Getting the Institutions Right: Designing the Public Sector to Promote Clean Innovation

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Introduction

Canada's current economic state of affairs has been described as a "low-innovation equilibrium" (Nicholson 2012). While Canada has an educated workforce and strong scientific capabilities, we fall short in creating new knowledge-based firms and industries (see Conference Board of Canada 2015; CCA 2013). There is a growing policy consensus on the need for more strategic and targeted approaches, capable of grappling with innovation problems and opportunities in particular sectors, regions, and technological areas (Breznitz and Wolfe 2015; Expert Panel on Business Innovation 2009). While Canada confronts its general innovation problem it must also face other challenges, amongst them climate change and environmental degradation. In this century, countries that are able to improve resource efficiency and reduce environmental impacts are likely to be rewarded in global markets (OECD 2011b; Dobbs et al. 2011). A transition towards sustainable development could create a mix of external pressures, windows of opportunity, and societal mobilizations that trigger an escape from Canada's state of low-innovation equilibrium. However, unless we develop new policy approaches clean technology sectors could fall into Canada's general pattern of innovation underperformance.

Previous discussions sponsored by Sustainable Prosperity highlighted that developing well functioning public sector institutions is a fundamental pre-requisite for policy aimed at promoting environmental improving technologies.[1] This report grapples with the question of how to get the institutions right to implement effective clean innovation policy by drawing on lessons from the academic literature and four case studies.

Innovation and Clean Innovation

The OECD's Oslo Manual (2005) defines an innovation as "the implementation of a new or significantly improved product (good or service), a new marketing method, or a new organizational method in business practices, workplace organisation or external relations". In general, innovation is a new or better way of doing valued things (CCA 2013). It is critical to understand that invention is the creation of a new idea and innovation involves actually putting that idea into practice - which encompasses the process of integrating a technology or idea into society (Fagerberg 2005). The creation of new ideas and the successful diffusion of innovation is influenced by a variety of factors in the larger environment or political economic structure, such as cultural milieus, pre-existing infrastructures; standards and regulations; availability of complementary technologies; human capital stocks; and political legitimacy (see Geels 2002; Lipsey and Carlaw 1996).

[1] Sustainable Prosperity sponsored a panel on Accelerating Clean Innovation at the Big Ideas Research Network Conference in April 2014, and a Conference on Accelerating Clean Innovation in March 2015.

Innovation does is not a solitary endeavor. A variety of individuals and organizations such as research institutes; small and large private firms; universities; governments; and user groups exchange knowledge and mutually shape technological development paths (Lundvall 1992; C. Freeman and Soete 1997). A "systems of innovation" perspective takes into account the multiple, interacting, factors that shape social and technological evolution. A system of innovation describes how different organizations interact with each other within a particular structural environment; often analyzed at national, regional, or local geographic scales, or within sectoral or technological boundaries (R. R. Nelson 1993; Asheim and Gertler 2005; Malerba 2004; B. Carlsson and Stankiewicz 1991).

While the prospect for human invention and technological opportunities might be virtually unlimited, history shows that technological change follows particular directions over periods of time – often labelled as paradigms and trajectories (Dosi 1982; C. Freeman and Perez 1988). This is because humans must take actions with limited knowledge; firms have particular technological competencies and have difficulty absorbing knowledge and techniques too far from these competencies; and the wider environment encompassing markets, social networks, and institutional rules can reinforce existing technological specializations (R. R. Nelson and Winter 1982; Bo Carlsson and Jacobsson 1997).

The tendency for innovation to follow different trajectories for significant periods of time has important implications for environmental policy. Innovation systems can become locked into polluting and environmentally destructive pathways (Unruh 2000; Haley 2011). In the 20th century the automobile, mass production and consumption, and fossil fuel based innovations created a "golden age" of economic progress, but also contributed to environmental problems related to climate change, reduced biodiversity, and pollution of air and water. Yet, innovation paradigms have changed in the past and public policy played a role in guiding these transformations (Perez 2002). It is possible to envision an innovation trajectory that specializes in creating products and/or processes specifically linked to reducing environmental impacts or improving environmental outcomes. This is *clean innovation*. If clean social as well as physical technologies (R. Nelson 2003) diffuse widely across the economy to create new sectors and follow-on innovations we could witness a change in technological trajectory and much wider transformations towards a sustainable paradigm (C. Freeman 1992).

Public policy plays a particularly important role in directing and accelerating innovation. Governments have the ability to shape the structures within which innovation takes place and they can introduce novel - potentially paradigm changing - social and technological options. A solid understanding of particular structural environments and innovation dynamics is important for governments to act wisely. After analyzing an innovation system, governments can target specific bottlenecks that hold back the development of new innovations – for instance, a lack of knowledge exchange, the need for complementary training and education institutions, or legacy standards and regulations that must be adapted to new technologies (see Bo Carlsson and Jacobsson 1997). Governments also re-charge and re-

direct innovation efforts by undertaking high-risk, high-reward initiatives in new technological fields. For instance, the public sector helped develop and commercialize technologies of primary importance today such as the Internet, and lithium batteries (see Mazzucato 2013; Block and Keller 2011).

Innovation policy requires a public sector that does not fit within contemporary perceptions of governments as overly politicized, risk-adverse, and out of touch with citizen and business needs (see Lynch 2009). Governments needs to interact with other players within technological systems and play a dynamic role within these systems. Inducing a transformation towards sustainable development through innovation is a long-term, highly uncertain process (Rosenberg 1996; René Kemp and Rotmans 2005) requiring governments to have significant foresight and an openness to failure and constant learning (Kuznetsov and Sabel 2014). Helping technologies develop and diffuse is also likely to require policy actions that are highly tailored to particular circumstances (Bergek et al. 2015; Tödtling and Trippl 2005) instead of the uniform administration of one or two policy instruments. These demands on government suggest that organizational innovation within the public sector is a prerequisite for promoting technological and social innovation.

This study seeks to expand the search for public sector arrangements that promote effective clean innovation policy design and implementation. The following section will discuss why good institutional design is important in greater detail by discussing useful warnings or pitfalls that can lead to government failures. The second section presents a list of common success factors found in the literature. The third section provides brief case studies of different public sector organizations dedicated to supporting clean innovation - the Advanced Research Projects Agency - Energy in the United States, the United Kingdom Carbon Trust, the Netherlands Energy Transitions Project, and Sustainable Development Technology Canada. The final section highlights key lessons from this research for the design of clean innovation institutions in Canada.

Why the Design of Public Institutions Matters

While there are many examples of governments successfully supporting innovation and guiding economic transformations (Block and Keller 2011; Mazzucato 2013; O'Riain 2004; Johnson 1982), there are also numerous examples of governments failing to play these roles (Lipsey and Carlaw 1996; Lerner 2009). Exploring the reasons why government can fail to successfully direct and accelerate innovation provides lessons that can inform a search for key institutional design principles.

Governments can fail in technology promotion efforts because they lack sufficient information on the technologies they seek to support. Government cannot be all knowing. However private sector firms also have limited knowledge. In an increasingly knowledge based economy both the private and public sector cannot assume they have adequate information, and must continuously seek out ways to learn

and access new knowledge. Given the increasing need to manage processes of knowledge creation and exchange there is now more collaboration between private sector firms (e.g. within supply chains, and research alliances) and public sector institutions such as government agencies, research laboratories, and universities (see Rycroft and Kash 1999; Chesbrough, Vanhaverbeke, and West 2006). Governments can play important roles within these collaborative networks by adding different types of knowledge, coordinating information exchange and making new connections, and steering learning and innovation towards public good objectives. The reality that governments lack information does not present a reason to limit government involvement in innovation policy. Doing so could further restrict information from both the public and private sectors. This important warning counsels that public sector institutions need to be open to learning from multiple quarters and flexible enough to change decisions based on new information.

Another warning is that private interests can "capture" the government to further their own ends. This can create a situation where the government provides policy support that promotes the industries that are the best at lobbying rather than the best at producing new innovations (Krueger 1974; Congleton, Hillman, and Konrad 2008). Rather than the state picking losers because of a lack of information or inflexibility, this situation creates a problem of "losers picking the state" (Mazzucato 2013). Of course political influence is ubiquitous and any actions taken by governments, even non-actions, will favour some industries over others (see Azar and Sandén 2011). Attempting to remove or insulate governments from private companies might be counter-productive because it will also restrict the public sector's access to knowledge and could reinforce status quo structures that create barriers to innovators. To avoid capture, public sector organizations need to be publicly accountable and have the competence and integrity to critically examine private sector attempts to shape technological expectations and policies.

A major breakdown in public institutions occurs when government decision makers fail to be guided by the public interest. A "predatory state" (Moselle and Polak 2001; P. Evans 1992) exists when those working the machinery of government aim to increase personal wealth or power rather than public welfare. This is a very important warning, yet it is possible to avoid falling into this situation. In addition to the potential for public servants to be motivated by illegitimate self-interest, public servants can also be motivated by *legitimate* self-interest such as the desire for promotion, pride, or prestige. They can also be motivated by idealism, altruism, and public service (Schmitz, Johnson, and Altenburg 2013). Public sector institutions can encourage the creation of a publicly minded culture that allows employees to be motivated by internal factors such as their beliefs and enjoyment as well as extrinsic factors that encourage public accountability (see Vandenabeele 2007).

Another pitfall concerns the potential inefficiency of government organization. Models of public bureaucracy warn that budgets can increase beyond desirable levels with few improvements in performance or service (Niskanen 1974; Savoie 2013). Yet, there are examples of nimble public sector

organizations, which will be discussed in our case studies. The key to judging the effectiveness of the public sector is to recognize that it has different strengths. In Savoie's (2015) exploration of "What is Government Good At?" he concludes that government is at its best when looking to the long term, grappling with complex or "wicked" problems, and making visionary investments. These are tasks particular to government administration and the objectives to keep in mind when evaluating public sector initiatives.

This discussion of reasons for government failures provide useful warnings that need to guide a search for good institutional design principles. The design of public organizations and the rules that govern them need to consider how these problems can be avoided. A review of the discussion above suggests that public sector institutions aiming to promote clean innovation should be able to access information from multiple quarters, yet avoid being captured by private interests; accountable and motivated by contributing to the public good; nimble, flexible, and cognizant of the unique role government plays in society. The next section will discuss institutional design principles that lead to success in greater detail.

Institutional Design Principles

This section will present a list of ten key institutional design principles derived from a review of academic and public policy literatures concerning innovation policy. The principles are:

1) Comprehensiveness
2) Flexibility
3) Autonomy from Short-term Political Pressure
4) Mission-orientation
5) Embeddedness within Policy Networks
6) Autonomy from Private Interests
7) Competence
8) Credibility
9) Stability
10) Accountability

The sub-sections below will present each principle, with relevant examples. Each section will also discuss different methods of achieving the principle and/or debates within the literature related to each principle. The reader will notice that many of the principles reinforce one another, while others exist in tension with potential to pull policymakers in different directions. After a discussion of each institutional design principle, this report will outline case studies demonstrating that creative tensions and synergies can be created out of these seemingly contradictory principles. Indeed, creating synergies between these principles is the task of good institutional design.

These principles relate to institutional design which is broader concept than the design of organizations. The word "institutions" refers to the rules that govern society (see Hodgson 2004). There are hard institutions such as powers and legal frameworks as well as soft institutions such as organizational cultures and the patterns of interaction between the public and private sectors. Thus this report's discussion of institutions does not refer to organizations, but the wider concept of how these organizations are structured, how they operate in practice, and how they relate to other players in the innovation system.

Comprehensiveness

Many different factors need to come together for an innovation to be successful, and as technologies and economies evolve different policy strategies and interventions are often required. As discussed above, innovation studies emphasize that policy needs to consider the *entire system* that influences technological development. Monitoring an innovation system involves understanding the roles of different innovation players such as universities, firms, associations, and users; considering the entire lifecycle of a technology; analyzing multiple innovation activities such as mobilizing financial and human resources, developing sectoral and regional innovation strategies, and building new networks to exchange knowledge; as well as examining how existing economic structures block or enable new technological developments (Bergek et al. 2008; M. Hekkert et al. 2011). Gaps such as missing players (e.g. lead users), weak innovation activities (e.g. missing interactions), or a lack of support during a critical moment in a technology's evolution can contribute to innovation failures. A policy mandate that is too restrictive could rule out promising technological options or policy strategies.

It is also important to tailor policies to particular technological circumstances. For instance, Bonvillian and Weiss (2009) note that market entry challenges differ in sustainable energy compared to other frequently targeted sectors such as information and biological technologies. These latter technologies can enter entirely new economic spaces or frontiers with high price products and then gradually reduce prices as technologies mature. In contrast, without policy actions, energy technologies have to compete on price immediately because the end product (e.g. heat, light) has the same characteristics regardless of the upstream technology used. Energy technologies also enter a "legacy" sector with structural lock-in characteristics (e.g. infrastructures and regulatory systems) designed to complement the old technologies and exclude new ones. Thus the market entry stage of development must not be neglected by innovation policy targeted to sustainable energy.

A comprehensive policy approach would consider how the entire system can help overcome market entry barriers. Policies such as feed-in tariffs could help sustainable technologies gain market access.

Furthermore, market entry needs could help inform challenges for basic science[2], supply chains could be examined to help reduce prices, and policymakers could grapple with infrastructure integration challenges. A good example is the US "SunShot Initiative", which undertakes a variety of activities focused on the market entry goal of making solar energy cost-competitive with traditional energy sources before 2020.[3]

The public administration challenge presented by clean innovation policy is that multiple policy tools might be relevant depending on unique sectoral, technological, and regional contexts, and policymakers will need to change policy strategies over time as technological systems evolve. It is not clear what public administration configurations best provide effective and comprehensive policy support. It is unlikely, and potentially undesirable, for one government department to have all the powers required to implement a tailored and comprehensive policy. Different sections of government might be best placed to implement innovation policy at any one time. There are historic examples of powerful pilot agencies leading industrial development missions, such as in Japan and Korea (Johnson 1982; Chang 1994). In the United States and Ireland, authors describe a more "networked" state with a decentralized structure of labs, agencies, departments, and specialized policy initiatives at multiple levels of government (Block 2008; O'Riain 2004). In this configuration some redundancy between government functions can be beneficial since it increases the chances of new ideas finding a space within the public sector. Further insights into achieving both coordination and policy innovation come from Breznitz and Ornston's (2013) case studies in Israel and Finland. They found that agencies with limited power and resources, yet a high degree of freedom and flexibility produced new policy models that were picked up by other sections of government at critical moments. Their findings emphasize the benefits of creating entities within government with independence (see below) and with an ability to move across administrative boundaries.

While policy implementation might require the use of organizations with specific skills and competencies, *discovering* the right policy interventions requires a wide analytical purview and an ability to adapt when confronted with particular innovation problems. To promote a comprehensive innovation systems perspective, Sweden created an agency called Vinnova. Foresight exercises and innovation systems analysis play a strong role in informing the agency's decisions on where to direct policy efforts and how to advise government (see Chaminade and Edquist 2006; Jacob 2006).

Achieving comprehensiveness will likely require the participation of multiple entities within government. The question of "who does what" might depend on a given jurisdictional context and pre-existing organizational and bureaucratic competencies. Innovation theory and case examples suggest that each organization engaged in promoting innovation should have a comprehensive understanding of the

[2] Donald Stokes (1997) describes use-inspired basic research as working within Pasteur's Quadrant.
[3] http://energy.gov/eere/sunshot/sunshot-initiative

innovation system and the role they can play within it, as well as an ability to solve innovation policy problems using a variety of policy tools.

Flexibility

Innovation is an ever-changing process beset with significant uncertainty. Policy should be able to adapt to new knowledge, and shifts in industrial dynamics by changing policy designs and methods of implementation. Technological and societal changes can also create time-specific windows of opportunity, when policymakers and entrepreneurs need to identify and exploit (Sartorius and Zundel 2005). Public agencies should be able to scale-up successful projects. It is also crucially important that the public sector has the capacity to cut off non-performing projects and change strategies in light of new information.

A relevant example of the importance of a flexible and adaptive approach comes from Japan's successful development of hybrid electric vehicles (Åhman 2006). Japan's Ministry of International Trade and Industry (MITI) defined an ambitious agenda to develop battery electric vehicles in the 1970s. Few of the technology targets were met, however the electric drivetrain technologies developed in search of developing a battery electric vehicle were used by car companies to produce hybrid vehicles. When government departments became aware of the hybrid technology they quickly extended purchase subsidies towards these vehicles, creating an initial market. Thus, R&D programs created technological learning in unexpected ways, and the government's flexibility in face of these unexpected technological developments helped Japan successfully develop hybrid vehicles.

Autonomy from Short-term Political Pressure

Innovation is a long-term processes that is characterized by significant uncertainty . An agency working on the frontiers of low-carbon innovation needs to be accepting of technological failures - recognizing them as normal occurrences that can contribute to learning (see Rodrik 2014). If low-carbon innovation policy is caught in what public administration scholar Donald Savoie (2015) calls "blame games", decision making will lose focus on fostering long-term transformations. Undue political influence might also prevent the timely cut-off of failing projects. Lipsey and Carlaw (1998) find examples where political optics and the search for prestige led to continuation of support for projects that should have been cancelled. The Solyndra case in the US demonstrates that expending political capital on one project can create liabilities for politicians, cause administrators to continue supporting a project when it should be cut off, and direct public attention away from the overall success of broader policy initiatives.[4]

[4] In the US, solar cell manufacturer Solyndra received loan guarantees from the US government and went bankrupt in 2011. President Obama used Solyndra as a poster child for his economic recovery policies and received substantial criticism after the company's bankruptcy. Despite the political

Autonomy from short-term political pressures is a common attribute in many innovation policy success stories, yet it is achieved in different ways. In Japan, sector development policy was housed within the powerful Ministry of International Trade and Industry (MITI). This Ministry had a high degree of political autonomy because Japan had a culture of bureaucratic dominance over politics where civil servants were held in very high prestige (Johnson 1982). In Israel and Finland, Breznitz and Ornston (2013) explain how innovation agencies achieved political autonomy because they were "low-profile" and were on the "periphery" of the public sector. The benefit of this peripheral position was that these agencies had flexibility, room to experiment with new policy approaches, and they avoided capture by powerful interests.

The drawback of an arms length or peripheral position within the public sector is that an agency does not have the ability to wield a full suite of policy tools.[5] It is also possible that outsourcing certain policy functions can reduce the competence and capabilities of other government departments (Mazzucato 2015). Breznitz and Ornston's (2013) case histories explain that peripheral agencies played the special function of introducing new policy models, which were scaled up by other departments of government. Thus other areas of government, and the ability of peripheral agencies to coordinate with them, was important.

The contrast between Japan, Israel, and Finland highlights that a country's political culture determines how political autonomy is best achieved. In Canada, Donald Savoie (2015) describes a condition where political leaders and civil servants can be very intolerant of risk, which creates a short-term rather than long-term focus. Keeping certain innovation policy functions at arms length could create a space for policy experimentation, while also shielding political leaders from what Savoie calls "blame games".

Mission-Orientation

Authors highlight the importance of having clear objectives for policy implementation as well as a mobilizing mission (see Narayanamurti, Anadon, and Sagar 2009). This mission should be grounded in a clear understanding of the unique role the public sectors plays within innovation systems. Mazzucato (2015) emphasizes that in contrast to the private sector, the state's role within innovation systems is to tackle large societal challenge and to "think big". She argues that government innovation activities can help create entirely new economic paradigms, such as a green paradigm shift.

controversy, the loan guarantee program was an overall success and supported technological winners such as the Tesla electric car.

[5] Note that MITI was not all-powerful. Internal struggles between MITI with the Department of Finance meant the use of subsidies were limited. MITI made greater use of coordination and regulation policies.

The clarity of the mission and policy objectives is another theme discussed in the literature. Lipsey and Carlaw's (1996) review of numerous case studies of successful and unsuccessful innovations highlights that multiple objectives are dangerous because introducing a variety of non-technological objectives can be used to maintain projects that should be cancelled. Likewise, Rodrik (2014) notes that political leaders often justify policies based on numerous rationales such as pollution reduction, jobs, and competitiveness, but these multiple goals cloud policy direction and make it difficult to know when a change of course is warranted. Politicians find it useful to justify the introduction of a policy based on multiple objectives, but these objectives could come back to haunt them because they encourage Savoie's "blame games" during policy implementation.

A benefit of clean innovation is that it is clearly associated with a public purpose mission of promoting environmental improvements. To meet the goals related to sustainable development and a low-carbon economy a large-scale transformation of society, or major shift in economic paradigm, is likely required (C. Freeman 1992). This transformative goal is distinct from more general innovation policies principally focused on economic growth or productivity. Transformative innovations can create disruptions in other economic sectors and induce larger structural changes (Christensen 2013; C. Freeman and Perez 1988). Innovation policies geared towards the general economy might have a bias towards supporting incremental innovations in existing economic sectors, while clean innovation aims to shift economic trajectories and create new sectors. Thus "innovation" and clean innovation can be quite distinct (Alkemade, Hekkert, and Negro 2011). A clean innovation mission should be recognized as separate and unique from more general innovation policy objectives. If the paradigm is truly shifting, clean innovation will become a goal that aligns all other areas of policy.

Embeddedness within Policy Networks

The second section of this report discussed a lack of information as a reason why governments might fail to implement successful innovation policy. This information problem can be alleviated by ensuring consistent relationships and information exchange with organizations outside of government. In Peter Evans' (1995) seminal study on the computer industry he discussed the need for the government to be "embedded" within the private sector. Consistent, sustained, linkages with the private sector increases the government's understanding of the sectors it aims to influence. Policymakers need to understand business strategies and anticipate how private companies will respond to a policy change. Embeddedness allows for a continuous negotiation of goals and the development of common projects, enabled by the build up of trust, mutual understanding, and reciprocity with respect to information exchange. An embedded public sector is not only smarter, it also increases its options for policy implementation - because soft instruments such as strategic planning, coordination, regulatory changes, and even suggestion can become more effective.

Embeddedness becomes even more critical in an increasingly knowledge based economy where innovation is an interactive process, based on collaboration between a large policy network which can include private firms, government agencies, multiple levels of government, universities, and customers (P. Evans 2008; Lundvall 1992). Private firms are more reliant on collaborations and knowledge sharing to keep up with fast-moving technological frontiers and market changes; and governments must continuously absorb knowledge from variety of partners to successfully design and implement policies (see Cooke and Morgan 1998). Governments cannot play their unique roles within these policy networks without being embedded within them.

In a more knowledge based economy with a need for larger information requirements and co-implementation Evans (2008) highlights the need to expand the notion of embeddedness from a concept principally concerned with government-business relations towards also incorporating civil society. Civil society groups can help identify and manage social barriers to technology adoption (e.g. how to promote low-income inclusion in sustainable energy), promote political legitimacy, and help policy initiatives stay on mission. This might require gathering constituencies that are more numerous and less organized. As Evans (2008) states, the 21st century calls for "more complex and demanding forms of embeddedness".

To understand the multiple innovation players that might need to interact to develop a technology, consider the vision of a "smart grid" (Fox-Penner 2010). Successful smart grid development likely requires the involvement of utility companies; information technology providers; and private sector companies developing energy management systems and digital applications. Governments will need to change regulations (e.g. time of use pricing) and help install new infrastructures. It is also critical that users become directly engaged because many smart grid technologies aim to change consumer habits (G. P. Verbong, Beemsterboer, and Sengers 2013). Users can also provide critical feedback to improve software technologies. Governments will not be able to understand how to best facilitate smart grid development without obtaining knowledge from each of these groups.

Autonomy from Private Interests

The second section of this report also noted the danger of governments becoming *captured* by groups in society, such as a particular industry lobby. An embedded public sector could be more prone to capture. As discussed above, attempting to insulate the public sector is unrealistic. It would cut off information flow needed to create effective policies and would significantly decrease the public sector's capacity to shape innovation trajectories through strategic leadership and coordination.

Institutional design can guard against capture by vested interests by promoting the *autonomy* of public sector organizations and personnel. In Peter Evans' (1995) study of the computer industry he emphasized the importance of state autonomy alongside embeddedness. He found that the most

successful states had the right mix of "embedded autonomy" to make the state both more competent with respect to their policy arena and capable of avoiding capture or corruption. Governments engage with private sector partners, but do so on their own terms.

Autonomy is achieved by ensuring those engaged in policy implementation have a high level of expertise and an ability to develop their own visions of technological futures. It can be promoted by following basic public administration principles such as merit-based hiring. A clear public purpose mission also helps set the rules for public-private collaborations. The idea is to collaborate on achieving the mission rather than having government work in the interests of a particular client or group. Schmitz et al (2013) call for "transformative alliances", highlighting that actors with different interests and objectives can nevertheless pull in the same direction.

Competence

The public sector must demonstrate competence in its policy area to support its autonomy and earn trust within its policy network. Leadership, culture, talent, and institutional fit are all factors that relate to the competence of the public sector.

Narayanamurti et al (2009) highlight the importance of leadership and a culture that promotes integrity and public purpose. They call for leaders with managerial as well as scientific/technical credentials. In the energy field, they highlight the need to understand the role of public organizations in the overall system, with capabilities to "integrate the different activities within and outside the institution".

The public sector must also attract talented individuals with deep "domain specific competencies" (Jacobsson and Bergek 2011). A mobilizing mission can act as a magnet for talented and motivated individuals (Narayanamurti, Anadon, and Sagar 2009; Mazzucato 2013). The method of finding and attracting this talent might depend on individual contexts. The US Defense Advanced Research Projects Agency's (DARPA) innovation model makes uses of temporary project teams. Former Directors, Regina Dugan and Gabriel Kaigham (2013) argue that finite timelines attract high-caliber individuals interested in working on problems, but not becoming permanent employees. In contrast, permanent groups with specialized knowledge of particular sectors are used in Finland's Tekes agency. The temporary projects model might fit the American context where a large pool of talent is available from industry and academia. DARPA also works on producing breakthroughs that connect basic science with user needs, which lends itself to short, focused projects. In contrast, jurisdictions that need to build new capabilities might opt for developing specializations in-house over longer periods. More permanent project teams might also be more relevant to promoting diffusion and conducting innovation system analyses.

The literature suggests that the competency of public institutions should be prioritized over theoretically ideal policy instruments (Lipsey and Carlaw 1998; Rodrik 2007). The choice of policy instruments should

be primarily determined by how effectively they can be wielded in practice. As Rodrik (2007) states, "it is better to employ a second-best instrument effectively than to use first-best instruments badly". Assessing what institutional competencies exist, where they are located in the public sector, and what competencies can be built up in the public sector or acquired by joining up with non-governmental organizations is an important aspect of governing innovation. The possible institutional fits within a given jurisdiction can help determine where policy functions are best placed.

The level of government (federal, provincial, municipal) best placed to play certain innovation policy roles is another aspect of promoting institutional competency. This issue is especially relevant in the Canadian context, given highly differentiated regional economies and federalist political structures (Simeon 1979; Jenkin 1983). Innovation theories emphasize the importance of interactive learning, collaborative policy networks and geographically specific concentrations of specialized capabilities and skills (see Morgan 2007; Wolfe and Lucas 2005). Local and regional levels of government are often best placed to foster meaningful collaborations and develop strategic priorities. However, these local innovation initiatives must be able to access resources and pull down policy supports and intelligence from upper levels of government (see Creutzberg 2011; Bradford 2004; OECD 2014b). The federal, provincial, and local levels of government have separate institutional competencies that need to work in concert.

Credibility

To gain trust within networks and to send the right signals to the private sector, the public sector must have the ability to do what it says it will do (Schmitz, Johnson, and Altenburg 2013). Private firms that change business strategies based on public policy expose themselves to investment risks in the case of unexpected policy change. The private sector must have confidence that the public sector's policy directions are credible and will not create unexpected changes. An unpredictable environment can stymie an otherwise robust policy framework. In Ontario, Holburn, Lui and Morand (2010) found that policy uncertainty was the most important factor in wind firm location decisions, and that uncertainty led to higher wind power prices.

Stability

The development of innovation often requires much longer periods than are typically resources through government funding cycles. A boom and bust funding cycle can disrupt long and complex technological trajectories (Khanberg and Joshi 2012; Narayanamurti, Anadon, and Sagar 2009; Foray, Mowery, and Nelson 2012), and result in the loss of talent in public sector organizations as employees look for work elsewhere. This in turn reduces credibility and trust with private sector partners.

Authors making recommendations for significant increases in clean innovation research and development activities have also called for steady changes in annual budgets (see Dechezleprêtre, Martin, and Bassi 2016; Dechezleprêtre and Popp 2015; Newell 2008). As demonstrated by Freeman and Van Reenan's (2009) study on the US National Institutes of Health (NIH) large increases and decreases in R&D budgets can create significant adjustment problems. In the face of rapid budget increases the NIH needed to rapidly attract researchers which needed time to develop their knowledge and expertise. Then a rapid decrease created career problems for these researchers who needed to compete for a smaller pool of research funds.

Accountability

Clean innovation policy must be designed and implemented in the public interest. Accountability is required to guard against political capture or self-interested behaviour on the part of agencies. Public organizations have a responsibility to "explain what they are doing and how they are doing it" (Rodrik 2014). This demands a high degree of transparency from the outset. Rodrik (2007) calls for a clear link with a political leader who is accountable for the consequences of innovation policy and capable of monitoring performance. He also notes that a political master should not only engage in oversight, but also be a *champion* with a high level of authority. This ensures that the issues related to economic transformation have a strong voice in government - equivalent to the role of the finance minister in promoting fiscal prudence.

A crucially important, yet difficult question, concerns the evaluation of clean innovation performance. Evaluation can maintain accountability, build political legitimacy, and promote policy learning. However, if done badly evaluation can dramatically increase overhead, impede flexibility, reduce comprehensiveness by narrowing activities to those that can most easily be evaluated rather than those that could be transformative in nature (see Savoie 2015).

There is no single metric to evaluate innovation performance. Restricting evaluation to a limited number of indicators (e.g. patents) will reveal only limited aspects of the innovation picture and could misdirect policymakers towards supporting only one aspect of the innovation system. A multitude of indicators can be used to monitor innovation such as the number of new products and firms, quality improvements, and price performance. In addition to monitoring output indicators, policymaker actions are often best informed by tracking innovation activities or processes such as network building, market formation, entrepreneurial experimentation, and initiatives to increase human capital (Edquist 2004; Marko P. Hekkert and Negro 2009; Bergek et al. 2008). To maintain focus on a clean innovation mission, environmental indicators should be tracked and given significant weight in the evaluation of projects.

The other important aspect of evaluating innovation is that failure of some projects is inevitable, since innovation is a process of learning and experimentation. An institutional structure should ensure that

technology successes are able to partially offset the inevitable losses, and therefore institutional evaluation should be based on the entire portfolio of "winning" and "losing" projects over a sufficiently long period of time. In addition, project success should be judged based on social or systemic objectives such as the creation of spillovers across the economy, which can occur in projects that both succeed and fail to reach commercialization stages (McDowall and Ekins 2014; Rodrik 2014; Mazzucato 2015). The key is to ensure policymakers learn from failures. In Lipsey and Carlaw's (1996; 1998) evaluation of innovation policies they list two types of successes. The first type leads towards the successful commercialization of a process or product. The second type of success is a situation where an attempt was worth making at the outset, the attempt fails, and the failure is recognized in a timely fashion and support is terminated.

Learning from both successes and failures requires government policymakers to have a high capacity for self-monitoring or "diagnostic monitoring" (Sabel 1994; Kuznetsov and Sabel 2014). Evaluation frameworks that support iterative learning and consider course corrections could be highly valuable (Arnold 2004). These types of evaluation frameworks might not easily fit within more standard cost-benefit frameworks, but they might be the best way to support the public sector's unique role in promoting low-carbon innovation.

How to appropriately evaluate clean innovation policy in the Canadian context deserves careful consideration from policy makers and this issue requires further research. The challenges of properly evaluating innovation should be discussed upfront to avoid misunderstandings that lead to unnecessary controversies.

Case Studies

This section will explore four different institutional designs to accelerate clean energy innovation - the US Advanced Research Projects Agency – Energy, the UK Carbon Trust, the Netherlands Energy Transitions Project, and Canada's Sustainable Development Technology Canada. These cases were selected to provide an overview of diverse policy initiatives in industrialized countries focused on the full process of innovation. The purpose of exploring these cases is to highlight useful policy lessons on how institutional designs grapple with the principles listed above. Linkages to the principles and sub-issues outlined in the previous section are highlighted in *italics* within the case descriptions.

Advanced Research Projects Agency – Energy (ARPA-E)

ARPA-E is an agency within the United States Department of Energy with a focus on promoting high-potential, high-impact energy innovations. The National Academies called for an energy agency modelled after the Defense Advanced Research Projects Agency (DARPA) in order to stem the erosion of the US advantage in Science and Technology.[6] The agency was created in 2007, but not funded until 2009 when it received $400 million as part of stimulus policies to fight the recession.

ARPA-E has a small staff (56 full-time equivalents) and a multi-faceted *mission* to improve US economic competitiveness, energy security, and the reduction of GHG emissions. It funds short-term projects (1-3 years) with potential to have a transformative impact. Projects are cost-shared with funding recipients, which have included universities, small businesses, large businesses, national labs, and non-profit organizations. ARPA-E is an actor in a larger *policy network* of energy innovation institutions incorporating federal labs, energy innovation hubs, and other activities within the Department of Energy (see Anadón 2012). While other agencies might focus on scale-up and diffusion, ARPA-E's principle role within the energy innovation system is to promote experimentation. This increases the diversity of technological options available in the US (Martin 2015, 106).

Hourihan and Stepp (2011) note ARPA-E's unique *culture*, stating "this is not your grandfather's politicized bureaucracy. It's a fresh and nimble organization that operates at the intersection of fundamental and applied research, bringing science research and technology development together under one roof". ARPA-E attracts program directors at the frontier of technological innovation, with experience in academia or industry (Anadón 2012; Bonvillian 2014). Dr. Stephen Chu (2006) explained that a separate mission-oriented agency would aim to "bring a freshness and excitement to energy research that will attract many of our best and brightest minds" (an example of the *mission* attracting *talent)*. The organization is given the *flexibility* to work outside of regular government hiring and contracting procedures, which enables it to hire quickly (Bonvillian 2014). Program directors serve 3-5

[6] DARPA was created in response to concerns that US scientific capacity was eroding after the Soviet launch of Sputnik in the 1950s

year terms, which creates a sense of urgency and *mission* (Dugan and Kaigham 2013; Sagar and Majumdar 2014). The program directors are given a high level of discretion to both support promising projects and terminate funding (*flexibility*). ARPA-E signs "cooperation agreements" with funding recipients, which differ from standard grants. These agreements ensure that government and funding recipients share responsibility for the project (*embededdness*), and program directors have the ability to request changes to project teams and redirect technical aspects of the project (*autonomy and flexibility)* (ARPA-E 2012).

An "island-bridge" model is used to manage the tension between the benefits of political *autonomy* and the drawback of limited power to use policy tools (Bonvillian 2014). This idea is that ARPA-E has an island where it is free to experiment, but it also has a direct bridge linked to government through the Secretary of Energy. This means ARPA-E is *accountable,* and has access to a high-level political champion that can work the machinery of government and keep energy innovation issues in front of the President. When ARPA-E received its funding the Energy Secretary was Steven Chu who was ready to champion the organization because he was involved in recommending its creation.

The linkages within government provided by the "island-bridge" model allows ARPA-E to coordinate across government to shepherd projects down the innovation pipeline. While ARPA-E helps make technologies in the lab ready for the market, the agency lacks the ability to create initial niche markets (something DARPA had readily available because of the procurement power of the Department of Defense).[7] Even though ARPA-E lacks certain powers, it takes a *comprehensive* view of the innovation environment. In evaluating projects, program directors consider how innovations will link with other competing or complementary technologies; market and regulatory risk; as well as political, cultural, and economic risks (Sagar and Majumdar 2014). The agency is described as working "right-left" across the innovation pipeline, because it decides what type of technological breakthroughs must be achieved in the market, and then pushes the boundaries of basic and applied science to meet these objectives (Bonvillian 2014).

ARPA-E uses its "bridge" to ensure its projects can face the challenges associated with scale-up and market entry. Projects are shepherded towards other Department of Energy programs focused on technological diffusion and ARPA-E has a memorandum of understanding with the Department of Defense to test, validate, and offer initial markets for its technologies (Bonvillian 2014). A team of tech-to-market advisors use their networks and market knowledge to connect technology developers with private sector funders and business partners. There is evidence of a "halo effect" as venture capital and commercial firms more readily fund ARPA-E projects (Bonvillian 2014). This demonstrates the *competence* of the organization to make technology choices and that ARPA-E is undertaking a unique public *mission* by taking on projects outside of the private sector's investment space. These examples

[7] Anadon (2012) also notes that the small budgets and quick timelines limit ARPA-E's ability to offer support for large-scale projects.

also demonstrate the importance of ARPA-E's *policy network* incorporating other government departments and the private sector.

ARPA-E's institutional design supports a mix of *embeddedness* and *autonomy* in relation to technology developers. The program creation strategy runs through five stages: envision, engage, evaluate, establish, and execute. In the envision stage program directors develop their own vision of the energy landscape, which leads to program concepts which are debated through workshops with both internal and external experts. While feedback from the business community and other technology developers is sought at this early stage, it is important to highlight that program directors develop their own visions, which lets them "define success early before others define it for you," (Sagar and Majumdar 2014). This ensures program directors have the requisite *autonomy* to make independent judgments. In the following "engage" stage program directors encourage competition for ideas amongst participants. This funnels information to the program directors, but avoids capture by one group. In the evaluation process constant information flow is encouraged. External reviewers evaluate program proposals, and applicants are invited to provide rebuttals.

Another way *embedded autonomy* is achieved is through ARPA-E's mix of open solicitations for proposals as well as focused challenges in particular technological areas. The focused challenges are based on ARPA-E's own visions of promising technological trajectories, while the open solicitations invite a flow of ideas from the private sector. During the final execution stage program directors have "substantial involvement" in projects - undertaking site visits; providing technical scrutiny; and engaging in support, networking, and stewardship activities (Sagar and Majumdar 2014). This hands-on relationship promotes mutually beneficial information exchange, while signaling to program directors the need to remove support if projects are failing (*embeddedness* leading to *flexibility)*.

Program directors promote a *culture* that encourages fast failure and the idea that "ideas fail, but people don't". If a project fails researchers are encouraged to return with a better idea (Sagar and Majumdar 2014). This convention can incent technology developers to resist advocating for a non-performing technology, and it can promote trust and mutual learning between ARPA-E and program participants – further encouraging *embeddedness*. For this principle to work technology developers must see ARPA-E's promise that they will not be penalized for declaring failure as *credible*. This convention provides an example of how *stable* relations and policy frameworks promote *flexibility* in program design and implementation.

Financial *stability* is a potential challenge for ARPA-E. Funding for the agency is insecure because of the lack of political consensus over climate change in the United States. Anadon (2012) notes that the agency received its initial funding because of the political window of opportunity created by the call for economic stimulus. She warns that funding instability could reduce business engagement. The multiple objectives associated with ARPA-E's mandate (GHG reductions, energy security, and competitiveness)

likely exist to make the agency more politically palatable. On the ground program directors seems to have the *autonomy* to develop more fine-grained visions of technology success. Yet ARPA-E's multiple objectives could trigger political debates over different ideas of success during *evaluation* stages. The National Academies is scheduled to complete an evaluation of ARPA-E by 2017.

Summary Lessons - ARPA-E

ARPA-E plays a unique role in the US energy innovation system. Its position at arms length from government furnishes it with flexibility and discretion, and allows it to foster a different type of culture that attracts talented individuals to engage in short-term projects. The organization demonstrates complementarity between many institutional design elements. The agency is independent from government, yet connected to seats of political power through the island-bridge model. It is embedded, yet autonomous, from technology developers. It seeks to be both flexible in its operations and ability to start and end projects, yet credible with technology developers by instituting conventions such as "ideas fail, people don't". The structure cannot support all energy technology policy goals. For instance, ARPA-E lacks the power to create initial markets, or undertake large-scale and long-term energy initiatives. Its connections with a broader policy network inside and outside of government enable it to provide more comprehensive support, while focusing on its unique role within the innovation system. The lack of political consensus in the United States creates the potential for funding instabilities and debates over its multiple missions.

United Kingdom Carbon Trust

The United Kingdom Carbon Trust was created in 2001 with a *mission* to "accelerate the UK's move to a low-carbon economy" (OECD 2011a). Its creation was closely related to the introduction of the Climate Change Levy that same year. The Advisory Committee on Business and the Environment proposed the creation of a body to help business react to the levy by improving energy efficiency and developing new low-carbon technologies. The Carbon Trust was set up as a not-for-dividend private company, with a Board of Directors comprised of government and stakeholder representatives. An early policy proposal suggested fully recycling climate levy revenues towards business (Lord Marshall 1998). In practice, initial funding came partly from the climate change levy and funds voted by the UK Parliament. In subsequent years funding came from general funds approved by Parliament (OECD 2011a). While the Carbon Trust is private, *accountability* to government is achieved through approval or disapproval of funding and government representation on the Board of Directors. The creation of a semi-private organization was influenced by the general trend towards outsourcing government services in the UK (which reduced energy policy *competencies* within the government) as well as a political bargain that sought to ensure the benefits of carbon fee revenues flowed to business (F. Kern 2011). The Carbon Trust's budgets grew consistently, until a 40% funding cut in 2011 (Carrington 2011). The government announced that the Trust would be cut off from core funding and would have to bid for future work. This transitioned the

organization into more of a private consultancy rather than an arms-length public sector organization. The Carbon Trust cut its workforce from 220 to 150, and reduced some of its program offerings (Moulds 2012). The history of changes at the Trust demonstrates a lack of policy *stability*.

While initially envisioned to focus on alleviating the "valley of death" funding gap (F. Kern 2011),[8] the Carbon Trust developed a large set of initiatives relevant to multiple stages of innovation (*comprehensiveness)*. Before the 2011 restructuring the Trust listed five business areas: Insights, Solutions, Innovations, Enterprises, Investments. "Insights" provided analysis and policy perspectives. "Solutions" aimed to help business reduce emission through actions like energy audits and interest-free loans. "Innovations" undertook applied R&D, business incubator initiatives to offer advice and attract investment to UK companies, and an accelerator programs to help technologies such as offshore wind and marine renewables move towards commercialization by conducting trials, demonstrations, and supply chain initiatives to reduce final costs. The "Enterprises" business area creates new low-carbon businesses. For example, the Trust engaged in joint ventures to deliver wind energy and waste heat recovery and distribution to end customers. The organization also set up separate companies to analyze carbon footprints and create a carbon reduction label for businesses. Through its "Investment" activities the Trust acts as a venture capitalist. The organization can make direct equity investments in UK companies, which has thus far provided it with 15 million pounds (about 30 million Canadian dollars) in investment portfolio financial assets in the 2014 fiscal year (Carbon Trust 2014).

This wide range of activities, coupled with its independent status, provides the Carbon Trust with significant *flexibility* to tailor programs to specific sectors and technologies, and to use various strategies to alleviate innovation barriers. The organization does not have complete power. Kern (2012) notes that its arms length position means it cannot pull certain policy levers. Like ARPA-E, The Carbon Trust cannot create markets through regulation or public procurement, nor can it support large-scale infrastructure investments. However, the Trust's *Insights* activities allowed it to act as an influencer. For instance, the the organization published studies on the impact of the EU Emissions Trading System on competitiveness and on renewable energy policy. The Trust's wide range of activities can also create potential conflicts of interest. To manage potential conflicts, the organization separated its Investment and R&D funding activities (NAO 2007).

The Carbon Trust currently lists its activities under the categories of Advice, Footprinting, and Technology (Carbon Trust 2012; 2014). It has expanded international operations (with offices in China, Mexico, Brazil, South Africa, and the USA) and increased efforts to develop revenues streams from outside of government. Some of its programming has been reduced or cancelled, for instance the Trust can no longer offer government-backed interest free loans for energy efficiency. It has partnered with the private sector to offer loans at commercial rates to be paid back by energy savings. The CEO of the

[8] The "valley of death" describes a funding gap between basic research and market entry, when technologies are demonstrated and tested.

Trust has stated that the changes reduce the amount of early-stage risk the organization is able to absorb through its investments (Moulds 2012).

The Carbon Trust model fully *embeds* an organization within the private sector as an entrepreneurial low-carbon actor. Leadership and personnel were primarily recruited from the business community (Anadón 2012) and close interaction with other companies enables the Trust to gain an understanding of the low-carbon technology sector. The Carbon Trust's *competence* is demonstrated in its role in the publication of "Technology Innovation Needs Assessments" to help the government identify strategic priorities and innovation needs in specific sectors. While embedded within the business community, Kern (2012) argues that the Trust is less connected to civil society and that it does not seek to engage a larger *policy network* of actors in making technology choices.

The risk of such an embedded relationship is that the Carbon Trust might lack *autonomy*. The organization was originally set up to cater to political demands from the business community for an organization that would work in its interest (F. Kern 2011). To offset the potential for business capture, the Trust has a *mission* focused on climate change, and it pays salaries broadly similar to corporate and energy companies to attract *capable* and talented staff (NAO 2007).

The changes since 2011 signaled that the Carbon Trust would move even further from government, which introduces questions of if the organization will be able to deliver on a *mission* associated with using the government's capabilities to complement private sector energy transition activities.[9] Establishing the Carbon Trust as more of a private entity could reduce its *credibility* and the intended benefits of *embeddedness*. The Energy Services and Technology Association noted that some members were unwilling to share commercial information with the Trust since it is viewed as a potential competitor (OECD 2011a, 275; Moulds 2012) – demonstrating how privatization can reduce information flow. The new funding arrangements could also paradoxically reduce *autonomy* from government because The Trust must *sell* its services to the government, rather than having a relationship where it can *speak truth to power* in deliberations over what is in the public interest. The Trust is undertaking less analysis work, previously conducted under its Insights portfolio – demonstrating that it is playing a less prominent role in promoting policy learning and providing independent advice to political leaders.

The Trust made an early decision to track outputs and outcomes of all projects, which helped it build *credibility* and demonstrate public *accountability* (Anadón 2012). The organization's *comprehensive* suite of programs mean it undertakes a number of measurable and less easily measurable activities. It reports on annualized and lifetime cost effectiveness of its energy savings measures, and the amount of dollars leveraged from the private sector. A novel evaluation of the Carbon Trust's activities was

[9] The full privatization of the Carbon Trust also raises questions of whether the principle of embedded autonomy is relevant. It is concept related to state theory and not publically minded private entrepreneurs.

undertaken by Kern's (2012) use of a popular theory in the innovation literature called the "multi-level perspective". This review focused on processes that can lead to transition and demonstrates how the Trust's *comprehensive* outlook and set of activities helped promote innovation from a systems perspective. Kern highlighted the role the Trust plays in areas such as supporting organizational (and not only technological) innovation, building credibility for technology developers to break into markets, and influencing regulations and practices that act as barriers. He notes that the Trust should pay greater attention to how large-scale societal trends such as the financial crisis, liberalization, and individualization can change the nature of energy demand and the organization's place within the policy landscape.

Summary Lessons - UK Carbon Trust

The Carbon Trust provides an example of an organization strongly embedded within the business community, with a clear mission to reduce GHG emissions, and a very comprehensive and flexible institutional design. The loss of core funding has transitioned the organization into more of a private consultancy with a social mission than an arms length public sector organization. Paradoxically this further move away from government could both reduce its autonomy from politics as government becomes a client, and this change threatens to reduce information flow with certain elements of the private sector because the Trust is viewed as a potential competitor.

The Carbon Trust acts as an environmental entrepreneur, which could play a role influencing the low-carbon transition not only within the UK, but globally. The organization has lost some of its capacity to use the power of the government to do things the private sector is unable to do, such as using the government's financing capabilities to offer low-risk loans and to make high-risk, high-reward investments. These changes change the Trust's mission and make it play a different role within low-carbon innovation systems.

Netherlands Energy Transition Project

In 2001 the fourth National Environmental Policy Plan in the Netherlands adopted a "transitions management" approach to the reduction of greenhouse gas emissions. The notion of transitions management was created by Netherlands academics studying how technological and social innovation contribute to structural changes (Rotmans, Kemp, and Asselt 2001; R. Kemp, Loorbach, and Rotmans 2007). The *mission* of transitions management is to bring about a large-scale social as well as technological transformation in society towards sustainability. This is understood in the transitions framework as the need to change or reform an existing socio-technical "regime" incorporating the system of technologies, regulations, infrastructures, political actors, and other structural elements that contribute to environmentally unsustainable lock-in (René Kemp 1994; Rip and Kemp 1998; Geels 2002). The transformative objectives of the Netherlands project differs from more general innovation policy

frames, primarily focused on economic growth regardless of the particular direction of innovation (Alkemade, Hekkert, and Negro 2011). The Netherlands transitions management policy framework is based on finding evolutionary pathways that connect present-day learning with long-term visions. Experimentation and an openness to failure are understood to be required to learn about the feasibility of different low-carbon futures. The framework also recognizes that the ideal sustainable energy pathway is uncertain, and thus policy should promote a diversity of experiments and pathways to keep options open.

Unlike the other cases explored in this report, the government did not create a separate agency to implement transitions management. The Ministry of Economic Affairs acted as the transitions manager, and groups of stakeholders were recruited to help design and implement the policy. The transitions approach was not centrally directed, but co-produced with a wider *policy network*. The Ministry produced a 2050 energy scenarios report to inform the process. Then a variety of "transition path" platforms were developed in consultation with stakeholders in technological areas such as supply chain efficiencies, bio-based raw materials, efficient and green gas, the built environment, and sustainable mobility. Stakeholders developed experiments to test new technological and social innovations which were funded and approved by the Ministry. The public administration of the energy transitions project was later changed to create an Interdepartmental Program Directorate to coordinate activities across six different ministries. An overarching coordinator for the stakeholder/private domain was also created, called the Taskforce Energy Transition. By 2009, 409 transition experiments were conducted (see van der loo and Loorbach 2012).

The involvement of stakeholder groups in the design and implementation of transitions policy creates a high degree of *embeddedness* within society. As noted by Kern (2011), the Netherlands has an "open *culture*" that welcomes informal interactions outside of government. Government departments also had the *autonomy* to suggest the creation of its own platforms and experiments. For instance, the Ministry of Housing, Spatial Planning and Environment was involved in creating a Built Environment platform and the government pushed electric vehicles onto the transitions agenda in light of the financial crisis (van der loo and Loorbach 2012). The policy sought to create constant interaction between the public sector and transition promoters in the private domain. A "frontrunner desk" was created for companies to report barriers created by existing policy and regulatory structures to government. This desk promoted information flow to government to improve policy design and implementation, and it helped innovators navigate government processes. Results between 2004 and 2006 show that 69 companies approached the desk and that 59% of cases led to problem solutions, 12% of cases could not be solved, and in 29% of the cases the issue was still under review (René Kemp 2011).

Kern and Smith (2008) affirm that the *policy network* invited to participate was heavily weighted towards the business community with fewer civil society representatives. They suggest that the process was captured by incumbent energy interests. This made the transition agenda overly weighted towards

technology-push policies rather than social innovations, and made it difficult to complement niche experiments with control policies (such as regulations and carbon taxes) to pressure for change. Kern and Smith's argument suggests that the inclusion of non-incumbents and civil society representatives would have attenuated the influence of incumbent interests, and helped maintain the project's transformative *mission*.

Van der loo and Loorbach (2012) highlight that the "energy transition requires a transition within the government and administration itself" and suggest that part of the strategy was to create interactions with private domain transition actors to place pressure on government departments to change policies. Their statement implies that the government was already strongly influenced by incumbent interests or prevailing policy paradigms, and highlights that the transitions management process sought to incrementally expand the *policy network* and redirect not only the private sector, but also the government itself. Their comments indicate that there was a lack of political *autonomy* and *mission* alignment for transition ideas within the government.

Reviews of the Netherlands projects also note that the transitions framework did not have a long reach within government as it failed to touch many critical areas of climate policy. Renewable energy was initially excluded from the transitions project and a transitions lens was not cast on government decisions in areas such as nuclear energy or carbon capture and storage (Florian Kern and Smith 2008). Even though the transitions project was housed within the powerful Ministry of Economic Affairs and was highly coordinated across government departments - potentially furnishing the project with a *comprehensive* policy reach - transitions thinking did not inform the overall energy policy framework.

The Netherlands case provides valuable lessons regarding evaluation. Transitions theory understands innovation to be a complex evolutionary process, where cause and effect relationships are uncertain. Furthermore, envisioned transition end-points should themselves be re-visited. Some monitoring and evaluation procedures focused on facilitating an understanding of how the transition was unfolding, threats and opportunities in current pathways being followed, and the consideration of relevant changes to experiments, long-term visions, and pathways (Taanman 2012).[10] The technological innovation systems approach was also used, which relies on quantitative and qualitative indicators to track a list of key innovation processes or activities (M. P. Hekkert et al. 2007). This approach uncovered the technological and non-technological barriers confronting the transition experiments. These evaluation methods were able to illuminate issues in a continuous learning process, but they did not provide indicators demonstrating clear results or immediate successes – which could have built political legitimacy.

[10] These methods are often titled reflexive monitoring and developmental evaluation.

In 2011, the energy platforms were abolished and the energy transitions project was reduced in scope by a new government implementing budget cuts and facing concerns regarding international competitiveness (Laes, Gorissen, and Nevens 2014). A new Netherlands innovation policy focused on nine sector-specific "top areas" (including energy and agriculture) where the country has a strong international competitive position (OECD 2014a). Thus a clean innovation agenda based on the need for a transition was enveloped within a more general innovation policy principally focused on economic growth regardless of its clean or dirty trajectory.

Summary Lessons - Netherland Energy Transitions Project[11]

The Netherlands Energy Transitions Project is an example of an ambitious mission promoting innovation for the purpose of inducing a long-term structural change towards sustainability. It introduces the idea of promoting experiments for the purpose of encouraging both technological and social learning and connecting these experiments to potential transition pathways and long-term visions. Evaluation frameworks reflected the focus on process and learning.

The case demonstrates the importance of considering the policy and politics of implementation. The energy transitions project promoted a high degree of embeddedness through co-production of the policy agenda with stakeholders. The leadership role of stakeholders might have left little room for government autonomy. Critics suggest this led to capture by incumbent interests. Yet other transition scholars raise the issue of pre-existing capture – highlighting the need to consider how to promote transitions within government and public administration. Unlike other cases where governments created arms length organizations, the energy transitions project sought to involve many different ministries to diffuse transition ideas within the public sector. This strategy did not provide a high degree of insulation from political pressures and competing policy paradigms within government. Ultimately this institutional configuration did not prove to be stable as political leaders changed agendas.

Sustainable Development Technology Canada (SDTC)

SDTC started operations in 2001. It was created to fill a gap in Canada's innovation system by helping companies cross over the "valley of death" between fundamental and applied research and market entry, when technologies need to be demonstrated and tested in real world conditions. SDTC operates three funds: The Tech Fund which support projects related to climate change, and clean air, water, and soil; the NextGen Biofuels Fund to support large demonstration-scale production facilities for 2nd

[11] The Netherlands case highlights a number of shortcomings. It is worthy to note that the critical examinations found in written materials might be best explained by the high level of academic interest in this case and the high ambitions of the project. The core purpose of this report is to learn lessons from the cases explored. The critical examination of the Netherlands case provides many valuable lessons. Yet it should be stressed that a different analysis is required to compare each case in terms of success of failure.

generation biofuels; and the Natural Gas Fund to support downstream natural gas technology. Each potential project receives multiple stages of evaluation. Internal personnel review statements of interests, followed by reviews by external experts, an Investment Committee, Project Review Committee, and then the Board of Directors. This thorough evaluation process helps build *credibility* for start-ups in the private sector investment community (Lawes 2012). Companies that were rejected from its application process are given feedback and invited to apply again.

While there was pressure for SDTC to remain within government, Parliament created the organization as a foundation - a not-for-profit organization governed by a Board of Directors. This organizational set-up was intended to allow for a non-partisan focus on its *mission* and enable multi-year funding (outside of annual budget cycles) that would provide the *stability* required to leverage private contributions (*stability* encouraging *credibility* with private sector) (see Montambault 2009). SDTC reports to Parliament through the Minister of Natural Resources and its funding agreements are developed with the Natural Resource and Environment Ministries (*accountability)*. It has a Board of Directors with a minority of its members appointed by government. The organization has undergone a number of audits and evaluations by independent consultants, Natural Resources Canada, the Auditor General, and the Commissioner of the Environment and Sustainable Development. A 2011 analysis examined 78 companies in which SDTC invested, and estimated a present discounted value of the projects' benefits to be 26 times the original investment (SDTC 2014, 9). A 2012 article in Research Money reported that industry watchers call SDTC "one of the best run innovation programs" (Lawes 2012).[12] The Jenkins report in 2011 listed SDTC as the 5th largest direct expenditure R&D program in Canada. In a survey of Science and Technology experts by the Council of Canadian Academies (2012), 47% said SDTC provides an advantage for Canada relative to other advanced countries, 36% said it provides neither an advantage or disadvantage, and 16% said it creates a disadvantage.

SDTC's leadership deliberately sought to create a different *culture* from that within government and created a *mission* wider than filling a particular funding gap (Montambault 2009). The original *mission* of SDTC was to "act as the primary catalyst in building a sustainable development technology infrastructure in Canada" (SDTC 2002). SDTC plays an active role in building up *policy networks* and defining the clean technology sector itself. To apply for a project a proponent must develop a consortium of partners with representation across the supply chain, such as researchers, manufacturers, and end customers. SDTC plays a role in finding consortia partners for prospective technology developers. It works to build capacity within the sector by providing coaching, building relationships, and developing business plans, through its "virtual incubator" program.

[12] See Woynillowicz et al (2013) for opinions on SDTC from clean technology developers.

While SDTC was intended to fill a particular funding niche, its programs have evolved to become more *comprehensive* as the clean technology sector's needs have developed. Its more recent initiatives are targeted towards the latter - market entry - stages of the innovation pipeline. The Follow-on Financing Program seeks to connect companies with private capital investors. The Technology Adoption Program seeks to match technologies with customers, and The Export Markets Access Program works with Export Development Canada to link with foreign buyers and investors. SDTC does not have the ability to create niche markets through public procurement or regulations. Thus it works with government departments and the private sector in a *policy network* to promote the success of the projects it supports.

The development of the SDTC Business Cases presents an example of how the organization built up its expertise and achieved a degree of both *embeddedness* and *autonomy*. Business cases were created to understand sector specific barriers and opportunities in areas such as renewable electricity, industrial freight transportation, and clean conventional fuel. Each business case provides assessment of the market; state of technology; potential risks; and sustainability across social, economic, and environmental dimensions. Short and long-term investment priorities are established and technical as well as non-technical political, regulatory, and financial barriers are outlined. These reports were co-produced with industry, government, and civil society representatives. The participation of this wide group of stakeholders was critical for SDTC to develop its knowledge of each sub-sector, however through the process SDTC also developed its own expertise and vision of technological futures. This example demonstrates information flow, mutual learning, and a level of coordination consistent with the principle of *embeddedness*, as well as the development of the organization's own expertise and vision to provide enough *autonomy* for SDTC to make independent judgments. These Business Cases have however not been updated in recent years.

The degree of SDTC's autonomy from both government and business is reduced because of funding uncertainties and funding stipulations. While arms length, the government has prescribed technology specific categories for investment. The Tech Fund was required to allocate 80% of its investments to climate change and 20% to clean air. In 2007, the government created a special fund for near-commercial, larger scale biofuel production facilities. For a number of years, the Tech Fund was depleted while monies in the biofuels fund went unspent as the development of these technologies was slower than expected. The technological prioritization made by government reduced SDTC's *flexibility* to allocate funds towards potentially more promising and dynamic technological areas.

In 2015, SDTC started accepting applications for the Natural Gas Fund focused on downstream technologies, such as combined heat and power, high-efficiency water heaters, and more efficient natural gas plants, with long-term goals associated with renewable natural gas. This fund is a partnership with the Canadian Gas Association, which contributes $15 million (over three years) to the fund, equally matched by SDTC. Individual companies go through the regular application process to access these funds. This is stated to be the first example of Market Innovation Funds initiated by

industry. It remains to be seen if this initiative will achieve the right *embedded autonomy* balance. On one hand this initiative leverages private sector funds, and it partners with an industry association to undertake projects based on environmental criteria. SDTC is able to make an independent assessment of the technology, while working to achieve broad objectives for the industry association. The danger is that these technology specific funds further reduce SDTC's discretion, *autonomy*, and *flexibility* as industry directs the prioritization of technology categories (while there is still discretion to choose specific technologies within a category).

Increasing private sector influence on technology direction could change the *mission* of the organization and reduce its ability to promote transformative and novel technologies, which is a critical role for governments within innovation systems. While using public money to leverage private sector funds has benefit, McDowall and Ekins (2014) warn that too much of it could "incentivize timidity on the part of programme managers". Another danger in supporting efficient fossil fuel technologies is that they compete against other green alternatives.[13]

While SDTC is liberated from the annual funding cycle it is reliant on government for recapitalization. The organization has faced *instability* as its funds were depleted. In 2012 SDTC faced an impending funding shortfall and floated the idea of taking equity stakes in some of the companies it supports (Lawes 2012). This possibility is prohibited by SDTC's legislation. Making equity investments could contribute to SDTC's *autonomy* from government and allow it to have technological successes offset the costs of inevitable technology failures, however it might not be beneficial to companies in earlier stages of development.

Summary Lessons – SDTC

SDTC is one of Canada's few direct technology support initiatives. It has sought to create a different culture from government and received high praise from clean technology entrepreneurs. Its initial rationale was to fill a funding gap - however it has developed a more comprehensive outlook of clean technology sectors. SDTC has extended beyond the "valley of death" stage by linking its projects with individuals and organizations that help progress into the next stages of technology development. The organization has built up expertise in clean technology sub-sectors through close interaction with the business community and other policy experts, while also developing its own vision of clean technology futures. The organization's flexibility is somewhat reduced by prescribed technology choices made by the federal government. The plan to develop new partnerships with business associations could leverage more funds and facilitate effective sector-specific initiatives, yet if these policies reduce the resources available to other clean technology areas this could lead to a further reduction in SDTC's flexibility and autonomy. SDTC is reliant on government for recapitalization when its funds are depleted,

[13] See the "sailing ship" effect whereby new technologies accelerate innovation in incumbent sectors, discussed in Geels (2002).

which creates periodic uncertainty and instabilities which reduce the independence from government sought in its arms length institutional design.

Institutional Principles in Practice - Lessons from the Cases

The four cases presented demonstrate how policy designers and implementers have grappled with the tensions between the institutional principles listed earlier and how these principles can combine to create synergies.

Some of the cases demonstrated that organizations became mission-oriented and took a comprehensive outlook even if they were not originally set up that way. Both SDTC and the Carbon Trust were originally tasked with the objective of helping companies bridge the "valley of death" stage of project financing. These organizations framed their activities around missions such as acting as a "catalyst in building a sustainable development infrastructure in Canada" or accelerating "the UK's move to a low-carbon economy". These are systemic and mobilizing policy missions rather than policy objectives more narrowly based on fixing a particular market failure. Both organizations did not limit themselves to the role of providing funds. They also worked to build up networks and took actions to ensure technologies received the support needed as they progressed along their lifecycles. The success of these organizations is partly explained by their ability to "think big" and to have a certain amount of flexibility to solve the problems they discovered through their work.

A mobilizing mission and the creation of a unique culture was a common attractor for talent across the case studies. Exactly where and how different organizations found high-quality personnel differed across jurisdictions. ARPA-E followed the DARPA temporary project teams model, drawing heavily on domain-specific expertise within the US university system. The UK Carbon Trust principally recruited from the business community, and SDTC recruited a team with a wide spectrum of backgrounds with the right motivation - increasing their knowledge of clean technology sectors over time. The Netherlands transitions project relied on academics and stakeholders for ideas and the implementation of experiments. While finding and building competency within the public sector is a common theme, how to do it might be context specific – dependent on where talent can be found and what role government needs to play to mobilize a region's innovation assets.

It is also important to note that none of the organizations examined played the role of a centralized and all-powerful pilot agency. The arms length status of SDTC, ARPA-E, and the UK Carbon Trust restricted their powers, and the Netherlands Energy Transitions Project worked with an inter-departmental directorate rather than a super-Ministry. These less centralized governance structures help us examine the trade-off an individual agency or department might face between political autonomy and political power. The Netherlands project conceivably provided the greatest access to the levers of power, being

implanted within an influential Ministry with access to other ministries in government. Yet the case revealed that the transitions agenda had little influence on government energy policy and remained a niche project. The project was eventually cancelled as government priorities changed, suggesting a lack of political protection for the sustainability transitions mission.

The arms length cases highlighted areas where organizations lacked certain types of powers, such as the ability to direct public procurement or create initial markets. However, greater political power for the organizations studied could have diminished key institutional design principles. Recall the argument of Breznitz and Ornston (2013) suggesting that political autonomy and political power might not easily co-exist as political autonomy is enhanced when innovation agencies are placed at a somewhat peripheral position within government. Such a position can enable an agency to seek out new policy approaches and develop policy network linkages with different groups of entrepreneurs. Less formal political power might also enhance flexibility, which was demonstrably achieved in various ways by ARPA-E, SDTC, and the Carbon Trust. However, a celebration of experimentally inclined autonomous agencies must not overshadow the critical role of government in deploying and scaling up technologies, especially since the market entry barrier is so important for many clean innovations. It is important to understand how to create complementarities between specialized public sector functions, which introduces the role of coordination and inter-governmental networks in successful policy implementation. This realization suggests it is important to look beyond building up the competencies of a particular arms length organization – it is also important to consider the wider public sector's level of expertise and alignment with clean innovation missions.

A lack of formal power does not prevent an organization from identifying problems within innovation systems and coordinating with the rest of government to promote policy comprehensiveness. ARPA-E provides a useful "island-bridge" model with potential to maximize the benefits of both political autonomy and political power through coordination. The question is where do you build the bridge and what travels over it. The island provides a space for flexibility and risk-taking. The cases demonstrated that creating arms length organizations, or policy niches in the case of the Netherlands, can promote greater administrative flexibility (e.g. ARPA-E's hiring policies) and the openness to failure needed for entrepreneurial ventures. These processes can create new policy models and technological options that flow over the bridge to be used by the rest of government. Assurance of accountability as well as an ability to coordinate should flow from government to the agency. ARPA-E provided the case where there was a clear link to a high-level political champion (the Secretary of Energy), while this link seemed to be missing in the case of SDTC. SDTC has a high level of formal autonomy (structured as a foundation), but it also ran into problems of neglect, demonstrated by periods of potential budget shortfall. This suggests the political leadership was either unsupportive or, more likely as funding was eventually delivered, not attuned to the needs of the organization. It is important to think about who plays the role of high-level political champion in Canada's Westminister system of government with potential for revolving Ministers and volatile departmental policy priorities. Given the urgency of environmental problems and

the cross-cutting nature of innovation policy there is an argument for the policy champion to be the Prime Minister, or perhaps a low-carbon transitions advisor within the Privy Council Office, or an Environment and Economy entity with the Prime Minister as chair.[14]

The cases also caution against directly associating political autonomy with distance from government. Amongst the arms length organizations ARPA-E (an agency) is closest to government in comparison to the UK Carbon Trust (a not-for-dividend private company) and SDTC (a foundation). ARPA-E seems to be able to maintain its independence because of its credibility, attraction of high-quality personnel, its unique culture, and support for the model by its political champion within government. Rodrik (2014) makes the point that DARPA, the defense agency upon which ARPA-E is modeled, has maintained its autonomy for so long because of its level of professionalism, despite its relative lack of formal independence. The Carbon Trust is the most independent from government amongst the cases explored because of its private status, however this can create its own problems by raising suspicions within the private sector about potential competition and requiring an organization to follow the politics of the day to access government funds. The principles outlined in this report highlight the need to foster autonomy from both central government and the private sector. Yet moving too far from government creates a situation where organizations lack the ability to use public sector resources to play a unique role within innovation systems, which is to do things that the private sector won't do.

The insulation of organizations from short-term politics is not only influenced by the organizational arrangement – who pays and how is also critical. ARPA-E's weakness is the lack of political consensus in favour of its mission, which leaves it vulnerable to potential funding shortfalls. SDTC is reliant on government to recapitalize its funds and governments have somewhat reduced the organization's flexibility by restricting funds to certain technological fields. The original conception of the Carbon Trust would have provided it with a dedicated revenue stream from the Carbon Levy, but its funding came from general government revenue, which created instabilities when cutbacks were introduced. As governments introduce fiscal instruments to achieve policy objectives like greenhouse gas reductions there is a rationale for using revenues raised for the same purpose. Dedicated revenue from carbon pricing towards funding clean innovation activities could reinforce many of the institutional design principles mentioned. There is a natural linkage with a clear mission to reduce GHG emissions. Under the right political conditions, carbon pricing revenues can promote organizational autonomy while maintaining accountability for the use of public funds.[15]

All cases demonstrated that it is possible to achieve the seemingly contradictory goal of embedded autonomy to some extent. For instance, both SDTC and ARPA-E develop insight and expertise by working within a larger network of technology developers and experts. Both organizations also created

[14] The author would like to thank Alan Nymark for providing these ideas of potential public administration configurations.

[15] See Beck and Wigle (2014) for a discussion on the possible uses of carbon pricing revenues

space for public servants to develop their own visions of technological futures so they could exercise independent judgments on how to deliver on their public purpose mandate. Embedded autonomy is reinforced by building independence and competence within the public sector.

The cases also unveiled critiques arguing that powerful incumbent interests had too much influence and that autonomy from the private sector was not strong enough. Florian Kern expresses these concerns in his work on both the Netherlands Energy Transitions and the UK Carbon Trust cases. SDTC's use of Market Innovation Funds could reduce the organization's autonomy in making technology choices and supporting paradigm-changing technologies. The academic literature highlights that civil society perspectives could guard against capture by broadening policy networks. Evans (2008) called for more complex forms of embeddedness combined with greater autonomy. This ideal was not achieved in our cases, as the role of civil society actors did not feature prominently. Civil society can play important roles in developing technological niches, dealing with the disruptive consequences of innovations, and helping technologies scale-up (see Smith and Seyfang 2013; Smith 2012). Building inclusive networks that expand the advantages of embedded autonomy is an important policy challenge.

The cases also explored how institutional rules could mix the need for credibility and stability with flexibility. All of the case study examples involved running projects and experiments that could be cut off from support in cases of non-performance or failure. The Netherlands transitions framework most clearly voiced the need to learn lessons from failure about sustainability pathways and visions. While experiments could fail and pathway visions could be changed, the goal of a sustainability transition remained stable. ARPA-E's conception that "ideas fail, people don't" communicates the potential to have stable interpersonal relations with flexibility in the area of project implementation and technology choices.

The cases provided insights on how to evaluate and monitor clean innovation to maintain accountability. Organizations can build political credibility by closely tracking indicators such as GHG reductions and the amount of dollars leveraged from the private sector. A diverse mix of programs could help organizations demonstrate both early successes while engaging in high-risk initiatives with potential to create long-term transformations. However, too narrow a focus on dollars leveraged or even short-term GHG reductions could direct innovation policy away from government playing its unique role in supporting higher-risk, more radical innovations that can lead to transition (McDowall and Ekins 2014). The Netherlands transition project, rooted in a vision of long-term, structural change incorporated evaluation procedures aimed at monitoring the transition process itself and tracking innovation activities. Yet, this project did not ultimately maintain political support and legitimacy. It remains an open question within the innovation literature on how to evaluate processes of long-term transformation. This question deserves further academic research and policymakers should approach this issue with an open mind.

Conclusion

Institutional design is fundamental to innovation policy because there is no prescriptive policy guide to follow and thus public servants have to be nimble and open to learning. Institutional design is also fundamental because public sector organizations need to fit the specific contexts of different systems of government and systems of innovation. The institutional design principles identified in this report are meant to help promote processes of social, technological, and policy learning - which will develop their own styles and patterns in different places and different times.

A major lesson from these case studies is that it is possible to move past potential pitfalls of "government failure". It is also possible to find positive interactions between the seemingly contradictory institutional principles found in the literature. To achieve synergies and avoid pitfalls policymakers need to take the question of institutional design seriously.

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Appendix: Review of Alberta Climate Change and Emissions Management Corporation

This appendix provides a review of Alberta's Climate Change and Emissions Management Corporation based on the institutional design principles outlined in this report.

The Alberta Climate Change and Emissions Management Corporation (CCEMC) was created in 2009. The organization is funded via a grant from the Province's Climate Change and Emissions Management Fund (referred to as the Climate Fund). Large greenhouse gas emitting companies can pay into this fund as a compliance mechanism under the Province's Specified Gas Emitters Regulations. In February 2016, CCEMC's website lists 89 projects receiving a total of $227 million.

CCEMC is a not for profit corporation governed by a Board of Directors. It is operated as a *virtual organization* where CCEMC contracts other government departments, consultants, and experts. In the beginning a group of contractors and service providers reported to the Board of Directors. More recently, CCEMC appointed a CEO and two other senior managers.

CCEMC selects projects through a multi-stage evaluation process, initiated by a call for proposals. These calls are either open ended, or focused on particular areas of technology and market applications (e.g. energy efficiency, carbon capture and storage, small and medium enterprise solutions). CCEMC initiates its project selection process by releasing expressions of interest. It creates an evaluation team by reaching out to external experts or within other government departments. Staff members at Alberta Innovates – Energy and Environmental Solutions (EES), a provincial corporation, often play a prominent role managing evaluation teams. After the evaluation committee reviews the public submissions a short-list of candidates is developed and approved by the Board of Directors. Project proponents who reach this stage are invited to develop a full proposal and CCEMC appoints a Project Advisor (who can be contracted from outside government or Alberta Innovates – EES). Projects undergo a technical and financial review, and a recommendation is made to the Board of Directors for final approval. After the project is approved CCEMC and the project proponent sign a contribution agreement.

CCEMC also launched a "Grand Challenge" which solicits proposals around the world to convert $C0_2$ emissions into carbon-based products. The challenge will disperse $35 million over three stages. In the first stage, CCEMC dispersed twenty-four $500,000 grants. In the second stage CCEMC will award a maximum of five $3 million grants. These projects will be expected to demonstrate a path towards 1 megatonne of net GHG reductions. At the end of two years, one of the five groups will be selected to receive a $10 million grant to fund technology commercialization.

CCEMC's role might soon expand and change. Alberta's government amended the Specified Gas Emitters Regulations to increase the carbon levy that funds CCEMC from $15/tonne of $C0_2$ to $20 in 2016 and $30 in 2017. Large emitters will also be required to pay into the fund at a higher level of stringency (from an emissions intensity level per unit of production of 12% below a baseline towards 15% below that baseline in 2016 and 20% below in 2017). The government's new Climate Leadership plan also calls for a carbon price with broad coverage across sectors, and the creation of a specific emissions standard for the oil sands with a carbon price of $30/tonne above a baseline consistent with low-emitting facilities. These policy changes will increase the province's carbon pricing revenues and creates the potential for a significant increase in CCEMC funding.

In addition, a report by Alberta's Climate Leadership Panel (Leach et al. 2015) recommended changes to CCEMC's design and approach. The Panel expressed concern that CCEMC and other government research entities were "hamstrung between funding already-promising technologies and deploying proven technologies versus taking risks which may lead to larger wins in the long term". They recommended re-focusing CCEMC "towards a portfolio-driven funding approach which invests in riskier ventures".

What follows is a discussion of CCEMC's institutional model and operating procedures based on the institutional design principles and case studies in this report. The institutional design principles from the report that were derived from an academic literature review are as follows:

1) Comprehensiveness
2) Flexibility
3) Autonomy from Short-term Political Pressure
4) Mission-orientation
5) Embeddedness within Policy Networks
6) Autonomy from Private Interests
7) Competence
8) Credibility
9) Stability
10) Accountability

These principles will be used to structure a discussion of the design and operation of CCEMC. Where appropriate, comparisons will be made between CCEMC and other case studies of public sector organizations with a sustainability mission. The other cases studied in this report include the Advanced Research Projects Agency – Energy, the United Kingdom Carbon Trust, the Netherlands Energy Transitions Project, and Sustainable Development Technology Canada.

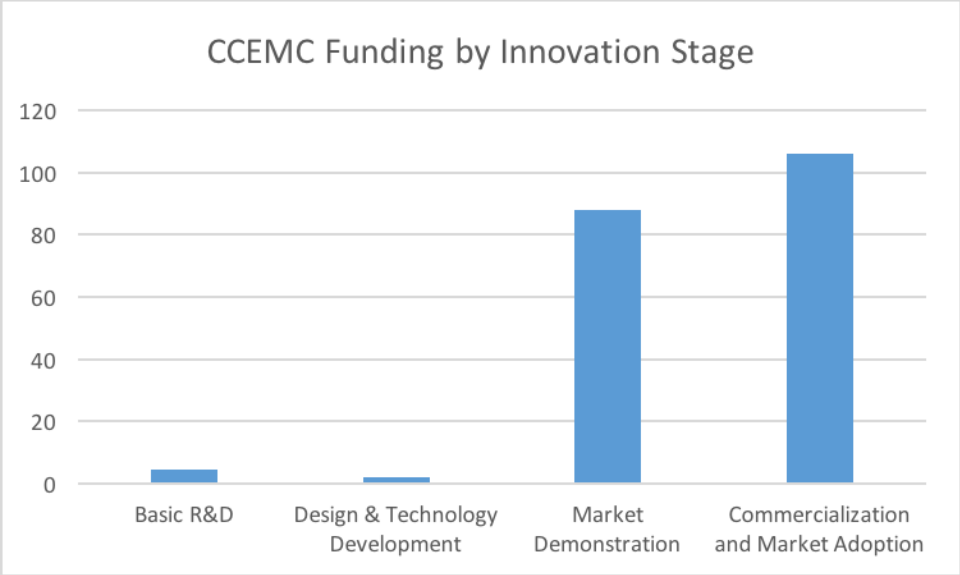
Comprehensiveness

CCEMC has the mandate to take a comprehensive view of Alberta's clean innovation system. It can fund projects across the innovation pipeline (which it lists as basic R&D, design and technology development, market demonstration, and commercialization and market adoption). In practice, a large majority of its project funding is focused on the latter stages of market demonstration and commercialization, while Alberta Innovates – EES supports many projects at earlier stages. CCEMC's websites states that this focus on latter innovation stages aims to "emphasize projects that will provide GHG reductions sooner, rather than later".

CCEMC is principally a funding body.[16] The funding function limits its policy actions and requires it to rely on other organizations to provide comprehensive policy supports. Statement's by CCEMC suggests that the organization recognizes the importance of breaking down barriers to innovation that are financial as well as non-financial in nature. For instance, a submission by CCEMC (2015b) to the Climate Leadership

[16] The organization engages in some other activities such as event hosting and networking.

Panel noted that Alberta's deregulated electricity market "discouraged investment in renewable energy development on the basis it makes for an uneven playing field". This is one example of how funding organizations must consider the influence of existing regulatory structures on the innovations they support. As noted by Weis and Bonvillian (2009) a number of structural barriers confront clean energy technologies at the commercialization and market adoption stages where CCEMC focuses its funding.



(CCEMC 2015a)

CCEMC's funding focus contrasts with other organizations studied in this report that also undertook activities aimed at shaping the larger innovation environment. For example, SDTC operates a virtual incubator program to develop capabilities within the clean technology sector. The organization found it needed to take a hands on approach towards encouraging existing firms to participate in clean energy partnerships. ARPA-E has a team of tech-to-market advisors that connect project developers with potential business partners and they have pulled a number of players together to grapple with barriers created by existing standards and regulations.

It is not possible to understand CCEMC's influence without looking at the broader policy network of public and private organizations. The other mission-oriented agencies and projects studied in this report also interacted closely with other organizations, and frequently handed off projects to other entities of government. As a virtual organization, CCEMC is uniquely dependent on the expertise and actions of the broader policy network in which it operates. Thus, a full review of Alberta's clean innovation system is required to assess the degree to which CCEMC provides comprehensive policy support. Such a review was recommended by the Climate Leadership Panel.

Flexibility

CCEMC's contribution agreements provide funding in installments. The agreement lists milestones and requirements for mid-year and annual performance reporting. When a project receives funding, they are linked with a project advisor representing CCEMC who has a position on the project's steering committee. The advisor monitors project development. They have discretion to terminate the

agreement, avoid paying installments, and work with applicants to change work plans if there are understandable external factors that have resulted in project delays. In cases of a "very major change" involving a complete shift in direction or abandonment of major lines of enquiry the project is re-evaluated by the Board of Directors (CCEMC 2013).

CCEMC contribution agreements can more readily control monetary flows and monitor progress than simple grants. Similarly, ARPA-E signs "cooperative agreements" that closely monitor project milestones. ARPA-E goes farther than CCEMC in requiring "substantial involvement", which allows their program directors to direct and redirect technical aspects of the project as well as administrative aspects.

CCEMC's initiation of projects is dependent on the timing of their proposal calls. This is the principle mechanism for CCEMC to collect information on potential innovations. In contrast, Alberta Innovates – EES dedicated staff resources provide it with the ability to identify technology gaps and opportunities and to seek out projects more proactively. It can accept proposals on an unsolicited basis, which then undergo a thorough evaluation process. Thus, Alberta – EES has more flexibility to initiate promising projects than CCEMC.

Autonomy from Short-term Political Pressure

CCEMC has a high degree of formal political autonomy. It is a non-profit corporation governed by a Board of Directors. Alberta opted for an arms length structure for reasons similar to other organizations in this report. Such a structure allows for a longer-term outlook, greater acceptability of risk, and the use of technical and market expertise to select projects. CCEMC's arms length status removes the Climate Fund from political budget cycles, which provides it with greater stability. Since CCEMC operates as a virtual organization the involvement of other government entities is substantial. The political independence of CCEMC's operations thus depends to a significant extent on the characteristics of the organizations it contracts as well as its Board of Directors.

CCEMC's closest collaborator within government is Alberta Innovates – Energy and Environmental Solutions.[17] Alberta Innovates – EES is a separate Provincial Corporation with 26 full time equivalent staff members. It has historic roots in the Alberta Oil Sands Technology and Research Authority, Alberta Water Research Institute, and Alberta Energy Research Institute. Alberta Innovates acts as the "implementation arms for the government of Alberta ministries of energy and environment". Its priority areas include energy technologies (strong focus on oil upgrading and refining), water and environmental management (oil sands tailing, carbon capture and storage), and its role has recently expanded towards renewable and emerging technologies such as energy storage, wind, and solar.

Mission-Orientation

CCEMC's mission is clearly related to climate change. This mandate flows from the policy decision to use revenues from regulating GHG emissions to promote further emission reductions. CCEMC's current mandate statement is to "participate in funding for initiatives that reduce emissions of greenhouse gases or improve Alberta's ability to adapt to climate change" and its *mission* is to "accelerate the

[17] CCEMC also works closely with Alberta Innovates - Bio Solutions for initiatives in the agricultural sector

achievement of actual and sustainable reductions in greenhouse gas emissions and support climate change adaptation through partnerships and collaboration in the discovery, development and deployment of technology for application in Alberta". The statements above reflect the current emphasis on funding and short-term GHG reductions.

Since CCEMC operates as a virtual organization it has not leveraged its mission to attract permanent or semi-permanent staff motivated by a decarbonisation mission and it is unclear if it is able to develop a unique mission-oriented culture. Its mission seems to have attracted a number of individuals willing to serve on various evaluation committees, both within Alberta and internationally. Alberta Innovates – EES has attracted individuals with an interest and expertise in energy and environment. Its mission however is not strictly related to GHG reductions and climate change. It also focuses on provincial government priorities related to the province's energy sector and its other environmental impacts.

Competence and Embeddedness in Policy Networks

CCEMC is heavily reliant on information and expertise from elsewhere, which means it must have an embedded relationship within provincial, national, and international networks to acquire technological and market expertise. As mentioned, much of this expertise is found with Alberta Innovates – EES and many external experts are asked to serve on CCEMC evaluation committees. CCEMC is perhaps quite unique amongst organization in how it pulls in expertise not only from within Alberta, but outside as well.

ARPA-E similarly pulls much of its expertise from the wider environment. It recruits experts to act as program directors and project developers for short periods of time. However, while program directors at ARPA-E might only be involved for 3-5 years, they represent ARPA-E, while CCEMC contracts individuals representing other governmental or non-governmental organizations.

CCEMC has demonstrated a high degree of openness towards encouraging technological solutions developed outside of its home province. It uses its funding leverage to entice the rest of the world to help solve Alberta's climate problems. This is particularly the case for Alberta's Grand Challenges program, where the initial list of projects includes a number of out or province technology developers.

CCEMC has sought to encourage knowledge flows between its international projects and Alberta organizations. It hosted a conference with applicants to the Grand Challenge, and all CCEMC projects must write a final report that is publicly available. Contribution agreements also include provisions to ensure any intellectual property developed through the projects can be used to benefit Alberta companies (see CCEMC 2013).

CCEMC could take a more active role in developing consortia between international and Alberta-based companies and organizations, similar to the active role SDTC plays in finding consortia partners for its projects. This could not only facilitate knowledge exchange, but also increase the potential for international technologies to be successfully adopted within Alberta.

Autonomy from Private Sector

CCEMC's heavy reliance on outside experts suggests its level of organizational autonomy is low. Without a dedicated management team (until recently) the Board of Directors and its contractors (such as Alberta Innovates – EES) can exercise significant influence. The Chair of CCEMC's Board of Directors is appointed by the Minister of Environment, and other Board members were originally chosen to come from specifically listed "groups or sectors" such as oil sands, electricity generation, pipeline industry, municipalities, environmental non-governmental organizations, as well as government representatives (CCEMC 2009a). The CCEMC's (2009b) Conflict of Interest policy however stipulates that it is not intended that directors serve as representatives of particular associations.

The Netherlands Energy Transition project also placed stakeholders in key leadership positions. This led to criticisms of the process being closed to non-incumbent and civil society viewpoints and the view that the influence of incumbent energy players quelled the exploration of more transformative social and technological options (see Kern and Smith 2008). CCEMC has likewise been criticized for lack of representation of environmental and clean technology sectors (it does not appear that an environmental NGO representative was ever chosen to serve on the Board) (Bramley et al. 2011).

Other organizations in this report governed by a Board of Directors include the UK Carbon Trust and SDTC. Neither organization explicitly creates representation for particular "groups or sectors" on their Board. In SDTC's case a Members Council is comprised of individuals with various public, private and academic backgrounds. However, they are not listed as sector representatives.

CCEMC has not developed a clear vision of the technological futures it seeks to promote, focusing instead of achieving short-term GHG reductions. CCEMC has no equivalent of ARPA-E's "Envision" stage in its program creation strategy, where internal staff analyze and vigorously debate present and future technology landscapes. Similar processes of foresight or visioning, and the development of sector-specific expertise were seen in SDTC's Business Cases, the UK Carbon Trust's "Technology Innovation Needs Assessments", and the Netherland project's development of transition paths. Developing an organization's unique vision of technology trajectories and sector-specific *competencies* helps ensures *autonomy* from the private sector, so a public purpose organization can "define success early before others define it for you" (Sagar and Majumdar 2014).

Like other organizations CCEMC emphasizes its high leverage ratio with the private sector ($6.30 invested by private sector for every $1 of public investment). Alberta Innovates – EES similarly co-funds projects with the private sector. Leverage with the private sector could indicate that public funding is enticing private firms to enter new innovation areas. However, a strong emphasis on co-funding could also reduce the ability of the organization to drive the private sector towards new technology trajectories.

Credibility and Stability

The regulations that delegate CCEMC as the authority capable of dispersing monies from the Climate Fund stipulates that money collected by CCEMC belongs to the Corporation (Government of Alberta 2009). This clause prevents government decision makers from using the Climate Fund for other purposes. A stable funding environment can help build credibility with private sector financial partners.

The level of financial stability afforded by the Climate Change Fund was not seen in the other cases explored in this report. For instance, the UK Carbon Trust was originally intended to use monies from a climate levy, however the government opted to partially fund it out of general revenues and eliminated its core funding during a period of budget cut-backs.

Accountability

The regulations governing CCEMC require the corporation to provide a business plan and annual report to the Minister of Environment and Parks, and the Minister has the ability to carry out an inspection or audit of the corporation. The government is currently represented by an Assistant Deputy Minister in Alberta's Department of Environment.

CCEMC's heavy focus on commercialization can create accountability challenges related to the accuracy of GHG reduction claims. Many of the GHG reduction targets and targeted towards the large final emitting sectors that fall under the province's Specified Gas Emitters Regulations. Financial support for near-commercial technologies from CCEMC might not be necessary if the regulations provide an adequate stimulus to adopt new technologies (see Bramley et al. 2011). To avoid this problem, proponents must validate that their project faces sufficient and appropriate barriers (CCEMC 2010).

CCEMC uses a software program called ProGrid to help track the performance of its projects. The software is novel in its tracking of quantitative indicators as well as intangibles such as business plans and commercialization potential.

ARPA-E's relationship with government not only sought to ensure accountability, but to also enable a high-level political figure to act as a champion for low-carbon transitions. The report's literature review highlighted the importance of political leaders playing this championing role. CCEMC's closest link to a high-level political figure is through its reporting to the Environment Minister, who is also leading the introduction of the province's climate change agenda.

Conclusion

CCEMC follows many of the best practices seen in other jurisdictions. The organization is arms length and mission oriented. It is embedded within a larger network of private and public sector players, and it closely monitors project milestones and has the flexibility to cut off projects that aren't working.

CCEMC also has unique features. The use of revenues from Alberta's climate regulatory system provides CCEMC with funding stability. This stability is an asset for an organization that must build credibility with outside partners and think about the long-term development of technologies. CCEMC's strong engagement with international technology developers is a novel feature that could help facilitate technology and knowledge flows to help the province meet its climate challenges. It also operates as a virtual organization, pulling expertise from other government departments and outside experts. This structure helps avoid duplication and means CCEMC works closely with Alberta Innovates – Energy and Environmental Solutions, which is an organization that possess the technological and market expertise required to evaluate and monitor projects. A Board of Directors with positions reserved to represent stakeholder views is a somewhat unique feature of CCEMC in comparison with other organizations.

CCEMC's virtual organizational structure and stakeholder representative Board of Directors could come at the expense of the autonomy of public servants to develop the unique technology visions and expertise required to fulfil a climate change focused mission. Ensuring the organization has greater autonomy to scrutinize projects and spur development of unique technology trajectories will likely become more important if CCEMC is to receive more funding and focus on longer-term, higher-risk ventures, as recommended by the province's Climate Leadership Panel.

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