies considerations relevant to subnational science policy applicable across a range of jurisdictional contexts, including Canadian provinces. Specifically, the CCA considered the following question:

What are the necessary considerations when creating science policy at the subnational level?

In responding to the question, the CCA sought to:
- *Debate and validate the main outcomes of a subnational science enterprise, particularly in relation to knowledge, human, and social capital.*
- *Identify the key elements and characteristics of a successful science enterprise (e.g., funding, trust, capacity, science culture, supporting interconnections and relationships), with a particular focus at a subnational level.*
- *Explore potential intents of a subnational science policy, important features of such a policy, and the role of the policy in informing investment decisions.*

In response to the charge, the CCA appointed a five-member expert Steering Committee to lead a workshop, identify and assess relevant literature, and develop a report. The workshop was held over two days in November of 2016 and brought together 16 experts from across Canada and the United States. This final report is the product of its deliberations and reflects the consensus of Steering Committee members. Although the report's primary focus is science policy at a subnational level generally, it also considers how the identified insights and findings apply to the case of Alberta.

1.2 SCOPE AND DEFINITIONS

1.2.1 Science and Subnational Governments

The Steering Committee adopted a broad conception of science for this project, encompassing the full range of research activities and technology development in the natural sciences, health sciences, engineering, social sciences, and humanities.

Subnational science policy was interpreted as applying to provincial or territorial governments in the Canadian context. The Steering Committee did not consider municipal support for science, despite its importance in some locations.

1.2.2 Implicit Versus Explicit Science Policy

Provincial governments play an important role in the science system through their support for higher education (e.g., post-secondary education, training, and research), and through research in government labs and facilities. Much of this support for science has historically taken place without explicit science policies. All provincial governments reveal *implicit* science policies through their actions (e.g., budgets and funding allocations, education policies, departmental and program objectives). However, this report focuses on *explicit* science policy, defined as comprehensive, cross-cutting policies that coordinate a set of programs and other government initiatives to promote the scientific system in ways that provide public benefits for the citizens of a province. While potentially providing crucial support for provincial science systems, individual policies, programs, and initiatives on their own do not perform this coordinating function or provide strategic direction. Explicit science policies focus on how government support for science is organized (i.e., policy for science). Ideally, they also consider how science is mobilized to support policy development (i.e., science for policy).

1.2.3 Distinguishing Between Science Policy and Innovation Policy

Public investments in science are frequently justified on the grounds that they contribute to innovation and its associated economic benefits. The temptation of governments to view science policy solely in instrumental terms, however, as an enabler of innovation and productivity growth, neglects the broader importance of science to achieving a wider range of public benefits. The Steering Committee agreed that, for the purpose of the workshop, science policy would be discussed as a separate policy area from innovation policy while recognizing the linkages between the two.

1.3 RESEARCH LIMITATIONS

The research on subnational science policy is limited and largely restricted to federal countries. Although some notable examples exist, few subnational governments have a comprehensive science policy and fewer still have a comprehensive science policy that has been evaluated rigorously for its impact. This report therefore draws on the expertise and experience of Steering Committee members and workshop participants and on the body of explicit and implicit science-relevant policies.

1.4 STRUCTURE OF THE REPORT

Chapter 2 describes the importance of subnational science policy, from the contributions of science to public welfare to the role of provincial governments and articulation of the contributions that an explicit science policy can make. Chapter 3 identifies the core elements of a science policy and potential areas of focus, and discusses key considerations for each. In Chapter 4, considerations for developing subnational science policy are explored and applied to the context of Alberta. Chapter 5 concludes with some final reflections on science policy development efforts in Alberta and other provinces.

2

Why Subnational Science Policy?

- **Importance of Science Policy**
- **Role of Subnational Governments in the Science System**

2 Why Subnational Science Policy?

The fundamental goal of science is to understand the world in which we live. Scientific advances can improve human health, strengthen national security, enhance education, address environmental challenges, and lead to innovations that contribute to economic growth, social resilience, and well-being. For these reasons and others, governments at all levels have a role to play in developing well-functioning science systems.

2.1 IMPORTANCE OF SCIENCE POLICY

The rationale for creating an explicit science policy at the subnational level is compelling.

Workshop participants identified five key benefits of establishing an explicit science policy:

- *Value proposition:* articulating the value and objectives of the science system;
- *Transparency:* clarifying how scarce resources are distributed;
- *Prioritization:* identifying science priorities (program, policy, and domain specific) and assigning resources accordingly;
- *Coordination:* identifying roles and responsibilities of different parts of the provincial government in establishing a framework for, and delivering programming and better integrating with, the national science and innovation system; and
- *Consistency:* protecting taxpayer investments by stabilizing spending commitments, thereby increasing the likelihood of investments reaping benefits and enhancing stability for scientists.

The value of science policy has been recognized in Canada since at least the 1960s. Even then, science policy grappled with issues of accountability, independence, social benefits, and the appropriate role of governments (Dufour, 1994). However, despite the value of an explicit science policy, the Steering Committee recognizes that it is not without risks, especially if a policy is poorly formulated or implemented. For instance, it may create expectations that cannot be fulfilled, it may steer in directions that are not ultimately useful, or it may skew university policies and practices in undesirable ways.

Quebec's history of science policy shows what a province can gain when it makes a determined, long-term effort. Responding to poor historical scientific performance, the Quebec government launched a number of initiatives during the 1960s through to the early 1980s, which, in building on federal investments, led to a dramatic transformation of the research environment in the province. These included the establishment of Quebec's medical research council in 1964 and of other university research funds in the late 1970s and early 1980s (Rousseau, 1977; Labrie, 2013; FRQS, 2017). Quebec is now an established research performer. With 23% of Canada's university faculty, it accounted for approximately 28% of federal research grants from the three granting agencies[1] between 2000 and 2010 and 27% of funds from the Canada Research Chairs (CRC) Program between 2004 and 2010 (Robitaille & Laframboise, 2013). In 2010, a higher share of the workforce in Quebec was employed in research and development (R&D) than in any other province (Robitaille & Laframboise, 2013). Quebec has also established a Chief Scientist who sits at the head of the province's three research funding councils, raising the profile of science and science advice and enhancing science coordination within government (Quirion *et al.*, 2016).

Subnational governments can serve as experimental test beds for science policy initiatives. For instance, in response to Ontario establishing the Centres of Excellence program in 1986, the Federal government launched its own version, the Networks of Centres of Excellence, two years later (Fisher *et al.*, 2001). In a different model of federal-provincial interface, some provinces have developed highly sophisticated and well-funded counterparts to the federal Genome Canada initiative. Both Quebec and British Columbia, for example, have been effective in their investments in, and returns on, federal funding that flows through this mechanism (DRA & EN, 2015; Génome Québec, 2016). Subnational governments can also work together to achieve joint progress. In a 1988 review of innovation policy in Western Canada, the Organisation for Economic Co-operation and Development (OECD) recommended extending cooperation through activities such as information exchange, the establishment of a Western Canadian Open University, and joint technology monitoring (OECD, 1988).

1 These are the Natural Sciences and Engineering Research Council (NSERC), Canadian Institutes of Health Research (CIHR), and Social Sciences and Humanities Research Council (SSHRC).

Current federal science policy interest and engagement create an opportunity for the provinces.

In Canada, there is currently an enhanced opportunity for provincial government action on science policy. Workshop participants pointed to several major developments including the current review of federal support for fundamental science, plans to appoint a Chief Science Advisor at the federal level, and ongoing work on a federal innovation agenda. These initiatives signal heightened federal interest in and engagement with science policy, and future provincial policies could benefit from considering federal policy changes. At the same time, strong provincial science policy capacity would likely have an influence on federal directions.

2.2 ROLE OF SUBNATIONAL GOVERNMENTS IN THE SCIENCE SYSTEM

Subnational governments play many roles in the science system.

Subnational governments contribute to a country's science system in myriad ways. They provide various types of science funding including broad-based funding for the post-secondary education system, often targeted funding for specific research initiatives, and support for science infrastructure. They conduct science within government, usually in service of their regulatory responsibilities and programming. They rely on scientific evidence to inform decision-making and to deliver public services. In addition to these core activities, subnational governments can also convene and lead, building capacity and connections across the science system, and work to understand and manage the social implications of scientific progress. In a collaborative science strategy for Canada's three territories, the territorial governments identify six roles for themselves in the science system: practitioners, consumers of science information, educators, facilitators of research within their own jurisdictions, regulators of research, and partners in "regional, national, and international science initiatives" (Gov. of YT *et al.*, 2016).

Subnational governments play many of the same roles as national governments in supporting science.

In many of these roles, subnational governments are not alone. Workshop participants observed significant overlap in the roles that national and subnational governments play in the science system. Unlike in some other domains, the constitutional division of powers does not draw many clear lines when it comes to science or science policy. Both levels of government fund university-based research, support science-based regional economic development, and conduct scientific activities within the public service. This reality is one of *uncoordinated entanglement* between levels of governments (Tupper, 2009), a term that, in the view of the Steering Committee and workshop participants, highlights the importance of having an explicit subnational science policy. Uncoordinated entanglement describes intergovernmental relations in which "both federal and provincial governments have major roles but operate without formal coordination" (Tupper, 2009). The term is derived from an analysis of Canada's university system where both levels of government play important and interdependent roles, with the federal government primarily involved in research and provincial governments in education.

Science is but one of many areas of overlapping jurisdiction. Other such realms include justice, food safety, agriculture, and income support. Mendelsohn *et al.* (2010) argue that significant efficiencies could be achieved from greater role clarity and that, in some cases, responsibilities should be uploaded to the federal government or devolved to provincial governments, while, in other cases, responsibilities should be streamlined or disentangled. They note that jurisdictional overlap can be inefficient, slow down policy responsiveness, and create challenges in attributing responsibility.

The lack of a clear division of responsibilities in relation to science is both a risk and an opportunity for provincial governments. It speaks to the importance of developing provincial science policy that articulates policies, programs, and thematic priorities and capitalizes on federal science policy and programs, and, more broadly, of ensuring coordination between the federal and provincial governments (Salazar & Holbrook, 2007). Indeed, to the extent that a distinct role for subnational governments exists beyond their areas of shared responsibility, workshop participants defined it as primarily related to leveraging, tailoring, or deepening federal science investments.

3

What Are the Elements of a Subnational Science Policy?

- Vision and Principles
- Areas of Focus
- Governance
- Monitoring and Evaluation

3 What Are the Elements of a Subnational Science Policy?

Science systems differ across jurisdictions, varying in size, institutional composition, research orientation, funding mechanisms, scientific cultures, and many other variables. This chapter synthesizes evidence from the literature and science-relevant policies and insights from the workshop on the elements relevant to subnational science policy development. The synthesis identifies five areas of focus as features of well-working science systems:

- *People:* deep and growing pools of scientific talent capable of participating in world-leading research, and effective means of training researchers and skilled workers;
- *Infrastructure:* infrastructure and facilities that allow for participation in advancing the frontiers of knowledge and are sustainably supported over decades;
- *Research:* research funding programs that meet multiple objectives, such as supporting early-career researchers and fostering scientific excellence;
- *Science Culture:* well-developed channels for public science outreach and engagement;
- *Knowledge Mobilization:* the means to mobilize scientific research for the development of new technologies; to attain the social license often necessary to de-risk the implementation of new technologies; to maintain an environment that fosters interactions between researchers and research users; and to access and integrate science advice to better inform public policy.

An effective combination of these areas of focus allows governments and society to maximally benefit from scientific work. These areas on their own, however, are, in the view of workshop participants, necessary, but insufficient, for defining a comprehensive science policy. Specifically, participants identified the importance of establishing a policy framework with a vision and principles, governance mechanisms, and an approach for measuring and evaluating science policy impacts. These elements are presented in Figure 3.1 and comprise a general framework capturing the core elements that should be considered in the development of an explicit science policy, be it at the national or subnational level.

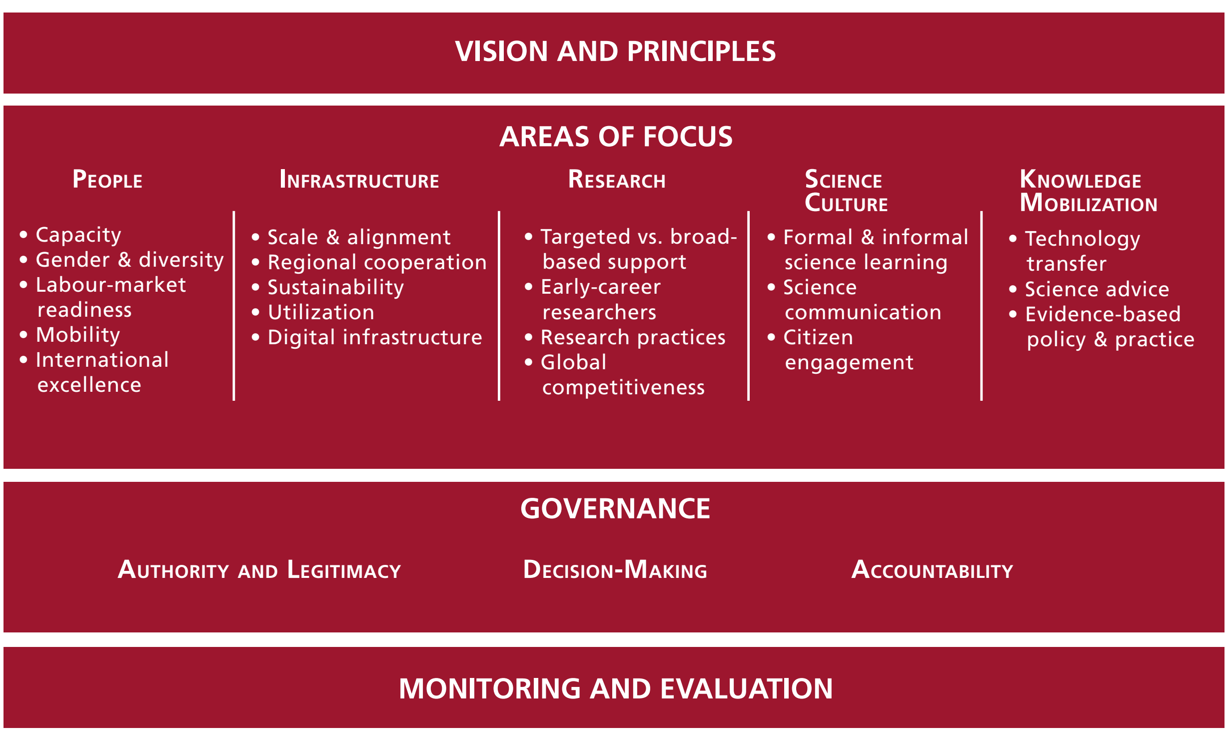


Figure 3.1

Subnational Science Policy Framework

The figure lists the key elements of science policy identified by workshop participants.

3.1 VISION AND PRINCIPLES

An explicit science policy is intended both to organize and rationalize public support for science. One function that science policies often perform, therefore, is to articulate an overarching vision that guides public support of science. Providing such a vision serves multiple purposes. At the most basic level, it gives a rationale for public support of scientific research. Governments frequently justify support for research by pointing to the ultimate economic and social benefits stemming from technology development, innovation, and economic competitiveness (Salter & Martin, 2001). By this argument, a robust science system is necessary to support a competitive, advanced economy, capable of ongoing social and economic innovation and reaping the benefit from the associated productivity gains. For example, Manitoba's support for research is positioned within its innovation strategy, which argues that innovation "generates new businesses and helps existing companies become more productive and globally competitive" (Gov. of MB, 2014). However, support for science can be advanced on other grounds related to public benefits such as improved health care, better environmental protection, and enhanced public safety and security.

Establishing a vision also provides strategic direction for governments, though policies frequently differ in the extent of detail in their vision of desired effects. Policies can go further and offer a more detailed vision based on regional science and technology clusters in a specific research domain or industry. Saskatchewan, for example, committed to becoming a leader in the biosciences by 2020 in its provincial economic strategy (Gov. of SK, n.d.). New Brunswick's 2012 innovation framework is organized around supporting growth in six priority sectors: information and communications technology, biosciences, value-added food, value-added wood, industrial fabrication, and aerospace and defence (Gov. of NB, 2012). In cases such as this, direct links can be drawn to subnational research priorities and related funding programs (see Section 3.2.3).

Policies can enshrine or articulate guiding principles for public support of science as part of an overarching vision. Commitments to open data and open science, for example, are becoming more common, with governments pledging support for the principle of making the results of publicly funded science ultimately accessible to the public (OECD, 2007). Governments can, either separately or within the context of a science policy, make commitments related to the promotion and use of science in policy. The Obama administration in the United States issued an overarching directive to federal departments and agencies in 2010 to reduce political interference and increase transparency in the use of government research and data to inform policy (Reich, 2010). In Canada, the federal government recently re-affirmed the importance of evidence-based policy-making and the role of science in advising the government, as demonstrated by the mandate letter delivered to the new Minister of Science (PMO, 2016).

3.2 AREAS OF FOCUS

3.2.1 People

Science is a human enterprise; a sufficient breadth and depth of expertise is a prerequisite to participating in world-leading research. In recognition of this, science policies often make commitments related to the development of scientific and technological skills (i.e., human capital) (see Gov. of QC, 2013; Gov. of BC, 2016). Public support for skill development related to science incorporates multiple objectives. At its core, it is about ensuring that the education system is capable of adequately supplying, attracting, and retaining the talent necessary to support advanced research.

Given direct jurisdictional authority over education, provincial government policies can shape post-secondary education and training, and provincial science policies can include commitments that target education and training initiatives towards specific programs or skill gaps. The British Columbia Tech Strategy, for example, included a commitment to expand co-op placements and improve labour market information related to the technology sector (Gov. of BC, 2016). Addressing deficiencies in the education and training of the next generation of researchers, however, also requires engagement and coordination with the post-secondary sector.

Commitments on Gender and Diversity

Policies can make explicit commitments to the composition of the scientific workforce with respect to gender and diversity. Concerns about gender disparities in research are widespread, in Canada and elsewhere. High-profile science initiatives such as the Canada Excellence Research Chairs (CERC) Program have been criticized in the past for failing to ensure adequate representation of women among participants, prompting widespread scrutiny of ongoing barriers to women's advancement in the sciences (CCA, 2012a). A recently launched new round of CERC recruitment will "require institutions to include detailed equity plans and recruitment strategies that promote the participation of women and other underrepresented groups" (GC, 2016). Workshop participants observed that subnational governments could learn from the success of initiatives such as Athena SWAN in the United Kingdom, which provides a structured process for participating institutions to assess their progress towards gender parity and adopt strategies for improvement (ECU, n.d.; RCUK, n.d.).

Science policies can pledge action to support training and career advancement of underrepresented minorities. In Canada, dedicated programs exist to support science, technology, engineering, and mathematics (STEM) training for Indigenous people, a growing demographic and one with comparatively lower levels of educational attainment and labour force participation (INAC, 2013; StatCan, 2013; Academica Group, 2016; UC, n.d.). Some programs also support people with disabilities in developing careers in science, although research from the National Educational Association of Disabled Students (NEADS) has found that such programs are more common in the United States than in Canada (NEADS, n.d.).

Labour-Market Readiness

Historically, science policies have focused on researchers working in traditional academic environments and trained at universities. There is a growing recognition, however, of the role that colleges and polytechnics can play in training researchers and technicians with skills directly relevant to local industries. Workshop participants pointed out that policies could support this role by encouraging better integration with the rest of the post-secondary system. In addition, programs supporting engagement and training in industry (e.g., co-op programs, internships and apprenticeships, mentorship programs) can encourage experiential learning and facilitate the development of research skills required for technology development and knowledge translation. Workshop participants pointed to the need for occupational training and education in the sciences throughout a person's career, and a corollary need for associated programs and public support.

Researcher Mobility

The mobility of students, scientists, researchers, and technicians can be a productive area of policy focus due to institutionalized barriers in many jurisdictions. For example, lack of recognition of coursework or degrees sometimes creates barriers to student transfers between institutions (Tupper, 2009). Barriers can also arise from university policies that impede the ability of researchers to move between academia and industry. Students in STEM fields can face barriers to employment outside of academia due to gaps in the curriculum (e.g., development of soft skills) and a lack of awareness of and exposure to various career options (SPE, 2016). Governments often lack direct authority in the area of researcher mobility and need to work collaboratively with post-secondary institutions to reduce any such barriers. The establishment of university-based research parks is another strategy to encourage such mobility.[2]

3.2.2 Infrastructure

The experiments that drive contemporary advances in science depend on state-of-the-art research infrastructure. Such infrastructure ranges in scale from comparatively inexpensive instruments and equipment housed in individual laboratories to massive, capital-intensive facilities such as synchrotrons, particle accelerators, and telescopes. While fields of science differ in the extent and nature of their infrastructure requirements, the importance of facilities and equipment makes infrastructure support a central issue for science policies. Due to the high costs of building and maintaining large research facilities, national governments often play a major role in funding and supporting them, and seek to share financial obligations with subnational governments, post-secondary institutions, industry, and international partners.

Scale and Alignment with Federal Support

Science policies grapple with many issues when it comes to research infrastructure. The scale of the investments required for large facilities makes questions of prioritization and alignment crucial. Governments are forced to be selective when it comes to these investments and to take national and subnational research priorities into account. Subnational governments typically have to adapt their support for scientific infrastructure to that already provided by national governments. Quebec, for example, has taken deliberate action to ensure that all initiatives advanced to the Canada Foundation for Innovation (CFI) for review undergo a concurrent provincial review (MESI, 2016). In the absence of collaboration between a province and its research organizations, provinces may have to adjust their support for research infrastructure based on federal decisions, and adapt subnational policy and research priorities accordingly. Challenges arising from this need led some workshop participants to raise questions about creating a national coordinating body in Canada to guide and inform public investments in large-scale scientific infrastructure and instrumentation (i.e., big science), as was recommended by the former National Science Advisor (ONSA, 2005).

2 Canada currently has 26 university research and technology parks that are instrumental in fostering engagement between technology companies and university-based researchers (AURP, n.d.-a ,n.d.-b).

Supporting Infrastructure Sustainability

Achieving a sustainable funding model for research infrastructure is crucial, according to workshop participants. Ideally, funding mechanisms provide comprehensive lifecycle support covering capital and operational costs. Funding for operational costs of research facilities has frequently been identified as a challenge in Canada. CFI, an independent non-profit organization funded by the federal government, provides federal financial support for research infrastructure. However, post-secondary institutions have argued that the mechanisms for funding the operational and indirect costs of research are inadequate (Tupper, 2009; UC, 2016). The resulting gap risks leaving research facilities underfunded on an ongoing basis (KPMG, 2009); this may, in the Steering Committee's experience, contribute to underutilization and deferred maintenance. Similarly, the standard CFI funding model, whereby CFI provides 40% of project funding and 60% comes from other sources, can create challenges for provinces. Workshop participants suggested that this funding model increases the need for coordination across stakeholders, and is particularly challenging for fundamental research and fields in which there is no obvious funding partner. It may also not be suitable for major national and regional (multi-provincial) facilities. On the positive side, participants concluded that leverage requirements encourage provincial commitment, which otherwise might be lacking if funding decisions involved only the federal government.

Maximizing Utilization

Governments face the challenge of how to maximize the benefits that flow from their infrastructure investments. Since underutilization of infrastructure and equipment is a constant risk, governments may take steps to promote access and use of publicly funded facilities. Science policies can protect or ensure industry access to publicly funded research facilities and equipment, promote private-sector use through collaborative granting programs, and, in some cases, physically locate research facilities near industries that benefit from them. Some policies have focused on developing nationally and globally competitive research clusters, through coordinated support for infrastructure and other elements (Sparks, 2013). Workshop participants suggested co-locating public research infrastructure to improve integration and promote joint use. In Canada, such approaches have been employed nationally, for example, through the National Research Council's Technology Clusters Initiative, and provincially, for example, in Prince Edward Island's commitment to create a nationally recognized centre of biotechnology excellence (Gov. of PEI, 2008). Institutions also play a role in ensuring efficient utilization of facilities. For example, Lakehead University's instrumentation laboratory allows faculty and students from multiple departments to access research instruments in a centralized facility rather than housing them in a specific department (LU, n.d.).

Computational and Digital Infrastructure

Rapid growth in the data requirements of many areas of scientific work is creating both physical and virtual infrastructure needs. Access to high-power computing capacity, data storage, and high-speed networking is increasingly vital to many domains of research activity, from oceanography to neuroscience. In Canada national organizations such as CANARIE and Compute Canada respond to these needs and focus investments in continued development of Canada's digital research infrastructure (CANARIE, n.d.; CC, n.d.). These may be supported further by provincial investments, such as the Ontario government's investment in Compute Ontario and the B.C. government's support for the WestGrid high performance computing network (Gov. of BC, 2011; CC, 2016). Data harmonization, interoperability, and standardization can accelerate research and lead to new advances, particularly in health research. At a pan-Canadian level, the Leadership Council for Digital Infrastructure is seeking to coordinate the diverse players in the digital infrastructure ecosystem (LCDI, n.d.). Subnationally, provinces must also consider the adequacy of regional digital infrastructure, taking into account the requirements associated with provincial research priorities and how best to coordinate provincial, regional, and federal support.

3.2.3 Research

Subnational governments are often active participants in research funding, both intramural (i.e., in-house) and extramural (i.e., research undertaken outside of government). Intramural research activities are often carried out in relation to the regulatory responsibilities that fall to subnational governments, which in Canada include natural resource management, environmental regulation, and the administration of provincial health care systems. In such cases, provincial government research labs and facilities contribute by producing new knowledge in response to local needs and by ensuring an absorptive capacity within government capable of interpreting and applying relevant research from elsewhere. Extramural research may also be sponsored by subnational governments to advance their science and technology priorities, to create internationally competitive centres of research and training, or to leverage grant-based support already provided through national programs.

Balancing Competing Objectives and Leveraging Federal Research Spending

The challenges faced by subnational research funding programs differ primarily in scale from those at the national level. While there is the added complexity of aligning national and subnational mechanisms for research support, many of the same tensions exist. These include balancing support for a diverse portfolio of research activities versus concentrating research support in areas of comparative excellence; supporting established versus early-career researchers; appropriately evaluating and supporting multidisciplinary and high-risk research; and meeting objectives such as promoting diversity, incentivizing public outreach and engagement, and supporting other forms of knowledge translation. For provinces, leveraging federal research spending is often an underlying objective. An explicit science policy can support provincial efforts to leverage federal funding by setting out a framework for making financial decisions and establishing clear mechanisms for collaboration with the federal government so that science investments serve both federal and provincial priorities.

Targeted Versus Broad-Based Support

With more limited resources than at the federal level, subnational governments may take a more focused approach aimed at identifying and supporting research activities of direct relevance to the local or provincial economies. In Alberta, for example, the Alberta Research Council was formed in 1921 to support research and technology development related to natural resource extraction (Millar & McNicholl, 2013); the province continues to direct significant resources to research related to these industries today through Alberta Innovates (AI, n.d.). In contrast, Quebec has taken a more broad-based approach, with the Fonds de recherche du Québec providing support across many areas of science and technology development through a structure similar to that of Canada's three national granting councils (Quirion *et al.*, 2016). Workshop participants characterized the Government of Ontario's orientation towards research funding in recent years as building peaks of excellence on top of federal support, while taking advantage of opportunities to match and leverage federal spending. The extent to which any government prioritizes targeted versus broad-based support depends on factors such as scale, the research base, the extent of resources and funding available, and the nature of regional economic development strategies.

Supporting Early-Career Researchers

Workshop participants noted the need for research funding programs that support established researchers as well as nurture new talent and fund early-career researchers. In the case of the former, funding programs can rely heavily on a researcher's track record in awarding and evaluating grant applications. For the latter, however, this can be problematic. Ontario's Early Researcher Awards, which limit eligibility to researchers within 5 years of starting their independent academic research career and 10 years from having completed their doctorate, are an example of a complementary program aimed at supporting early-career researchers (Gov. of ON, n.d.). In Quebec, the Fonds de recherche du Québec have developed salary award programs to support early-career researchers and the Chief Scientist has established an interdisciplinary student advisory committee to provide advice on improving access to graduate education, fostering excellence among new researchers, and establishing future research directions (SEC, 2016).

3.2.4 Science Culture

Workshop participants suggested that subnational governments have a role to play in supporting a strong science culture through education, public science outreach, engagement, and communication. This begins with science education at the primary and secondary levels, which provinces can direct through provincial science curricula in the K-12 system. Overall, Canada performs well in student science achievement relative to other countries as measured through the OECD's Programme for International Student Assessment (PISA) (OECD, 2016). The development of K-12 science curricula in many provinces benefitted from the 1997 *Common Framework of Science Learning Outcomes* created by the Council of Ministers of Education, Canada (CMEC, 1997), and from the 1984 Science Council of Canada report, *Science for Every Student* (SCC, 1984). That report reviewed science education at the primary and secondary levels, and established a vision for public science literacy in Canada. Research has since confirmed the fundamental role of science education as a key determinant of civic science literacy (Miller, 1998).

Support for Informal Science Learning and Engagement

Beyond formal science education, there are many avenues through which subnational governments can support public engagement in the sciences. Science centres and museums provide opportunities for the public to experience science in interactive, hands-on forums, which increasingly harness new digital and communication technologies. Expert science communicators and science ambassadors can make scientific work more accessible to the public, illuminating its relevance and potential. Non-profit organizations can build interest and knowledge among youth in the STEM fields (LTS, n.d.). Science fairs and festivals can also foster excitement about science. Contemporary science festivals often involve collaborations of musicians, artists, technologies, engineers, researchers, and communicators of many types.[3] Governments can promote scientific and technological awareness through designated science and technology days or weeks. Chief scientists can officially support public science engagement, as is the case in Australia (see Gov. of AU, n.d.). Granting programs can create incentives to encourage researchers to participate in science communication and outreach activities. However, such incentives require careful structuring because not all researchers have the inclination or skills needed to communicate their work to a broader audience.

Subnational governments often support science centres, museums, and other forms of public science outreach. In Quebec, science culture is explicitly identified as a sub-priority in the provincial science policy (Gov. of QC, 2013), but such support is not always connected to or formally recognized in subnational science policies. Leaving such support unconnected to the larger policy framework that outlines the government's approach to supporting science may contribute to a lack of alignment and coordination of government support.

3.2.5 Knowledge Mobilization

The benefits of science for society can fail to materialize when the technological and social opportunities enabled by new knowledge are not appreciated or acted on. Many barriers can interfere with and delay the productive application of new knowledge. As a result, workshop participants identified a need for efforts to mobilize knowledge emerging from the science system, thereby accelerating and enhancing its translation into social benefits.[4] The term *knowledge mobilization* includes the translation of research into new technologies, but is broader, speaking to a wide range of activities, "including knowledge synthesis; dissemination; transfer; exchange; and co-creation of knowledge with users" (SSHRC, 2015).

The concept of knowledge mobilization is closely connected with social capital. Enhanced connections between actors in the science system support increased information exchange, among other things. Salazar and Holbrook (2007) highlight the particular importance of networks in Canada owing to the country's low population density, distribution of research institutions, and political system.

Technology Transfer

Technology transfer refers to enhancing or accelerating the uptake of new knowledge as applied to the development of new technologies (including devices, therapies, products, and services). For this to occur, knowledge must first be translated into technologies through applied research and experimental development, which are then brought to market through successful commercialization. One potential barrier to this process is a simple lack of awareness. Firms may be unaware of new research and associated opportunities for technological advances. Recent efforts to address this barrier have included a focus on open access and open data policies, aimed at making research findings accessible to the wider public (see SGC, n.d.). Research networks (e.g., the federal Networks of Centres of Excellence) and consortia offer a more sophisticated approach that fosters ongoing interaction between researchers and research users, with the transfer of highly qualified personnel frequently viewed as a key pillar of the technology transfer process.

Other potential barriers to technology transfer and commercialization include access to venture capital and early-stage financing, trade barriers, issues relating to R&D tax credits and incentives, and the extent and effectiveness of government support for industry-university partnerships and collaborations (EPC, 2006). Intellectual property (IP) regimes are another potential barrier. Although they are intended to enhance technology commercialization by giving firms and researchers the ability to financially benefit from investments in research, IP regimes can actually impede the flow of research and development of technologies as well as abet them. In Canada, post-secondary institutions manage their own IP policies, which differ by institution. Provincial governments lack authority in this domain, and therefore can act mainly as conveners and instigators.

Science Advice and Evidence-Based Policy

Governments routinely face complex policy challenges involving scientific and technological issues. Effective decision-making in these contexts requires the ability to understand and incorporate scientific evidence into the policy-making process. Governments employ a wide range of advisory mechanisms to this end. The scientific capacity within regulatory departments and agencies informs policy development and contributes to the government's ability to absorb and respond to emerging research findings. Building on this capacity, dedicated channels for science advice can provide access to independent forums whereby

3 Examples of such initiatives can be found across Canada through the Science and Technology Awareness Network (STAN; see www.stanrsst.ca).

4 This recognition is not new; in 1995, for example, the National Advisory Board on Science and Technology's advice on federal science and technology strategy called for improved capacity in this regard, arguing that "Canada's ability to apply research results should attain a level of excellence that matches our current level of excellence in research" (NABST, 1995).

scientific experts can be consulted. Such channels include chief scientists, science and technology offices (such as the Office of Science and Technology Policy in the United States), national academies and research councils, and other expert advisory processes and panels. In Canada, relatively few provincial governments have been active in developing dedicated channels for science advice. Quebec and the Yukon are the only jurisdictions with official chief scientists or science advisors, though other provinces have scientific or technological advisory councils with differing levels of responsibility.[5] Knowledge mobilization efforts in this area can also include programs aimed at building scientific awareness and engagement among politicians, such as the schemes that pair scientists and Members of Parliament in the United Kingdom, or legislative briefings on scientific issues provided by the Chief Scientist in Quebec.

3.3 GOVERNANCE

The five areas of focus discussed in this chapter attest to the diversity and complexity of the science policy landscape. Even without an explicit science policy or strategy, national and subnational governments are often active in these areas by virtue of other regulatory or legislative responsibilities, and have mechanisms in place for supporting education, infrastructure, and research funding. One of the key functions of a science policy at any level of government is to provide an overarching framework that facilitates cross-government coordination and alignment (i.e., a framework for science policy governance). The concept of governance refers to "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions" (Hufty, 2011). More simply, governance relates to three fundamental dimensions: authority and legitimacy, decision-making, and accountability (IOG, n.d.).

In the public sector, departmental authority is formally established through legislative frameworks, though this does not necessarily prevent areas of overlapping responsibility. Particularly within a federal context and the uncoordinated entanglement that can characterize federal and provincial activities in shared domains (Tupper, 2009), an explicit science policy can help clarify lines of responsibility and illuminate the extent to which the objectives of different levels of government are conflicting or complementary. Workshop participants noted the value of establishing coherent priorities and directions across government departments. Authority is also related to questions of legitimacy, and the extent to which stakeholders in the science system have meaningful opportunities to express preferences and concerns. With respect to developing science policy, to achieve a broadly held perception of legitimacy, governments need to provide research institutions, researchers, R&D performing firms, and other stakeholders in the science system with channels through which they can provide input into policy development. In a review of the history of science policy development in Canada, Dufour (1994) points out that "in many instances… the process that was undertaken was just as critical, if not more so, than the product."

Decision-making is the second key dimension of governance, a key aspect of which is the designation of a particular body or bodies within government responsible for policy integration and alignment. Effective organizational and decision-making models vary and are context specific, taking into account the configuration of government and stakeholders, and ensuring that decision-making processes minimize program and policy duplication. For subnational governments, inter-jurisdictional (and inter-regional) coordination is key, and decision-making mechanisms that facilitate this coordination are therefore advantageous.

Public support for science accounts for non-negligible levels of expenditure. There is an obligation for accountability, both from funding recipients in reporting back to governments and from governments in reporting spending outcomes publicly. Science policies establish the basis on which government performance can be assessed on multiple levels. Overarching goals articulated in a policy provide the basis for assessing the entire government's collective performance — to the extent that these goals are measurable. Science policies can clarify the distribution of accountability across departments and agencies. While this kind of accountability can be established through departmental or ministerial mandates (rather than through the science policy itself), integrative decision-making bodies related to science and technology policy can further advance this objective by transparently specifying accountability for particular goals or functions. The accountability requirements for subnational governments do not differ appreciably from those for national governments, though the challenges associated with attribution may be exacerbated given that most research likely benefits from both national and subnational support. A science policy's ability to foster accountability is ultimately dependent on the extent to which it is conducive to effective monitoring and evaluation.

5 Alberta created a Chief Science Officer in 2016; however, this position is housed within the Alberta Ministry of Environment and Parks, with a mandate focused on environmental monitoring (Gov. of AB, 2016b). Ontario is currently in the process of creating a Chief Science Officer role, with the position to be filled in 2017 (Gov. of ON, 2016).

3.4 MONITORING AND EVALUATION

Demonstrating the value of specific public investments in science can be a challenge. The vision, objectives, and goals set for a policy or program can inform the appropriate methods for evaluating science policy, while recognizing that there are limits to evaluation, particularly in science where the returns to research are often unpredictable and can be difficult to trace. Diverse qualitative and quantitative approaches and measures can be used to assess both the overall health of the science system and the effectiveness of specific science policies and programs. Sufficient science policy capacity within government is then required to interpret, and learn from, the data.

Evaluation of the effectiveness of and returns on public investments in research is a constant area of interest and inquiry. There is a growing push for a *science of science policy* in which spending choices are informed by evidence (Marburger, 2005; Husbands Fealing *et al.*, 2011). This is not to say that monitoring and evaluation of science investments are easy; a lack of research in this area, gaps in data availability, and difficulties associated with attribution and incrementality all contribute to the challenges (Husbands Fealing *et al.*, 2011; Litan *et al.*, 2014). As Husbands Fealing *et al.* (2011) point out:

> There are several major data challenges before science policy research achieves the same level of sophistication as these other fields [health, labour, or education]: the information within administrative systems must be reoriented to connect investment with outcomes, and there must be a broader and deeper collection of information on both inputs and outputs, particularly on the scientific workforce. Finally, a deeper challenge, one not faced by other policy fields, must be addressed, namely, how to describe the scientific enterprise in general and scientific advances in particular.

Sarewitz (2011) underscores the importance of the ecology of science institutions and the institutions that put science to use to influence social outcomes. He argues that metrics that measure the outputs of research institutions cannot be expected to map to the social impacts of research, citing the example of the agriculture sector where some scientific advances have contributed to rural decline.

Figure 3.2 provides a list of indicators that could be used to support monitoring and evaluation (Litan *et al.*, 2014).

INDICATORS

Actors
- Individuals
- Collectives
  - Teams
  - Governments
  - Education and research institutions
  - Businesses
  - Private nonprofit organizations

Activities
- Research
- Invention
- Development
- Engineering/design
- Innovation
- Diffusion
- Education
- Training
- Capital investment
- Job mobility
- Firm dynamics
- Policy, regulation, and governance

Linkages
- Grants
- Contracts
- Collaboration
- Partnerships
- Codevelopment
- Copublication
- Social networks

Outcomes
- Knowledge stocks
- Social capital
- Intangibles
- Products and services
- Productivity
- Product life cycles
- Trade in S&T products
- Trade in R&D services
- Job mobility
- Firm dynamics
- Socioeconomic impacts/well-being

Adapted with permission from *Capturing Change in STI*, 2014, Courtesy of the National Academies Press, Washington, D.C.

Figure 3.2

Indicators for Evaluating Science Policy

A range of indicators can be used to assess the returns on science expenditures. These indicators can provide information on the actors, activities, linkages, and outcomes of the science system.

A strong monitoring and evaluation framework requires adequate resourcing, independent evaluation mechanisms, and establishing sufficient and appropriate information on which to base evaluation together with a solid data analytics capacity (which is currently limited in Canada). Subnational governments need to be realistic about the resources available to support evaluation and not commit to an overly sophisticated evaluation strategy that cannot be maintained or that imposes undue burden on institutions and researchers. Box 3.1 provides additional guidance for effectively developing the data required for monitoring and evaluation.

Workshop participants also emphasized the limits of evaluation in science policy. The results of investments in science are widely accepted to be "unpredictable as to when they will occur, who will be responsible for them, and even more so with respect to their end uses," thus limiting the potential of performance measurement for informing decision-making (Feller, 2012). Challenges include undervaluing failure, selecting performance measures, and the measurability of various objectives (Feller, 2012). Inevitably, expert judgement will continue to play an important role in government decision-making. However, expert panels and peer review processes come with their own set of challenges including "ability to forecast important trends in fundamental research, not only within, but across, fields of science; ability to properly support discontinuous, radical, transformative research; bias in support of interdisciplinary research" (Feller, 2007). While there is considerable scope for progress in improving evaluation practices for informing science funding, ultimately there are conceptual and methodological limits to what can be attained, and value judgements cannot and need not be avoided.

Box 3.1
Guidelines for Developing Data Required for Monitoring and Evaluation

Workshop Participants and Steering Committee members identified the following guidelines for the monitoring and evaluation of science policy:

- Clear and measurable program objectives must be established as part of program design.
- To inform monitoring and evaluation, data must offer the requisite degree of granularity, be made available in a timely manner, and be policy relevant.
- Process indicators are often the easiest to collect but performance indicators are what is most needed.
- Data should allow for trends to be assessed over time (particularly for baseline data collected prior to a new program commencing) and for comparisons across jurisdictions; collecting a consistent and widely adopted set of indicators is therefore important.
- Qualitative indicators are an important complement to quantitative indicators, allowing for consideration of a wider range of program impacts and stakeholder values.
- Indicators of social capital, such as professional mobility, spillovers, innovation supply chains, and deal-makers within the science system, can all help identify strengths and weaknesses in the networks that connect science inputs to societal outcomes.
- Comparing program results to a counterfactual can be informative for understanding the gains achieved by an intervention while recognizing the opportunity costs.
- Evaluation approaches will shape the incentive structures for those involved in program delivery, and skew results towards what is measured. Choosing the right measures, therefore, is paramount.

4

Considerations for Subnational Science Policy

- Federal Influence
- Coordination
- Prioritization
- Long-Term Commitment
- Science Versus Innovation

4 Considerations for Subnational Science Policy

This chapter synthesizes the main findings stemming from the workshop and from the documentary evidence as they pertain to science policy development and design, both generally and for Alberta specifically.

4.1 FEDERAL INFLUENCE

An explicit science policy allows subnational governments to more systematically and strategically leverage national science funding towards their priorities.

In 2015, the federal government funded approximately 20% of all R&D expenditures in Canada, with provincial governments (including provincial research organizations) funding an additional 6% (StatCan, 2015a). Given their much smaller investment levels, provincial governments can bring a strategic and systematic approach to supporting science that can help maximize federal investments from granting councils, regional development agencies, and other departments. They can, for example, choose whether to complement federal investment decisions with additional funding, thereby building critical mass in priority research areas (e.g., via CFI), or seed capacity in emerging research areas that are aligned with federal funding priorities in the expectation of securing research investments in these areas.

A science policy can therefore support provincial efforts to leverage federal funding by setting out a framework for making financial decisions and establishing clear mechanisms for collaboration with the federal government so that science investments can serve both provincial and federal priorities where possible. Provincial governments can perform a convening and coordinating function to support large applications, offer matching funds and be transparent about matching mechanisms, co-locate provincial and federal science and technology resources, and establish young faculty with early research grants that would better position them to go on to be competitive in applying for national grants.

Alberta in Focus

In 2013, the provincial government funded approximately 11% of Alberta's total R&D, a share well above that provided by other provincial governments though not as high as the share covered by territorial governments in recent years (StatCan, 2015a). This reflects a long-standing trend in Alberta; in the 1980s the government's share of R&D investments ranged from 15 to 21% (StatCan, 2015a). In 2014/15 Alberta's contributions to R&D in the higher education sector exceeded federal contributions whereas in all other provinces federal contributions far exceeded provincial contributions (StatCan, 2015b). The question of why Alberta is an outlier in these respects may warrant investigation.

Workshop participants identified working with the federal government to maximize federal investments in Alberta as the top opportunity for Alberta's science system. With 12% of Canada's population and 19% of GDP in 2014 (StatCan, 2015c, 2016), Alberta attracted 9% of all CIHR funding, 10% of NSERC funding, and 6% of SSHRC funding (AEDT, 2016). Of all awards issued through to September 2016, Alberta attracted 8.3% of CFI's funds (CFI, 2016). Alberta has fared better in the recently launched Canada First Research Excellence Fund in which it was awarded 12% of total funds (CFREF, 2016a, 2016b). A science policy designed to complement and build on federal investments could further improve federal funding levels in the province.

4.2 COORDINATION

Cross-sectoral and cross-governmental coordination and cooperation are central to effective subnational science policy.

The development and implementation of a science policy benefits from high-level engagement across government. Science is an increasingly pervasive influence on society, the economy, and public policy, and few government departments are unaffected by the impacts of science or the critical influence of research and knowledge in shaping their ability to deliver on mandate. In this context, science policy should not be seen as the purview of a single department. A science policy can clarify where various authorities lie, create ownership for the policy, and establish coordination mechanisms across departments to maximize the overall contribution that science can make to addressing priority issues. In addition, the development and implementation of a science policy benefits from strong relationships between those who tender science advice and senior officials across all government departments.

Beyond government, stakeholders can also inform policy development. Subnational governments have a key role to play in creating an environment for cooperation, networks, and strong relationships among researchers, institutions, sectors, and regions. In this respect, their relationships with local firms, institutions, and research facilities are often more direct than those of federal governments.

Subnational science policies can lay the groundwork for international cooperation; however, international collaborations and linkages are best forged by those who will deliver on them, namely researchers and institutions themselves. What subnational governments can do is identify important poles of international connection (geographical and domain specific) and support exploratory visits and workshops to catalyze such connections. These actions, however, need to be carefully monitored and assessed to ensure that their returns justify public investment.

Alberta in Focus

In Alberta as in many other jurisdictions, multiple departments are involved in the science system. The Ministry of Advanced Education provides operating grants for Alberta's post-secondary institutions and works with the Ministry of Infrastructure to support capital costs (AAE, n.d.-a, n .d.-b). Alberta's Ministry of Economic Development and Trade plays a leading role in shaping science and innovation policy for the province. Among its activities, the department administers the Research Capacity Program, which supports up to 40% of research infrastructure costs for projects in post-secondary institutions, complementing CFI funding (AEDT, n.d.-b); and the Campus Alberta Innovates Program, which was developed to fund 16 research chairs across Alberta's universities (CAIP, 2014; AEDT, n.d.-a). Other Government of Alberta departments, including Agriculture and Forestry, Advanced Education, Energy, Environment and Parks, and Health, also have a science component to their work, employing their own scientists, providing external funding, and interacting with and shaping the broader science system.

The provincial government also funds the Alberta Gambling Research Institute, a consortium of the University of Alberta, University of Calgary, and the University of Lethbridge that supports and promotes research into gambling in Alberta (AGRI, 2016). In addition, it participates jointly in the National Institute for Nanotechnology with the University of Alberta and the National Research Council (NRC-OAE, 2016); and supports Genome Alberta through multiple funders (Genome Alberta, 2015).

There is potential for overlapping roles between departments. For instance, both Alberta Economic Development and Trade and Alberta Advanced Education provide funding to the post-secondary system. Enhanced coordination between these departments could ensure alignment and potentially reduce the administrative burden for funding applicants. Workshop participants noted the potential role of a champion in enhancing the profile of and support for a science policy, highlighting the leadership of former Premier Peter Lougheed's with regards to oil sands research and investment in health research. Political engagement is important to establish adequate resourcing for implementing a science policy.

Coordination with stakeholders across the science system is also critical in establishing and implementing a science policy. Alberta has 21 public post-secondary institutions and a further 5 independent institutions (AAE, 2016). Of the 21 post-secondary institutions, 4 are considered Comprehensive Academic and Research Institutions: Athabasca University, University of Alberta, University of Calgary, and University of Lethbridge. Alberta's two polytechnics, Northern Alberta Institute of Technology and Southern Alberta Institute of Technology, are also important actors in the science system, often linking faculty researchers to industry partners to develop research applications that can serve industry. All these institutions play a significant role in the science system, whether by training students, conducting research, or developing and applying new technologies. Workshop participants identified a lack of connections among stakeholders as a key weakness for the province. Industry's funding of university-based R&D is limited, and industry in turn receives very little outside funding for its own R&D (StatCan, 2015a).

4.3 PRIORITIZATION

A subnational science policy can bring clarity to provincial research priorities.

At a basic level, provincial science priorities can be discerned from statistics on areas of funded science activity. Human health, environmental protection, and social well-being, for example, were among the largest categories of science and technology expenditures as reported by six provincial governments for 2010/11 (StatCan, 2012). An explicit science policy, however, provides an opportunity to be more strategic in the allocation of science resources. Indeed, provincial governments are well placed to strategically support research areas that are aligned with their regional strengths (Creutzberg, 2011). As noted above, they have often done so explicitly and implicitly by selectively supplementing federal science investments. Workshop participants noted a lack of attention to government-performed "public goods" science and observed that this was an important component of subnational science policy. Since the benefits of science are not readily foreseeable, it is important for provinces to ensure a broad base of research capacity beyond priority areas.

Alberta in Focus

Alberta has a long history of supporting scientific research in the province. As noted earlier, the Alberta Research Council was established in 1921 as Canada's first provincial research organization (ACT, 2016). Almost 100 years later, its legacy is carried on through research and technology development activities under the auspices of Alberta Innovates. Workshop participants pointed to two sectoral initiatives that are regarded as particular research success stories in the provincial research landscape: the Alberta Oil Sands Technology and Research Authority (AOSTRA) established in 1974, and the Alberta Heritage Foundation for Medical Research (AHFMR) established through an endowment in 1980 (AIHS, 2016; ACT, n.d.) (see Box 4.1 for a brief discussion of each). Both initiatives are seen as "big bets" that have delivered significant benefits for the province; workshop participants cautioned that small investments over short periods are less likely to deliver noticeable impacts.

Today, Alberta is home to a dynamic science system and its scientific contributions are nationally and internationally competitive by many measures. Workshop participants identified the talent pool and a strong university research system as key strengths of Alberta's science system. While bibliometric indicators (indicators based on research publication and citation patterns) are not valid measures of strength across all areas of academic research, they are valuable in many domains, especially when used to compare like with like. Using data collected by the CCA (2012b, 2016) in its studies of the state of science and technology and industrial R&D in Canada, a snapshot of Alberta's strengths is revealing. Alberta's research output and impact are broadly on par with Canada's other large provinces: it has the second highest rate of publications per faculty researcher, the fourth highest Average Relative Citation (ARC) score[6] among the provinces, and the third highest rate of doctoral graduates per population after Quebec and Ontario (CCA, 2012b, 2016). Bibliometric analysis indicates that Alberta's research output is comparatively high in fields such as Public Health and Health Services; Earth and Environmental Sciences; Philosophy and Theology; and Psychology and Cognitive Sciences (Figure 4.1). Fields in which Alberta has a high research impact (as reflected by citations) include Clinical Medicine; Physics and Astronomy; Agriculture, Fisheries and Forestry; Historical Studies; Economics and Business; and Information and Communication Technologies (Figure 4.2).

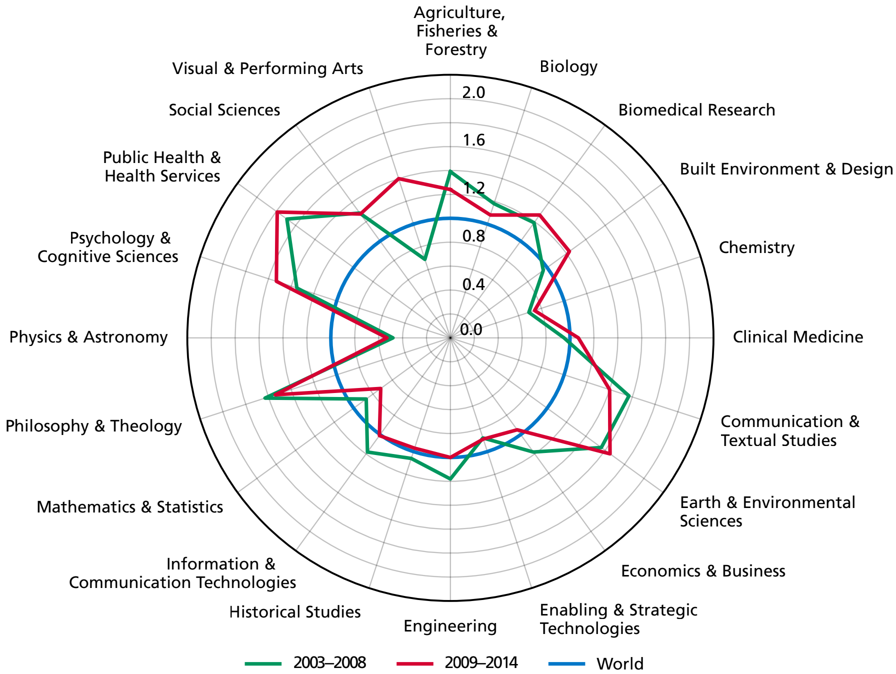
Box 4.1
Two Provincial Research Successes: AOSTRA and AHFMR

AOSTRA, a Crown corporation, used government funds to catalyze industry research on oil sands exploitation, typically matching industry's investments (ACT, n.d.). The development of horizontal well drilling for steam-assisted gravity drainage, which enabled in-situ extraction and today accounts for over half of production, is seen as AOSTRA's biggest achievement (CCA, 2015). The CCA's Expert Panel on the Potential for New and Emerging Technologies to Reduce the Environmental Impacts of Oil Sands Development observed that "[t]he AOSTRA model demonstrates the importance of collaboration among academia, government, and industry in addressing complex challenges" and pointed out that a similar approach could be used to address environmental challenges associated with the oil sands today (CCA, 2015).

AHFMR invested over one billion dollars in medical research in Alberta and has been widely credited with transforming the province's medical research system (Lampard, 2008). It stemmed the loss of talent to other jurisdictions, constructed four medical research buildings, increased access to federal medical research grants, and improved the relationship between the medical research community and the province (Lampard, 2008). Zwicker and Emery (2015) found that medical research investments improved local health outcomes. Other provinces have instituted funds and organizations based on the AHFMR model (Lampard, 2008).

The four themes of Alberta Innovates give a sense of current research priorities, with the government offering significant funding support under bio solutions, energy and environment, health, and technology futures (AI, n.d.). Nanotechnology is another area of focus with the National Institute for Nanotechnology as an important piece of a broader nanotechnology cluster and strategy for Alberta. The province has developed a nanotechnology strategy that seeks to expand the sector, focusing on commercialization, talent, and infrastructure (Gov. of AB, 2007).

6 The ARC score "is a measure of the frequency of citation of publications" (CCA, 2012b).

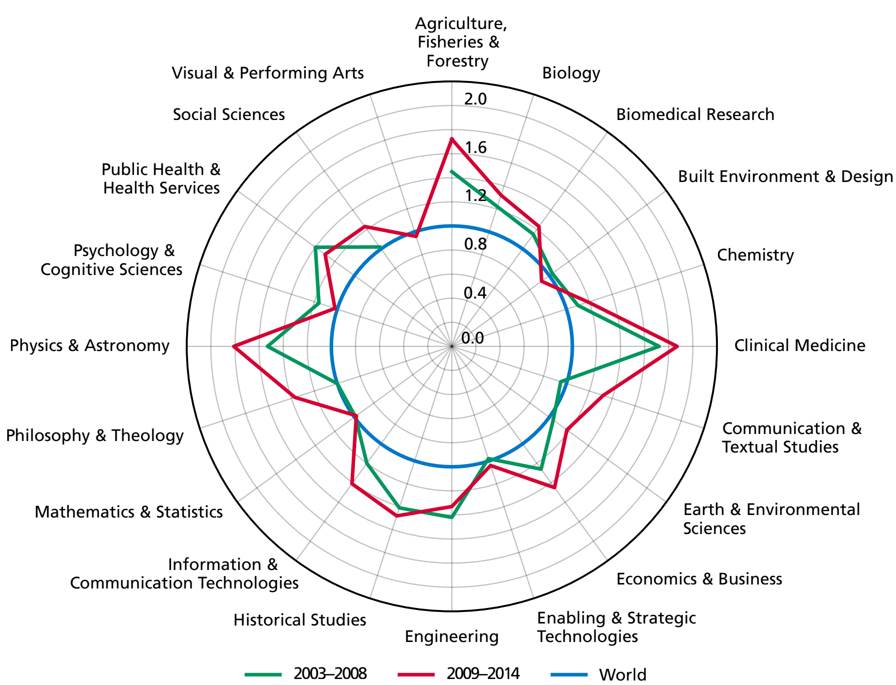


Data source: Calculated by Science-Metrix using Scopus database (Elsevier)

Figure 4.1

Specialization Index Scores by Field of Research for Alberta

The Specialization Index (SI) represents the extent to which Alberta over or under produces research in a given field relative to the world average (1.0). SI scores are shown for two periods: 2003–2008 and 2009–2014.



Data source: Calculated by Science-Metrix using Scopus database (Elsevier)

Figure 4.2

ARC Scores by Field of Research for Alberta

The ARC represents the frequency with which Alberta's publications in a given field are cited relative to other countries. ARC scores are shown relative to the world average (1.0) for two periods: 2003–2008 and 2009–2014. An ARC score for Visual and Performing Arts was not calculated for 2003–2008 due to the low number of publications in that field for that period.

In the current context of fiscal constraint, one of Alberta's key weaknesses, as identified by workshop participants, is the lack of a framework for making difficult financial decisions. While it was beyond this project's charge to identify the most suitable science priorities for the province, participants emphasized that, beyond the oil and gas sector, agriculture and climate change are two areas of potential growth closely tied to science. A science policy focused on climate change and agriculture would build on the province's natural endowments and harness science to address major social problems, namely, climate change and the current economic downturn. Participants also highlighted the importance of looking beyond STEM fields to consider the potential contribution of social sciences and other bodies of knowledge to the province. In addition, supporting clusters with other Western provinces was identified as a key opportunity that could help achieve a critical mass and improve research outcomes (Salazar & Holbrook, 2007). The strong research affinity between the Western provinces, as demonstrated by the extent of co-authored research papers between the provinces (Archambault *et al.*, 2014), could provide a foundation for further collaboration.

4.4 LONG-TERM COMMITMENT

Committing long term to a subnational science policy is important for maintaining and developing the science system.

Policies that are quickly replaced or revoked, whether due to changing political or fiscal circumstances, will not provide a foundation for long-term planning and the investment required to develop scientific institutions and networks. According to the Steering Committee, many factors can contribute to policy sustainability, including:

- *Broad political support:* Adequate, cross-party political support for policy requires cultivation at all stages, from the original development of the science policy, through frequent media reports on the science system, to discussions about its impact.
- *Policy breadth and scope:* A science policy that focuses only on the outputs of technology and innovation will not capture the public attention or imagination required for political support. For such a policy to resonate with citizens, there must be clear links to the public good, improved policy decisions, education, capacity building, preparedness for the unexpected, science communication, and a sense of aspiring to excellence.
- *Assessing, learning from, and demonstrating success:* Subnational science policies need to build into their implementation plans a means of monitoring progress, learning from experience, assessing and demonstrating successes, and communicating them. This means that the framework for assessment must reflect the breadth of rationales for funding science and the principles that underlie the science policy.
- *Stakeholder involvement:* The key stakeholders in the science system (e.g., researchers, funders, educators, communicators, translation intermediaries) must be engaged in development and monitoring of the science policy. They are more likely to champion it and argue for sustainability if they feel part of the policy rather than having it imposed on them.
- *Public engagement:* While public attitudes to science are often generally positive, technological advances are not always seen as benign. Sustained public engagement is another key element of ensuring that the ethical, legal, and social implications of science and technology are effectively incorporated in a science policy and that social license is an integral part of decisions on implementing developments in science and technology.

Alberta in Focus

Approaches to supporting science in Alberta have been unstable due to fluctuating government finances and prolonged experimentation with a range of resource distribution models. For instance, funding for research on the oil sands was provided through the AOSTRA Crown corporation from the mid-1970s through to 1994, at which point AOSTRA moved under the umbrella of the Alberta Department of Energy. In 2000, AOSTRA was replaced with the Alberta Energy Research Institute, and 10 years later this became Alberta Innovates — Energy and Environment Solutions (ACT, n.d.). In 2016 this was one of four groups consolidated to form a new Alberta Innovates (AI, n.d.). Similarly, the impacts of the funding decreases and reorientation of AHFMR are still being felt today (Zwicker & Emery, 2015). Workshop participants emphasized the challenges presented by this constant flux of programs and underscored the importance of sustained policy.

Public engagement with science in Alberta could contribute to policy stability. Alberta benefits from a strong K-12 education system and from generally high levels of public science knowledge and engagement. According to the OECD's PISA test of science knowledge, among 15-year-olds Alberta performs above the national average (O'Grady *et al.*, 2016). Results from a recent survey of the state of Canada's science culture also indicate strong support for science within the province. Close to 60% of the population reports being very interested in new scientific discoveries and technological developments. While a shared sentiment is reflected across the country, Albertans stand out as being the most interested residents of any region (CCA, 2014).

Rates of science literacy are also above average in Alberta, based on an index of close- and open-ended scientific knowledge questions and responses (CCA, 2014).

4.5 SCIENCE VERSUS INNOVATION

Science and innovation policies are distinct, but inextricably linked, for all levels of government.

Science policy is a distinct and complex area of policy with its own challenges and opportunities. It is essential for tackling major societal challenges at all scales (global, national, and regional); it serves the public interest and responds to public values by contributing to nation building, to national security, to health and well-being, to inclusiveness, and to societal resilience and preparedness. It is important for informing robust public policy such that governments, in the view of workshop participants, would be well served by formalizing their own reliance on science for evidence-based decision-making as part of their science policy. Not least, science and science policy make a significant contribution to innovation and related economic development, particularly through the development of highly qualified personnel.

Science, therefore, is a policy area that has value unto itself. It can neither be readily subsumed within innovation policy or other such areas, nor isolated from these areas. It is cross-cutting and interfaces equally with the broader social, environmental, cultural, and innovation policy contexts.

Alberta in Focus

In many respects, the value of science is already widely recognized in Alberta. Scientific discovery has been essential to the progress of the oil and gas sector, there is a capacity for high-impact research in the university system, and there is widespread interest in science among Albertans. Previous provincial governments recognized the linkages between science, technology commercialization, and industrial development (Gov. of AB, 1984, 2008); distinctions between science and innovation policies, however, have rarely been acknowledged. The policy context in Alberta is also changing. Declining oil prices over the last couple of years have had significant impacts, leading to high unemployment and negative growth (Gov. of AB, 2016a). This has led to provincial budget cuts and increased scrutiny of all public expenditures. In this new context, science expenditures, particularly those related to discovery research, have become more vulnerable. At the same time, the potential benefits of science and science policy can help address the new challenges that have emerged with the economic downturn, not only in relation to innovation but also to health and societal well-being in the province over the long term.

5

Final Reflections

5 Final Reflections

In Canada, science is as much a provincial endeavour as it is a national one. The institutions that perform science, together with the infrastructure and funding that enable it, are a part of a multi-level system of science that is as uncoordinated as it is complex. Having an explicit subnational science policy is an opportunity for provincial governments to make this essential resource work towards government priorities and achieve impacts that matter to them, such as developing knowledge or social capital, promoting economic diversification, and addressing environmental problems. Science policy, however, is not only a policy for science. It can also provide a mechanism to help science better inform decision-making on the many problems that governments now face.

In bringing together the expertise, insights, and experience of workshop participants with documentary evidence, this report is intended as a roadmap for subnational governments, such as Alberta, in the process of considering or developing a science policy. Context, however, matters. It is expected that the report's messages will be adapted to correspond with provincial strengths and weaknesses and policy environments. In the case of Alberta, workshop participants proposed that considerations related to better leveraging of federal research funds and to ensuring the long-term sustainability of policy should merit particular attention. Going forward, however, the province can continue to build on its strengths, including high levels of public awareness of and respect for science, an extensive talent pool, and a strong university research system.

Finally, science is changing rapidly. Research activities are increasingly globalized, multisectoral, and collaborative. Pressure for open access to publicly funded research continues to mount. The scale of data resources and analysis has grown exponentially, as has the power of the available computational tools. These factors, and others such as "citizen science" and public debates about the ethics and risks of new technologies, are all part of a continuously changing science landscape to which governments must be responsive. Science and science policy, therefore, require a commitment from governments towards both continuity and flexibility, so that the science system can adapt to trends and science can reach its potential.

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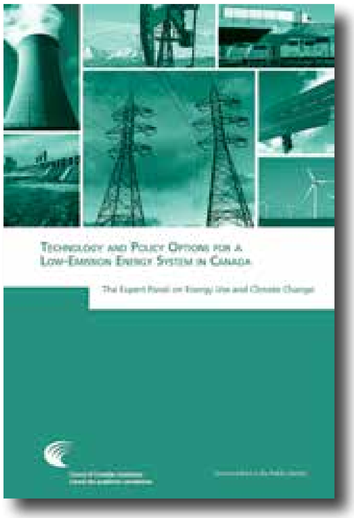

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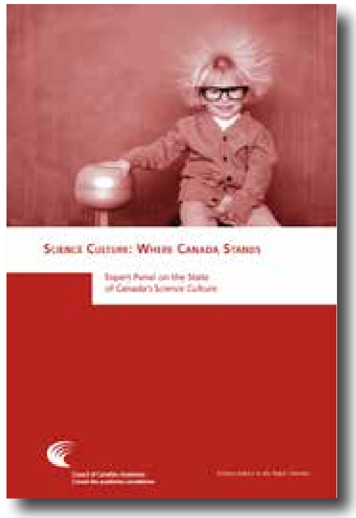

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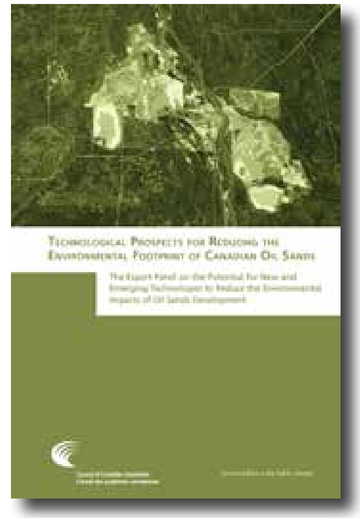

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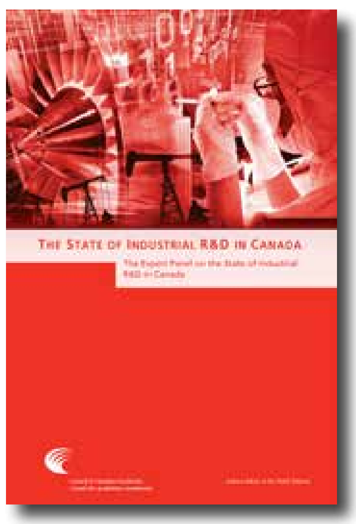

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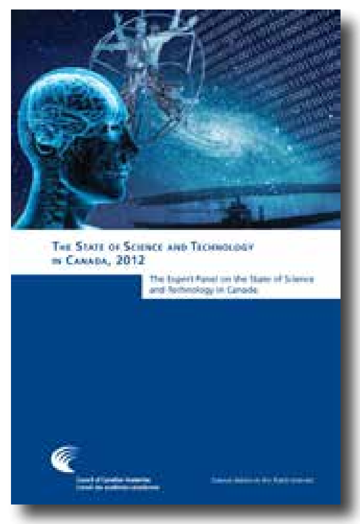

The State of Science and Technology in Canada, 2012 (2012)

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