Smart Prosperity Institute

DISCUSSION PAPER

CANADA'S NEXT EDGE

WHY CLEAN INNOVATION IS CRITICAL TO CANADA'S ECONOMY AND HOW WE GET IT RIGHT

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About Smart Prosperity Institute

Smart Prosperity Institute is a national research network and policy think tank based at the University of Ottawa. We deliver world-class research and work with public and private partners – all to advance practical policies and market solutions for a stronger, cleaner economy.

About the Institute of the Environment

The Institute of the Environment has a 20 year history of engaging professors from across campus in interdisciplinary research and public outreach. Since 2014, the Institute of the Environment is home to a new graduate program in environmental sustainability, offering a Master's of Science with strong foundations in science, law, economics and policy.

The Institute of the Environment also fosters cross-cutting research and dialogue through collaborative initiatives, attracting visiting scholars and experts, as well as sponsoring conferences and seminars at the University and with partners in the National Capital and across the country.

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Any errors or omissions remain the sole responsibility of the authors.

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Executive Summary

Clean Innovation: A Global Economic Opportunity

The global demand for clean innovation – new technologies, products and practices that improve environmental performance – is rapidly growing. Accelerating the pace of clean innovation in Canada is not only an important tool for meeting climate and environmental goals, it also represents a critical economic opportunity across all sectors of Canada's economy.

The cleantech sector can tap into a fast-growing global market that is expected to be worth as much as $2.5 trillion by 2022. Canada's resource and manufacturing industries can also gain market advantage through clean innovation. For example, McKinsey estimates that improvements in energy and resource efficiency will represent a $3.6 trillion economic opportunity by 2030.

Accelerating clean innovation will also be critical for meeting Canada's climate and environmental commitments. That is why the landmark Pan-Canadian Framework on Clean Growth and Climate Change highlights clean technology innovation as essential in order to lower the costs of emission reductions and achieve Canada's 2030 climate emissions target.

Canada performs comparatively well in the early stages of clean innovation, such as research and development (R&D). But our performance drops off as budding clean technologies move towards commercialization and market deployment – where the majority of jobs and wealth are created. Canada's share of the global cleantech market has fallen from 1.6% to 1.4% since 2008 – a 12% decline.

Canada has started taking steps to improve its performance. In the past few years, the federal and provincial governments, have committed to a series of new policies, programs, and investments aimed at boosting low-carbon innovation. This, along with a promising cadre of early-stage cleantech firms, has helped Canada jump up to #4 on the global Cleantech Innovation Index, which assesses where entrepreneurial cleantech companies are most likely to emerge from over the next 10 years.

The challenge now is to turn these policy and finance commitments into action, while continuing to flesh out other key parts of the clean innovation policy framework. This will require a sustained commitment over a number of years, and close coordination between governments, the private sector, and civil society.

Smart Prosperity Institute's findings for this report have been informed by over three years of work on clean innovation, including a conference, two workshops, in-depth studies, and **over 40 interviews with a broad cross-section of Canadian and international experts in clean innovation** (listed in Appendix 1). It forms the beginning of a broader research program that will explore in more depth the particular challenges and resulting policy implications facing different parts of Canada's clean innovation system.

The Clean Innovation System

Entrepreneurs, researchers, and investors are the main engines of innovation. But government also has an important role to play in correcting market failures, removing barriers, and providing incentives to stimulate *clean* innovation. In fact government has played a key role in the development of almost every major new commercial technology of the past century, from smart phones to the oil sands.

It is widely recognized that government action is needed to address the **knowledge spillover market failure.** Those who create new ideas or inventions are rarely able to capture their full value – the benefits 'spill over' to other researchers, firms or sectors. This results in an under-provision of research and development by the private

sector, which governments seek to correct by funding research in universities, institutes, and public labs. Evidence suggests that this knowledge spillover failure is particularly large for clean innovations.

Clean innovation faces an additional market failure in the form of **environmental externalities**. A healthy environment is of fundamental value to society, but because market prices do not reflect environmental harm, there is little economic reward for most pollution-reducing innovations – and therefore offer little profit incentive to invest in or develop such products. The end result is that too few clean innovations are produced or used and the market fails to deliver the environmental solutions that society needs.

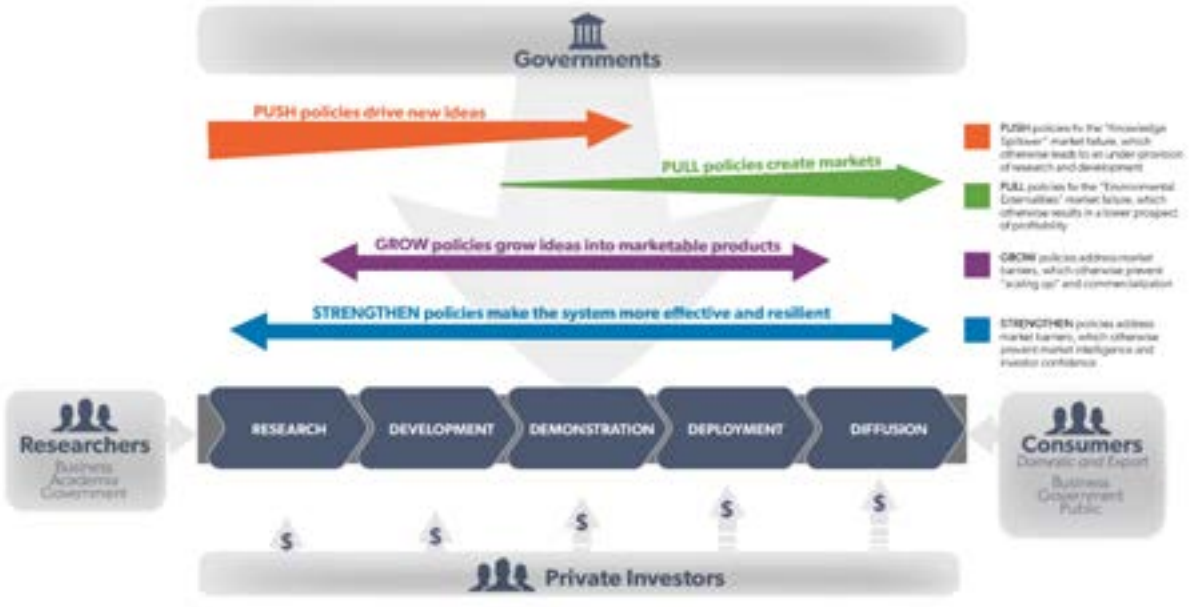
In addition, clean innovations can face a number of other market barriers, such as policy uncertainty, network effects, and incomplete information, among others. [See Section 2.1 for more on market barriers]

Therefore, governments have a particularly important role to play when it comes to clean innovation: not only to ensure Canada meets its climate and environmental goals; but to fix the double market failure and other barriers that impede clean innovation, so that markets can then do their job.

Government involvement must be undertaken wisely, with transitional measures targeted at specific trouble points in the clean innovation system, that have the purpose of reducing market uncertainty and unleashing private initiative and investment to carry new technologies through to market.

Innovation is a complex system, with five main stages: research, development, demonstration, and ultimately commercial deployment and diffusion. (Although the process rarely works in a linear way; each innovation takes its own path.) This report identifies the four types of policies that can be used together in order to accelerate clean innovation across these stages: (1) PUSH policies drive new ideas, (2) PULL policies stimulate markets, (3) GROW policies help ideas develop into marketable products, and (4) STRENGTHEN policies make the system more effective and resilient.

This model shows these four types of policies and how they relate to the main stages of clean innovation as well as the key forces and players involved.



Accelerating the rate of clean innovation in Canada, by its nature, is not an exact science. It is about shaping the future, with all its uncertainties. Like any investment, it involves taking risks in order to succeed. Those risks should

be smart, informed, and calculated. But a big part of innovation involves trying different approaches, seeing which work best, learning from that (fast), and adjusting nimbly. In other words, it means embracing risk-taking and (sometimes) failure – and seeing those as necessary parts of finding success in the dynamic, complex world of innovation. The idea of "failing fast", in which failures are caught early and seen as learning opportunities, applies both to public policy design and technology investment.

PUSH: Policies that Drive New Ideas

Successful clean innovation usually begins with research. Whether that research is initiated by academics, entrepreneurs, businesses, or governments, it can produce early intellectual property that then gets refined through the subsequent stages of innovation before potentially becoming a commercial success. The more research that is happening in the clean innovation system, the more possibility for commercial successes to emerge.

However, the 'knowledge spillover' market failure means the private sector will undertake less innovation research than would be societally optimal. And there is evidence that clean technology research tends have above-average spillovers (with levels comparable to the IT sector). Therefore, government has a particularly important role to play for clean innovation in fixing this market failure and encouraging early stage research and development (R&D).

Doing so requires **PUSH policies.** Generally, these policies seek to do one of two things: incentivize private research, either through direct incentives (e.g. tax credits), funding (e.g. grants) or by helping firms capture the economic returns from that research (e.g. intellectual property rights); or they focus on supplementing private research with public research through government-funded labs and universities.

Canada's public research foundation is strong and well-regarded internationally thanks to a history of solid PUSH support. However, evidence shows that *private* investment in research and development generally has been weak in Canada, and getting worse. More importantly, business R&D for cleantech is not yet translating into marketable outcomes on the scale it should. This is borne out by Canada's global share of clean technology patents, which is on the decline (although still outpacing other sectors). PUSH policies that target clean innovation can help to address this business research gap, and focus Canada's public research muscle more on this critical area. [See Section 3.1 for more on this topic.]

Governments around the world are making strategic investments in developing new clean technologies in an effort to claim a large slice of the growing global cleantech market. And while it is true that the trajectory of these nascent technologies is uncertain, it is also true that the need for cleaner solutions is only going to increase as populations grow, resources become scarcer, and climate change impacts increase. Since research funding is not limitless, there is a need to place strategic bets in areas where Canada could build global advantage. That does not mean governments should simply throw money at clean technology R&D indiscriminately. Indeed, it calls for a thoughtful, strategic, well-informed and—most importantly—credible and transparent process for injecting public funds into specific research areas. Identifying where to place focused efforts is difficult, and will require expert and multi-stakeholder input. [For more on strategically picking priority research areas, see Section 3.2]

Canada also needs to better connect public and private researchers; to build stronger links between universities, government labs and business researchers in order to align efforts on priority research areas for clean innovation. Extending research collaboration internationally is another way Canada can leverage talented researchers and international knowledge spillovers to catalyze opportunities in new markets. [Section 3.2 speaks to connecting research efforts]

Above all, accelerating clean innovation with PUSH policies requires smart, far-sighted, and sustained government actions to enable private initiative to flourish.

PUSH Policy Implications

1. *Target Canada's considerable research capacity on clean innovation*, by making it a sustained priority in public research labs (e.g. NRC), funding (e.g. granting councils, departments), and other programs (e.g. research chairs, Mitacs).

2. *Boost private R&D* on clean innovation, by exploring options such as targeting clean innovation with research tax credits.

3. *Strengthen international research linkages* on clean innovation, through programs such as global visiting chairs, exchanges, and joint research funding, to bolster Canada's role in cutting-edge global research collaborations.

4. *Break down the walls between university, government and private research*, by promoting collaboration and facilitating exchange (via incentives, programs, etc.).

5. Ensure *Canada's clean innovation needs and market opportunities better inform research priorities*, and vice-versa, through mechanisms to strengthen information exchange and alignment across researchers, innovators, investors, and public funders (such as networks, clusters, and coordinating bodies).

6. Create a *'breakthrough' office* that can proactively drive strategic research and uptake on promising clean technologies; it should draw on other successful models, such as ARPA-E (nimble, far-sighted, systems approach, public-private) and build on existing capacity (e.g. IRAP, SDTC, BDC, NR Can).

7. Pursue other *innovative tools to stimulate breakthrough cleantech R&D*, such as prizes, grand challenges, etc.

PULL: Policies that Boost Market Demand

When inventors propose a smarter phone, a more resilient grain, or a better medical device, the prospect that people will pay for it attracts investors. That is normally not the case for inventions that improve environmental outcomes; they are important to society but generally have no little or market value (because environmental costs are an 'externality' – a type of market failure).

The environmental externality market failure has two profound implications for the clean innovation system: first, there is insufficient market demand for most pollution-reducing technologies without government intervention; and second, even where there are policy measures in place, it is difficult for entrepreneurs and investors to predict what government's environmental requirements will be in 5-10 years (the payback period for many clean tech investments) – and this 'policy risk' is greater than for most other types of innovation.

PULL policies have a role in rectifying this market failure. Governments can help "pull" the market in three ways: (1) they can implement environmental policies – pollution pricing, standards, or incentives – that place market value on clean innovation solutions, (2) they can use their power as large-scale buyers to boost demand for cleaner goods and services, and (3) they can build the infrastructure platforms (energy, transportation, water) to support clean innovation. PULL policies not only help stimulate the market for clean innovations, they also signal to entrepreneurs, investors and researchers that there is profit to be gained from clean products and services.

To achieve these important outcomes, environmental policies need to be well designed. The OECD has done extensive research on this topic, identifying five design features that are critical for policies to spur innovation. This report focuses on three: **stringency, flexibility and predictability**.

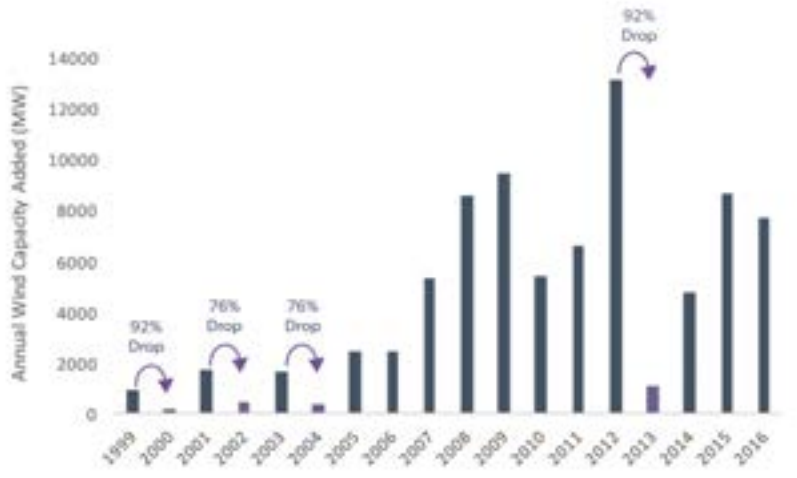
Stringency refers to how strict a policy is, and can be thought of as how much change the policy induces. Stringent environmental standards are more likely to encourage innovation, as firms seek new ways to minimize the cost of meeting significant new requirements. There are many examples of this happening globally and in Canada. In Ontario, for example, stringent drinking water quality laws in the early 2000s (after the Walkerton crisis) drove innovation and helped create water technology innovation expertise in the province – home now to more than 900 water technology companies. For policy makers, a key challenge is to manage the adjustment period for affected industries, and help them to gain market advantage from the stronger environmental performance that comes from meeting stringent targets.* [Flip to Section 4.1 for more on policy stringency]

Environmental policies need also allow businesses and households **flexibility** in meeting their objectives. Flexible policies create an incentive to innovate because firms can select the lowest-cost method of compliance, including by adopting clean innovations. Pollution pricing is the prime example of a flexible policy. It provides a clear financial reward for firms that reduce their impact – the greater the reduction, the greater the reward – while allowing creativity in how to get there. Another flexible policy approach is to use performance-based standards, rather than technology-specific ones, to allow firms to decide how best to meet the target.

Finally, to draw in private capital and investment for clean innovation—as well as motivate inventors and entrepreneurs—environmental policies must also provide **predictability**. Many clean technologies have long timelines before they can expect to make a profit. As a result, potential investors require a view of the market demand for these innovations into the next decade, at least. And since government actions are important drivers of the clean innovation market (at least initially), government has the unique ability to shape and provide a level of certainty for future demand.

For example, increasing predictability has been critical to the success of the wind production tax credit in the United States. The graph below illustrates how new wind energy capacity dropped off in every year that the US government allowed the production tax credit to expire (in 2000, 2002, 2004, and 2013). And when the government locked in the tax credit for 8 years (from 2005-2012, it led to increased investment over that time (except during the global economic slowdown in 2010-11).

The Importance of Predictability in US Wind Energy Policy



Environmental policies that chart out a predictable path for increasing levels of stringency can significantly reduce the "policy risk" that chills investment in clean innovation. Of these three criteria for innovation-boosting policies, predictability is the one that is least understood and practiced, and where potential for improvement is greatest.

* At the same time, it is important that policies to support incumbent firms adjust to new regulation don't unfairly exacerbate market entry barriers to new firms. This can be the case with vintage differentiated regulations (also commonly known as 'grandfathering') that set different standards for existing and new facilities.

While creating predictability is problematic given the relatively short lifespan of governments, there are many ways in which governments can create greater policy "stickiness", such as by setting a "default schedule" for future increases in stringency that will be reviewed at specified intervals with clear criteria. [Flip to Section 4.1 for more on policy predictability]

The most effective innovation-driving policies combine stringency, flexibility and predictability. For example, a carbon pricing policy could lock in the price ramp-up schedule for the first 5 years (as B.C. did) and also set a *default* schedule for years 6-10 (or beyond), with a review process built in after 5 years to allow for recalibration. This review process could include an independent, expert advisory group, and set out pre-defined criteria for the review and recalibration, which would enhance the predictability of the future price trajectory, combined with increasing stringency and flexibility (a rising price).

Designed this way, carbon pricing would come with little short-term shock to the economy yet it would create the expectation of longer-term rising stringency in order to drive investment in clean innovation from the outset. Further, the need for high public financing to boost low-carbon solutions would decline over time as the market takes over and provides both more demand and more investment. In other words, **it is much less expensive for governments to use smart environmental policies (with stringency, flexibility and predictability), rather than ongoing high public spending, to overcome market failures and stimulate clean innovation demand – and much more effective too**.

Stringent environmental standards drive innovation, but they can also increase costs for firms and households, at least in the short-term. (Over time, the innovation and efficiency gains can reduce those costs.) There are a variety of incentive-based tools that governments can use to complement stringent environmental policies – ones that minimize costs, maintain competitiveness, and support the transition to a cleaner economy. These include:

- **Recycling revenues** from environmental pricing, to provide offsetting cuts to other taxes (as BC does), or low carbon incentives to households and firms (as Ontario, Quebec and Alberta do).
- Designing policies to **minimize total cost** – such as carbon pricing systems that apply only to 'marginal' emissions, not all emissions, and thereby reduce firms' total compliance costs (often by 90% or more) while keeping the economic incentive to reduce emissions (as Ontario, Quebec and Alberta do).
- Providing **tax incentives** to promote clean innovation, while helping maintain cost competitiveness as firms transition to cleaner production. For example, *accelerated capital cost allowance* can be used to reduce the cost for firms to adopt low carbon technologies; or an *investor tax credit* could be used to expand investment in growing clean technology companies (as Alberta and B.C. do)

At the same time as designing policies to *promote* clean innovation, it is also important to **avoid designing rules that *impede* clean innovation**. For example, rigid environmental compliance rules can discourage innovative approaches that could offer longer-term environmental benefits; similarly, overly-prescriptive public procurement regimes, that focus just on lowest short-term cost, could impede solutions that might have lower costs (and environmental impact) in the longer run.

Promising options for reducing regulatory barriers include: building a "regulatory sandbox" in which firms and regulators work together to test innovative new products and systems under streamlined regulatory requirements (as the UK has done); or, creating a trouble-shooter office that helps innovators navigate and overcome government barriers to innovation (as the Netherlands has done). [Section 4.2 discusses how to achieve environmental outcomes without deterring clean innovation]

Looking beyond environmental policies, greening **government procurement** can also drive market demand for clean innovations, while also providing a test bed for promising new clean technologies. This is particularly important for innovations where public procurement can help overcome market barriers that prevent uptake by

the private sector – for example, by using economies of scale from a large government purchase to lower the price of the innovation to the public.

Governments are the largest single buyer of goods and services in Canada, and they can use this market power to accelerate clean innovation in two main ways. The first is **leading by example**. Governments can drive down the environmental footprint of their own operations, to help set the pace for Canada's clean economy transition, while simultaneously boosting demand for Canadian clean innovations. For example, as it brings in carbon pricing for the private sector, a government could impose an even stronger internal carbon price on its own emissions; the revenues could be reinvested into a low carbon innovation fund, or used to buy carbon offsets from private providers (as B.C has done).

Second, governments can **boost Canadian clean innovators**, by acting as a test-bed and showcase for Canadian clean technologies, spurring private investment and exports. This could be achieved, for example, by requiring that a percentage of procurement spending be directed towards research, development and demonstration of new Canadian clean technologies that could address government needs, as the U.S. has done through its successful SBIR program (and as the new Innovative Solutions Canada program can do, if targeted at *clean* innovation.) [See Section 4.3 for more on how procurement can stimulate clean innovation]

Lastly, large parts of the economy are public. Major **infrastructure** such as energy, transportation, waste and water systems, for example, are mostly publicly owned and play a vital role in underpinning the overall economy. Not only do infrastructure choices have immediate environmental impacts (through their construction footprint, for instance), but the choices made about these public infrastructure systems – what is built, how it is built – can have a major influence on the direction of Canada's economy, including driving it towards cleaner outcomes and supporting clean innovation.

By building advanced expertise in clean, low carbon infrastructure, Canadian firms can not only help build a cleaner, stronger Canada, but they can also tap into a massive, growing global market that offers tremendous potential for wealth and jobs.

A clean growth infrastructure strategy is therefore essential to ensure that governments are investing in the infrastructure for a 2030 clean economy, not a 2018 one. Such a strategy is needed not just at the federal level, but particularly at provincial and local levels, where 85% of infrastructure spending occurs. The federal government could require such strategies as a condition of federal funding, or provide incentives to encourage them. To complement and support a clean growth strategy, governments could include environmental costs in infrastructure and capital spending through lifecycle carbon costing. [Section 4.4 elaborates on ways to build the infrastructure for a clean economy]

Getting PULL policies right – through ambitious and well-designed pricing, environmental regulation, and government market power – is fundamental to accelerating clean innovation across all sectors. The presence of strong market demand for clean innovation and the expectation that this demand will continue and grow is what creates the incentive for researchers to invent new technologies, entrepreneurs to develop them, and investors to finance them.

PULL Policy Implications

1. Enact *world-class environmental policies* to help stimulate market demand for clean innovation and unleash private initiative. These policies should be:
    - *Stringent* – to drive best-in-class performance across Canada's economy
    - *Flexible* (market- or performance-based) – to promote innovative approaches
    - *Predictable* – to send long-term signals that de-risk clean technology investment

For example, a carbon price, or energy efficiency standard, that ramps up predictably over 10+ years, with a mid-term review based on set criteria.

2. Complement pricing and standards with *targeted environmental incentives*, where needed, to promote clean technology adoption and enhance competitiveness, such as accelerated capital cost allowance for clean technology.

3. Ensure environmental *compliance* rules enable innovative approaches; for example, a 'regulatory sandbox' that allows a flexible trial stage for innovative technologies, to promote learning-by-doing and nimbleness by firms and regulators

4. Review existing policies to identify and *reduce inadvertent impediments to clean innovation;* and create a government office to assist innovators who encounter unnecessary regulatory impediments (e.g. in the Clean Growth Hub), drawing on models like Netherlands' front-runner desk.

5. Lead by example, as Canada's largest purchaser, through *clean procurement policies* that drive environmental innovation, including:
    - Imposing a substantial, rising carbon price on all procurement decisions, and including other environmental costs over time;
    - Setting world-class environmental performance targets for buildings, energy efficiency, vehicle fleets, etc.; and
    - Serving as a *test-bed and showcase for Canadian clean technologies*, through spending targets (e.g. 1-2%), supported by incentives and expertise (e.g. through the Innovative Solutions Canada program).

6. Invest in advanced infrastructure to support Canada's transition to a clean, resilient economy, including by:
    - Developing clean growth strategies to inform the infrastructure needed for a 2030 low carbon economy;
    - Factoring a substantial, life cycle carbon price into all infrastructure decisions (and adding other environmental costs over time); and
    - Build these approaches into federal-provincial infrastructure funding agreements and institutions (like the Infrastructure Bank).

GROW: Policies that Help Ideas Develop into Profitable Products and Companies

Many good ideas that have the potential to ultimately become profitable environmental solutions falter between the research stage and the market diffusion stage for preventable reasons. GROW policies address this gap, by helping entrepreneurs and firms secure the capital and support they need to turn promising inventions into pilot projects and then scale up for market entry.

This can be a long and difficult journey. For manufactured products it typically involves an initial demonstration (or "proof of concept") and then scaling up through a series of larger and larger facilities. Navigating this growth – and financing it at each stage – is particularly challenging for clean innovation. As the Advisory Council on Economic Growth recently stated, "the (cleantech) industry has unique barriers to scale: it is capital intensive and includes systemic adoption constraints." It is not unusual for a clean technology venture to require ten or more years and hundreds of millions of dollars of investment in order to reach commercial viability.

Further, the fact that cleantech is a relatively new sector and faces additional barriers, such as dependence on public infrastructure systems, adds to the uncertainty and risk for investors. **This combination of higher risk**

profiles and longer scale-up timeframes chills private investment in many emerging clean technologies, particularly capital-intensive ones.

It also explains why most clean innovations depend on a mix of public and private funds to reach market. A number of studies have found that targeted public investment—such as grants, loans, and access to growth capital—is a necessary complement to overcome market barriers and enable clean innovations to scale up. However, government's role here should be limited and transitional – aimed at *de-risking* investment in early stage clean innovation, in order to draw in private investors who will then play a larger and larger role in developing the technology and carrying it through to market. These public investment decisions are normally best made through arm's-length bodies (such as SDTC or BDC) that combine private financial expertise with public mission. [Flip to Section 5.1 to see Guiding Principles]

It's not just about money. Other factors can be just as important for helping firms navigate growth, such as help in business development and management, recruiting skilled employees, and securing access to export markets. (These needs are further addressed in the section on STRENGTHEN policies.)

The types of GROW policies needed can differ based on stages of a technology's development, and the kinds of support needed at each stage.

At the early **R&D stages**, GROW policies are needed to build off of PUSH policies. Evidence suggests that Canadian cleantech entrepreneurs create their innovations differently than most other sectors, with 82% of initial intellectual property (IP) coming from company founders and researchers rather than from academia. This suggests a need to improve the incentives for academics to turn research into patents. Finding ways to better connect public research (in universities and government labs) with cleantech companies could also help to convert research to patents, which in turn helps companies to raise more funds. Existing institutions which play this connecting role, such as IRAP or OCE, may need more focus on clean tech. [See Section 5.2 for more on GROW policies targeted at R&D stages]

At the **demonstration stage**, GROW policies are needed to help innovations secure financing and cross the first so-called "valley of death". While venture capital (VC) investors fill a critical niche in financing the growth of new technologies and firms (traditional investors are generally reluctant to invest at this stage), we have a VC gap in Canada, with average investments and round size about half of that in the US (when adjusted for the relative size of economies).

Because of the extra market failures and barriers facing clean technology, government support plays an important role in leveraging VC investment – both in Canada and globally. Government sponsored VC funds are involved in over a quarter of all VC financing deals around the world. In Canada, for example, Budget 2017 announced the new Venture Capital Catalyst Initiative, which provides $400 million to BDC as VC for growth stage companies – with the expectation that it could leverage over $1 billion in private sector participation.

Canada has begun to build solid public institutions to support the development and demonstration of clean technologies, such as in Nova Scotia (Innovacorp), Alberta (ERA), and Ontario (MaRS). The most well-known – and well-regarded – federal program is Sustainable Development Technology Canada. SDTC – which was recapitalized with $400 million in Budget 2017 – provides cleantech companies with project financing for development and pre-commercial demonstration, along with coaching to help them bring their innovations to market. An important (and relatively simple) role for government is to helping cleantech firms navigate all the different funding institutions and programs (as the new Federal Clean Growth Hub aims to do). [Refer to Section 5.3 for more on GROW policies targeted at the Demonstration stage]

At the **commercialization and deployment stages**, GROW policies are needed to help companies scale up and prepare to compete in international markets. Evidence indicates that while more and more Canadian firms are

getting close to the deployment and diffusion stages, this is not yet resulting in growing commercial successes. Many firms appear to be stalled.

One reasons is that many new clean technologies involve **high capital costs ('high-capex')**; they require expensive plants or machinery – often a series of three or more stages of scale ups over 5-10 years, each more expensive, before the technology is considered sufficiently proven to attract institutional investors. Obtaining financing for this time and scale is difficult, particularly for unproven companies. This financing challenge is compounded when the end product is one that faces commodity markets with fixed prices (e.g. energy, chemicals, or fuel). In that case the new technology must compete with larger, incumbent technologies – and all their inherent advantages – without the prospect of price premiums that help to attract investors to other technologies (like smart phones, new drugs, etc.). Fortunately, some of these new clean technologies are becoming increasingly viable as potential 'end game' alternatives to incumbents, as their performance improves and costs come down – like solar power, electric vehicles, bio-chemicals and advanced building materials.

Equity remains critically important for technologies at this scale-up stage, but there is insufficient VC funding in Canada to support very many companies – especially at later stages. As a result, Canadian cleantech companies obtain the bulk of their private financing from foreign sources (the only developed country where this is so). Moreover debt, at least affordable debt, is also hard to come by for clean innovators at this stage, with Canadian cleantech firms facing particularly high costs to obtain financing.

To help fill these gaps, federal Budget 2017 allocated $1.4 billion to BDC and EDC, to support cleantech firms looking to scale-up, commercialize, and export. The challenge for these institutions is to find ways to draw in private finance, and generate returns, without acting like private finance. Public funding institutions have to find ways to accept risk and consider not just the financial bottom line, but also the environmental bottom line, if Canadian cleantech is to be given an edge.

Finally, at the diffusion stage, GROW policies are needed to help firms secure **export markets**, which are critical for cleantech. No matter how important the Canadian market, it is a small fraction of the size of the global market – currently $1.15 trillion. Exports make up over 50% of revenue for the Canadian cleantech sector.

Tapping into a growing international export market is a tremendous opportunity, but it's a challenge. Each country has its own unique policies, programs and procurement rules. Canadian cleantech companies need help to successfully navigate this export challenge – sometimes in the form of financial support, and more often in the form of local connections, country-specific intelligence and support to build networks and partnerships in the markets of highest promise.

Canada has both general export support programs (like CanExport) and a targeted finance institution (EDC) to help meet these needs. The challenge, again, is to prioritize clean tech in these programs, and build specific expertise to support its needs.

Equally important, Canada has an important role to play on the international stage in helping to forged strong climate and other environmental commitments to address these critical challenges and accelerate the shift to a greener global economy. Action on the part of other countries creates global demand for solutions -- which Canada's cleantech companies are keen to meet.

While specific GROW policies are important for each different stage of clean innovation, these policies must be linked together into an integrated approach that helps clean technologies develop from concept through to commercialization.

GROW Policy Implications

1. *Smart public investment is essential to de-risk and unleash private investment* in clean technologies, and overcome market barriers. Recent federal and provincial funding commitments go a long way to filling this gap. In designing and implementing these public investment programs, it is important to ensure that
    - Public funds reach the hardest-to-fund technologies and stages, particularly commercialization and scale up of capital intensive clean technologies.
    - Public funds leverage substantial private funding, particularly from large, patient investors (banks, pension funds, etc.)
    - Public investment bodies weigh both financial and environmental returns in their investment decisions
    - Public investment bodies at all levels should cooperate closely to promote aligned, coordinated investment strategies and priorities, to ensure they are all pulling in the same direction.

2. Smart public investment requires institutions that are *nimble, risk tolerant, expert and apolitical*. Arm's length bodies (such as SDTC or BDC) are normally best-suited for this. Department-based funding programs should also include these traits, as far as possible, and have independent expert advisory groups.

3. Governments should signal a *long-term commitment* to public funding programs, to provide the certainty that private firms need to make 10-15 year investments.

4. A major public investment in clean technology is necessary, but should be *transitional in nature*. Over time, as PULL policies ramp-up and build market demand, private capital will increasingly support clean innovations, lessening the need for public support.

5. Governments should explore new approaches to spur greater private investment in clean technologies, such as:
    - Setting stronger rules for reporting and disclosure of climate-related risks and investments; and
    - Appointing an expert task force to advise on ways to increase climate finance.

6. Grow international markets for Canadian clean technologies by:
    - Prioritizing clean technology in trade missions and export support programs (building on the funding in Budget 2017);
    - Leveraging opportunities for Canadian clean technologies that arise from international agreements (e.g. ITMOs) and commitments (e.g. climate finance); and
    - Supporting the development of ambitious climate and environmental agreements that drive the global demand for clean innovation.

STRENGTHEN: Policies that Make the Whole System More Effective and Resilient

While there is value in identifying the different stages of innovation, and targeting polices for each, ultimately innovation functions is an interconnected overall *system*. STRENGTHEN policies – those that support the system as a whole – magnify the impact of all other policies, making the clean innovation ecosystem more effective and resilient.

The experts interviewed for this report indicated a number of important roles for government to strengthen the overall clean innovation system's health. Their comments fall into seven main themes: (1) translating vision into strategies; (2) public institutions for clean innovation; (3) networks, connections and clusters; (4) investing in skills for clean innovation; (5) bridging the data gap; (6) policy mix; and (7) ensuring accountability and continuity.

First, accelerating clean innovation in Canada must start with a bold and inclusive **vision**, which is then supported by an effective **strategy** – one that draws on the best existing knowledge and expertise. An effective strategy should not only articulate high-level objectives, priorities and actions, it must also dive deep and articulate potential pathways for different sub-sectors, regions, and technology areas. It will be important to identify the different challenges and opportunities that each sub-sector faces across the clean innovation system – from R&D, to demonstration, and ultimately to market diffusion – and how public policy can be tailored to help meet these specific needs and unleash private initiative. The six economic sector strategy tables recently initiated by the federal government (including clean tech and clean resources) could be an important vehicle for developing such clean innovation and growth strategies. And Ontario's new Cleantech Strategy provides a good example of how this can be done. [Flip to Section 6.1 for more on translating vision into strategies]

Second, **public institutions** perform important STRENGTHEN roles throughout the clean innovation process. For example, public institutions conduct and fund research (PUSH); enact flexible regulations to induce innovation and bolster markets, and also act as a first customer through public procurement (PULL); support demonstration, commercialization, market entry, and exports (GROW); and facilitate knowledge exchange, set the vision of change, and develop structures of implementation (STRENGTHEN). And some institutions can provide cross-cutting support across different stages, such as the new Clean Growth Hub. In order for governments to be effective at accelerating clean innovation, these public institutions must be nimble, risk-tolerant, smart, and able to learn and adjust quickly. [Section 6.2 sets out 10 guiding principles for effective design of public institutions for innovation]

Third, strengthening the system through supporting **clusters and networks** is particularly important for clean innovation, because of its large knowledge spillovers and environmental externalities. As Lundvall and Borrás point out, "more and more of the innovation process takes place in networks as opposed to hierarchies and markets… only a small minority of firms and organisations innovate alone… most innovations involve a multitude of organisations."

Evidence and experience indicate that, to be most effective, government should focus on supporting already-emerging or existing clusters. Moreover, cluster- and network-building should combine a mix of approaches, reflecting the differing pathways for clean innovation, including: a traditional 'vertical', sector-based approach; a 'horizontal' approach, that cuts across sectors, environmental pressures, regions and technology platforms; and, a 'systems' approach, focused on meeting systemic challenges facing a particular region (e.g. transportation, food, energy). The five economic 'superclusters' recently chosen and funded by the federal, though not focused on clean innovation, each include it to some extent. [Section 6.3 explores the role of clusters and networking]

Fourth, STRENGTHEN policies are necessary to help develop the **skills** needed to meet the growing demand for clean innovation-related jobs across the Canadian economy. The first step is to identify the needs and skills gaps in the evolving labour market in this area – and there is a real need for more and better data in order to do so. The next step is to focus on closing identified skills gaps, with targeted education, training, and retraining initiatives to develop the skills required by a cleaner, more innovative economy across all sectors. This includes not only technical skills, but also a range of business-related knowledge and skills, in areas such as operations management, finance, international business development, sales, and capital-raising. Where these talents cannot be found sufficiently in Canada, there is a need for better programs to bring in skilled foreign workers.

The last two federal budgets included substantial support for building innovation-related skills through training and education, including for under-represented groups. The challenge now is to turn that funding into outcomes, and build the workforce for a clean innovation economy. [See Section 6.4 for more on skills]

Fifth, STRENGTHEN policies are needed to bridge the **data** gap. Accurate and accessible data is necessary for investors and governments to target clean innovation support where it is needed most and there are significant

shortcomings in the amount, quality, and consistency of the currently-available data on clean innovation. Improved data is needed with regard to industry (employment, revenues, exports), public programs (quantifying their effectiveness), jobs, and firm-level data (to track firms as they progress through the system), as well as financing and public procurement, among others.

The new Clean Technology Data Strategy (created under the Pan Canadian Framework on Clean Growth and Climate Change) is driving progress to improve this situation in Canada. For example, Statistics Canada has recently expanded its Survey of Environmental Goods and Services, broadened its natural resource accounting, and created a new 'satellite account' for environmental and clean technology, all of which positions Canada among the world leaders in environmental, resource, and cleantech accounting (although all countries still have a ways to go). For Canada to continue to build on this progress, and pioneer in the important area, will require coordination across regions, jurisdictions, sectors, and government departments and private actors to build a comprehensive picture of the clean innovation ecosystem. [Go to section 6.5 to learn more about data.]

Sixth, effectively addressing the double market failure and additional barriers that impede clean innovation requires an **aligned suite of policies**. These policies transcend innovation policy; they include environmental policy (as demonstrated in PULL), finance and trade policy (GROW), IP, science and technology policy (PUSH), and even education, labour, and immigration policy (STRENGTHEN). It is important to understand how these policies interact in the clean innovation system.

Evidence shows that the combination of innovation and environmental policy instruments can be more effective in supporting clean innovation than either in isolation. Further, combining policies effectively can help compensate for any negative side-effects of clean innovation policies. For example, PUSH policies can help prevent carbon leakage (from strong climate policies) by fostering R&D of new technologies that help firms to boost productivity and reduce emissions at lower cost. It is also important that polices be *coherent* – i.e. pulling in the same direction. For instance, subsidies for fossil fuel production can run at cross-purposes to climate policies.

It is therefore important to take a systemic view and consider the policy mix at all stages, from design through to monitoring and evaluation. Some suggest that 'policy patching', the gradual implementation and updating of policies, may be more effective than attempting to design a comprehensive policy package all at once. [Section 6.6 delves into the issue of policy mix]

Lastly, STRENGTHEN policies can provide **accountability and continuity**, fostering a long-term commitment to accelerating clean innovation that transcends political cycles. Such predictability about future policy trajectory is critical to encourage private capital to co-invest in clean technologies that make take a decade (or more) to show a profit. One promising approach to build this 'stickiness' is to *establish arms-length, expert advisory bodies* – such as an independent commission or council – to provide ongoing expert advice on development and implementation of clean innovation policies and programs. The UK's Committee on Climate Change is a good example of how such a body can help to guide direction and sustain momentum. [Section 6.7 says more about providing accountability and continuity.]

STRENGTHEN Policy Implications

1. Governments should develop *clean innovation strategies,* informed by expert advisers, in collaboration with key actors (business, research, investor, community).* These strategies should
    - Identify goals, priority areas, and key actions to advance clean innovation, based on Canada' strengths and comparative advantages;
    - Address different sectors, regions and technology areas, considering both short- and long-term opportunities; and

* This could be nested within a larger clean *growth* strategy (or strategies).

- Inform and align all government research, investment, resource allocation and policy-making across the clean innovation system.

Federal sector strategy tables, by prioritizing clean growth, could partly meet this need.

2. To catalyze clean innovation, governments themselves must be more innovative. They must encourage more experimentation, risk-taking, learning and adjusting (fast) from successes and failures. Public institutions supporting clean innovation must be designed to embody these traits (see 'ten institutional design principles' in Section 6.2)

3. Prioritize clean innovation in clusters and networks that combine a mix of the following approaches:
   - A traditional 'vertical' approach focused on a particular sector(s);
   - A 'horizontal', cross-cutting approach focused on building novel solutions and connections across sectors, environmental pressures and technology platforms; and
   - A 'systems' innovation approach, focused on meeting systemic challenges (food, transportation, northern energy) by linking across a range of actors and tools (investment, infrastructure, policy).

   The federal superclusters program offers an important opportunity to grow large-scale strategic clusters, but need to include clean innovation as a priority. It is also important to prioritize clean innovation in *network* support programs (NCE, tri-council, OCE).

4. Support regional incubators and hubs, to build capacity and connections with an emphasis on clean innovation.

5. Identify and close skills gaps for clean innovation by supporting training initiatives, education programs, and re-training or upskilling opportunities in changing sectors, with a particular focus on affected workers and under-represented communities.

6. Improve clean innovation-related data, including as it relates to industry (revenues, exports), public programs (their effectiveness) and jobs, and firm-level data (to track firms as they progress through the system), as well as financing and public procurement. This data should be coordinated across jurisdictions, sectors and departments, and be available to researchers to enable better evidence based policy-making and investment.

7. Ensure that the overall mix of PUSH, PULL, GROW and STRENGTHEN policies are aligned, comprehensive and reaching intended goals. This requires better policy and program coordination, measurement and evaluation across governments. (Institutions like the new Clean Growth Hub can help to meet this need.)

8. Establish an independent clean innovation advisory council or institute, with sufficient staff and resources to provide ongoing expert advice to guide the development and implementation of policies and programs. This is important to provide 'stickiness' and drive continued momentum for clean innovation initiatives.

1.0 DEFINING THE OPPORTUNITY

1.0 DEFINING THE OPPORTUNITY

1.1 Why clean innovation?

The world is facing unprecedented and growing environmental challenges. With global temperatures forecasted to rise beyond the 2°C target,[1] climate change may be the most urgent environmental pressure, but it is not the only one. Water scarcity currently affects more than 40% of the world's population.[2] More than 80% of the world's city-dwellers live with air quality that exceeds healthy limits.[3] Biodiversity levels have reached historic lows and are half what they were 40 years ago.[4] In the World Economic Forum's 2018 Global Risks Report, six of the top ten global risks (in terms of likelihood of occurrence and magnitude of impact) are environmentally-related.[5]

In response, Canada has joined other governments from around the world in committing to address these challenges. The Paris Agreement (2015) marks an unprecedented global commitment by governments to tackle climate change. It joins other pivotal agreements related to biodiversity loss, water security, air quality, and the Sustainable Development Goals, among others.

These global environmental commitments also reflect a new economic outlook. Governments are taking the cue from business, community, and civil society leaders, who increasingly see environmental sustainability as being critical for a healthy economy and livable communities. And meeting environmental obligations will require new technologies, new products, new business practices, and new approaches to generating economic growth that put less strain on the planet. **This is the clean innovation opportunity.**

Box 1: Clean Innovation Defined

Clean innovation includes new technologies, products and business practices that improve environmental performance. Clean innovation can happen in all sectors of the economy, from traditional resource sectors, to manufacturing, to services.

Clean technology - or cleantech - is the sector of the economy focused exclusively on developing next-generation green innovations such as renewable energy, biochemicals, and electric vehicles.

Accelerating clean innovation across all sectors of the economy presents a double opportunity for Canada. It can help meet environmental commitments as well as secure competitive economic advantages that grow the economy and create jobs. Accelerating clean innovation across all sectors of the economy can position Canada to be a leader in an increasingly lucrative global market for resource-efficient, low-pollution, and particularly low-carbon, technologies.

In this report, we first identify clean innovation as a global trend that presents an economic and environmental opportunity – one that could well be Canada's next economic edge. We then begin to evaluate Canada's current performance, the different drivers and stages of the clean innovation system, and the role for targeted government interventions to catalyze clean innovation across all sectors of the economy. After exploring Canadian clean innovation at the system scale, this report then digs deeper into four areas where public policy can be designed to leverage private action: (1) PUSH policies that drive new ideas, (2) PULL policies that stimulate markets, (3) GROW policies that help ideas develop into marketable products, and (4) STRENGTHEN policies that make the system more effective and resilient. While our treatment of each is not exhaustive, it provides an important overview of some of the key policy* levers to consider and raises important questions for future analysis.

Most importantly, this report makes clear the need for governments to strategically intervene to accelerate clean innovation, and provides a framework to understand the many interrelated drivers of a vibrant clean innovation system. This is significant. There has been lots written on individual elements of the clean innovation system and

* Note: In this report, 'policy' is used as a catch-all term to cover government regulations, programs, and investments.

Canada's performance in it – but to effectively choose where to intervene and spend scarce public funds requires an understanding of the system as a whole, including its strengths and weaknesses.

Smart Prosperity Institute's findings are informed by over three years of work on clean innovation, including a conference, two workshops, in-depth studies and **over 40 interviews with a broad cross-section of Canadian and international experts in clean innovation** (listed in Appendix I). It forms the beginning of a broader research program on clean innovation. Future Smart Prosperity Institute work on clean innovation will explore in more depth the particular challenges and resulting policy implications facing different parts of Canada's clean innovation system.

A Global Economic Opportunity

According to some of the world's most respected economic and business authorities, countries and companies that excel at clean innovation and efficient resource use will be rewarded in growing global markets.[6] These predictions are supported by market projections for various economic sectors.

We can begin with the cleantech sector itself, where the global export market is projected to more than double from its $1.15 trillion value in 2015 up to $2.5 trillion by the year 2022. The growth in the clean technology export market represents an opportunity for Canada's cleantech sector, which currently owns 1.4% of the global market.[12] Moreover, demand in this market also cascades through to other sectors, such as mining. Because of the dependence of many clean technologies on rare earth elements, Canada's mining sector stands to benefit from an increase in demand for rare earth elements by as much as 2600% by 2025.[13]

Box 2: The Cleantech Market Boom

US$80 billion: Estimated size of the energy-efficient vehicle market by 2020[7]
US$83 billion: Estimated value of the renewable chemical market by 2018[8]
US$55.4 billion: Estimated global market for water treatment technologies by 2020[9]
US$221 billion: Estimated global investment in energy efficiency in 2015[10]
30%: Estimated growth in the market for smart homes and buildings by 2020[11]

Market projections similarly point to growth in clean innovation opportunities outside the cleantech sector itself. The Business and Sustainable Development Commission estimates that achieving the Sustainable Development Goals can bring an economic prize of at least US$12 trillion across sectors by 2030. [14] McKinsey estimates that resource-based sectors stand to benefit from a $3.6 trillion investment in boosting resource efficiency and innovation worldwide by 2030.[15] For Canada's oil & gas sector for example, this could bolster a market for carbon-capture-and-storage (CCS) technologies, where Canada has world-leading expertise having pioneered three of the world's 17 currently operating large-scale CCS projects.[16] And, for Canada's forestry industry, which has already cut water and air pollution by over 50% from 2005,[17] it could ramp up new opportunities in wood pellet manufacturing for bioenergy, for example.

Meanwhile, an estimated US$90 trillion is also projected to be invested worldwide by 2030 in new infrastructure for urban, energy and resource systems – to lay the foundation for a global clean economy.[18] By showing leadership in building clean infrastructure at home, Canada can give its domestic firms the advanced skills and experience to tap into this massive global economic opportunity.

While the market projections paint an exciting picture, the growing global economic opportunity for clean innovation is more than an abstract prediction. The market trends are already visible.

Consider the electric vehicle (EV) market. A series of innovations in EVs have increased affordability, which has in turn increased widespread adoption. From 2011 to 2015, annual EV sales increased by more than 7.5 times, and

estimates predict they will represent 54% of new car sales by 2040.[19] This rapid growth is driven by process improvements that have seen EV battery costs fall by nearly half over the same period.

Figure 1: Total Electric Vehicle (EV) Sales and Battery Prices[20]

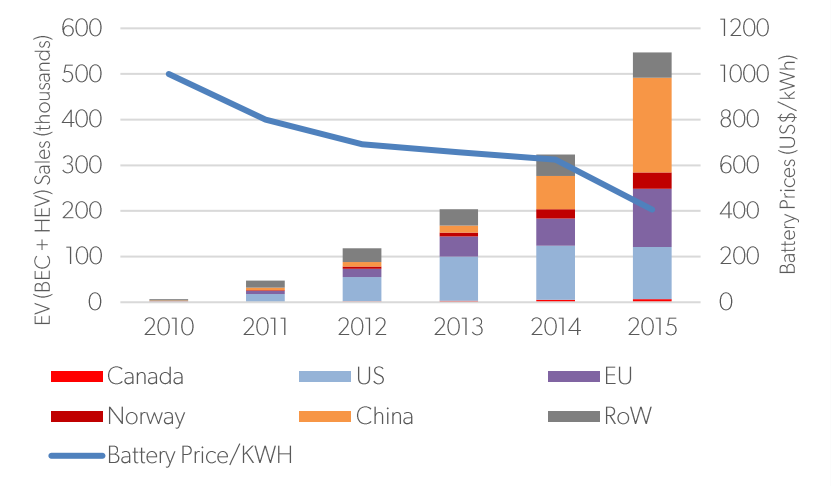
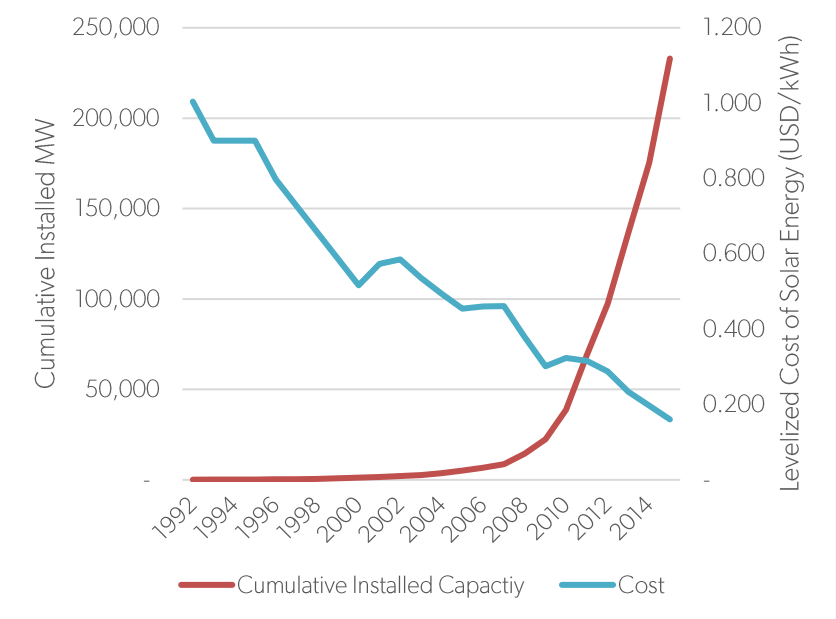


Figure 2. Solar Power Installations and Costs[24]



Data courtesy of the Pembina Institute (2016)

The solar power industry shows a similar trajectory. Globally, solar installations have risen by 58% per year on average since 2010.[21] This growth has been driven by solar innovations (many of which were spurred by government action) that have steadily lowered technology costs—the cost of photovoltaics (PVs) has dropped on average 10% per year since 1980, a trend that experts predict will continue.[22] According to Bloomberg New Energy Finance, solar* is expected to be the lowest-cost electricity generation technology in most countries by 2030.[23]

Electric vehicles and solar power are only two examples of global clean innovation trends. Advances in energy storage technology, methane emissions mitigation, bio-plastics, renewable chemicals, and water treatment technologies, among others, all represent burgeoning markets with large forecasted growth for the years ahead (see Box 2).

The overall pace of clean innovation is accelerating. Patents for innovations in clean technologies—like wind, solar, and carbon capture and storage—are outpacing technology patents in almost all other sectors.[25] Five out of the World Economic Forum's Top 10 emerging technologies are related to addressing climate change and other environmental challenges.[26]

These new frontiers are not isolated to the cleantech sector. The clean innovation opportunity applies across all parts of the economy. It is giving rise to new industries, while at the same time rewarding traditional industries for making existing products more efficiently with lower environmental impact and creating altogether new products.

* Intermittency is a concern with solar, and many forms of renewable energy; however even intermittency is becoming less of a concern as grids become more connected and more energy storage options become available.

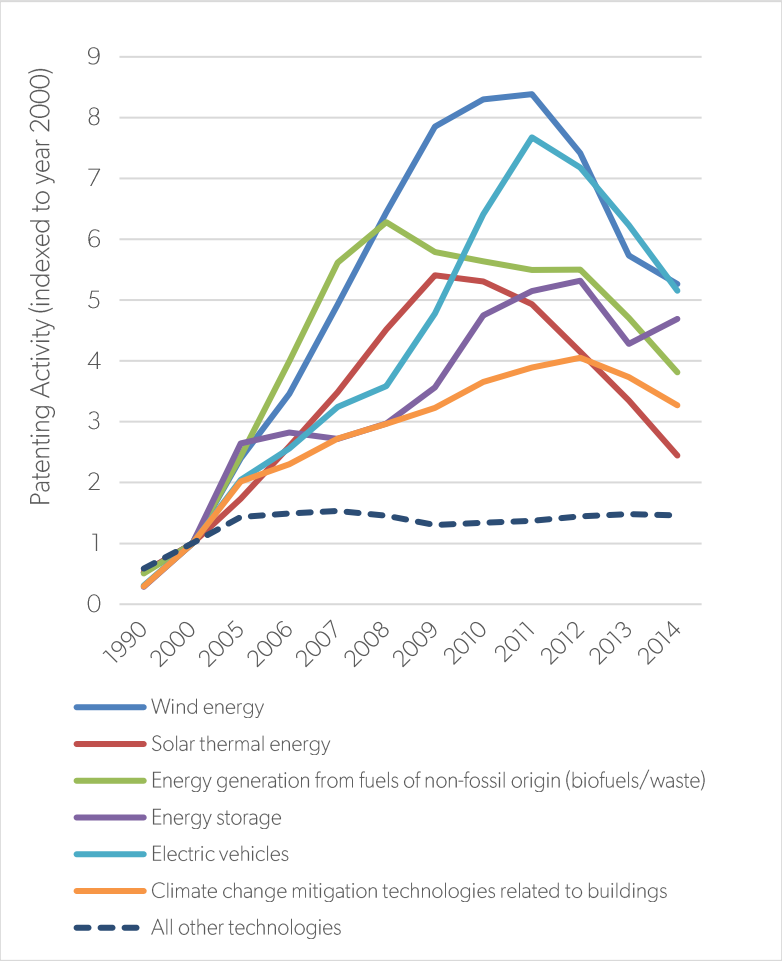
A Canadian Economic Opportunity

The global shift underway presents an economic opportunity that crosses all sectors of Canada's economy – from the burgeoning new cleantech sector to traditional sectors like resource development, forestry, fishing, and manufacturing, which have underpinned Canada's economy for generations. Low-pollution and low-carbon solutions are increasing in every field.* And the firms who can deliver those solutions – whether in the form of a renewable energy source or a significantly decarbonized manufacturing process, for example – will be poised to deliver them to an international market looking for solutions.

In other words, the demand for clean technologies and innovation exists and will only grow as policies are put in place to value the environment. Government and market demand for better environmental performance creates a major economic opportunity for Canadian firms at the forefront of clean innovation in everything from smart grid and energy-efficient buildings to low-carbon cement and carbon capture and storage.

These are opportunities not only to increase the competitiveness of Canadian firms but also to establish a global brand, where "Made in Canada" becomes synonymous with the highest standards of environmental performance in the world.

Figure 3: Clean Technology Patents Outpace Other technologies[27]



Cleantech

When we think about the business opportunities of a global clean economy, it's natural to think first of cleantech – the sector dedicated to the development of green innovations. And for good reason. The global cleantech market is undergoing extraordinary growth.[28]

To understand the business opportunities for Canadian cleantech companies, we need look no further than our own communities. Cleantech success stories already dot Canada – from tidal energy and low-carbon cement in Atlantic Canada, to vertical farming, bio-chemicals, and flywheel energy storage in central Canada, to biochar and carbon capture and storage in the Prairies, to nuclear fusion and water purification in Western Canada, to cold-climate energy solutions in the North.

The numbers reinforce this economic opportunity. Statistics Canada estimates that revenues from environmental and clean technology goods and services exceeded $11 billion in 2015.[29] The Canadian cleantech sector has seen jobs grow at an average annual rate of 10.42% from 2012-

* These solutions are increasingly in demand, particularly where they are low-cost. In a world in which pollution regulations and pollution pricing increase in stringency, this will be even more true.

2015.[30] The sector already accounts for 55,200 jobs.[31]

While the cleantech sector is certainly a major driving force in Canadian clean innovation, and a massive business and investment opportunity for Canada, the opportunity extends into Canada's traditional sectors, which stand to gain significantly from new technologies, processes, and business models that grow profits while shrinking environmental impact.

Clean innovation breakthroughs in the resource and manufacturing sectors in particular are critical to helping Canadian firms compete in a changing marketplace. These include massive opportunities to reduce energy and water use in the oil sands, to increase efficiency and divert waste in auto manufacturing, and to advance next generation bio-products to spur growth in the forestry and agriculture sectors.

"Canada can be an energy and resources powerhouse developing the technologies that not only lead to more successful businesses and higher paying jobs but also to environmental improvements around the world." — Canadian Council of Chief Executives

McKinsey & Company identified a number of comparative advantages for Canada that build directly on our existing strengths and expertise—from sustainable resource development to carbon capture and storage, uranium mining, and hydroelectricity experience.[32]

"Innovation tends to happen around the things you already do well in an economy. It is usually not a bolt of lightning that hits somewhere where nobody's looking. All of the expertise we've built up around resources, energy, auto-making and other regional strengths in our economy, will be the places where we're most likely to innovate." — Prof. Stewart Elgie, University of Ottawa*

Doing the things we already do, and producing the things we already produce, in a better, cleaner, more innovative way offers tremendous economic opportunity and societal value. For example, McKinsey estimates that improvements in resource efficiency—by reducing material waste in production processes, transporting goods more efficiently, boosting energy efficiency in buildings, and improving water efficiency in irrigation systems—could represent a $3.6 trillion global economic opportunity by 2030.[33]

It also offers the vast potential to maintain and improve the quality of our lives – generating the values we want and need from energy to transportation to food – while significantly reducing our environmental footprint.
Diverse sectors are already pioneering and beginning to benefit from these clean innovation advancements. The examples below offer just a sample of what is taking place, and where opportunities for clean innovation lie across our entire economy.

1.1.2.2 Forestry, Fishing and Agriculture

With the world's largest forest trade balance, no nation derives more net benefit from forest products than Canada.[34] Since enacting policies in the early '90s, Canada has been a global leader in sustainable forest management and is now home to the largest area of third-party certified forest in the world.[35] But downturns in the global forestry market have made innovation – particularly clean innovation – a necessity. To build its competitive edge, Canada's forestry industry is aiming to generate $20 billion in economic activity by harnessing clean technology and breaking into new markets.[36] Canada established the world's first nano-crystaline cellulose plant, following research showing how forestry products can be transformed into bio-chemicals with wide applications, from bone-replacements, to bullet-proof vests, to tires, and cosmetics.[37]

* As quoted in Natural Resources Canada (2016) Clean Technology in Canada's Natural Resource Sectors: A Discussion Paper.

"The opportunity for new uses of wood fibre from Canada's abundant renewable forests is limited only by our imagination." — FPAC

Canada is also home to one of the world's most valuable fishing industries. It contributes $2 billion to GDP annually, accounts for more than 70,000 jobs, and represents our second largest food commodity export.[38] A clean innovation revolution is critical if Canada's fisheries are to endure the rapid decline of fish stocks and increasing market demands for sustainable seafood—more than 41% of global fish consumers are now actively seeking sustainably fished products.[39] This revolution has already begun. Two decades after the collapse of east-coast cod, Canada's fisheries are now considered global leaders in sustainability. Sixty-seven per cent of the Canadian catch now comes from Marine Stewardship Council certified fisheries—the most rigorous certification program in the world.[40]

"There is virtually no major buyer in the world now who doesn't have or isn't developing a sustainable seafood sourcing policy." — Jake Vanderheide, President of the Pacific Halibut Management Association

The Canadian agri-foods sector was identified as high growth potential sector by the Advisory Committee on Economic Growth[41] – with primary agriculture alone representing 1.1% of Canada's GDP, and 1.6% of all employment, and agri-food exports increasing at a rapid pace over the past decade.[42] As a sector highly dependent on natural resources (like water) and ecosystems (that provide pollinator services), and with a significant environmental footprint (through land-use and fertilizer and pesticide use), it has a strong imperative for clean innovation. In many cases, the incentive for adopting clean innovation may in fact be cost savings and superior products – such as through precision agriculture that reduces water and fertilizer waste while increasing yields. With existing strength in producing stocks for biofuels, technical expertise in precision farming (which also maximizes carbon sequestration in soils), and new approaches to pest management, the Canadian industry can build upon its existing strength to accelerate its growth in a clean, resource-efficient way.

1.1.2.3 Oil and Gas

Price Waterhouse Cooper's 2016 Oil and Gas trends reports offers this direct challenge to the traditional resource sector: "If you are a business leader in [the oil and gas] industry, your most important task…is to address…a vital existential issue: how to successfully do business as an O&G company in an increasingly carbon-constrained world."[43]

"We must not abandon, but must in fact reinvent our traditional energy industry." — Lorraine Mitchelmore, President and CEO of Enlighten Innovations, former President and Country Chair of Shell Canada

This so-called existential challenge itself presents enormous economic opportunities. McKinsey estimates that innovation in Canada's energy sector could add up to 60,000 new jobs per year by 2020, while contributing up to $9 billion/year in incremental GDP.[44]

Already we see examples of industry leaders embracing this opportunity. Shell Canada, for example, collaborated with both the federal and provincial governments to invest in and launch Quest, the first carbon capture and storage facility in the oil sands. Quest is capable of capturing over 1 million tonnes of CO_2 annually, equivalent to taking 250,000 cars off the road.[45] And—as one of only a handful of these projects worldwide—Quest represents expertise that Canada can share globally.

Decreasing other environmental impacts of the resource sector, for example on freshwater ecosystems, also matters. Canada's Oil Sands Innovation Alliance (COSIA) brings experts in the oil sands industry together with technology experts from other industries—including GE, Lockheed Martin, and IBM—for the sole purpose of accelerating innovations that improve environmental performance. The companies capture, develop, and share the most innovative approaches to addressing tailings, water use, land impact, and greenhouse gas emissions. To

date, the alliance has invested $1.3 billion to develop and share over 900 different technologies.[46] And these innovations have led to concrete results, for example reducing freshwater use in bitumen production by 39%.[47]

Manufacturing

Sustainable manufacturing practices increase production efficiency, lower material and input costs, and also lower the cost of waste removal and transportation costs through lower product weight.[48] In the US "the domestic remanufacturing industry (focused on recycling post-consumer waste) grew by 15% between 2009 and 2011 to at least US$43 billion, supporting 180,000 full-time US jobs" despite the global recession.[49]

Companies like Unilever, GM, and GE are pioneers in this field. Unilever, for example, reduced its waste impact by 29% between 2010 and 2015 through innovative recycling and recovery programs and the development and deployment of new technologies such as MuCell moulding that reduces the plastic component in bottles by up to 15%.[50] GM creates $1 billion in cost savings annually from reusing and recycling materials such as steel, cardboard boxes, and worn-out tires. The company now boasts 104 landfill free sites worldwide, including 84 manufacturing sites that reuse or recycle 97% of their waste and convert the remainder to energy.[51] GE is using world-leading water treatment technologies from Canada, the UK, and Austria to develop an end-to-end wastewater treatment system capable of powering itself with the very materials it seeks to eliminate from the water.[52] Recent innovations such as 3D printing also offer promising opportunities to reduce waste in manufacturing and move toward a 'circular economy' model.

"I have no doubt that this technology is the future of concrete." — Brendan Quinn, President, Bay Ready Mix[53] on Nova Scotia-based CarbonCure

Services

Canada is renowned for its strong banking system, financial institutions, and services sector. While often not seen as key clean innovators, the services sector has a key role in both enabling other sectors and in reducing the impact of its own operations. For instance, TD bank and CoPower have each issued two green bonds – bonds that are just like any other bond with the notable exception that their proceeds are earmarked for green/climate-related projects.[54] So whether it's offering LEED-certified office space for lease, offering sustainable mutual funds and green bonds to investors, providing consulting and advisory services with sustainability in mind, making financing available to companies developing or adopting clean innovation, or disclosing the climate risks in their operations and portfolios in line with the Task-force on Climate-related Financial Disclosures,[55] all service sectors have a role to play in clean innovation.

The insurance industry may have a particularly important role. Just as action on the part of insurers led to crime reduction (via incentives for businesses putting bars on windows and pushing auto manufacturers to integrate new theft prevention technologies), so too may the insurance industry help advance adoption of clean technologies (such as charging appropriate rates for overland flooding insurance, based on updated knowledge of flood risk in a changing climate).*

Clean innovation across all sectors of our economy offer vast economic opportunities. They lower costs. They meet an increasing market demand for environmental solutions that will only surge in value in the years ahead. And they both open and strengthen global market avenues for Canadian firms across every field.

1.2 How Does Canada Measure Up

Canada has all of the ingredients needed to become a leading supplier of clean innovation, rising to meet both our environmental commitments and the global economic opportunity. According to Dominic Barton, Global

* For more on climate change and the insurance industry, see this recent article: https://hbr.org/2017/08/how-the-insurance-industry-can-push-us-to-prepare-for-climate-change

Managing Partner of McKinsey & Company and Chair of Canada's Advisory Council on Economic Growth, "Canada has an unparalleled mix of resources to deal with the implication of these global trends. We are a leader in natural resources and energy production. We have a skilled labour force… We have a strong financial system that helped us survive the financial crisis remarkably well. Canada has never been in a better position to be a global leader."[56]

So how is Canada doing when it comes to the development, deployment and adoption of clean innovation? Available evidence suggests a mixed record, with stronger performance in the earlier stages (such as research) and weaker performance in the later stages (like commercialization).

However, measuring clean innovation is not simple. There is no single established global benchmark; available metrics sometimes present conflicting information; and there are recurring data and analytical gaps. But there are some valuable sources of data available.

Canada's General Innovation Performance

Reviewing Canada's general innovation performance is an important place to start. Current research outlining broader trends suggests that Canada is not meeting its potential. A landmark study from 2011, *Innovation in Canada – A Call to Action*[57] (widely known as the Jenkins report), put forth significant evidence that, while Canada has substantial public research muscle, it has failed to translate this strength into marketable application.* The report pointed to trouble spots such as low business enterprise research and development investment (BERD) and an unnecessarily complex innovation funding system. The report offered a number of recommendations, which to date have been at least partially implemented.[58]

However, Canada's overall innovation performance remains underwhelming, a point underscored in the second report from the Advisory Council on Economic Growth in February 2017.[59] "Canada needs to significantly strengthen its innovative capacity", it wrote, "specifically by providing stronger support for the commercialization of new ideas and facilitating the 'scale-up' required to fully capitalize on them."

In 2015, the Conference Board of Canada compared Canada's general innovation performance with peer countries. It too found Canadian performance lacking, giving Canada a "C" grade, ranking it 9th out of 15 comparators.[60,†] The research finds that while Canada's innovation performance has improved slightly in the past few years thanks to strengthened venture capital (an indicator of entrepreneurial ambition), Canada has seen declines in already low BERD spending, slow growth in patents, and declining public research and development (R&D) expenditure – all important performance indicators for innovation.

Finally, the World Economic Forum similarly ranked Canada "lukewarm" on its Global Competitiveness Index—putting Canada 15th overall (or just above average for an advanced economy) and ranking it significantly lower on specific metrics, including capacity for innovation, company spending on R&D, and government procurement of advanced technology products.[61]

The causes and solutions to Canada's innovation inertia are not all clear.‡ As the Conference Board and others like the Council of Canadian Academies have pointed out, the story seems to be one largely of business being sluggish on innovation and, in particular, poor results when it comes to commercialization. As the Council of

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* The innovation discussion was continued in 2013 with *Paradox Lost: Explaining Canada's Research Strength and Innovation Weakness*, which told a similar story of Canada's failure to capitalize on early research strength.
† Internationally, the World Intellectual Property Organization in conjunction with Cornell and INSEAD have published the Global Innovation Index, this year the index ranks Canada at 15 among 128 countries.
‡ The low share may be due to factors like a large share of economic activity from natural resource sectors, which tend to have lower R&D intensity than other sectors, a significant number of branch plants, and/or many other factors. Similarly, the decline may be due to structural change in the economy and/or other reasons.

Canadian Academies notes: Canadian businesses, on the whole, have been only as "innovative as they have needed to be" and no more.[62]

Canada's Clean Innovation Performance

Clean innovation, being a subset of innovation more generally, appears to share some of the same characteristics as Canada's lackluster general innovation performance, but with some notable exceptions. While clean innovation can be more challenging to measure than general innovation, a combination of broad and specific metrics provide important insight into Canada's clean innovation performance.

Performance of Canada's Cleantech Sector

In the cleantech sector specifically, the most recent Global Cleantech Innovation Index, published by World Wildlife Fund and the Cleantech Group in 2017, examines a series of factors that drive both innovation in general as well as clean innovation in particular. The Index assesses where, relative to GDP, entrepreneurial cleantech companies are most likely to emerge over the next 10 years.[63] Out of 40 countries, Denmark, Finland, Sweden, Canada, and the United States ranked as top performers. Canada moved up to 4th from 7th in the 2014 rankings due to an improvement in evidence of "emerging cleantech innovation", demonstrated by growing public sector support, increasing domestic cleantech investor activity, and the presence of companies on the Global Cleantech 100 list.

However there are gaps in the performance of our cleantech sector. While the Cleantech/WWF study found that Canada is showing increasing potential based on our early strengths, it also found that we are not yet turning this potential into successful companies with marketable solutions. In fact, Canada's share of the global environmental goods and services export market has fallen by 12% since 2008, to a 1.4% market share, according to Analytica Advisors.[64]

This drop in market share comes despite the fact that Canada's cleantech firms had estimated revenues of $13.27 billion in 2015, up 8% from 2014, and do very well at securing exports (over half of their sales), generating employment (55,200 jobs), and investing in research (approximately 11% of revenue).[65]

We are not yet doing well in connecting the stages of our clean innovation system together. Findings from Smart Prosperity Institute's interviews with over 40 clean innovation experts and practitioners reinforce this patchy assessment: Canada does well in the early stages and has high potential for clean technology development, but needs to improve commercialization and deployment of clean innovation – which is where most wealth and jobs are created – if we want our cleantech sector to reach its full potential.

Other Measures of Canada's Clean Innovation Performance

We gain further insights about the performance of both Canada's cleantech sector and clean innovation more broadly by looking at metrics that are confined to specific stages of the clean innovation process. For example in the early stages of clean innovation (research), the generation of publications and patents provide important metrics.

Canada consistently ranks well in generating academic publications, including in earth and environmental sciences.* Canada's academic publications related to clean technology, proportionally, are about 1.5 times higher than those of the US.[66]

* This finding of strength in early research is consistent with the preliminary data analysis of The Expert Panel on the State of Science and Technology and Industrial Research and Development in Canada, which shows that in earth and environmental sciences, Canada outperforms the G7 average (though with a slight recent decline). Source: Council of Canadian Academies (2016) Preliminary Data Update on Canadian Research Performance and International Reputation.

When looking at how publications are converted into patents, however, the reverse is true. Overall, there are 2.3 times as many academic clean technology patents per capita in the US than in Canada.[67] Looking at industrial clean technology patents, Canadian patents are roughly on par with US patents relative to the size of their economies. However, a 2016 report by Cycle Capital and Sustainable Development Technology Canada (SDTC) finds that, in most sectors, the majority of the top patent assignees (i.e. owners) are non-Canadian multinationals. In short, Americans convert clean technology research into patents much better than Canadians do.[68]

When we look at the conversion of patents into technologies, metrics show a similar pattern where Canada's clean innovation performance falls off as innovations move closer to market. While 3.4% of the world's environmentally-related patents were registered in Canada, only 1.6% of the world's clean innovations were actually developed here – suggesting a significant breakdown between Canada's ability to generate new clean innovation ideas and our ability to get them to market.[69,*]

In the middle stages of clean innovation (demonstration and deployment), venture capital investment is a telling metric. The study by Cycle Capital and SDTC finds that, over the period 2010-2016, "relative to the size of the economies, the number of venture capital rounds in Canada is comparable to that in the US (9.8%), however round size is about half (56%) so that the total amount invested is about half as well (5.5%)."[70] The study also found that the Canada-US gap in round size is wider in later stage financing. This is consistent with a paper released by the Centre for International Governance Innovation (2017) that finds that Canadian clean technology firms rated growth capital as their largest and most immediate barrier.[71]

Taken together, these indicators suggest that Canada is falling short when it comes to financing the scale-up and commercialization of clean technology firms.

Evidence also suggests that Canadian businesses lag in the adoption of clean technologies. For example, Statistics Canada (2014) surveyed firms on their adoption of four different kinds of advanced technologies, and found that clean technology adoption was by far the lowest. While a large portion of Canadian firms adopted advanced technologies in the areas of logistics (43.3%), design and fabrication (38.4%), and business intelligence (29.2%), only 9.9% adopted clean technologies (air, energy, water or waste).[72]

While these numbers do not provide cross-national comparisons, there is anecdotal evidence pointing in the same direction. For example, in 2015, electric vehicles represented only 0.59% of new car sales in Canada, which was less than the US where they had 0.91% of market share, and far behind the world leader, Norway, where EVs represented 28% of all new car sales.[73] Similarly, Canada lags behind most peer countries in solar and wind power generation (as a percentage of all power), although some provinces such as Ontario are closing this gap, and others already have significant clean energy resources in hydroelectricity.[74]

So, as the global clean innovation race heats up, how is Canada doing in relation to major competitors? Not well enough. The available evidence – strongly supported by the findings of the interviews undertaken in our clean innovation research – shows that Canada is strong in the early stages (R&D), slows down in the middle (turning ideas into companies and growing those companies), and stumbles towards the finish line (commercialization and deployment). We have the foundational strengths and skills to succeed, but are not making the most of them.

[*] It is worth noting the limitations of patent data – including the fact that patents are a proxy for technological innovation and that the country of registration does not necessarily correlate with where the technology has been developed or will eventually be commercialized.

2.0 SEIZING THE CLEAN INNOVATION OPPORTUNITY

2.0 SEIZING THE CLEAN INNOVATION OPPORTUNITY

The clean innovation opportunity will not wait. As the world rapidly embraces low-carbon and other resource efficient, low-pollution solutions, Canada cannot afford to fall behind. In order to seize this growing global economic opportunity, and meet our climate and environmental commitments, Canada must move swiftly to accelerate clean innovation.

Clean innovation depends on private initiative by researchers, entrepreneurs and businesses. But government also has a vital role to play in overcoming market failures (a point not widely understood) and directing innovation to serve the public good. Accelerating clean innovation in Canada requires identifying the levers available for unleashing and catalyzing private initiative, and optimizing the role of each of these actors.

This section presents a framework for understanding clean innovation that then permits us to identify the opportunities for accelerating it. The framework includes a breakdown of the stages of clean innovation, the roles of specific actors, and where the key market failures and barriers are.

After presenting this framework, this section explores the four areas where public policy has a role to play in unleashing private initiative: 1) PUSH policies that drive new ideas, (2) PULL policies that stimulate markets, (3) GROW policies that help ideas develop into marketable products, and (4) STRENGTHEN policies that make the system more effective and resilient.

Perhaps most importantly, the clean innovation framework equips governments and other stakeholders to understand the many interrelated drivers of a vibrant clean innovation system. This is important – there has been lots written on individual elements of the clean innovation system and Canada's performance in it – but to effectively choose where to intervene and spend scarce government resources requires an understanding of the system as a whole, including its strengths and weaknesses.

2.1 Understanding Clean Innovation

How does clean innovation happen? What drives and guides the search for new ideas and inventions? How do these inventions get developed into commercially viable products? And where is government help most needed to remove barriers and create incentives to foster clean innovation?

Innovation is complex: a product of many different forces. A number of different models help explain the theory of how innovation works. Three of the most commonly-cited ones are described below. These are models for general innovation, which can then be adapted for a clean innovation context.

The Stages or "Pipeline" Model

Dating back to 1945, the linear or "pipeline" model of innovation is the foundation for much of the language and structure we find used in innovation discussions today.[75] It conceives of the process of innovation as a pipeline – with new ideas and technologies fed into one end and commercially marketable innovations coming out the other end. It identifies sequential stages for innovation: (1) research and development (R&D), (2) demonstration, (3) deployment, and ultimately (4) diffusion to the market. While there are variations of the Pipeline Model that use different labels for each phase, or break these phases down differently, they all share the same basic principle – innovation as a mainly linear, sequential process.

The Systems Model

The Systems Model differs from the linear model in that it emphasizes the interactions between various actors in the economic system – for example the relationships between firms, universities and polytechnics, research labs, and technology users. This perspective emphasizes the role of interactive learning across the stages described by the linear model.[76] Users and producers interact and co-develop innovations, taking lessons from demonstrations or market entry and feeding them back towards defining problems for basic research and applied science. The systems model acknowledges that information flows in different directions and that technologies can develop through different pathways that are not necessarily linear.

The Evolutionary Economic Geography Model*

This model builds on both the Stages and the Systems models, but focuses on regional interactions as determinants for technological pathways. Economies tend to evolve differently in different regions, due to particular strengths (such as resources, skills, access to markets, etc.) or historical factors, and this has implications for potential innovation pathways. This theory adds a spatial and contextual perspective, grounding innovation in real places in real time, which can be critical to policymakers concerned with issues of regional prosperity and competitiveness.

While these models accentuate different aspects of innovation, they are compatible. It is possible to see them as three layers, each layer adding depth and complexity to the one beneath it. The Stages model sets out the basic stages. The Systems model adds the complexity of the real-world interactions that takes place between these stages and players. And the Evolutionary Economic Geography model adds the further dimension of space and context, showing how various stages differ by region, by sector, or by technology.†

To show how *clean* innovation happens, we begin with a model (see Figure 4) that is similar to the Stages Model, showing the main stages or components of innovation.

Figure 4: The Stages of Clean Innovation

Central to the model is the notion that innovation involves two major forces: a push force, whereby new ideas and inventions are generated through R&D (public and private), and a pull force, whereby societies and markets determine which of those inventions have value, generating market demand for the products and processes. In between the push and pull stages, there is a middle stage where the promising inventions secure investment, initial commercialization and (often) grow into viable businesses. We call this stage (which is often not identified in models) 'grow'.‡

Most innovations go through these stages, though not always in this same sequence and sometimes with differing emphasis on different stages. For example, a technology like nuclear fusion requires a bigger than usual push on basic research; others, such as bio-based chemicals, need a major investment to support demonstration and

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* See, for instance: Arthur, W. B. (1989) Competing Technologies, Increasing Returns, and Lock-In by Historical Events, *The Economic Journal*, 99(394):116–31.

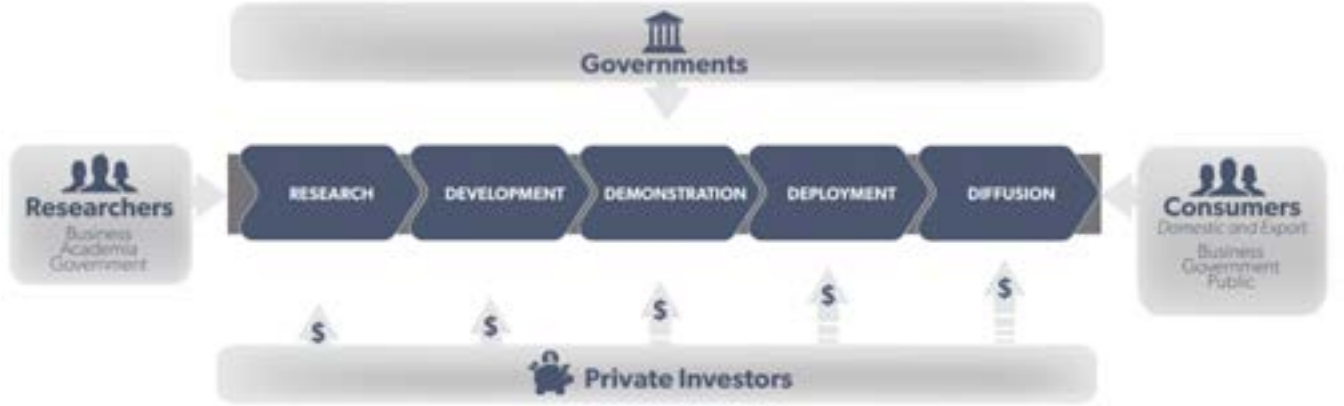
† For a more in-depth discussion of innovation models, see Haley, Elgie, and McCarney, G. (2016) Accelerating Clean Innovation in Canada's Energy and Natural Resource Sectors – The Role of Public Policy and Institutions, *Smart Prosperity Institute*.

‡ Models usually merge this stage into push or pull. But it involves different actors, processes, challenges, and tools. So it is best to treat it as a separate stage.

growth; while others, such as advanced thermostats or car sharing systems, face a more critical challenge in deployment and diffusion.
Figure 5 adds the main actors. Researchers are involved mainly in the early stages. Consumers – both Canadian and foreign – enter at the final stages. Firms and entrepreneurs are active throughout, from private research to technology development to ultimate commercialization and deployment.

Traditionally, government has been seen as playing a larger role in the earlier stages, particularly by funding R & D (to correct "knowledge spillovers", explained below). Then, as technologies are developed and move closer to market, private investors take over and play a larger role at later stages. This is one important way in which *clean* innovation is different. Because it faces additional barriers such as "environmental externalities", governments must play a more active role in the "grow" and "pull" stages. This will be discussed further below.

Figure 5: The Clean Innovation System and its Primary Actors



While the arrows point in one direction (for simplicity's sake), in reality the information flows can be multi-directional and there are interactions and feedback loops among all these players and stages.

Similarly, while not shown in this figure, the complete system fits within a real-world context that can vary by region and jurisdiction as well as for different types of technologies. Functions like knowledge creation and diffusion, entrepreneurial experimentation, infrastructure support, and resource mobilization are critical considerations within this model, as is the importance of having accurate clean innovation data at all stages and for all sectors, along with vibrant knowledge clusters, incubators and exchanges.

Market Failures and Market Barriers for Clean Innovation

Understanding the particularities of the clean innovation system, including where it is working well and where it is falling short, is critically important in order to direct government interventions at the right places and to design them to effectively support private initiative. Using the above diagrams, it is possible to identify where there are market failures and other barriers that impede the development, deployment and adoption of clean innovation. Some of these market failures and barriers apply to innovation in general, while others are unique to clean innovation in particular.

Knowledge Spillover Market Failure

Looking at the earliest stages of research and development, clean innovation is not unlike other forms of innovation. In these early stages, when researchers discover something new, their findings and the new knowledge they create are generally available to anyone. This means at least part of their findings 'spill over' to benefit other researchers, firms or sectors, meaning that innovators are not always able to capture the full value of their discoveries. This knowledge spillover market failure is well documented and leads to an under-provision of

research and development.[77,78] As a result, innovation—which stands to benefit everyone—occurs at lower than optimal levels. This is true for all kinds of innovation, although there is evidence that clean innovation suffers from even greater spillovers.[79]

There is widespread agreement that governments have a role to address this market failure through push policies, which are those that stimulate and support the generation of new ideas, for instance through post-secondary research funding, investment in government labs, and incentives for private research. (More on this in Section 3)

Environmental Externality Market Failure

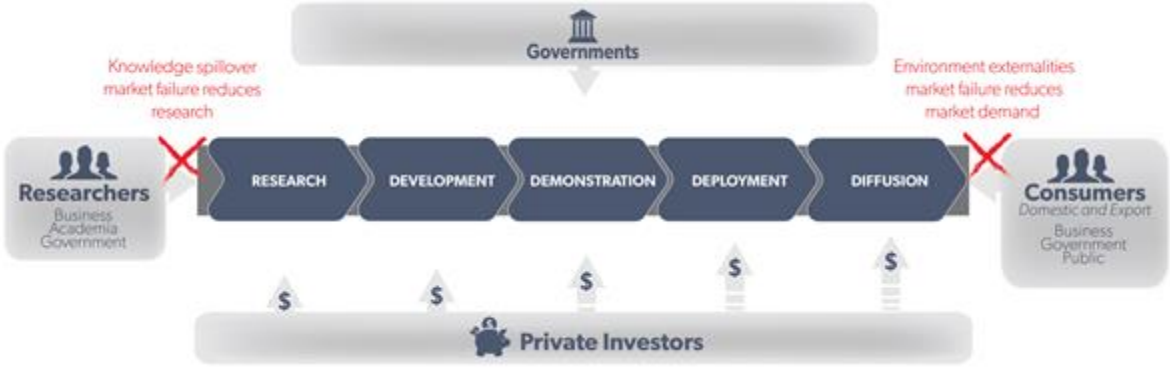
Once past the R&D stage, new ideas and inventions typically depend on market demand and the prospect of profit to pull them through to commercialization. New medicines, faster growing wheat, smarter smart phones – these inventions succeed because customers are willing to pay more for them, or because they lower production costs. This clear prospect of profit is what attracts investors and businesses to finance their commercialization and deployment, getting the inventions through the final stages of the innovation system.

The difference for clean innovation is that the benefits produced – cleaner air and water, lower greenhouse gas emissions, or less waste – are ones that normally have little or no market value, because markets do not put a price on most environmental costs and benefits. In other words, there is little market demand, resulting in little profit incentive to invest in or develop such products. The end result is that too few clean innovations are produced or used, and the market fails to deliver the environmental solutions that society needs. This is the environmental externality market failure, and it is a distinct and fundamental challenge faced by most types of clean innovation.*

To correct this market failure, there is a vital role for governments to introduce pull policies, which help stimulate market demand for clean innovation – for example tax credits for technology adoption, pollution pricing, environmental codes or standards, or targeted procurement policies.

Together, the knowledge spillover failure and environmental externality failure are referred to as a 'double market failure'†, making clean innovation distinct from innovation more generally. Only governments can fix these market failures. This creates the public policy challenge: to address both the knowledge spillover and the environmental externality market failures concurrently, so that markets for clean innovation can work effectively.

Figure 6: The Clean Innovation System and its Market Failures and Barriers



* Some clean innovations *do* create benefits that have a market reward. For example, energy saving devices reduce energy costs. But even those cost savings still do not reflect all of the product's benefits, such as reducing air pollution or greenhouse gases, which are normally unpriced.

† While the double market-failure is a well-recognized concept, some have argued that there are other market failures present as well – such as that of technological lock-in. For more on this, see Van den Bergh (2013)

1.1.1.3 Market Barriers

In addition to the double market failure that impedes clean innovation, there are a number of additional market barriers* that create risk and uncertainty and discourage private investment. Some of the key market barriers facing clean innovation are summarized below.

Barrier	Where it Occurs	Description
Incomplete information and technology risk[80]	Can impact any stage, but is most substantial at the Demonstration to Diffusion stages	Because clean technology is a rapidly emerging area, many of the actors involved don't have a lot of experience. For example, where technologies remain new and unproven, investors see additional risk. Many lenders (especially traditional ones) are unfamiliar with the profile of the clean technology sector and have a poor understanding of the potential markets and future returns from investments, even for clean technologies that have been proven. End users may also be hesitant to adopt new technologies, particularly as first users.
Policy uncertainty[81]	All stages	Unlike other technologies, much of the demand for clean technologies is driven by government policies (pollution pricing, regulations, public procurement). The Paris Climate Accord, for example, is likely to spawn a raft of domestic policies that will create growing global demand for low-carbon technologies. However, it is very hard for investors to predict the pace and scale of these future policy changes (unlike other types of market risks), which tends to chill investment in these technologies.
Capital intensity[82]	Demonstration and Deployment stages	Many clean technologies require costly plants and equipment, as well as longer time frames for testing and scaling up before they can get to market and realize a return on investment – making the cost of capital more of a driver of overall cost. This combination of high capital needs and longer return periods can make financing a bigger challenge than in other sectors, such as information technology.
Network effects and infrastructure risk[83]	All stages	Some innovations increase in quality and value (such as FaceBook) or decrease in cost (such as electric cars) the more they are adopted. This is commonly known as a network effect or learning-by-doing, in which large scale deployments are required in order to diffuse the technology and lower costs. For many clean technologies, successful deployment depends on changes to existing infrastructure platforms (for example transmission lines, rail networks, vehicle fuel station networks). Financing innovations is inherently risky because the path to growth and profitability depends on large-scale investment in new forms of infrastructure – which investors cannot predict. Further, once infrastructure investments are made, it can pose as a barrier to future innovation in the form of technological lock-in.
Lack of policy congruency[84]	A lack of policy congruency can impact the entire system	Clean innovation is dependent on many policies – including those that target different technologies, stages of readiness, economic sectors, and/or types of companies. Further, different policy regimes – from trade policy and IP frameworks to skill and immigration policies to financial regulations – all impact clean technology companies. If these oppose one another or are not well aligned, they can create a barrier for clean innovation. The same is true for non-alignment between governments, either within a country (federal, provincial, municipal) or across countries (international regimes).
Behavioural gaps[85]	Deployment and Diffusion stages	In clean technology adoption, incentives between the technology adopter and end user may misalign. Principle-agent problems and split incentives – in which one person can make choices on behalf of another (such as when building owners may be responsible for the choice of home heating technology, but the tenant is responsible for paying bills) can slow widespread adoption of investments that have positive returns and that would have otherwise occurred. Even when adoption makes economic sense, behavioural lock-in, uncertainty in outcomes, (over) discounting of the future and other behavioural gaps can occur. This is particularly relevant for technologies like energy efficiency and water conservation, where solutions are often cost-effective with short payback periods and yet have not penetrated the market as would be expected.
Imperfect competition[86]	Particularly Diffusion	Imperfect competition is known to exist in key sectors – such as the electricity sector – and can lead to disadvantages against new entrants. This can be exacerbated when there is an uneven playing field due to the presence of subsides for conventional technologies (which ties in to technological lock-in noted under infrastructure risk). Additionally, some regulations include 'grandfather' clauses that favour incumbents and hamper new market entrants.

* Market failures, like the knowledge spillover and environmental externality noted earlier, lead to an allocation of goods and services that is not efficient. Here we use market barrier to refer to additional impediments that stand in the way of the market working well.

2.2 A Role for Well-designed Public Policy

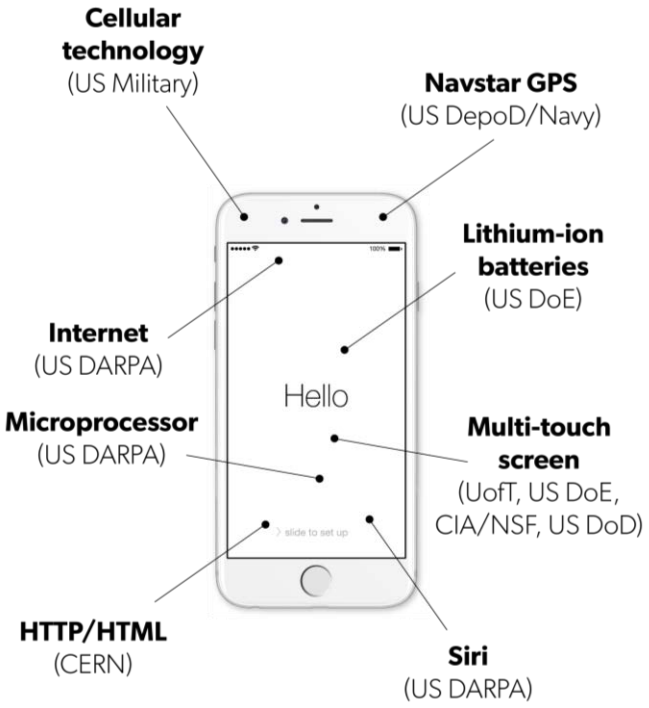
If Canada wants to tap into the double economic-environmental opportunity of clean innovation, then we need to make significant strides in the next 5-10 years. While private initiative and investment will need to be the primary driver for this, a critical catalyst for this transition is smart policy and smart investment at every level of government.

This type of bold action by government is justified by the scale of the opportunity, the urgency for action, and most importantly the presence of specific market failures and barriers.

To be clear, bold government action does not mean sole government action. Policies must be designed to encourage and crowd in private sector action and investment. Public investments should seek to leverage private investment, while public policies should spur the private sector ambition and remove barriers that impede private investment in clean innovation.

The role for government must also be targeted strategically at those areas where Canada has a comparative advantage, where the potential exists to be among the global leaders, or where environmental performance improvements are critical to competitiveness.

Figure 7: The Long History of Government Investment in Technology Innovation [87]



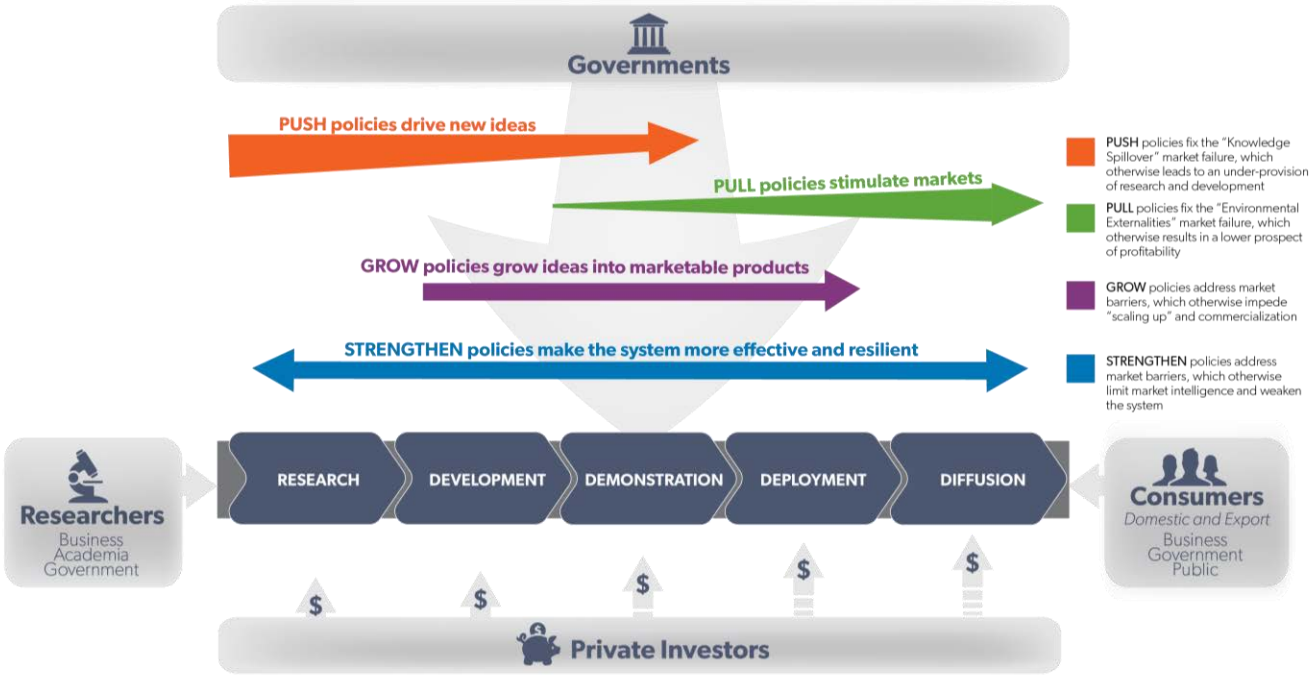
While a government's role in accelerating clean innovation is particularly important, it is not unusual. In fact, most of the major commercial innovations of the past century have involved significant government support[88] – including the smart phone,[89] civil aviation,[90] and the technologies that unlocked Canada's oil sands.[91]

An Ecosystem of Policies: PUSH, PULL, GROW, STRENGTHEN

Government's options for targeting policy to accelerate clean innovation are presented in the Clean Innovation Model displayed in Figure 8.

The Model groups potential public policy interventions into four categories: PUSH (policies that drive new ideas), PULL (policies that help create market demand), GROW (policies that grow ideas into marketable products), and STRENGTHEN (policies that cut across the clean innovation system, making it more effective and resilient). The model then maps these policy categories against the stages of clean innovation, providing a high-level illustration of how the government's role can be tailored to the different needs at different stages of the clean innovation system.

Figure 8: The Clean Innovation Model



Starting on the left-hand side of the model, this is where the knowledge spillover market failure occurs and where the role for government is well understood. As Popp has stated, "long-term benefits, spillovers, and uncertain R&D returns all suggest a role for public R&D support, either through direct financing or targeted policy incentives."[92]

A variety of **PUSH policies** can be used to address this market failure. Generally, these programs seek to do one of two things. Some seek to incentivize private research initiatives, either through direct incentives (e.g. tax credits) or by helping firms capture the economic returns from that research (e.g. through intellectual property rights), while others focus on supplementing private research with public research through funding for government labs and universities.[93] While these types of PUSH policies focus on the early stages of innovation, they generate ideas that carry through to later stages.

The far right-hand side of Figures 8 is where **PULL policies** have a role in rectifying the second market failure – the environmental externality, which is a particular problem for *clean* innovation. It is widely accepted that market prices do not reflect the full costs of pollution and environmental harm. What is less well understood is that this market failure results in too little investment in clean innovation. Because firms and households do not pay the real costs of pollution, there is little market reward for developing innovations to reduce pollution. Government action is necessary to fix this failure, so markets can work as they should.

PULL policies can have an impact on all stages of innovation development, but are particularly important at the later stages: deployment and diffusion. Moreover, there is mounting evidence that PUSH and PULL policies work best in combination.[94]

PUSH and PULL policies are essential, but not sufficient. The interviews undertaken for this research project underscored this point -- without exception, every interviewee mentioned other important types of government intervention needed to build a vibrant clean innovation ecosystem. These other policies can be thought of in two groups: GROW and STRENGTHEN.

GROW policies are the bridge between PUSH and PULL. They are important to help promising inventions move from the R&D stage to the point where they are ready for market entry. This can be a long and difficult journey, for example manufactured products can require an initial demonstration stage (or "proof of concept") before scaling up through a series of larger and larger facilities.

Navigating these stages – and financing them – can be a challenge for any kind of innovation, but particularly for *clean* innovation. As the Advisory Council on Economic Growth recently stated, "the [cleantech] industry has unique barriers to scale: it is capital intensive and includes systemic adoption constraints."[95] It is not unusual for a clean technology venture (in biochemicals, energy storage, water treatment, etc.) to require ten or more years and hundreds of millions of dollars of investment in order to reach commercial viability.[96]

Further, the fact that cleantech is a relatively new sector, and faces the additional barriers discussed above (such as dependence on public infrastructure systems), adds to the uncertainty and risk for investors. This combination of higher risk profiles and longer scale-up timeframes chills private investment in many emerging clean technologies, particularly capital-intensive ones.

It also explains why most clean innovations worldwide depend on a mix of public and private funds to reach market.[97] A number of studies have found that targeted public investment – such as grants, loans, and access to growth capital – is a necessary complement to overcome market barriers and enable clean innovations to scale up.[98] However, government's role here should be limited and transitional – aimed at 'de-risking' investment in early stages of clean innovation, in order to draw in private investors who will then play a larger and larger role in developing the technology and carrying it though to market.

Similarly, **STRENGTHEN policies** – those that support the system as a whole – magnify the impact of all other policies. Those interviewed for this research indicated a number of important roles for government to strengthen the overall clean innovation system's health. Their comments fall into seven main themes: translating vision into strategies; public institutions for clean innovation; networks, connections and clusters; investing in skills for clean innovation; bridging the data gap; policy mix; and ensuring accountability and continuity.

For instance, in the Pan-Canadian Framework on Clean Growth and Climate Change, federal and provincial governments noted that "there is inadequate data on Canada's clean technology capacity and potential" and better information would "inform future government decision making, to improve knowledge in the private sector and stakeholder community, and to foster innovation."[99]

Similarly, Harvard competitiveness guru Michael Porter has argued that clusters – geographic concentrations of interconnected companies and institutions in a particular field[100] – increase companies' productivity and drive innovation, which has been shown to hold true in real world analysis.[101]

Each of these four categories of policy intervention and the innovation stages and barriers they address will be discussed in more detail in subsequent chapters.

Setting the Vision, Approaching Risk Differently

Beyond the specific policy levers that influence the clean innovation system, government also needs to follow two important policy guidelines if it is to play an effective role in accelerating clean innovation in Canada. Those have to do with vision and risk.

Vision

Making Canada a clean innovation powerhouse is vitally important, but it won't be easy. It will require focused, sustained, coordinated effort across a broad range of public and private actors. And this effort must be guided by bold leadership and vision.

Box 3: Inclusive Clean Innovation

A 2017 report by the Institute for Competitiveness and Prosperity[102] points out a link between increased innovation and higher inequality. It argues that sharing the gains from innovation is important to "help prevent a public backlash against innovative technologies like automation that cause widespread job loss." The report authors suggest this can be done through a mix of solutions, including a focus on commercialization (where there is more job creation) and facilitating skills training for those jobs, among others, so as to raise worker wages and not just the profits of firm owners.

The Vancouver Declaration on Clean Growth and Climate Change, signed by all Canadian First Ministers in March 2016, marks a huge step towards such a vision. It notes that "Canada stands at the threshold of building our clean growth economy. This transition will create a strong and diverse economy, create new jobs and improve our quality of life, as innovations in steam power, electricity and computing have done before."[103]

Further, the Pan-Canadian Framework on Clean Growth and Climate Change, signed by most First Ministers in December 2016, notes that "Fostering and encouraging investment in clean technology solutions can facilitate economic growth, long-term job creation, and environmental responsibility and sustainability. Taking action on climate change will help to capture new and emerging economic opportunities, including for Indigenous Peoples and northern and remote communities."[104] This last point will be key to the vision – ensuring that all Canadians can benefit from clean innovation (see Box 3 on Inclusive Clean Innovation) will be critical for garnering public support, which in turn will help ensure its longevity and success.

"Together, we will leverage technology and innovation to seize the opportunity for Canada to contribute global solutions and become a leader in the global clean growth economy." — The Vancouver Declaration on Clean Growth[105]

Canadian governments, working with key actors across the economy, can set an ambitious-but-achievable vision for clean innovation in Canada and work together to drive alignment for clean innovation – across institutions, governments, and innovation stages. Given the diversity of regions, economic sectors, natural strengths and opportunities for creating synergies, this vision may translate into different strategies for different regions and sectors (a point we return to later in STRENGTHEN).

A bold vision is only achievable with a bold level of action. This requires that governments approach policy design and investment differently for clean innovation.

Approaching Risk Differently

Driving clean innovation, by its nature, is not an exact science. It is about shaping the future, with all its uncertainties. Like any investment, it involves taking risks in order to succeed. Those risks should be smart, informed, and calculated. But a big part of innovation involves trying different approaches, seeing which work best, learning from that (fast), and adjusting nimbly. In other words, it means embracing risk-taking and (sometimes) failure – and seeing those as necessary parts of finding success in the changing, complex world of innovation. The idea of "failing fast", in which failures are caught early and seen as learning opportunities, applies both to policy design and technology investment.

By their very nature, governments are not used to embracing risk. As large institutions with built-in checks and balances, they are cautious by design in the ways they serve the public interest. However, serving the public interest in clean innovation means taking some (carefully planned) risks. Innovation is an uncertain process and governments can push companies to innovate when they are willing to share the risk of failure.

In the sections that follow on PUSH, PULL, GROW, and STRENGTHEN policies, we raise specific policy considerations regarding how to encourage risk taking while also mitigating the potential downside of failure. For

example, as governments invest in R&D, they can work with partners to identify prospective areas for innovation and to thus share risk. Similarly, government agencies seeking to help commercialize technologies can invest in a portfolio of companies. Further, governments can help de-risk emerging solutions by acting as test-beds in their own facilities and by serving as first buyer through their procurement practices – in effect taking on a bit of risk themselves, but in a controlled way.

As we show in the STRENGTHEN section of this report, there are a number of ways governments can design the public institutions that are part of the clean innovation system, be they for R&D, financing or other areas. A number of design principles exist that enable these institutions to be nimble at decision-making and course correction, as well as sheltered from political pressure and changing government mandates (among other objectives that may be identified).

Yet while increasing the degree of risk can in fact result in better public outcomes, the public perception of government risk is problematic. For example, the US government has often been criticized for investing US$528 million in Solyndra, a now-defunct solar panel start-up. However it is rarely recognized for investing almost as much (US$465 million) in Tesla in its very early days, a winning investment call.[106] In fact, the US Government has supported 88% of the country's most important inventions between 1971 and 2006, from the internet to Google's original algorithm.[107]

The current public narrative is that governments are very bad at making economic bets and routinely waste taxpayer money. The reality is somewhat different. It is true that governments have made some poor investment decisions, particularly when motivated by politics. At the same time, most major technological breakthroughs in the past century have had significant support from the government.[108] For example, nearly all of the innovations that make smartphones so 'smart' (internet, GPS, multi-touch screens) were at least partly government-funded (see Figure 7). In fact, multi-touch technologies were being developed through public and private funding at the University of Toronto (UofT) as far back as 1984.

Box 4: Policy Experimentation as a Form of Risk

Needing to create space for governments to take risk is not unique to clean innovation. Rather, there is a growing call for governments to embrace "policy experimentation" in all areas of their programming. The Mowat Center has gone so far as to suggest a "Minister of Failure" with responsibility to ensure smart, well-calculated risks are embraced.[109] The idea behind policy experimentation is to try out more risky policies or programs on a small scale before implementing on a broader scale. Policy experiments can focus on different trials for different regions, times or sectors, and like all experiments, they are best designed with a 'control group' of a more traditional policy approach against which to measure change.

However, governments are under public pressure to show 100% success rates. In fact, 100% success rates for any investor – public or private – mean that they are being too cautious and only backing 'safe' projects that are very likely to succeed.* Innovation, by its nature, involves risk – trying new things which, if successful, can generate big returns (and societal benefits, in the case of clean innovation). Therefore, some reasonable share of public investments should be expected to fail, within acceptable bounds.†

To support innovation, governments must be prepared to take risks, but do so in smart, informed ways, such as working with arm's-length institutions and independent experts, risk-sharing to leverage private investment, building in evaluation and course correction, and

* While the private sector expects and plans for a level of risk, government may be as well (or better) positioned to do so because it can afford to invest in a diversified portfolio unlike a small investor or company whose success depends on the outcome of one or a few projects.

† When it comes to commercialization and scale-up in particular, some argue as well that governments should ensure that the public is able to reap some of the returns of public investment (beyond those result from successful projects leading to greater economic activity, which in turn leads to greater tax revenue), such as holding equity in investments. See for instance betsandreturns.ca for exploration of these concepts by the Broadbent Institute and the Atkinson Foundation, based on the work of Mariana Mazzucato.

effective institutional design (see Box 22). At the same time, the public, media, and stakeholders must be prepared to accept governments taking some degree of risk – and having some failures – provided it is done in smart ways, and programs achieve success overall.[110]

Canada's Recent Clean Innovation Policy Progress

Canadian governments have made substantial progress in recent months in building the policy architecture that will boost clean innovation. This has happened through a series of new policies, programs and commitments at the federal, provincial and municipal levels. While this report does not delve into that progress in detail, two particularly important recent initiatives are worth highlighting here.

In December 2016, the Prime Minister and most Premiers signed the **Pan-Canadian Framework on Clean Growth and Climate Change**.[111] This landmark national accord sets out a range of federal and provincial policy commitments designed to move Canada towards meeting its Paris climate targets and help stimulate low-carbon innovation. These include a national floor price on carbon (building on existing provincial regimes) and commitments to ambitious standards for low-carbon energy, vehicles and transportation, buildings, industrial production and government operations. All of these, if well designed, will serve as important PULL policies that stimulate market demand for clean innovation across the Canadian economy.

The 2017 federal budget built on this framework by making a major investment in all stages of clean innovation, including: more than $400 million targeted primarily at supporting R&D on clean energy, transport and other clean technologies, with a particular focus on resource sectors; support for development of the ambitious low-carbon regulations set out in the Pan-Canadian Framework; $21.9 billion in green infrastructure investments, such as advanced buildings, energy and transportations systems (Fall 2016); $1.4 billion to invest in the scale up and commercialization of clean technology firms; and related initiatives like $950 million for superclusters, $14.5 million for a Clean Technology Data Strategy, and $12 million for a Clean Growth Hub.[112]

With these initiatives buoyed by others at the provincial level, such as Ontario's recent Cleantech Strategy – Canada has begun to make real progress in building and strengthening its foundation of policies and programs to accelerate clean innovation. These new commitments are important, but they are just a start. The challenge ahead is to turn them into action by designing new policies and programs, implementing them, and then evaluating and adapting them. In addition, there is still more to be done to flesh out Canada's clean innovation policy framework, for example to tackle other emerging clean innovation challenges, such as water, waste, and biodiversity (the current commitments apply mainly to carbon).

All of this will require close coordination between all levels of government, the private sector, researchers, and civil society, so that all the key actors are pulling together in the same direction. And it will require sustained effort and leadership over a decade or more, to seed these changes and allow them to grow into a stronger, cleaner, more innovative economy – one that builds on Canada's strengths and

Box 5: Smart Government Support Can Catalyze Private Investment

Like government, private investors have a critical role in all stages of clean innovation from early research all the way to broad adoption and diffusion. As innovations move beyond the R&D stage, and government intervention transitions from "pushing" research to "pulling" demand, there is an increasing need for private investment to take on a larger role. This is a sensible place for private investors to exert their influence as the closer the technology gets to market, the less risky it becomes, and the greater the prospect of profit.

The aim of government policy and funding should be to *draw in* private funding as technologies develop. Over time, as strong public policies (like rising carbon prices) help create a growing market for clean innovation, the private sector will naturally take on a larger role in creating and adopting clean innovation, allowing governments to scale back their efforts.

positions us to prosper in a changing, 21st-century global economy.

The rest of this report now turns to exploring the policy levers that governments can use to help accelerate clean innovation. It explores Canada's strengths and opportunities in more depth, raising implications that policymakers would be wise to consider, and then concludes with some overarching implications for policy development and implementation.

The fact remains, however, that understanding innovation – and clean innovation in particular – and why a country or industry excels or underperforms is not simple. This is an emerging area for both research and policy formation and while we have pretty good information on Canada's strengths and weaknesses in some areas, we have limited knowledge and experience in others. As such, we identify a number of points for further research and exploration, particular to Canada.

3.0 PUSH:
Policies that drive new ideas

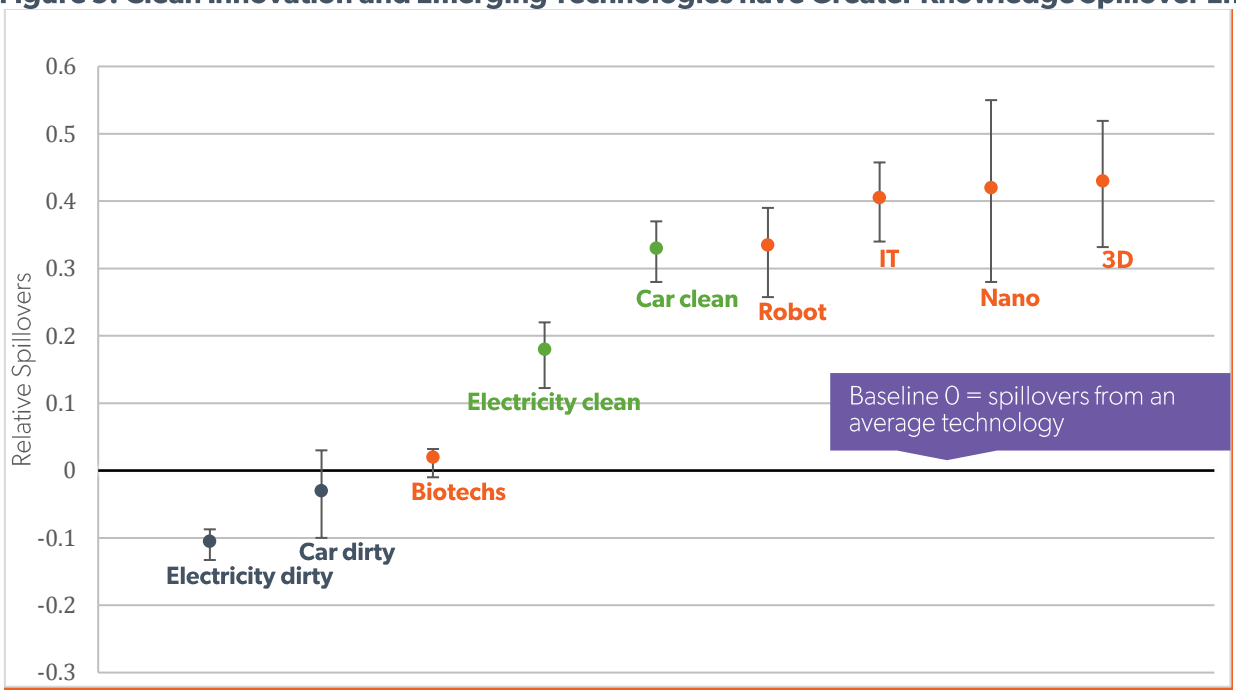
3.0 PUSH: Policies that drive new ideas

Successful clean innovation usually begins with research. Whether that research is initiated by academics, entrepreneurs, businesses or government, it can produce early intellectual property that then gets refined through the subsequent stages of clean innovation before potentially becoming a commercial success. The more research there is happening in the clean innovation system, the more possibility for commercial successes to emerge.

However, the presence of the knowledge spillover market failure, which means that private actors who generate new ideas are not able to fully capture the rewards of those ideas, has the effect of limiting the amount of research that happens in the clean innovation system. Public policy is needed to fix this market failure. PUSH is a category of policies that aim to do just this, unleash new research and new ideas at the early stages of clean innovation.

While the knowledge spillover market failure affects all types of innovations, research suggests that clean innovations have more spillover effects than other forms of innovation, particularly dirty forms.[113] This is due to the interdisciplinary nature and broad applicability of clean innovations, which results in applications and benefits for multiple sectors, driving economic growth and environmental benefits beyond the innovation's initial scope.* Figure 9 shows that patents for clean technologies are cited by subsequent patents more often than 'dirty' technologies in the same sector (close to the general purpose technology levels of IT).

Figure 9: Clean Innovation and Emerging Technologies have Greater Knowledge Spillover Effects



* In other words, there are four reasons for PUSH policies in clean innovation: 1) They are always a good idea because of the presence of spillovers, 2) They are particularly good because the spillovers are greater, 3) They can help address the environmental externality (which can theoretically be addressed by PULL policies but may not be), and 4) PUSH and PULL policies work best together.

Given the high economic and environmental rewards offered by clean innovation, and the greater challenge presented by these spillover effects, there is clear justification for government to use PUSH policies to drive new ideas and support the earliest stages of the clean innovation system.*

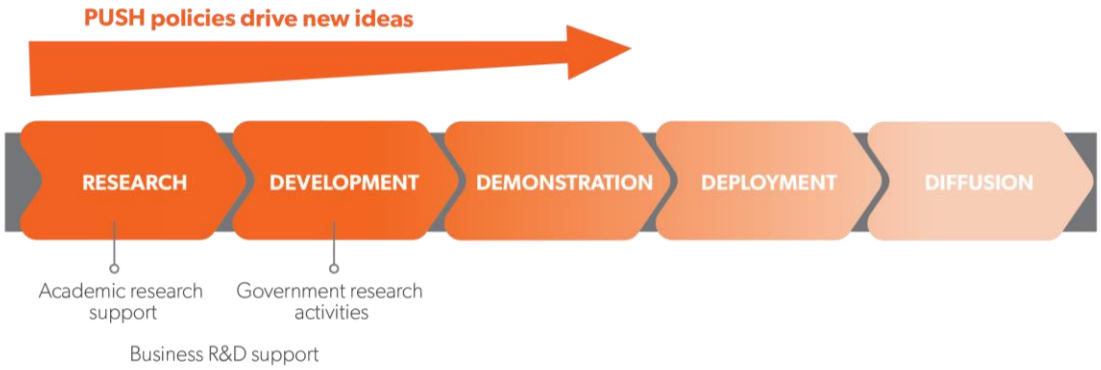
Further, evidence shows that well-designed PUSH policies have impact not only at the research and development stages, but that their impact continues through the other stages of innovation all the way to deployment and diffusion.[114] † In other words, with PUSH policies, governments have an important tool to energize not only the early stages of clean innovation but also the system as a whole.

In this section on PUSH policies, we start with Canada's well-recognized strengths in public research as a potential point of leverage, then move to our challenge in generating business R&D, before exploring the idea of better focusing our research efforts, and considering the role of collaboration in early stage innovation. The implications for policymakers are that to accelerate clean innovation we need to both boost the areas where Canadian performance is lacking, and leveraging the areas where we have strength.

3.1 Policy Tools

PUSH policies include a variety of specific policy tools that target the knowledge spillover market failure. Some of these tools are captured in Figure 10 and explored below.

Figure 10: PUSH Policies and Clean Innovation



Government Research Activities

As Section 1.2 of this report notes, Canada's research system has both strengths and weaknesses. A key strength – volunteered by a significant number of this report's interviewees – is publicly supported research institutions. A number of strong Canadian public institutions carry out research and development in close collaboration with industry partners and academics.

As a research institution supporting many forms of innovation, the National Research Council (NRC) is the Government of Canada's primary research and technology organization. For over a hundred years it has conducted world-class research and operated labs across the country in a diversity of fields. While it supports broad areas of research interest, it also undertakes research related to some areas of clean innovation: e.g., the

* And, it is particularly important that PULL (and GROW and STRENGTHEN) policies are in place to ensure that the entire clean innovation system is robust and that there is market demand for clean innovation.
† The combination of PUSH policies with a PULL pricing mechanism can also help ensure that if greater clean R&D comes at the expense of R&D in other fields, that those innovations be in "dirty technologies", not innovation in other socially valuable domains.

research infrastructure of NRC Energy, Mining and Environment includes an anaerobic bioprocessing pilot plant, diesel engine emissions and efficiency testing, and state-of-the art transmission and scanning electron microscopes, as well as wind tunnels and fuel-flexible gas turbine test cells.[115] It also delivers the Industrial Research Assistance Program (IRAP) which supports some 10,000 SMEs annually with business and technical advisory services, financial assistance, networking and linkage services, and support for youth employment (See Box 10).

Canada also has highly-regarded clean energy specific labs. Housed within Natural Resources Canada (NRCan), CanmetENERGY works in a number of clean energy areas including clean fossil fuels, renewable energy, buildings and communities, industrial processes, and bioenergy. It has labs across the country including in Devon, Alberta; Ottawa, Ontario; and Varennes, Quebec.[118] These have played a critical role in the development of new clean technologies. For example, the Devon lab has been central in R&D for carbon capture and storage and technologies to reduce the oil sands' environmental footprint. However, a number of our interviewees noted that the private sector is often unaware of the excellent work going on in these labs – potentially missing opportunities for collaboration.*

Box 6: Public Funding for Academic Clean Innovation Research

The Social Sciences and Humanities Research Council (SSHRC) has identified six Future Challenge Areas, which have been integrated into three of its funding programs. While clean innovation is not one of these areas per se, two of the six questions could be directly relevant to clean innovation: What effects will the quest for energy and natural resources have on our society and our position on the world stage? And, how can emerging technologies be leveraged to benefit Canadians?

The Natural Sciences and Engineering Research Council (NSERC) is targeting strategic areas for clean innovation such as photovoltaics, biofuels, smart grids, and net-zero energy buildings.[116] One example, NSERC's Energy Storage Technology Network (NEST) based at Ryerson University brings together more than 25 Canadian researchers and 15 universities with 26 companies and government agencies to develop innovative energy storage solutions.[117]

A number of provinces have programs that support innovation. These include:

- Ontario Centres of Excellence (OCE) which manages the Ontario government's $74 million clean technology initiative;
- Ontario's TargetGHG, which is primarily focused on driving technology adoption by large emitters, but also includes $12 million for collaborative work with the Natural Sciences and Engineering Research Council (NSERC);
- Alberta Innovates is a provincially-funded Crown corporation that delivers research and innovation priorities for Alberta, including the Climate Change Innovation and Technology Framework to drive innovation to support Alberta's Climate Leadership Plan; and,
- Public utility Hydro-Québec operates Institut de recherche d'Hydro-Québec (IREQ), a research centre that invests an average of $100 million annually in innovation projects in technologies to improve energy efficiency, electrify land transportation, and integrate renewables into the grid, among others.

A number of federal and provincial initiatives also support innovators,† such as the Canada Foundation for Innovation, the federal-provincial-territorial Canadian Agricultural Partnership (previously known as Growing Forward), and the various Regional Development Agencies, among others.

A significant benefit of these programs and government laboratories and research centres is their ability to take long-term views, extending beyond the usual private research planning horizon, to identify priority areas for research. For instance, Canada is a leader in quantum computing because of early efforts at the NRC to develop

* This is often referred to as network failure.
† Appendix B of the Final Report from the Working Group on Clean Technology, Innovation and Jobs contains examples of key programs supporting clean technology.

Canadian expertise in this area. Evidence also suggests that government labs play a critical role in linking basic and applied research, and are cited in more energy patents than any other type of research institution.[119]

However, several of our interviewees noted that while there is excellent work being done in these public research institutions, there is too little connection between researchers in public labs and the private sector. Promoting greater collaboration could increase the volume and impact of clean innovation research. This could begin with greater communication and transparency about projects underway, paired with more institutional support for joint work efforts.

Supporting University Research Excellence

A second key strength of Canadian public research relates to university research excellence. Canadian universities (and also polytechnic institutions) play a critical role in R&D, ranking well against global peers and showing strong publication records.

Regarding general innovation, Canada makes up over 15% of the top-cited publications and ranks 7th in terms of total number of publications.[120] Government plays a direct role in this success. For instance, Natural Sciences and Engineering Research Council (NSERC) grants help fund 12,000 research professionals and 30,000 students through $500M in investments annually.[121] Similarly, the Social Sciences and Humanities Research Council (SSHRC) had expenditures of approximately $400M in 2016-17, supporting over 4,300 new grants and fellowships. Expanded investments in Canada's research granting councils and public labs announced in Budget 2018 looks to build upon this strength.[122]

Box 7: How Canadian Research Ranks[123]

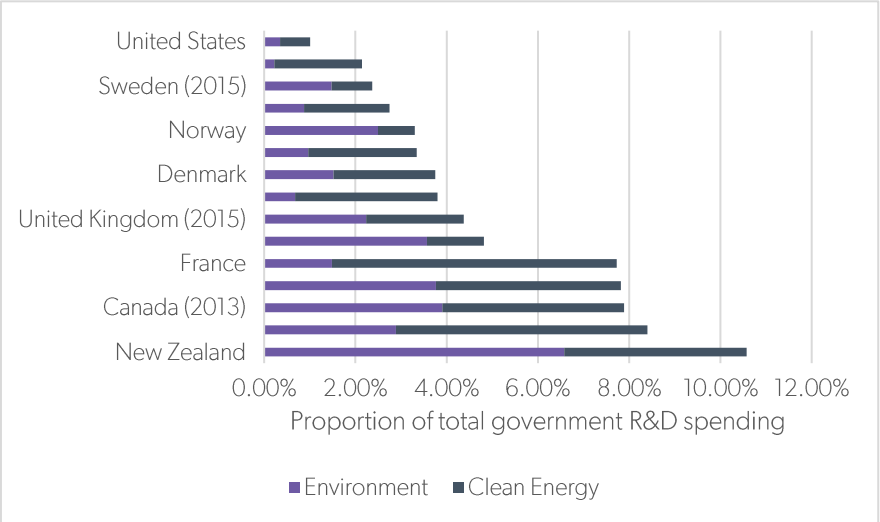
5th: Canada's rank in terms of productivity and impact of patents on the 2017 Global Innovation Index
17th: Canada's global rank for scientific and technical articles
5th: Canada's university ranking on the 2017 Global Innovation Index
5.5%: Canada's contribution to the global share of earth and environmental science publications
22nd: Canada's rank on university-industry research collaboration[124]
3.4%: Canada's share of global cleantech publications
0.7%: Canada's share of global cleantech patents (academic)
1.1%: Canada's share of global cleantech patents (industrial)

Overall, most analyses, such as the Jenkins report, conclude that Canadian academic research is strong and well regarded internationally. While there are few statistics on clean innovation research (or research that may eventually find clean innovation applications) carried out in Canadian universities, this report's interviewees generally agreed that Canada has strength in academic research for clean innovation.

With Canada's wealth of natural capital and energy resources, environment and energy represent key areas for public investment in R&D, as shown in Figure 11. These categories do not reflect all clean innovation across sectors, and not all this research would necessarily fit our definition of clean, however, it is encouraging to see that Canada ranks in the top 3 among peer countries in percent of public R&D expenditure on environment and clean energy.[125]

In order to build on this existing public strength in R&D, the 2017 federal budget reaffirmed Canada's commitment to Mission Innovation, to double its investments in clean energy research, development, and demonstration over the next five years.[126] The initiative also includes seven mission-oriented *Innovation Challenges* to address certain high-potential opportunities for innovation including smart grids, carbon capture and storage (CCS), and biofuels.[127] As part of this commitment, the 2017 federal budget included $229 million to support R&D in clean energy and transport, and $200 million for cleantech R&D, development, demonstration, and adoption in natural resource sectors.[128]

Figure 11: Government (including University) Expenditures on Environment and Clean Energy R&D (2016)*



Provinces are also increasing their efforts: Alberta has recently created Emissions Reductions Alberta (ERA), (from the former Climate Change Emissions Management Corporation), with a focus on accelerating innovative solutions for a lower carbon world; while Ontario has created TargetGHG to be delivered by OCE (as noted above).

With a strong public R&D investment record and research strength in Canadian universities, the challenge for Canada is to use these assets to leverage the creation of more and higher impact clean innovation ideas, by findings ways to augment and target that research capacity to focus more on clean innovation specifically. The models used to do so in the United States' National Renewable Energy Laboratory (NREL) and the Netherlands Organization for Applied Scientific Research (TNO) may be ones worth exploring for lessons for Canada. There are a number of ways for governments to increase and target public research activities towards clean innovation over the coming decade, such as:

- Making clean innovation outcomes a greater priority for government labs, and letting potential research partners outside of the public lab systems know more about what research is underway and planned in order to stimulate more collaborations and promote uptake by potential receptor companies;
- Creating focal points within existing labs for clean innovation in areas of strategic importance for Canada;
- Launching targeted research competitions for clean innovation and clean technology R&D through granting councils, (including social science research regarding the policy levers to achieve clean innovation success);
- Creating additional Canada Research Chairs targeting priority areas for clean innovation with a focus on building interdisciplinary and public-private synergies.

Box 8: Breakthrough Energy Coalition[129]

In a parallel commitment to Mission Innovation, the Breakthrough Energy Coalition, composed of more than 30 of the world's wealthiest CEOs and investors (including Bill Gates, Jack Ma, Jeff Bezos, and Mark Zuckerberg), committed to invest at least US$1 billion in patient capital through *Breakthrough Energy Ventures* to finance early-stage technology development in countries that are a part of Mission Innovation.

* Note: Government spending represents federal budget appropriations and outlays for R&D as well as General University Funds (including provincial and other contributions). Clean energy refers to research in energy efficiency, renewable energy, nuclear, hydrogen and fuel cells, and other power and storage technologies as well as carbon capture and storage. Environment covers R&D aimed at improving the control of pollution, including the identification and analysis of the sources of pollution and their causes, and all pollutants, including their dispersal in the environment and the effects on humans, species (fauna, flora, and micro-organisms) and the biosphere. The development of monitoring facilities for the measurement of all kinds of pollution is included, as is R&D for the elimination and prevention of all forms of pollution in all types of environment

Addressing the Business Research Gap

The private sector has also historically been a principal contributor to research and development in the early stages of innovation. This source of research and development is measured through Business Enterprise R&D (BERD), which takes stock of the quantity – though not the quality – of private sector investment. Evidence shows that despite Canada's strength in public research, private investment in R&D generally has been lacking. This is a cause for concern.* Canada's BERD as a percentage of GDP has been falling over the past 15 years. This is a departure both from Canada's own historical track record and the growth trend in the rest of the OECD (see Figure 12).

Box 9: Mission-driven public research: ARPA-E

ARPA-e (Advanced Research Projects Agency – Energy) is an agency within the US Department of Energy that funds high-potential, high-impact energy innovations to encourage experimentation and support potential breakthrough solutions with a path to commercialization. The expert staff focuses on supporting innovations to address urgent societal challenges including energy security, GHG emissions, and economic competitiveness. (See Section 6.2 for more on ARPA-E). Federal Budget 2018 recently announced funding for NRC to develop a new program based on the ARPA model.[130]

The reasons for Canadian business's recent lackluster performance are not entirely clear. One likely factor is that big corporations in Canada are often branch-plants of multi-nationals, which keep their R&D centres in other countries. Another contributor may be the significant portion of Canada's business activity that stems from commodity producers which do not typically invest as much in innovation (although there are exceptions, such as the oil sands). However, the Expert Panel on Business Innovation found that "generally lower Canadian R&D spending within the same sectors in both the United States and Canada accounts for a greater portion of the gap [in BERD between the two countries]…than does Canada's adverse sector mix—i.e., the greater weight in Canada's economy of resource-related and other activities that have inherently low R&D spending."[131] In general, Canadian business sectors lag their American counterparts when it comes to investing in the creation of new ideas.

Canadian governments have attempted to encourage growth in private research through PUSH policies. One of the primary policy tools for this is tax incentives, which are often considered attractive policy tools to encourage R&D because they leave it to the marketplace to determine the appropriate technologies for investment.

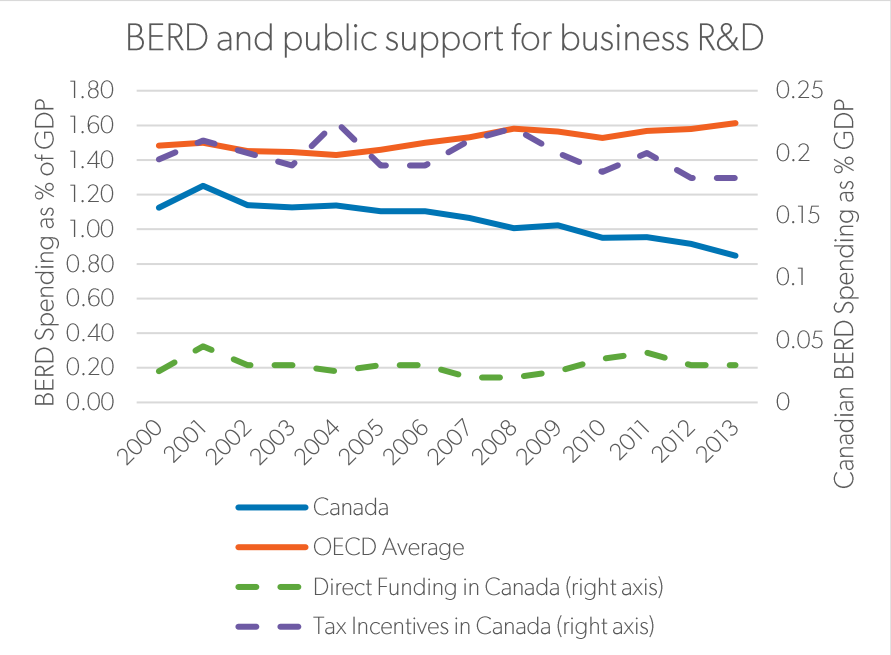
The primary way in which the federal government has helped support BERD is through the Scientific Research and Experimental Development Tax Credit (SRED).† According to a recent OECD study, in 2015 federal tax credits accounted for 85% of total public support for business R&D, giving Canada the third largest proportion of indirect support among OECD countries. The remainder of the support is through direct support, such as procurement and grants.[132] Most provinces also support private R&D through tax credits and (in some cases) procurement and grants.

* While the data on BERD have limitations and there is ongoing debate in Canada about what level of BERD is ideal (particularly relative to peer countries, in the context of generally favourable business performance in Canada), it remains clear that BERD is a good thing – it supports competition and economic sustainability, which in turn raise standard of living. Further, clean innovation BERD can support climate change mitigation and adaptation.

† There is an ongoing debate about the effectiveness and best possible structure of tax credits for BERD, focused on the current SRED. While that issue is beyond the scope of this report, we do note that there is evidence that these types of tax supports work best in tandem with business supports, such as those offered by IRAP.

However, as Figure 12 shows, government support for R&D – both direct (like grants) and indirect (like tax measures) – has remained relatively steady even as BERD has fallen, which indicates that there are more factors driving private research investment than government support.

Figure 12: BERD and Public Support for R&D



The figure also shows Canada's disproportionate reliance on tax measures (such as the SRED) relative to direct funding for R&D.* Whether or not the SRED program has been effective at improving business R&D expenditures and how it might be improved, are the subject of much debate and research. The Jenkins report suggested a number of changes that were intended to make the SRED program more effective, some of which were implemented from 2012-2014. However, it is too early to determine their impact.

Looking specifically at the cleantech sector, we see that while Canada generates 3.4% of global cleantech publications, only 1. 1% of global industrial cleantech patents are registered here. And yet some evidence suggests that cleantech companies in Canada are investing more in R&D, at least compared with other sectors. Cleantech firms reviewed by Analytica Advisors spent 11.3% of their revenue on R&D (in 2016). Analytica Advisors also found that cleantech firms came in second only to firms in health care, biotechnology and the pharmaceuticals industry, and with higher rates of BERD than the computer software and internet services industry.[133] Meanwhile, a recent survey of cleantech companies in BC found that "half of respondents indicate that current SRED tax credits and IRAP funding are the two government programs that are most beneficial to the cleantech sector." Three quarters of respondents file SRED claims (and 79% own at least one patent).[134]

During our research interviews, several companies from the cleantech sector and other sectors who engage in clean innovation R&D indicated the importance of SRED to their R&D efforts. However, several also noted that the recent changes to SRED, and in particular the exclusion of capital costs, did not favour cleantech – particularly the high capex firms that face particular challenges in financing scale-up. Other interviewees questioned how much SRED-funded R&D would have still taken place even without the incentive (i.e. how much additionality there is). Understanding the effectiveness of SRED (and other tax measures) for cleantech and clean innovation more generally is an important area for further research.

* And where Canada uses direct support (like grants), the funding is often capped at lower levels than other countries.

Box 10: Industrial Research Assistance Program[135]

A number of our interviewees credited the NRC's IRAP as an important program helping companies with early-stage innovation development. IRAP supports some 10,000 SMEs annually with business and technical advisory services, financial assistance, networking and linkage services, and support for youth employment.

For example, IRAP was a key ingredient in supporting Saskatchewan-based Papa Bravo to focus R&D planning on industry needs, which shifted their primary business from experimenting with traditional EVs, to becoming a producer of zero emission vehicles for use in the mining industry. IRAP continued to support the company's scale-up through financing and the youth employment program to be able to produce a suite of state-of-the-art electric vehicles for use in the confined underground spaces of mines.[136] PapaBravo experienced rapid growth to meet high demand and was later acquired by Saskatchewan-based Prairie Machine & Parts, which plans to convert all future mobile mining equipment to PapaBravo's rechargeable battery technology.

"Really, the sky's the limit, and that needs to be credited back to IRAP support. We wouldn't have been able to bring on the people we needed at the times we needed them if IRAP hadn't been there to help us." – PapaBravo CEO Patric Byrns

More importantly, business R&D for cleantech is not yet translating into marketable outcomes on the scale it should. One indicator of this problem is patent rates – the most common means of measuring innovation and an important indicator of how well countries turn knowledge into protected and ultimately marketable inventions.*

Canada's global share of patents for clean technology is on the decline. In 2013 Canada filed 2.14% of global environmental technology patents – down from 2.35% in 2000 and 2.6% in 2005 (Figure 13).[140] This may not be surprising given that public R&D (at which Canada does relatively well) tends to lead to fewer patents than private R&D which accounts for 82% of patents (and where Canada has been lagging).[141]

In its survey of 324 cleantech companies, MaRS found a strong correlation between the creation of ideas (via patents) and finance. As they point out, "cleantech ventures compete on the strength of their technological innovations," so patents have an outsized importance. Compared to fintech, advanced health, ICT and education, cleantech has more patents-per-company.[142] This corresponds with success in securing funding; those companies that filed patents in 2014 were more likely to raise funds the next year – over $1.1 million more, on average.

There is no doubt that the challenge of translating ideas into market-ready solutions partially results from the market failures that undermine demand for clean innovation solutions (see the Section 4 on PULL policies). However, Canada's overall BERD performance is so poor that it argues strongly for

Box 11: Patents and IP Regimes

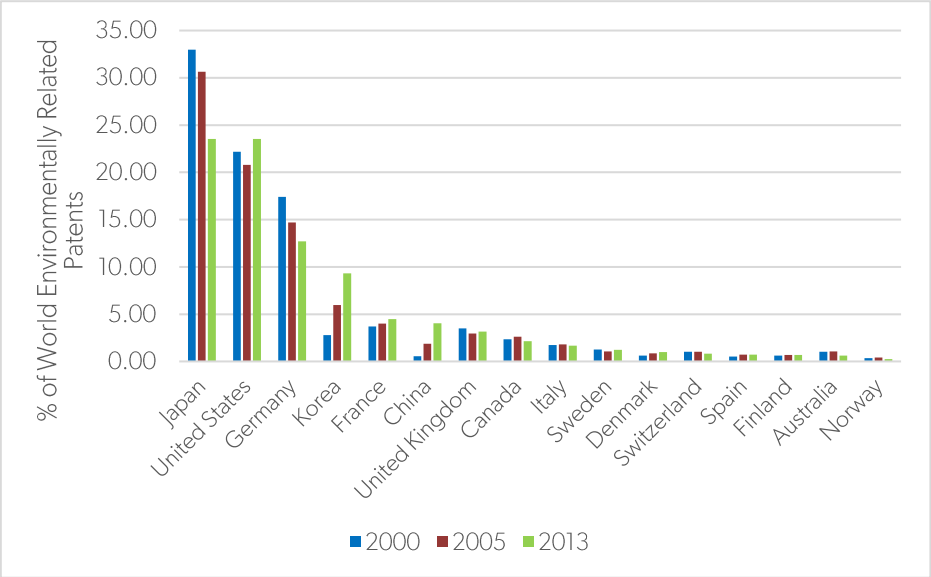
Intellectual Property (IP) regimes and copyright law can support or deter innovation. Because Canadian clean innovation is driven in large part by export opportunities and because of the larger-than-average spillover effects for clean innovation, these policy regimes can be particularly relevant for clean innovation and protecting valuable ideas.[137] At the same time, there is a movement towards greater collaboration across companies and more open forms of IP.[138] Budget 2018 recently announced an investment of $85.3 million dollars over five years to develop a new IP Strategy for Canada. This is anticipated to include an intellectual property marketplace, a Patent Collective pilot program, and expert and legal advice for entrepreneurs.[139]

* As noted earlier, patent data should be interpreted with caution. Further, Canada's global shares should be noted against a backdrop of a rise in patenting in countries like China and Korea. Further, there are often important differences in patents' inventor country, assignee/owner country and/or application country. Many Canadian inventors and assignees file in the US before Canada, even if their technology targets the Canadian market.

policies that encourage more private clean innovation investment. Government action to boost BERD could take a number of forms, including:

- Exploring the potential effectiveness of targeted tax incentives for clean innovation R&D, beyond the general SRED credits;
- Leveraging Canada's public R&D strength by improving incentives for academics to turn research into patents;
- Building greater synergies between public and private R&D efforts, via collaborative partnerships, exchanges, co-funded research, or identifying commercial applications early in the public R&D process;
- Exploring ways to attract foreign-owned companies to situate their R&D operations in Canada, including stronger collaborations with government research labs;*
- Examining opportunities to improve the Canadian Intellectual Property (IP) regime;
- Identification of regulatory barriers impeding R&D in Canada; and
- Developing strategies for developing, maintaining, and attracting top research talent.

Figure 13: Patents for Select Environmental Technologies[143]



3.2 Focusing PUSH Policies Strategically

Governments simply don't have the resources to give a major boost to research and development across all sectors and all technologies. For that reason, when it comes to clean innovation, it makes sense to explore focusing PUSH policies strategically.

Focusing R&D resources strategically can be a controversial approach. Governments, like all investors, don't make the right picks all the time. Predicting the course of innovation, including the emergence and impact of new technologies unimaginable in the present, has inherent risk and can result in misallocated resources.

Though history offers some examples of government investments gone wrong, it also offers plenty of examples of big efforts gone right – especially in cases where government was required to set a long-term vision, to stimulate

* And where warranted, consider if/how some of these R&D investments can stay in Canada through to commercialization (i.e., linking PUSH with GROW).

demand, and to build on existing strengths. The US Apollo program that put an American on the moon is maybe the most famous example of this. Canada's own investment to invent canola oil in the 1960s is another.

So, should Canada strategically target its research and development support for clean innovation?

Liscow and Karpilow argue that governments should directly encourage innovation in clean technology over "dirty" technologies – and even sometimes choose between different types of cleantech – to overcome the natural 'lock-in' in innovation systems to continue building on historical pathways (i.e. high carbon ones). "A big government push in cleantech innovation can lead to a permanent reorientation of the energy sector toward cleantech, resulting in more emissions reductions at lower cost." [146] Others, like Mazzucato, argue the same for public efforts to finance commercialization and scale-up (see Section 5 on GROW policies).

Additionally, evidence suggests that global BERD investment in clean energy related R&D is disproportionately lower than other sectors. One study of 2,000 firms globally found BERD of energy firms to be around 1% of sale revenue, compared to 3% for other industrial sectors, and as much as 14% in computer services and pharmaceuticals, two sectors with similarly high levels of knowledge spillovers to clean innovation.[147]

Box 12: Canada's Strategic Investment in Carbon Capture and Storage

Over the past decade and a half, Canadian governments have identified innovation in CCS as a priority for meeting Canada's climate commitments, but also as a significant global economic opportunity.[144] According to the International Energy Agency, CCS could account for as much as 20 percent of the emissions reduction required by 2050 to limit global warming to under 2 degrees.[145]

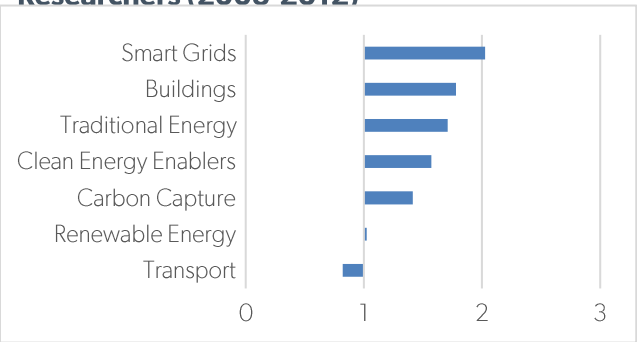
Canadian efforts to validate the potential of CCS began in 2000 with The Weyburn Project in Saskatchewan, one of the first international large-scale CCS demonstration efforts in the world, which captured CO_2 emissions in North Dakota and transported them by pipeline back to Canada to be injected into oil mines as a means to test and prove enhanced oil recovery. More recently, the federal and Alberta governments supported Shell Canada's Quest CCS project with $865 million to leverage similar private investment. Quest is the world's first commercial-scale CCS project focused on the oil sands, and is capable of sequestering one million tonnes of CO_2 annually.

There is no shortage of areas in which Canada could choose to focus efforts. This report's interviewees suggested some niches where we might start, such as: smart grids and "everything electrical", supply chain and logistics, nanomaterials, advanced manufacturing, water treatment, waste, agri-food, biofuels and biochemicals, and nuclear, among others. However, identifying Canada's strategic areas of investment in clean innovation R&D is a job that should be done carefully. Governments should engage the best experts, from Canada and abroad, as well as stakeholders with valuable applied experience (in business, investment, adoption, etc.) to help inform priority-setting. Then specific funding decisions within those priority areas should be left to arm's length institutions, as far as possible – or at least be informed by experts, where government makes R&D funding decisions. (For more discussion of institutional design, see the Section 6.2).

That being said, Canadian governments are starting to move in the direction of mission-oriented challenges. Provincial governments have initiatives like Ontario's TargetGHG. And the federal government, through Budget 2017, created the Impact Canada Fund**,** initially focused on two streams: a Cleantech stream supported by $75 million to address challenges for Canada's rural and remote communities in transitioning from diesel to renewable and cleaner power sources; and a Smart Cities Challenge supported by $300 million to find innovative ways to "improve the quality of life for urban residents, through better city planning and implementation of clean, digitally connected technology including greener buildings, smart roads and energy systems…" Further, Budget 2017 included $229 million to support R&D in clean energy and transport and $200 million cleantech R&D, development, demonstration, and adoption in the natural resource sectors.[148]

Some evidence of Canada's comparative advantages for clean innovation R&D can be found in patent data. Figure 14, from a report by Innovation Science and Economic Development Canada (ISED), shows how Canadian researchers compare to other countries in terms of areas of specialization related to climate change mitigation patents. Smart grids, buildings, traditional energy, clean energy enablers, and carbon capture all stand out.[149] In contrast, the study finds that Canadian *businesses* are relatively unspecialized when it comes to patenting in climate change mitigation areas, with the exception of carbon capture and storage.[150] This underscores earlier evidence that while Canada has the research talent to excel, Canadian businesses are failing to capture this talent and convert it into commercialized innovations.

Figure 14: Revealed Technological Advantage (RTA) Index for Canadian Researchers (2008-2012)*



Evidence such as this, combined with analysis of market potential and stakeholder consultation, would be an important input into a priority-setting exercise. Key to establishing target areas is setting clear, transparent principles for their selection. For instance, a recent study by the Technopolis Group argues for selecting clean innovation areas for public support (in this case – for cluster support, which we discuss more in the section on STRENGTHEN policies), based on how climate innovations can diffuse within existing manufacturing clusters.[151] This plays to Canada's existing strengths.

Priorities can also be based on a nation's major challenges – which require mission-driven solutions. For example, the Impact Canada focus on shifting rural, northern and remote communities from diesel to cleaner energy is an area in which Canada has a particular challenge, and can be a world leader in remote clean energy solutions by solving it.

Creating well-designed institutions to help set these priorities is also important (and is explored more in STRENGTHEN). Not all these focused strategic investments will be successful, but as noted in Section 2.2, governments must accept a level of risk greater than what they have traditionally been used to, communicate with taxpayers about their new risk tolerance (promoting its benefits), and find ways to fail fast and learn from experience when course corrections are needed.

The scale of the clean innovation challenge, combined with the way existing technologies are embedded in our current systems, argues for governments to consider placing some bigger, strategic bets. To do this, governments should consider:

- Targeting technology areas based on an overall clean growth strategy and independent expert advice, ensuring an integrated effort with best chances of success;
- Focusing clusters of leading researchers (public, academic, and private) and collaborating with other countries around priority areas where synergies exist (see more on clusters in the Section 6.3);
- Dedicating funding to support these priority areas and developing ways to allow for "failing fast", both by increasing risk tolerance for failure and responding nimbly to adjust and reallocate funding to the most fruitful efforts; and
- Addressing concerns about government selecting priority areas for investment, by drawing on institutional and governance models that can help protect the selection process from undue political influence, which we discuss in STRENGTHEN.

* The Revealed Technological Advantage (RTA) index, developed by the OECD to measure specialization in certain technologies, is a ratio representing the share of global patents for a specific technology field relative to the share of all patents. The RTA index equals zero when a country has no patents in a specific field; one when the share in that field equals the share of all patents; and greater than one indicates an observed specialization in that field.

Box 13: The Power of Prizes

Whether called prizes or grand challenges – there's been a recent resurgence of offering big rewards to spur innovation. Such awards in past times have been credited with bringing new food preservation techniques, the lifeboat, and the vaccine inoculation.[152] While this incentive method largely fell off in the 20th century, recent years have seen the number of innovation prizes skyrocket following the launch of the X-prize. Prizes have increased in number, size and variety, with some estimates suggesting the philanthropic prize sector is worth as much as US$2 billion.[153]

McKinsey has studied innovation prizes and found that they are most effective when three conditions hold: 1) They have a clear objective (for example, one that is measurable and achievable within a reasonable time frame), 2) There is a relatively large population of potential problem solvers, and 3) There is a willingness on the part of participants to bear some of the costs and risk.[154]

One exciting example of a clean innovation prize is the NRG COSIA Carbon XPRIZE. The Canadian Oil Sands Innovation Alliance (COSIA) and US-based NRG have put up US$20 million for breakthrough technologies that convert CO_2 into one or more products with a high net value. The field has been narrowed to 23 promising semi-finalists representing six countries, including eight Canadian teams, with diverse uses for captured CO_2 ranging from fish food to building materials.[155] There is also an XPRIZE for water, aimed at alleviating global water shortages by finding ways to extract water from air in an energy-efficient way.[156] And Emissions Reductions Alberta currently has a $35 million prize for technologies to reduce GHG emissions.*

In Canada's North, the Government of Yukon funds an annual contest, open to all Yukon residents and businesses, to stimulate interest and engagement in developing and commercializing local products and services that address northern issues and opportunities. The theme was energy efficiency in building construction in 2015, and food security and northern agriculture in 2016. The $70,000 received by the winners is used to support the commercialization of the innovation. The first winner, who proposed an energy-efficient radon gas mitigation system, has partnered with a manufacturer in the south to bring their solution to market next year. The 2016 winner, a passive energy greenhouse designed to extend Yukon's growing season from four to eight months, is using the funds to build a prototype unit.[157]

3.3 Connecting Research Efforts

In addition to increasing the amount of clean innovation R&D, Canada also needs to find ways to better connect the research activities happening in universities, government research labs, and business in order to align efforts on priority research areas for clean innovation.

While there are many success stories of Canadian researchers collaborating across public-private lines, in order to achieve the scale of ambition needed on clean innovation, even more is required. There are indicators that connection may be one area where we have room to improve. For instance, we have public research strength in our government labs and universities, yet according to the Cycle Capital and SDTC study, these research strengths are not converting into a proportionate number of patents.[158]

Several interview respondents applauded Canada's connections between universities, government labs and private research, while a greater number of interviewees felt that there remained a significant gap in collaboration – and an opportunity to realize greater success simply by better connecting researchers. Some expressed specific ideas, such as that major research projects should require partners from academia, government labs, and industry in order to be funded.

* This, and other prizes offered by Mission Innovation countries, can be found on the Mission Innovation website: http://mission-innovation.net/resources/prizes-and-competitions/

For example, better collaboration may be key to addressing the patenting challenge identified earlier. A recent report by the Conference Board of Canada suggests that enhanced partnerships between private researchers and those in university and government would help take ideas from the lab bench to the patenting stage.[159] And other experts have noted that increasing efforts to collaborate with industry on innovation can provide a competitive advantage for Canada.[160]

There already is a degree of collaboration between industry, academic, and government researchers in Canada. For instance, the CanmetENERGY lab enters into more than 150 industry-sponsored projects each year, which include R&D agreements with individual companies, research consortiums or collaboration on demonstration projects.[161] Further, Canada's public research institutes administer programs to support private research efforts, such as the NRC's Industrial Research Assistance Program (IRAP), which helps Canadian small and medium enterprises (SMEs) develop and commercialize technologies destined for domestic and international markets. It also offers licensing opportunities for industry to collaborate in advancing the commercial potential of technologies it develops.[162] Similarly, Ontario Centres of Excellence (OCE) includes a number of industry-academia connection programs, including a 'voucher' model for connecting and funding academic R&D for selected companies.[163] It also has a program specifically for automated vehicle research. Research granting councils also promote public-private connection, such as through the Networks of Centres of Excellence program, and SSHRC's Partnerships program. Further, the 2018 federal budget included new measures to encourage research collaboration, such as the College and Community Innovation Program.[164]

Building on these efforts, and spurring greater collaboration, can increase the output and impact of Canadian R&D. (And making clean innovation a priority focus of these programs could help even more.) However, there remain impediments to greater collaboration. Most often, the expertise needed to unlock research breakthroughs is spread across private, university and government researchers, presenting a particular challenge in a spread-out, sparsely populated country like Canada. It is therefore important to identify and remove barriers and create specific incentives for more exchanges and collaboration among researchers in universities/polytechnics, and private and government labs. To that end, one area for further examination is around institutional design: how it could enhance collaboration between public (government labs and universities) and private researchers; and how it might help to better target research funding for clean innovation (either through existing granting councils or standalone bodies, like Genome Canada).

Extending research collaboration internationally is another way Canada can leverage talented researchers and international knowledge spillovers to catalyze opportunities in new markets.[165] Programs such as exchanges, joint research funding, and global visiting research chairs could help drive greater international research linkages and Canada's role in cutting-edge global research collaborations.

In sum, achieving Canada's environmental and economic objectives will require targeting and accelerating collaboration on clean innovation R&D. By enhancing public-private and international collaboration, businesses in Canada could gain greater access to research capacity and markets, which can help reduce technology risk and accelerate product development and commercialization. Similarly, by increasing the focus of government labs on clean technology (in strategic areas), including programs like IRAP which connect research to businesses, Canada could boost the ability of research to drive commercial innovation and cleaner growth across the country.

3.4 Summary of Policy Implications: PUSH Policies

If Canadians aspire to a future where clean innovation is driving a vibrant and competitive Canadian economy, sustainable jobs, a healthy environment, and a high standard of living, then we need to boost our research efforts and maximize their impact. The market failure of knowledge spillovers, combined with the inherently risky nature of research – where for every good idea that makes it to a final commercial product, there are many that ultimately

do not succeed – provide a strong justification for governments to act on behalf of society to accelerate clean innovation R&D efforts.

Here are seven key implications, arising from this report, for how policymakers can do this through PUSH policies:

1. *Target Canada's considerable research capacity on clean innovation*, by making it a sustained priority in public research labs (e.g. NRC), funding (e.g. granting councils), and other programs (e.g. research chairs, Mitacs).

2. *Boost private R&D* on clean innovation, by exploring options such as targeting clean innovation with research tax credits.

3. *Strengthen international research linkages* on clean innovation, through programs such as global visiting chairs, exchanges, and joint research funding, to bolster Canada's role in cutting-edge global research collaborations.

4. *Break down the walls between university, government, and private research*, by promoting collaboration and facilitating exchange (via incentives, programs, etc.).

5. Ensure *Canada's clean innovation needs and market opportunities better inform research priorities*, and vice-versa, through mechanisms to strengthen information exchange and alignment across researchers, innovators, investors, and public funders (such as networks, clusters, coordinating bodies).

6. Create a *'breakthrough' office* that can proactively drive strategic research and uptake on promising clean technologies; it should draw on other successful models, such as ARPA-E (nimble, far-sighted, systems approach, public-private) and build on existing capacity (e.g. IRAP, SDTC, BDC, NR Can).

7. Pursue other *innovative tools to stimulate breakthrough cleantech R&D*, such as prizes, grand challenges, etc.

4.0 PULL:

Policies that stimulate market demand

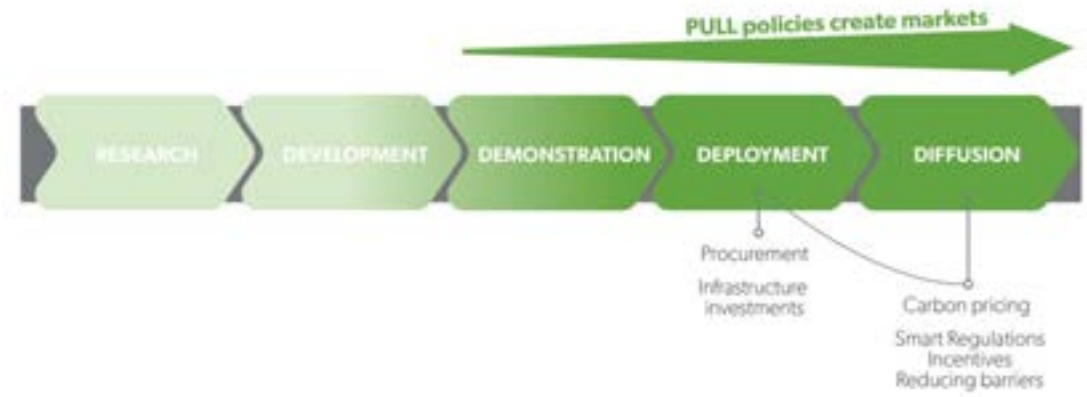
4.0 PULL: Policies that stimulate market demand

Clean innovation is fundamentally different from most other kinds of innovation because the thing being innovated around – a cleaner environment – has little or no market value. When innovators develop a smarter phone, a more resilient grain, or a better medical device, the prospect that people will pay for it both incentivizes the innovators and attracts investors. This is not the case, or at least not sufficiently the case, for cleaner air, less-polluted water, or protected habitats, which are important to people but have little or no market value.

This is the environment externalities market failure at work. In the absence of government action, this market failure leads to a lower prospect of profitability and so results in less clean innovation. PULL policies target this market failure by stimulating market demand. The three key policy tools that can do this are: pollution pricing, environmental regulation, and green government procurement. If they signal growing demand over the long term, that will pull in investors and customers.

Designed well, PULL policies also need to provide certainty. But if there is doubt about the longevity of given environmental regulations, pricing, or procurement policies, it will have the opposite effect.

Figure 15: PULL Policies and Clean Innovation



4.1 Setting the Stage with Well-designed Environmental Policies

The primary aim of environmental policies like pricing, regulation, and procurement is to solve an environmental problem. However, these policies can be doubly important if they also incentivize clean innovation. And in a virtuous circle, new clean innovation can bring down the costs of achieving current and future environmental objectives while also creating competitive advantages.

In essence, environmental policies should be aimed at meeting climate and other environmental targets at lowest cost while simultaneously helping Canada's economy gain a competitive edge in a global clean marketplace.

Without exception, the experts interviewed for this report indicated that environmental policies are a critically important driver for clean innovation. However, there remain gaps in environmental policy, despite recent action, and existing laws were often not designed with innovation in mind. In particular, Canada's federal and provincial governments have committed to bring in a slate of ambitious climate policies over the next few years – from carbon pricing, to clean fuels, to zero emission vehicles and more. It is critical that these new laws not only meet our climate goals, but also promote clean innovation – to achieve both environmental and economic success.

Fortunately, there is now a large body of real-world experience to guide environmental policy, with an increasing number of studies showing how to design policies so that they support both environmental outcomes and innovation. The OECD has done perhaps the most extensive research on this topic, looking at countries around the world and finding that design plays a major role in the effectiveness of policies to spur innovation. They look at five key features of environmental policies: stringency, flexibility, predictability, incidence and depth. They find that environmental policies that drive innovation share key features. We focus on three: **stringency, flexibility, and predictability**.* [167]

Box 14: The Porter Hypothesis [166]

In 1991, Harvard Business School professor Michael Porter, a world-respected competitiveness expert, challenged the conventional wisdom that environmental regulation always reduces business profitability. He suggested that well designed regulations need not hurt competitiveness and may even help it, for example helping firms identify eco-inefficiencies, trigger innovation, or overcome organizational inertia. The "Porter Hypothesis" has since spawned hundreds of studies, which generally show there is real-world truth behind Porter's theory, though it appears to hold particularly true for flexible policies.

Stringency

Stringency refers to how strict a policy is, and can be thought of as how much change the policy induces. For example, policies that put a higher price on pollution, or require greater emission reductions are more stringent. More formally, the OECD defines stringency as "the policy-induced cost of polluting."[168]

When policies are less stringent, they are more likely to lead to firms meeting them through small, marginal changes in their practices. However, stringent, world-class environmental standards are much more likely to encourage innovation, as firms seek new ways to minimize the cost of meeting significant new requirements, particularly when companies have an expectation of continued future stringency.

Stringent policies can spur innovation to reduce industry costs while at the same time facilitating access to global markets. This is true of individual policies, as well as of overall policy regimes. Table 1 shows that, overall, countries that have the highest level of environmental performance tend to be among the most globally competitive.[169]

Table 1: Stringent Environmental Policy Correlates with Competitiveness

Country	World Economic Forum Global Competitiveness Index Ranking (2014-2015)	Global Competitiveness Index Environmental Performance Ranking (2014-2015)†
Switzerland	1	1
Finland	4	9
Germany	5	8
Netherlands	8	11
Sweden	10	7
Norway	11	3
Denmark	13	12
Canada	**15**	**19**

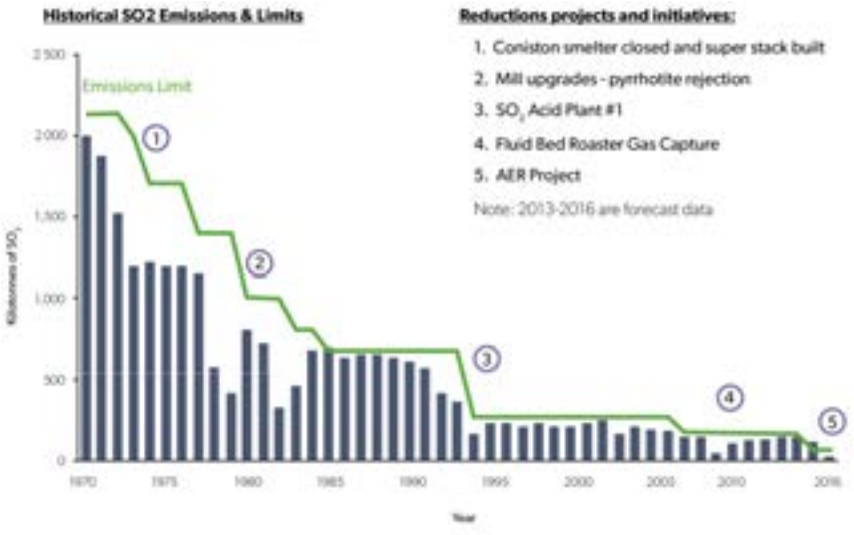
There are many examples of cases where stringent environmental laws have resulted in impressive clean innovation. In Ontario, stringent drinking water quality laws brought in after the Walkerton crisis, are driving innovation and helping create world-class water technology expertise in the province – now home to more than 900 water technology companies.[170] In Nova Scotia, bold waste diversion targets have helped the province beat all others to achieve the lowest amount of annual waste generated per capita (386 kg), [171] and fostered the emergence of new firms like Sustane Technologies that aims to convert

* The OECD also includes 2 other characteristics, incidence (i.e. does the policy target directly the externality, or is the point of incidence a proxy for the pollutant?) and depth (i.e. are there incentives to innovate throughout the range of potential objectives (down to zero emissions?).
† While the GCI has been updated to the 2016-2017 version, 2014-2015 was the most recent year where the Environmental Performance Ranking was included.

waste into clean-burning fuels and recyclable materials, with a demonstration plant under construction in Chester, Nova Scotia.[172]

A well-known historical example is the stringent regulations enacted by Ontario beginning in the 1970s to combat acid rain. The regulations affected a nickel smelter in Sudbury, Ontario owned by Canadian mining company INCO (now owned by Brazilian mining giant, Vale). INCO's Sudbury nickel smelter was one of the world's biggest point sources of sulphur dioxide (SO_2) emissions. With a control order imposed by the Government of Ontario, and increasingly stringent targets set over the following decades, INCO was forced to innovate. And it did so successfully, ultimately reducing SO_2 emissions by 90% while also reducing plant costs by $70 million per year and finding markets for its new waste by-products.[173]

Figure 16: Stringent SO_2 Regulations in Ontario and Resulting Clean Innovation[174]



Japan's Top Runner program has also proven an effective model for encouraging best-in-class energy efficiency, it sets progressively stringent targets for energy-intensive products – continually adjusting to keep pace with state-of-the-art technology – and gives companies that exceed the targets a Top Runner label at the point of sale. This drives companies to innovate and compete for the award of 'Top Runner' as well as disincentivizing laggards through the threat of bad publicity.[175]

By design, stringency induces change. The OECD has studied the stringency of environmental policy in detail and found that, at the level of country, sector and firm, more stringent environmental policy generally has neutral or positive effect on productivity. At the sector level, a tightening of environmental policy is associated with an increase in sector-level productivity growth for the most technologically advanced country-industry pairs. At the firm level, those firms already technologically-advanced show an increase in productivity, while the least productive firms, see a negative impact on their productivity.[176] This suggests that stringent policy induces disruption, with those that start from positions of lower productivity and/or technology adoption being the least resilient and least able to benefit, while globally competitive, productive firms can benefit the most.*

Flexibility

Traditionally, environmental policies prescribed specific technologies or processes to achieve environmental goals, such as mandating that a particular scrubber be installed on a smoke stack or that one material be replaced with another.† While this approach is simple and encourages compliance, it typically does so at a higher overall cost and with limited innovation, because it requires all firms to adopt the same solution. Moreover, if the

* For a look at how forecast costs of environmental regulation are often significantly larger than realized costs, see Smart Prosperity Institute's Green Tape Measures Up

† These approaches are simple and can provide strong incentive to innovate – or at least to adopt leading technology – particularly when they are stringent. However, technology-specific regulations may fail to provide an on-going incentive to innovate. Solutions include converting them to an equivalent performance standard and ensuring the standard rises in stringency over time.
Johnstone, Hašcic, I, and Kalamova, M. (2010) Environmental Policy Characteristics and Technological Innovation, *Economia Politica, 27*(2):277-302.

Box 15: Flexibility in Low-carbon Fuel Policy[177]

Fuel blending requirements came into vogue in the late 2000's, requiring a certain content level (%) of renewable fuels (biofuels) in diesel and gasoline. These policies aimed to reduce GHG emissions as well as support a nascent biofuels sectors by favouring a specific technological solution.

Since then renewable fuel policy has evolved, with BC along with California, Oregon, and the European Union instituting Low Carbon Fuel Standards (LCFS). An LCFS is a flexible regulation that specifies mandatory reductions in the GHG intensity of fuels but allows that reduction to be met with a variety of innovative technologies including biofuels, EV charging infrastructure, hydrogen, or propane. It also allows trading of credits between firms allowing reductions to be made at the lowest cost. This flexibility allows the policy to support innovative solutions that can reduce the GHG intensity of fuels, without 'picking a winner'.

The Governments of Ontario and Canada are both developing versions of this policy, with Ontario targeting only gasoline and Canada looking to extend the policy beyond transportation fuels to include fuels used in buildings and industry, in hopes of reducing GHG emissions by 30MT annually by 2030.

standards are not regularly adjusted it provides less incentive to keep innovating.[178] In contrast, policies that set stringent environmental targets but allow businesses flexibility in how to meet those targets create an incentive to innovate, because they promote creativity in finding the least-cost method of compliance.*

Pollution pricing – such as a carbon price or charges for municipal waste – is the prime example of a flexible policy. By putting a price on pollution, firms have an incentive to find new ways to reduce their impact as much as possible because there is a financial reward for doing so; new innovations that reduce more emissions at lower cost are valuable.[179] As Nobel-winning economist Milton Friedman famously said, "I would like to tax those activities that create pollution, but we are going about it in a very foolish and unwise fashion. We are going about it by trying to regulate the equipment which people use, and that's a very bad way to do it. Far better to impose an effluent tax,† and then leave it to the ingenuity of people to minimize the cost."[180]

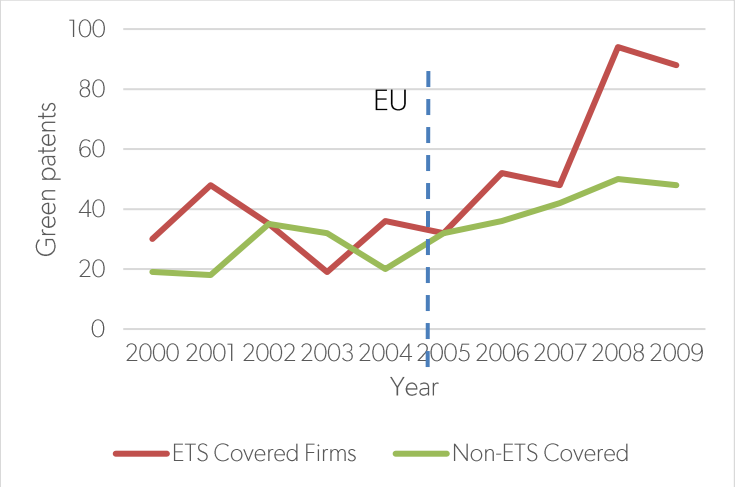
Environmental regulations and standards, which often complement or support pricing, should also be flexible, or non-prescriptive, whenever possible by prescribing the performance outcome, rather than the process or technology to achieve it.‡ Increasingly, environmental regulations are moving this way. For example, air pollution standards for new cars and light-duty trucks allow manufacturers to decide what vehicle and technology mix to use in order to meet the standard across their entire fleet of vehicles.[181]

Another example is the introduction of regulations to address acid rain in the US. As emissions were regulated with increasingly tighter limits from the late 1970's onwards, US patents in this area grew.[182] These early regulations, which included modest flexibility mechanisms (such as 'bubbles' or offsets), were followed by the introduction of the world's first large-scale emission trading system in 1990, which led to a new wave of technology diffusion and innovation, and helped achieve SO_2 reductions at a significantly lower cost than anticipated.[183] All while also creating profit opportunities for clean innovators.

* It is of course possible to convert technology standards into performance-based regulations, in order to encourage firms to innovate beyond a minimum requirement.
† While Friedman uses the word "tax," his observation holds true for all pricing mechanisms, including—for example—cap and trade systems.
‡ In cases where the objective is to eliminate a certain type of pollution or toxin completely, pricing is not the best option; regulations or standards are required. For example, eliminating lead content from paint or mercury from consumer goods requires regulation because even small amounts of these toxics pose a significant public risk.

More recently, Figure 17 shows the impact of the EU's emissions trading system on low-carbon innovations and reveals a big uptick in clean innovation patents after the introduction of the system.[184] (The control group refers to firms not covered by the EU-ETS that were matched with similar firms covered by the EU-ETS in the same country and sector.) Importantly, Taylor shows that cap-and-trade regimes can serve to dampen innovation if the price stays too low or does not ramp up over time[185] – underscoring the need for stringency, flexibility and predictability to go together.

Figure 17: The EU Emissions Trading Regime and Low-carbon innovation



Box 16: Rewarding Environmental Performance

Most products and services are not economically rewarded for their environmental performance. Recent years have seen a rise in products advertising their environmental credentials as a way to differentiate themselves from their competitors, in some cases allowing them to charge a price premium or access new markets. One of best-known examples is the Forest Stewardship Council (FSC). Founded in Toronto in 1993, FSC has grown globally and now certifies almost 200 million hectares worldwide and represents roughly 10% of global forest-based trade.[186]

Predictability

Well-designed environmental policies can help to draw in much-needed private capital to invest in clean innovation. To achieve this, one of the most important things governments can do is give as much *certainty* as possible that there will be a trajectory of increasing policy stringency over several years. This message came out time and time again in our interviews with investors and companies.

Clean technology inventions often require 10 years or more – for testing and scale up – before they can expect to reach the market and make a profit.[187] That means potential investors need confidence in the market demand for these innovations into the next decade, at least. Because government actions are the main drivers of the clean innovation market (at least initially), government has the unique ability to shape and provide a level of certainty for future demand. Environmental policies that chart out a predictable path for increasing levels of stringency can significantly reduce the "policy risk" that chills investment in clean innovation.

Of these three criteria for innovation-boosting policies, predictability is the one that is least understood and least practiced, and where potential for improvement is greatest.

Creating future policy predictability is challenging for governments, as they cannot bind their successors. However, there are some things they can do to create future policy trajectories that, while not fully certain, are at least more likely to endure. Political scientists call this creating policy "stickiness".[188] This can be done in different ways, such as:

- **Setting a "default schedule" for future increases in stringency**. If the initial regulation sets a presumed trajectory – and businesses and investors have relied on it – it will be harder for future

governments to deviate significantly from that path. The longer the time period the better for reducing policy risk.

- **Specifying in law the criteria for adjusting future policy levels.** Predictability does not necessarily mean certainty; specifying the criteria, indicators, and schedule policymakers will use for evaluating and adjusting policy can allow firms to evaluate risk and make informed investment decisions, similar to the transparency around the factors that influence the Bank of Canada's interest rate adjustments.

Figure 18: The Importance of Predictability in US Wind Energy Policy[189]

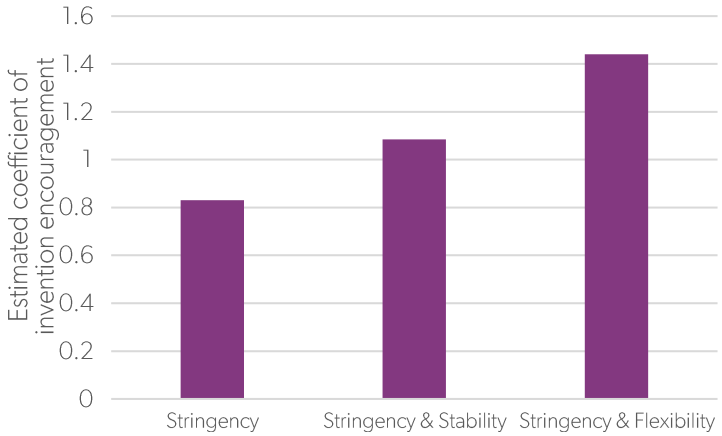
Creating "stickiness" through approaches like these takes effort, but it is key to advancing clean innovation in the most cost-effective way. If governments fail to provide the policy predictability that will draw in private investment, they may instead need to increase levels of public spending and subsidies to make up the difference. Better policy predictability means more private investment and less government spending to support clean innovation.

Predictability of support programs has been critical to US wind energy installations. Drawing on historical data, Figure 18 illustrates how new wind energy capacity dropped off in every year that the US government allowed the production tax credit to expire (in 2000, 2002, 2004, and 2013), and picked up again when it was put back in place.[190] And when the government locked in the tax credit for an 8 year period, from 2005-2012, it led to increased investment over that time (with the exception of the global economic slowdown in 2010-11).

Combining Stringency, Flexibility and Predictability in Carbon Pricing

Environmental policies are most effective at driving innovation when they combine stringency, flexibility, and predictability, as Figure 19 below shows. A well-designed carbon price – achieved either through a tax or emissions trading system – is a perfect example of how this can be done. Carbon prices are flexible by nature. They internalize the cost of carbon, providing a market incentive for firms to find the best and least-expensive ways to reduce emissions. The more stringent the policy (i.e. the higher the price and the wider the coverage), the greater the impetus for firms

Figure 19: Effect of Environmental Policy Characteristics on Innovation[191]



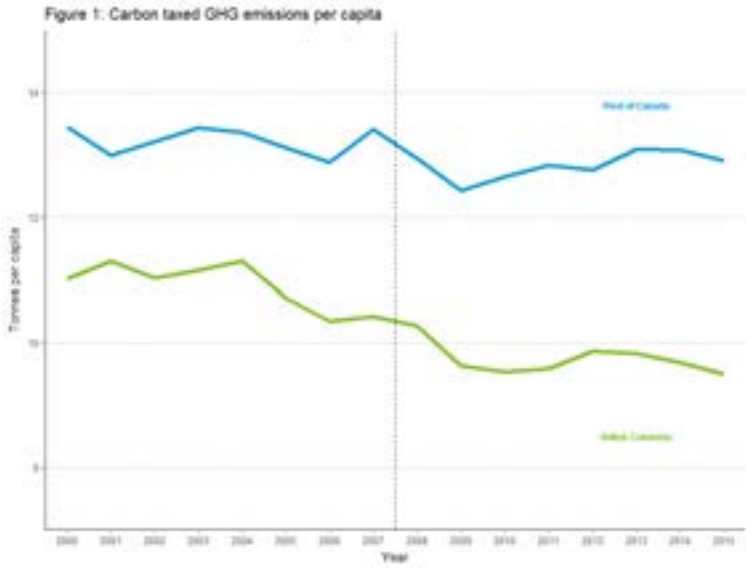
This figure, originally produced by the OECD, shows the estimated coefficient of invention encouragement, representing the likelihood of patenting innovative means of air and water pollution abatement and solid waste management from different combination

to act and to innovate. However, introducing the pricing system at a high price may not allow firms and entrepreneurs the time needed to invent and implement solutions to reduce both carbon and costs. The solution is to create a predictable policy trajectory, whereby carbon prices rise over time, starting at a modest level and ramping up predictably.

British Columbia did this with its carbon price: ramping up steadily from $10 to $30/tonne on a 5-year schedule. This predictability – combined with the flexibility of a price – has been cited as one reason why BC's tax has achieved greater emissions reductions than expected (and more than the rest of Canada). Over the period 2008-2015 GHG emissions per capita fell by more than 7% while GDP per capita grew by more than 6% – outpacing the rest of Canada on both counts.[192] The predictable ramp up sent a signal that motivated firms and households to make investments to lower their carbon footprints, in anticipation of rising future prices. The federal government's proposed carbon pricing backstop will do the same, with a 5-year ramp up from $10-$50/tonne.

By contrast, the EU's emission trading system is a prime example of the perils of failing to provide predictability. The EU carbon price has fluctuated wildly over its 11 year history – from around 30 Euros/tonne down to near zero, due in part to policy changes between phases – with a generally falling price trajectory over that time (see Figure 21). This lack of predictability (and insufficient stringency)* has hampered long-term investment in carbon reducing technologies and innovation because of uncertainty about future returns. †

Figure 20: British Columbia's Carbon Tax: Emissions fall, while the economy remains strong[193]



*British Columbia's carbon tax prescribed an initial 5-year ramp-up in prices. This has been cited as one reason the policy has achieved greater-than-expected reductions (on the order of 5-15% of emissions) without harming the economy.**

While the BC (and proposed federal) approach is a good example of smart policy design, one limitation is that it only provided predictability for 5 years. After that time, the price stalled at $30/tonne for 5 years (although recent commitments from the BC government promise to change that). A 5-year price trajectory, while helpful, provides only limited predictability for those making investments in low-carbon technology and equipment, which often has a payback period of 10+ years and a lifespan of decades.

While providing policy certainty beyond a government's 4-5 year mandate is inherently difficult, there are things that could be done to at least reduce the longer-term risk, and tilt the scales in favour of greater predictability.

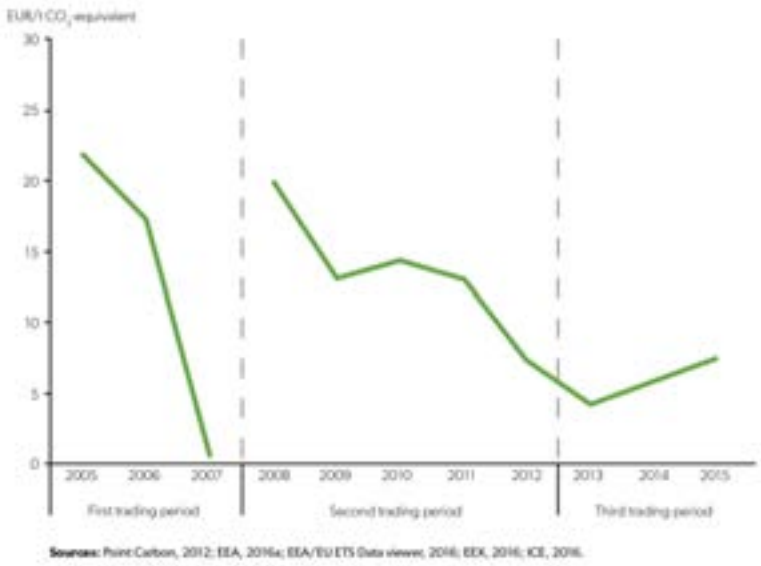
For example, the initial 5-year price schedule could be combined with a default schedule for years 6-10 (or beyond), with a review process built in after 5 years to allow for recalibration. This review process could include an independent, expert advisory

* Of note, sometimes these policy characteristics can work against each other. For example, by improving predictability of the EU ETS with longer-term planning of future caps, when the price crashed following the 2008 financial crisis policymakers were did not have the flexibility to reduce the cap, without undoing the policy predictability.
† Of interest, Figure 17 shows a rise in EU patents for low carbon technologies in 2006 and 2008, the years when EU ETS prices were high, and a plateau or decline in patenting in 2007 and 2009, when ETS prices fell.

group, and set out pre-defined criteria for the review and recalibration, which would enhance the predictability of the future price trajectory.

Designed this way, carbon pricing would come with little short-term shock to the economy yet it would create the expectation of longer-term rising stringency in order to drive investment in clean innovation from the outset. Further, the need for high public financing to boost low-carbon solutions would decline over time as the market takes over and provides both more demand and more investment. In other words, **it is much less expensive for governments to use smart environmental policies (with stringency, flexibility and predictability, rather than ongoing high public spending, to overcome market failures and stimulate clean innovation demand – and much more effective too**.[194] Figure 22, provides an illustration of this trade-off.

Figure 21: Emissions Prices in the EU ETS, 2005-2015



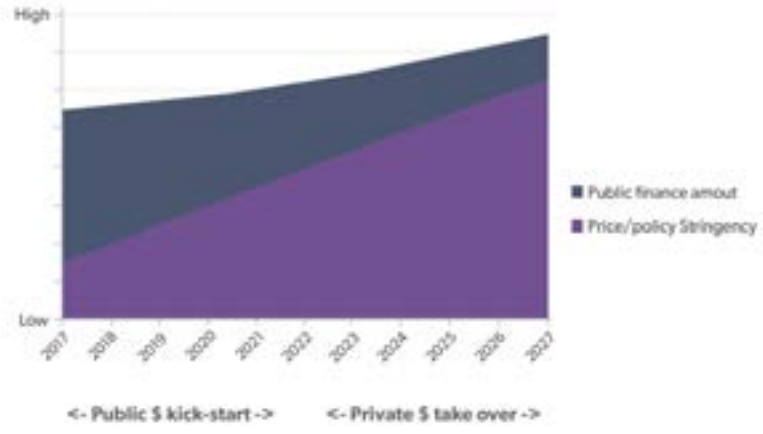
Sources: Point Carbon, 2012; EEA, 2016a; EEA/EU ETS Data viewer, 2016; EEX, 2016; ICE, 2016.

These lessons apply not just to carbon pricing but to all types of environmental policy. For example, building codes or appliance standards can build in flexibility (e.g. via performance standards rather than prescribed technologies), and as much increasing, predictable stringency as possible (e.g. through ramp-up schedules, or ratcheting-up mechanisms like Japan's 'Top-Runner' approach, described above).

The example of wind installations in the US shows how predictability and stringency matter for an individual policy, however it also matters for higher-level policy direction. The UK provides a real-world example that shows how high-level policy goals that include stringency and predictability can be set (see Box 17).

The main PULL policies at a government's command are generally those that can stimulate domestic markets rather than export markets. While nurturing export markets and seizing export opportunities is critical to the success of Canadian clean innovation, domestic market demand plays an important role. Having a strong domestic market for Canadian solutions was cited by a large number of this report's interviewees as fundamental for developing and demonstrating Canadian clean technologies' credibility and readiness to potential export markets. Empirical evidence backs up this interview finding: looking at PULL policies for wind energy in OECD countries, Dechezleprêtre and Glachant find that while export markets are far larger in size, the effect of domestic policies on innovation, as measured by patents, is 12 times greater.[195]

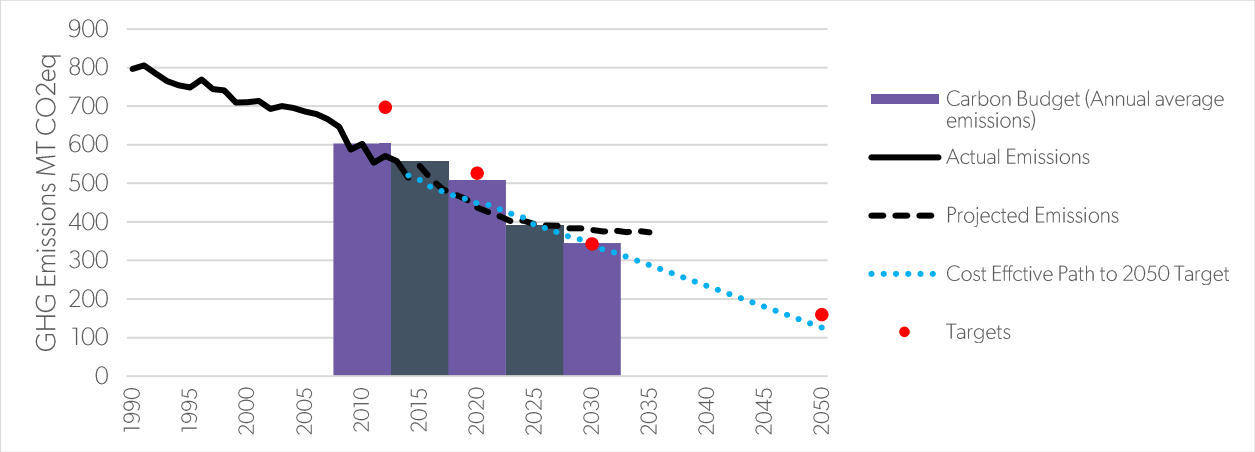
Figure 22: Government Finance vs. Policy Stringency



Box 17: The United Kingdom's Carbon Budgets

In 2008, the UK Government set a precedent by establishing the world's first legislated climate change target, to reduce GHG emissions 80% below 1990 levels by 2050.[196] The Climate Change Act (2008) established the Committee on Climate Change, an independent body of experts mandated to report on progress toward achieving GHG reduction targets annually and provide recommendations for policies to achieve future targets and policies.[197] The Act also calls for legally binding carbon budgets for rolling five-year periods set 10 years in advance. The fifth carbon budget for 2028-2032 was set in June 2016 and included a target reduction of 57% below 1990 levels by 2030, as shown in Figure 23. [198,199] The UK has continued to increase stringency with its commitment to the Paris Agreement (2015), and with a target of net-zero carbon emissions by 2050 enshrined in law.[200] Despite recent political changes in the UK, these targets seem to have political traction; the new government of Theresa May supported maintaining the current schedule of carbon budgets.[201] And the recent plan to require zero emission cars by 2040 is a good example of policy stringency, predictability and flexibility.

Figure 23: United Kingdom GHG Emissions



Sticks and Carrots

Stringent environmental standards drive innovation, but they can also increase costs for businesses and households, at least in the short-term. (Over time, the innovation and efficiency gains can reduce those costs, and ultimately provide market advantages.*) There are a variety of incentive-based tools that governments can use to complement stringent environmental policies – ones that minimize costs, maintain competitiveness, and support the transition to a cleaner economy. † These include:

* There is often a 'lag effect' of several years before the innovation and efficiency gains from stringent environment standards offset the increased costs and lead to overall productivity gains (although each policy and industry is different). Incentives can help firms stay competitive through this transition period.
Ambec, S., Cohen, M. A., Elgie, S. and Lanoie, P. (2013) The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness? *Review of Environmental Economics and Policy*.
Lanoie, P., Patry, M., and Lajeunesse, R. (2008) Environmental Regulation and Productivity: New findings on the Porter Hypothesis, *Journal of Productivity Analysis, 30*:121-8.
† At the same time, it is important that policies to support incumbent firms adjust to new regulation don't unfairly exacerbate market entry barriers to new firms. This can be the case with vintage differentiated regulations (also commonly known as 'grandfathering') that set different standards for existing and new facilities. For more see: Kozuk, T. and Johnstone, N. (2017)

- **Recycling revenues from environmental pricing:** Revenue recycling can reduce or eliminate the net cost to businesses and households: For example, BC's carbon tax legally required that all carbon revenues be matched by other types of personal or corporate *tax cuts*.* Alternatively, Ontario, Quebec, and Alberta use their carbon price revenues to provide a variety of low carbon *incentives* to households and firms (for energy efficiency, clean technology, public transit, etc.)†
- **Designing policies to minimize total cost**: Flexible policies minimize compliance costs. Another option to further reduce costs, while maintaining effectiveness, is to design a pollution pricing system so it applies only to 'marginal' emissions, not all emissions. For example, the carbon cap & trade systems in Ontario and Quebec require most emitters to pay for only a small percentage of their total emissions. Alberta uses a similar approach for large emitters, requiring firms to pay only for emissions that exceed a performance benchmark. These features reduce firms' total compliance costs (often by 90% or more), while keeping the economic incentive to reduce across all their emissions.
- **Tax incentives** or subsidies are another way to promote pollution reduction and clean innovation. Whereas an environmental price or standard adds to a company's costs (at least initially), an incentive reduces their costs. So incentives can be an effective tool to maintain cost competitiveness as firms and households transition to cleaner technologies and practices, in response to strong environmental prices or standards. For example, **accelerated capital cost allowance** can be used to reduce the costs for firms to invest in adopting low carbon technologies (as Canada currently does for a limited number of clean technologies).[202] Alternatively, an **investor tax credit** (as Alberta and B.C. currently have) could be used to support and expand investment in growing clean technology companies.[203] Any type of environmental incentive or subsidy program needs to be carefully designed to ensure it is cost effective, transitional, and encourages firms or investors to go beyond what they normally would have done.[204]

In summary, accelerating clean innovation requires that governments **implement well-designed environmental policies, including pollution pricing, incentives, and regulations** that are as **flexible, stringent, and predictable** as possible.

- Price-based policies should be the preferred tool, wherever feasible. They should be complemented by regulations and other complementary measures as needed, in order to allow flexibility to try innovative approaches.[205]
- Canada should set world-class environmental standards, paired with complementary measures and incentives to strengthen both environmental and economic performance.
- These environmental prices and policies should be designed to ramp-up in stringency over 10 years or more, with as much predictability as possible to draw in private investors to support clean innovation (and lessen the need for public spending over time).

4.2 Removing Regulatory Barriers to Clean Innovation

While it is critical to design policies to *promote* clean innovation, it is also important to avoid designing policies or rules that *impede* innovation. Regulatory systems – both environmental and other - can often, unintentionally, discourage innovative approaches and practices. Rigid compliance rules can discourage innovative approaches that could offer longer-term environmental benefits. Or prescriptive public procurement regimes, focused on

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Vintage Differentiated Regulations and Plant Survival: Evidence from Coal-Fired Power Plants in the OECD, *OECD ENV/EPOC/WPIEEP(2017)1.*

* In practice, those income tax cuts have exceeded the carbon tax revenues, meaning taxpayers have come out ahead. The new Government of BC has indicated that, as the carbon price rises, revenues will be used to provide low carbon incentives as well as tax cuts.
Elgie, S. and McClay (2013) BC's Carbon Tax Shift is Working Well After Four Years, *Canadian Public Policy 39*(2):S1-S10.

† For more see Ecosfical Commission (2016) Choose Wisely: Options and Trade-offs in Recycling Carbon Pricing Revenues

lowest short-term cost, can impede solutions that might have lower costs (and environmental impact) in the longer run (we discuss procurement on in Section 4.3). Budget 2018 announced funding aimed at modernizing Canada's regulatory frameworks to support innovation, including targeted reviews, international regulatory cooperation, and developing an e-regulatory system.[206]

Our interviews mentioned some environmental rules, as well as interprovincial trade restrictions, IP regime limitations, and other regulatory regimes that impede the use of new technologies and practices.* Rules can compound one another; their interactions and aggregate impact are ultimately what matter. Rectifying inefficiencies is important - a shorter regulatory process, all else equal, is a competitive advantage.

Canada can learn from experiences in other countries finding ways to reduce regulatory impediments to innovation, without sacrificing policy objectives, such as:

- **The Netherlands Front-runner Desk**: A "frontrunner desk" was created as part of the Netherlands' energy transition 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. In its first three years 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.[207] (The new federal Clean Growth Hub could potentially play a similar role.)
- **The UK Regulatory Sandbox**[208]: Part of the UK's regulator of financial authorities, the regulatory sandbox "aims to create a 'safe space' in which businesses can test innovative products, services, business models and delivery mechanisms in a live environment without immediately incurring all the normal regulatory consequences of engaging in the activity in question." It focuses on promoting and supporting new financial technologies and helps position the UK as an attractive market for emerging technology companies. The same approach could be used to develop nimble regulatory regimes for innovative clean technologies.

Rigid environmental compliance rules also can discourage innovation. For example, imagine a firm has two choices for meeting an environmental requirement: (a) a promising new technology that could cut emissions in half and reduce costs, with a 70% chance of success; or (b) an existing technology that is almost certain to meet the emission target, but do no better, and at higher cost. Under normal compliance rules, most firms would choose option (b), in order to avoid the 30% risk of non-compliance, with its heavy penalties and stigma of a conviction. But this will discourage (or at least delay) the adoption of a new technology that could result in much better environmental and economic outcomes.

Innovation is about risk (and reward), and normal compliance rules discourage risk. And often for good reason. They are meant to ensure acceptable levels of health and environmental quality. But there are often other ways to achieve those environmental objectives and also encourage clean innovation and risk-taking. For example, compliance rules that permit emissions trading or offsets allow firms to experiment with new, lower cost technologies, and have the fallback of buying credits for compliance if the technology fails. Alternatively, compliance rules might enable firms to enter into compliance agreements that impose better-than-required emission levels over a 5-year period, but with some flexibility about meeting annual targets – to give a firm time to apply and refine a new technology, and work out the bugs. (This is best done on a limited scale initially, in ecosystems that can tolerate some short-term variance in annual pollution levels.)

* One interviewee noted that a cleantech solution existed in one province and had a welcome application in another province, but required dozens of permits – and delays – simply to be transported across provincial boundaries.

4.3 Public Procurement

In addition to their regulatory powers, governments also have tremendous market power as buyers to help direct Canada's economy towards clean innovation.* After households, governments are the largest final consumers of goods and services in Canada, and the second largest spender on capital (after oil, gas and mining).[209] In 2015, governments in Canada spent over $230 billion on goods, services and infrastructure.[210] Provincial and municipal governments account for over 85% of that total.[211] And approximately half of the experts interviewed for this report mentioned public procurement as an important lever to accelerate Canadian clean innovation – and one where Canada lags behind other nations.

This is particularly important for innovations where public procurement can help overcome market barriers that prevent uptake by the private sector – for example when economies of scale from a large government purchase can lower the price of the innovation to the public, or by serving as a first commercial demonstration for a promising new technology, providing the confidence private investors require.

Governments can use this market power to drive clean innovation in two main ways:

- **Leading by example**: governments can drive down the environmental footprint of their own operations, to set the pace for Canada's transition to a clean economy while simultaneously helping to address the environmental externality market failure by bolstering demand for clean innovations; and
- **Boosting Canadian innovators**: governments can be a test-bed and showcase for Canadian clean technologies, spurring private investment and exports.

Leading by example

Putting a price on pollution is an effective way to encourage clean innovation across governments, for all the same reasons that it works with the private sector – it creates an incentive that influences countless daily decisions across organizations. However, government can catalyze even further pollution reductions because its own building and fleets operations have significant environmental impact and it is a large consumer of Canada's goods and services. Taking carbon emissions reductions as an example,[212] there are two different approaches governments can use:

First, governments could impose their own internal carbon tax/fee on direct or indirect emissions (net of any provincial carbon prices), reinvesting revenues within government or creating an incentive fund for low-carbon innovation. An internal baseline-and-credit system could be used to reward departments that reduce more.

Alternatively, governments could commit to carbon-neutrality, using carbon credits from projects external to government to offset emissions (with a robust monitoring and verification regime). **Since committing to carbon-neutrality, the Government of BC has reduced emissions by 54,000 tonnes below 2010 levels as of 2016** (see Box 18)**.[213] It also has created a growing offset market, contributing $372.5 million to provincial GDP and 4,500 person-years of employment between 2008 and 2014**.[214] Following B.C.'s lead, the Government of Ontario aims to achieve carbon-neutrality in 2018 and the Yukon Government has set a target of 2020.[215]

Both of these systems price carbon; the main difference is whether the revenues are reinvested within government (under a tax/fee) or flow to external offset projects (under carbon neutrality).

* For a recent report on public procurement in Canada see: Clean Energy Canada (2017) The Power of Procurement –How governments can drive clean growth, cut carbon and create jobs, *Clean Energy Canada.*

In both approaches, the importance of setting an ambitious price on carbon cannot be understated. The Government of Canada estimates the social cost of carbon to be more than $40, rising to more than $54 in 2030 and nearly $75 in 2050.[216] If governments were to apply this price to all of their operations and decisions, it would help drive clean innovation significantly, creating a huge incentive to test out ever more advanced carbon-reducing technologies. It is particularly important to apply a rising price on carbon over time when estimating the lifecycle costs of new assets. This way, when investing in long-lasting assets, like a building, power system or highway, governments will be encouraged to make far-sighted choices that prepare Canada for a low-carbon future, and ultimately saving money over time.

For example, in 2016 the federal government announced The Centre for Greening Government to be housed within the Treasury Board that will centrally track and coordinate progress toward government targets such as using 100% renewable electricity in its buildings and operations by 2025.[217] The federal government has set a more ambitious GHG reduction target than the country as a whole, aiming for a 40% reduction below 2005 emissions levels by 2030, and an 80% reduction by 2050.[218]

The more broadly government applies these actions – to contracts, leases, and indirect impacts embodied in purchased goods and services – the greater the potential environmental and innovation results.

Box 18: Carbon Offsets: BC's approach – and how it is stimulating a First Nations-led conservation economy

British Columbia uses a unique approach to reduce emissions from government operations– one that bolsters private and Indigenous innovation. BC's carbon neutrality commitment requires that public sector entities must buy offsets for the emissions they generate at $25/tonne – in addition to the existing $30/tonne carbon tax on all goods and services. This has created new demand for low-carbon technologies across the BC public sector as departments seek to reduce their carbon costs, such as the installation of an innovative bioenergy plant at UNBC that has reduced annual fossil fuel consumption by 72% and emissions by 3,700 tonnes.[219]

This has created a valuable new market in carbon-offsets, stimulating innovation and local economies. First Nations communities, in particular, have risen to meet this new demand, supplying many of the offsets the BC government requires. The source of these offsets: innovative, First Nations-led forest stewardship efforts such as the Great Bear Forest Carbon Project. The initiative converts forests previously scheduled for logging into protected forests that sequester more carbon, restores and reforests previously logged forests, and protects the broader ecosystem as well as culturally important sites. The revenue supports the development of a Coastal First Nations conservation-based economy, creating local jobs and opportunity while generating significant environmental value.[220]

"[I]nvesting in carbon is having a positive impact on the provincial economy. As well as being involved in a forest carbon project that allows us to take care of our lands, it also enables Coastal First Nations communities to invest in sustainable business opportunities." –Art Sterritt, Executive Director, Coastal First Nations.[221]

As governments adopt advanced clean technologies, and cleaner goods and services, it will build markets, grow Canadian capacity (including in the clean service sector), enable learning within the private sector, and support a broader cultural shift among Canadian consumers. What's more, these types of efforts provide evidence that large institutions can successfully transition to low- carbon operations.

Boosting Canadian Innovators

As the country's largest buyer, governments can play a key role as early adopters of Canadian clean technologies. By serving as a test-bed for the development of promising new technologies and/or providing the initial contract

for new technologies, governments can play an important role in attracting private investment and opening export markets.

In our interviews, clean technology entrepreneurs frequently emphasized that governments in the U.S. and other countries are better at doing this than Canadian governments. Improving access to government procurement is seen as an important way to boost the development of Canadian clean technologies.* By pointing to a successfully-performed Canadian government contract, emerging companies gain a track record and credibility that are important for future sales, particularly export sales.

There are a number of approaches governments could use to do this. They could:

- **Require a percentage of procurement spending be directed to Canadian cleantech research and/or demonstration of technologies**. The US has the Small Business Innovation Research (SBIR) program that encourages domestic small businesses to engage in Federal Research and Development that has the potential for commercialization. SBIR has proven successful in the US, and since been adapted to the procurement activities of many other governments (including Japan, the UK, and the Netherlands),[222] with participating firms demonstrating higher performance on measures of innovative, financial, and commercial success. [223] Canada recently launched a new procurement program called Innovative Solutions Canada modelled on the US SBIR, where participating agencies set aside at least 1% of procurement and R&D funding to support Canadian SMEs with early stage R&D and procurement of late-stage prototypes that address government needs where commercially viable solutions are not yet available. This program has could help drive clean innovation in Canada if given a specific *clean* mandate.[224]
- **Create an incentive fund to support investments in unproven, riskier Canadian cleantech for use in their own operations**. . The Government of Canada has the Build in Canada Innovation Program,[225] which includes an environmental technologies component and which aims to be a "first contract" for technically proven but not yet commercial solutions. BCIP has been met with some enthusiasm from Canadian innovators. In its first year the program expected in the range of 100 proposals being submitted. It received 375. The average over the lifetime of the program to date has been 271 proposals per year. Looking at the Environment component alone, 351 proposals have been received since 2010 (about 22% of the total). In a similar vein, the Government of Ontario recently developed the Green Focus on Innovation and Technology (GreenFIT) strategy to support the demonstration of innovative green technologies for use in public sector facilities.[226]

- **Utilize Canadian centres of excellence and clusters of expertise on relevant clean technologies to help inform government investment and purchasing decisions**. These can draw on the existing network of government labs and public research institutes—such as the National Research Council and Natural Resources Canada labs, which already have expertise in energy and buildings, and funding institutions such as Sustainable Development Technology Canada (SDTC).

4.4 Building the infrastructure for the clean economy

Large parts of the economy are public. Energy, transportation, waste and water systems, for example, are mostly publicly owned and play a vital role in underpinning the overall economy.

Not only do infrastructure choices have immediate environmental impacts (through their construction footprint, for instance), but the choices made about these public infrastructure systems – what is built, how it is built – can

* It's critical to note that government procurement of clean Canadian technologies must comply with trade agreements, and equal treatment requirements, as is the case with other countries.

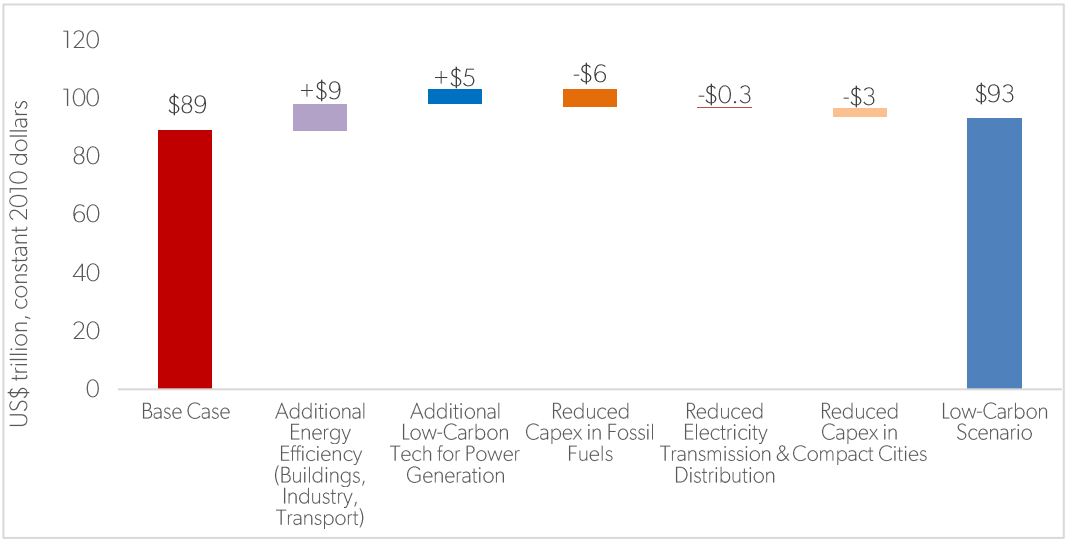
have a major influence on the direction of Canada's economy, either by driving it towards cleaner outcomes and supporting clean innovation or locking it in to unsustainable technologies.

One the most ambitious and impactful government actions would be to develop and implement **long-term low-carbon, resilient infrastructure planning that informs all public infrastructure decision-making**. To make far-sighted infrastructure choices today, governments need a strategy for what a low carbon economy will look like in the next 15 to 25 years. For example, what kinds of energy and transportation systems does Canada envision and aspire to? What infrastructure is needed to enable that vision? And how can we leverage emerging clean innovations to design construct, operate, and maintain that infrastructure?

A strategy could start to answer those questions, and in doing so, could both support the cleaner economy of the future in which climate adaptation and mitigation are critical objectives, while also driving innovative infrastructure systems and construction. The federal government has committed to make a once-in-a-generation investment in infrastructure over the next 11 years, including $21.9 billion for green infrastructure.

A clean growth infrastructure strategy is essential to ensure that governments are investing in the infrastructure for a 2030 clean economy, not a 2018 one. Such a strategy is needed not just at the federal level, but particularly at provincial and local levels, where approximately 85% of infrastructure spending occurs.[227]

Figure 24: Traditional vs. Low-carbon Infrastructure Investment Scenarios[228]



Modelling by New Climate Economy shows how infrastructure costs could differ between a business-as-usual scenario and a low-carbon scenario. While there are some additional costs to investing in sustainable infrastructure such as additional energy efficiency and low-carbon power generation, there are also cost savings in other places like reduced electricity transmission and distribution and reduced capex in fossil fuels and compact cities. This helps mitigate the premium to be paid up-front resulting in a slightly larger investment for the low-carbon infrastructure that will be needed to underpin the clean economy of the future.

Because provinces and municipalities ultimately make most infrastructure spending decisions, infrastructure agreements between different levels of government will play a critical role in aligning clean infrastructure efforts across Canada. The federal government could require such strategies as a condition of federal funding, or at least encourage them.[229] Where necessary, incremental funding may be required to put clean infrastructure decisions into practice. The Global Commission on the Economy and Climate estimates extra upfront costs of building low-carbon infrastructure of 5% between 2015 and 2030, though they note that lower operating costs could almost fully offset these upfront costs (see Figure 24).[230]

To complement and support a clean growth strategy, governments could **include environmental costs in infrastructure and capital spending** through lifecycle carbon costing. The carbon costs would rise over the asset's life, to reflect future prices, encouraging investment in disruptive innovations that lower the environmental footprint of infrastructure. Think, for example, of roads built with lower-carbon concrete or office towers redesigned with new energy retrofitting techniques. Even more important, lifecycle carbon costing should drive the systemic innovations—smart grids, clean energy powered transit, waste-to-energy systems—that will provide the platform for a future clean economy. This should apply to decisions made by all departments. It could also be incorporated into the mandate of the new Canada Infrastructure Bank that the federal government has recently announced. Other initiatives that could support this transition include:

- Creating pooling mechanisms to bundle small clean infrastructure projects to a scale where they can be "bankable" for large investors, and large enough to attract the development and application of clean innovations.
- Developing financial instruments to address any "green premium" perceived by infrastructure investors and proponents
- Creating a national centre of expertise on clean and green infrastructure procurement to help procurement managers identify and share knowledge, experience, and innovation opportunities across jurisdictions; and
- Adopting an approach that includes private sector capitalization for projects, and favours user-fees and other self-funding mechanisms to encourage greater resource efficiency on the part of users, and minimize ongoing financial pressures for project proponents.

A clean growth strategy and carbon costing are natural complements -- the strategy focuses on *what* we build, and tools like carbon costing determine *how* we build it. And these approaches are not limited to climate-related impacts; other environmental impacts can be considered as well through their counterpart tools, like natural capital accounting and natural asset management to value other aspects of the environment.*

Box 19: Federal Infrastructure Funding

Details were announced in Budget 2017 that show how infrastructure can support the implementation of the Pan-Canadian Framework on Clean Growth and Climate Change. The Government of Canada will invest $21.9 billion in green infrastructure, including initiatives that will support the implementation of the Framework. A series of national programs (in areas like smart grids, building codes, and infrastructure for a changing climate, among other) valued at $2.8 billion focus on climate mitigation and adaptation. However, there is still lots of work to be done to ensure infrastructure investment won't lock Canadians into a high-carbon future or result in stranded assets.[231]

Designing the right public infrastructure can bring innovation, economic and environmental benefits. This is an opportunity to give Canadian clean technologies a first application while at the same time creating growing export opportunities. The world will spend an estimated US$90 trillion on infrastructure between 2015 and 2030.[232] Canada already has existing strengths in infrastructure building and engineering. This includes expertise in many of the technologies needed for the transition to a cleaner economy, for example long-distance transmission lines, energy storage and the integration of renewables into a smart grid.

* For more information see Smart Prosperity Institute's report Natural Capital Measurement in Canada and our recent work with the Municipal Natural Assets Initiative.

By building advanced expertise in clean, low carbon infrastructure, Canadian firms can not only help build a cleaner, stronger Canada, but they can also tap into a massive, growing global market that offers tremendous potential for wealth and jobs.

In summary, building the infrastructure needed to support the transition to a low carbon economy requires that public investment be designed thoughtfully and with a long-term view. To accomplish this important objective, Canadian governments should:

- Ensure that infrastructure decisions are informed by clean growth strategies in order to build the infrastructure needed for a 2030 clean and climate-resilient economy; and
- Build these approaches into federal-provincial infrastructure funding agreements, with financial support.

Box 20: The Low Carbon Economy Fund[233]

The federal government announced $2 billion in 2016 for projects that will support the PCF to generate clean growth and reduce greenhouse gas emissions towards meeting or exceeding Canada's commitments under the Paris Agreement. This will include funding for provinces to implement cutting edge projects as well as $600 million for a Low Carbon Economy Challenge open to provinces, municipalities, Indigenous governments, and both private and not-for-profit businesses.

4.5 Summary of Policy Implications: PULL Policies

Getting PULL policies right – through ambitious and well-designed pricing, environmental regulation, and government market power – is fundamental to ensuring the clean innovation system achieve its full potential. The presence of strong market demand for clean innovation and the expectation that this demand will continue and grow, is what creates the incentive for researchers to invent new technologies, entrepreneurs to develop them, and investors to finance them.

There are six key implications for policymakers to accelerate clean innovation through PULL policies:

1. Enact *world-class environmental policies* to help stimulate market demand for clean innovation and unleash private initiative. These policies should be:
   - *Stringent* – to drive best-in-class performance across Canada's economy;
   - *Flexible* (market- or performance-based) – to promote innovative approaches; and
   - *Predictable* – to send long-term signals that de-risk clean technology investment.

   For example, a carbon price, or energy efficiency standard, that ramps up predictably over 10+ years, with a mid-term review based on set criteria.

2. Complement pricing and standards with *targeted environmental incentives*, where needed, to promote clean technology adoption and enhance competitiveness, such as accelerated capital cost allowance for clean technology.

3. Ensure environmental *compliance* rules enable innovative approaches; for example, a 'regulatory sandbox' that allows a flexible trial stage for innovative technologies, to promote learning-by-doing and nimbleness by firms and regulators

4. Review existing policies to identify and *reduce inadvertent impediments to clean innovation;* and create a government office to assist innovators who encounter unnecessary regulatory impediments (e.g. in clean growth hub), drawing on models like Netherlands' front-runner desk.

5. Lead by example, as Canada's largest purchaser, through *clean procurement policies* that drive environmental innovation, including:

- Imposing a substantial, rising carbon price on all procurement decisions, and including other environmental costs over time;
- Setting world-class environmental performance targets for buildings, energy efficiency, vehicle fleets, etc.; and
- Serving as a *test-bed and showcase for Canadian clean technologies*, through spending targets (e.g. 1-2%), supported by incentives and expertise (e.g. through the Innovative Solutions Canada program).

6. Invest in advanced infrastructure to support Canada's transition to a clean, resilient economy, including by:
    - Developing clean growth strategies to inform the infrastructure needed for a 2030 low carbon economy;
    - Factoring a substantial, life cycle carbon price into all infrastructure decisions (and adding other environmental costs over time); and
    - Build these approaches into federal-provincial infrastructure funding agreements and institutions (like the Infrastructure Bank).

5.0 GROW:
Policies that help ideas develop into profitable products and companies

5.0 GROW: Policies that help ideas develop into profitable products and companies

Lots of good ideas do not realize their commercial potential. While some stumble in the early stages of clean innovation for good reasons – such as hitting a technical dead-end – many good ideas that have the potential to become marketable environmental solutions falter between research and commercialization because of unfortunate and preventable market barriers. Chief among these barriers in the middle stages of the clean innovation system are capital intensity, long timelines for investment return, and the absence of a price reward for clean innovations.

GROW policies are ones that seek to fill this gap, helping entrepreneurs and firms secure the capital and business support required to turn their ideas into demonstration products and to then scale up their solutions to meet market demand. GROW policies pick up where PUSH policies trail off, ensuring that promising R&D has a pathway to commercialization, where it can generate economic returns and jobs.

Figure 25: GROW Policies and Clean Innovation

Box 21: Develop or Adopt?

Why develop these solutions and companies in Canada? In theory, Canada could achieve its environmental goals largely through the adoption and adaptation of technologies developed in other countries. But we'd be passing up the opportunity for clean innovation to be our next economic edge. (And we have some economic strengths such as in natural resources that make us the best place to develop these solutions.) As discussed in Section 1, the economic case is clear – clean innovation (and in particular commercialization of technologies) brings good jobs, higher standard of living, huge export potential and the ability to source environmental solutions from our own companies.

The objective of GROW policies is to support the development and commercialization of promising innovations through public investment that de-risks and catalyzes ('crowds-in') the private capital which is critical for a healthy clean innovation system over the long term. While some private capital is already engaged in clean innovation, most investors are still wary, seeing too much risk and uncertainty in the long-term and often high-capital requirements associated with clean innovation.

The previous section in this report, on PULL policies, showed how stringent, flexible, and predictable environmental policies would go a long way towards stimulating market demand, which in turn will draw in private capital and reduce the need for government investment. But PULL policies will never fully eliminate the need for

public GROW investments because of the number of market barriers in the middle stages of clean innovation. While the middle stages are typically tricky for any innovation, a number of these barriers are particular to clean innovation, or manifest themselves in unique ways for clean innovators. In Section 2.1, we summarized many of these barriers:

- Incomplete information and technology risk
- Policy uncertainty
- Capital intensity
- Network effects and infrastructure risk
- Lack of policy congruency
- Behavioural gaps
- Imperfect competition

GROW policies help surmount these barriers. Governments have a history of strategically helping to grow new technologies and investing to catalyze transformative sectors at key times, both in Canada and elsewhere.

Normally this has taken the form of public investment paired with complementary policies.
Take the recent (and ongoing) rapid growth of the cellphone market for example. The Finnish Government invested in Nokia in the early '90s, which found success and effectively pulled the Finnish economy out of recession. Similarly, US government investment was critical to developing the aerospace sector. Not only was NASA able to pioneer space travel, but the public agency helped develop countless spin-off products and industries, from solar panel technology and lithium ion batteries to cordless vacuums and cochlear implants.[234] The US government also played a critical role in the development of shale gas – with the Department of Energy leading from R&D through to mapping shale gas reserves – which has revolutionized both the energy and chemical industries.*

We've seen similar action in Canada. Government-led agreements and investments built the forestry sector across Canada, drawing in private firms to build mills and plants that have formed the backbone of the economy across much of northern Canada for decades. The same is true of Canada's oil sands; co-investment by the federal and provincial governments and private firms helped develop the technologies to unlock this valuable resource which has become a massive source of wealth, exports, and jobs (albeit with environmental issues to solve).

Without timely and strategic government support, these companies and sectors may have never grown into the economic powerhouses that they became.

GROW investments are particularly important for cleantech, with its double market failures and all the above-noted barriers. Strategic investments will be required to galvanize the breakthrough technologies that will shape the clean economy of tomorrow. This is why leading governments around the world have played an active role in providing support – financial, capacity-building, regulatory, export-support, among others – for clean technologies.† Denmark was early with its support for wind energy technology, and Vestas, founded in 1945, remains the largest wind turbine manufacturer in the world. The UK created a Green Bank to fund renewable energy and energy efficiency projects – its initial £3.9 billion absorbed investor risk, ensured well-structured projects proceeded, and eventually had sufficient success that the private sector displaced the government funding, freeing it up for further investments. And in Canada, over almost 15 years of operation, Sustainable Development Technology Canada (SDTC) has allocated $928 million to 320 projects – drawing in an additional

* For more on the US federal government's role in the shale gas revolution, see https://thebreakthrough.org/archive/shale_gas_fracking_history_and
† As we have shown, these investments work best when complemented with PULL and PUSH policies and strategies to connect the system as a whole (as we will discuss in STRENGTHEN)

$2.45 billion of leveraged funding from the private sector to build a portfolio of emerging clean technology firms across Canada.[235]

5.1 Canada's track record in growing clean technologies

Is Canada on track for big rewards? Understanding Canada's track record in growing clean technology companies is no small challenge – we have some good data, but not enough, and what we have comes from different sources. It largely tells a consistent story, though each study provides its own supporting details. Suffice to say that more – and more consistent – data is high on the wish list of clean innovation analysts (see Section on 6.4 for more on data). But while limited data and lack of agreed-upon metrics make it a challenge to assess how we are doing with certainty, there is enough current information to understand the general picture – and thus to draw policy implications.

The information we rely on comes largely from six key reports (see Box 22). These reports tell a story of a country performing well in the early stages of innovation, but dropping off as technologies mature and companies grow.

In other words, Canada has great potential, but it's not yet being fully realized. We have real strengths in the early stages of clean innovation (as described in PUSH), but we're not doing enough to convert them into successful companies with marketable solutions. In fact, Canada's share of the global environmental goods export market has fallen by 12% since 2008, to 1.4%, according to Analytica Advisors.[236] This is despite the fact that the firms surveyed have increased their revenues (up 8% from 2014-15, to $13.27 billion), do very well at securing exports (over half of their sales), generate employment (55,200 jobs), and invest an impressive 11% of their revenue in research.[237]

And yet there's reason for hope. The most recent rankings show Canada's recent efforts may be starting to bear fruit. Canada's governments, working with private investors, have increased their efforts to address these barriers in recent years (which we explore in more detail in this section). The 2017 Global Cleantech Innovation Index ranked Canada 4th on where entrepreneurial clean technology companies are most likely to emerge over the next 10 years.[238] Canada's jump in the rankings (from 7th place in 2014) was due mainly to growing public sector support, increasing cleantech investor activity and a rising number of companies on the Global Cleantech 100 list. (See Box 24)

The story behind this ranking mirrors our finding that Canada starts strong but falters in commercializing clean technologies. Canada does very well at early stages of innovation (ranking 4th on both "cleantech innovation drivers" and "emerging cleantech innovation"), our ranking falls to 6th when it comes to "*commercialized* cleantech innovation". And we rank only 8th at "converting" clean innovation inputs into commercial outputs – well behind the global leaders like Germany, South Korea, Finland and France. When we dig further into the data, we see a divide between early and late-stage companies and between high capex and low capex companies when it comes to their successes and challenges.

In this GROW section, we focus our attention on cleantech companies more than on the other companies in the more traditional sectors of the economy that are developing or adopting their own clean innovations. That is because, when it comes to securing financing for technology development, we know cleantech companies face particular challenges. It's also the case that almost all the reports and global rankings (see Box 22) focus on the cleantech sector. Further, because the cleantech sector provides solutions to all industries, it serves as a viable indicator of clean innovation across various sectors. However, this is not to say that other companies developing and implementing their own environmental solutions do not also face challenges.*

* One advantage for a company with multiple business lines (including cleantech) is that it may be able to leverage its other business for financing, or as a home for its own cleantech products or services. A cleantech company focused just on developing new solutions for others does not have this advantage.

This message that cleantech firms face significant challenges in growing – both at the early stages of development and demonstration, and at the later stage of scaling up for full commercialization – came through consistently in our interviews. If Canada wants to realize on our emerging potential and become a globally competitive player in fast-growing clean technology markets these investment barriers will need to be overcome.

Not surprisingly, this is largely a story of money. In the middle stages of creating solutions, when a technology and the company team is unproven, financing is hardest to obtain. A recent survey by Cleantech Canada found lack of financing/investment and lack of government incentives/policies as the top two challenges to growth faced by cleantech firms.[239] That is because the risks are difficult for investors to understand and predict, and the prospect of profit is years away. As noted earlier, for this reason, governments around the world typically play a significant role in supporting the early stages of innovation and technology development and demonstration. Both for economic reasons (the market barriers mentioned above) and environmental ones (nations' commitments to meet climate and other environmental goals), governments in different countries have developed a range of financial support programs to help boost the growth of clean technologies through to commercialization, filling the investment gaps while drawing in private capital.

But it's not just about money – other factors can be just as important. As innovations move closer to adoption, they require additional non-monetary support, like strong, stable environmental policies that drive demand; help obtaining the right skilled employees, business development support; and help securing access to export markets. While we focus mainly on the capital needs of cleantech companies in this section, we also discuss these other important complementary needs here and in PULL and STRENGTHEN.

The following discussion on GROW policies is organized by the different stages of a technology's development, and the different kinds of support needed at each stage. These stages must be linked together into an integrated approach that helps clean technologies develop from concept through to commercialization. We start with hand-off from the R&D stages. We then focus in particular on the financing needs of cleantech, as companies move through development and demonstration and then on to scale-up through to deployment. Finally, it is important to remember that this will not be effective without strong *market demand* for clean innovation and companies may need help accessing those markets. As noted above in PULL, government has a critical role to play in driving that demand, both through its policies and procurement.

But for the companies just coming out of R&D, the road they see ahead is a bumpy one. Having proven their technology or innovation in a lab or small project, how do they move forward?

Box 22: Cleantech Companies Please Raise Your Hand

It can be challenging to get a clear picture of the cleantech sector in Canada, with a range of companies working across a number of sectors, there is not yet one clear definition or data collection process for all. In looking at financing in the Canadian cleantech sector, we relied significantly on 5 major reports with distinct samples of cleantech companies across Canada. The results of these reports largely reinforce each other; however, it is worth noting the distinctions between the methodologies they use:

2017 Canadian Clean Technology Industry Report Analytica Advisors (2017)	Survey of 148 companies in 2017; to build on six years of annual surveys that have included 341 companies and firm level data of 800+ in the sector as well as data from trade and patent databases. Clean technology firms are defined as being predominantly engaged in the development and/or use of their proprietary technology to deliver products or services that reduce or eliminate negative environmental impacts and address social needs, while delivering competitive performance and/or using fewer resources than conventional technologies or services.
British Columbia Cleantech 2016 Status Report KPMG (2017)	Survey of 273 BC-based cleantech companies, defined as companies whose primary purpose of developing new technologies related to: – clean energy production, transmission, storage or use; – water treatment and management; and/or – efficiency in energy or resource management and use
Innovation in Cleantech MaRS Data Catalyst (2017)	Data were collected from 324 early-stage cleantech companies that are clients of the MaRS Discovery District in Toronto and the Ontario Network of Entrepreneurs. A cleantech company is defined as one that "is focused on the creation of intellectual property, new products and services that protect and/or increase efficient utilization of land, energy, water or natural resources"
Benchmarking the Canadian Cleantech Ecosystem Cleantech Group (2016)	Data were collected from the Cleantech Group's (proprietary) i3Connect Platform, where cleantech "comprises new technologies or business models that help people do more with less" (where more is in terms of output, economic growth, value creation, productivity and less in terms of environmental impact, energy consumption, material or natural resource inputs.)
Forging a Cleaner and More Innovative Economy in Canada SDTC/Cycle Capital (2016)	Relies on proprietary information from Cycle's and SDTC's deal flow, as well as an analysis of databases on scientific publications, patents and venture capital investment and investors. SDTC defines cleantech as those that "increase business and industry performance while improving resource efficiency and reducing or eliminating negative environmental impacts."
The Global Cleantech Innovation Index 2017 WWF/Cleantech Group	The Cleantech Innovation index presents a composite index looking at "where, relative to GDP, entrepreneurial clean technology companies are most likely to emerge over the next 10 years." The index is calculated for 40 countries and composed of 15 indicators from a range of sources across 4 pillars: general innovation drivers, cleantech specific innovation drivers, evidence of emerging cleantech innovation, and evidence of commercialized cleantech innovation.

Box 23 Guiding Design Features

In helping to boost clean innovation, it is important to learn from both the successes and failures of the past. In addition to the successes noted throughout this report, there have also been some ill-fated government efforts to boost economic development, in Canada and elsewhere. The key is to take smart risks and to design programs well – to tilt the odds in favour of success. Our research and interviews have identified important principles that should guide any government investments in clean innovation:

1) **Independent:** Governance of any policy delivery entities should be removed from political influence. And while the *policy framework* should not pick winners, any *delivery entity* must pick winners. Further, the "failure" of some companies and projects is inevitable. Although valuable lessons should be learned, resolve in handling criticism is necessary. Further, arm's-length agencies or similar arrangements, can often act more like private investors with respect to being risk-tolerant, far-sighted, nimble, expert, and objective. (See the Section 6.2 on Institutions for more on this point.)
2) **Informed by Expertise:** Public investments – whether done by departments or (ideally) arms-length agencies – should be informed by expert advisors (who understand the delicate balance between public accountability and driving effective and efficient processes that resonate with the private sector) and should rely on the best knowledge – including from within and outside of Canada.
3) **Evaluated based on Performance**: Best results will follow from clear objectives, tracking performance, timely evaluations and adjusting approaches as need be. Governments can set out desired outcomes and build a full performance evaluation plan with metrics that can measure success, and enable timely adjustments to improve performance. (See STRENGTHEN for more on data)
4) **Transitional**: Government's main role is to remove barriers and provide incentives to help ramp up private investment. Over time, its financing role should diminish, as the sector matures and a robust private finance system emerges – as has happened with public support for other emerging technologies (e.g. oil sands). The aim is to pull in private investors to contribute more – for example by sharing hard-to-manage risks (such as policy risk).
5) **Aligned with private action**: If we want to drive clean innovation and technology in Canada, it is vital that the public and private parts of the economy are well-aligned: pulling in the same direction within a larger strategy to build Canada's areas of economic advantage, for example in natural resources or infrastructure. At the same time, allocations from the public purse should be targeted to address market failures and help companies overcome market barriers rather than crowd out or compete with private players.
6) **Completes the Ecosystem**: As we pointed out earlier (and come back to again in STRENGTHEN), any policies or investments that fail to consider the entire ecosystem will see sub-optimal success – including return on investment. It's important to examine each player at each stage of innovation and ensure mandates are well-defined and that each institution "hands-off" to the next organization/policy.* This decreases for applicants community, avoids unhealthy competition, reduces overlap and inefficiencies, enables better cost control and improves "horizontal" performance

* While program duplication is inefficient (and confusing for companies), one reviewer noted that "coordinated overlap" – in the form of a slight overlap that allows for companies/projects to move from one program to the next can be good – as can some degree of duplication of government funding programs so there is resilience and competition in the system.

5.2 Proving Technologies (Development and Demonstration)

When a promising new technology moves past research and development, it often leads to the formation of a new spin off company, which then undertakes further development and demonstration of the technology – to show it can work in practice and at scale. This stage is often called the "valley of death" because of the challenges in securing finance for this initial development when a technology is unproven and its prospects are unknown (see Figure 26 below). The challenge here is largely that these young companies do not have internal funding and need to raise their capital from outside investors. If they fail to do so and can't find a way across this valley, the innovation chain is broken.

Companies at this stage of development find themselves in a tricky spot. They've got good ideas that need more refining, and/or an opportunity to be demonstrated in the real world. Now they need to access capital to take their solutions to the next level.

The good news is that there's a lot of hungry companies in this stage, but the bad news is that there isn't a lot of funding to go around. Analytica Advisors found that cleantech firms spent $8.2 billion on R&D from 2009-2015 – and most of them are small, with less than $50 million in annual revenues.[240] As R&D intensive companies, they need to spend a lot on research but financing is difficult to secure because they are not yet generating significant sales revenue, and have limited assets (for collateral). As a result, many of these firms are starving for capital to grow.*

A MaRS survey of Ontario cleantech companies found that most are at these earlier stages of development, perhaps having secured some angel or early VC funding while they refine their product, and validate their technology.†[241] Using a different (narrower) definition, the Cleantech Group study finds 34% of cleantech firms are in what they call the pilot/early revenue stage.[242] These small firms are the ones with their sights set on serious growth to become one of the top-tier firms that represent the vast majority of jobs, revenues, and financing.[243] By either definition, these young cleantech companies are the feeder group from which tomorrow's success stories come.

Box 24: Canada's Cleantech Companies – and the ones to watch

In 2018, Canada had an impressive showing on the Cleantech Group's "Global Cleantech 100" and "100 Ones to Watch" lists. Despite being just 2% of global GDP, and 1.4% of the global cleantech market, Canada took 13 spots on the 2018 Global Cleantech 100, and 3 on the 100 Ones to Watch list.[244]

Regardless of their technology, young companies at this stage need to do one thing above all else: access more capital.

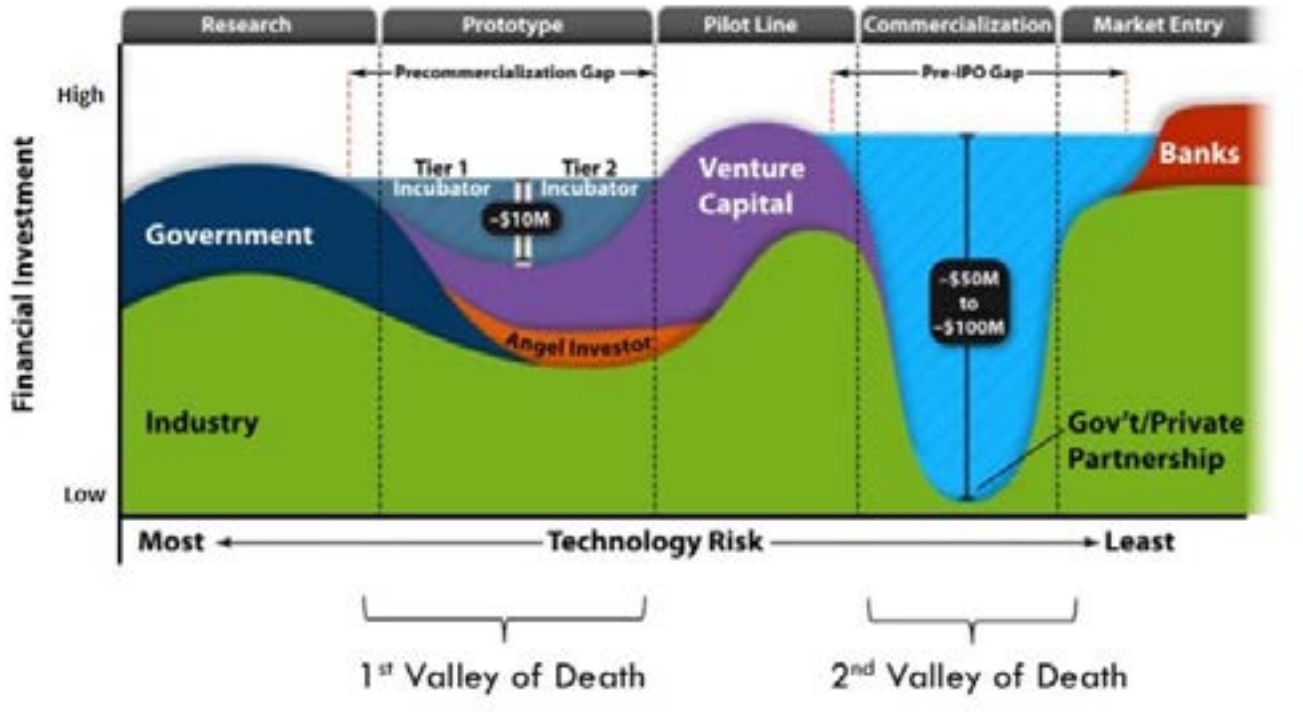
Proving an idea takes money, but that capital is hard to come by. At this stage in technology development, funding is most likely to come from angel investors, the entrepreneurs themselves (or their friends and families) or perhaps the venture capital community (limited). Figure 26 shows a simplified model of cleantech with some of the key types of financing overlaid over the stages.

Analytica Advisors finds that companies in this stage of technology development and demonstration find most of their financing from equity.‡ The importance of venture capital for companies in this stage cannot be underscored enough. Traditional lenders are generally not interested in companies until their technologies have been further

* One cause for concern cited by many reports and some of our interviewees is that these companies are appealing acquisitions for larger foreign companies because their low-revenue-high-IP situation is appealing.
† And if they have revenues from early sales, they are often plowed right back into development.
‡ Ideally in the future other institutional investors like pension funds would also support these earlier stage cleantech projects.
Analytica Advisors (2017) The 2017 Canadian Clean Technology Industry Report, *Analytica Advisors*

tested and proven, and their commercial viability established – leaving few sources of funding available for earlier, riskier stages of growth.

Figure 26: Private Funding for Cleantech – and the Valley(s) of Death[245]



This diagram, developed by the US Department of Energy (2015), represents a simplified version of the clean innovation finance system for high-capex technologies for illustrative purposes. The US system is somewhat different from the Canadian system and this does not capture the role of funding bodies like SDTC, BDC, and EDC.

Box 25: Financing Cleantech

There are a number of ways in which cleantech companies raise funds, either through debt (which has to be repaid) or equity (in which they give up a share of their company) including:

- Family and friends often provide early funding, either as loans to be repaid or for equity;
- Angel investors are affluent investors who provide early funding, either in exchange for equity or as convertible debt (i.e. a loan that can be converted to equity later on);
- Venture Capital (VC) is provided by funds or firms to help high-risk/high-potential companies grow, often (but not always) at early stages, before larger, conventional funders (e.g. banks, pension funds) come in – usually in exchange for equity, but venture debt also exists in specialized situations. VC also tends to bring management and sector-specific expertise and guidance to help the company succeed;
- Banks and traditional lenders can offer loans, generally with low risk tolerance and to established companies, lending against assets;
- Pension funds invest in companies, funds and projects, though generally with low risk tolerance; and
- Public markets can be used to raise funds by issuing shares in the company, which trade on a secondary market, usually at later stages when a company has proven its viability.

Equity's Important – and most of it comes from Venture Capital

Because of its important role in driving innovation (a public good), government investment in venture capital (VC) is common. Government sponsored VC funds are involved in over a quarter of all VC financing deals and provide over $4 billion in investments annually around the world.[246] Canada's VC industry, while growing, is not as developed as in the US or some of our other peer countries. The Jenkins report recommended government invest to help build Canada's VC capacity. In response, in 2013, the federal government announced the Venture Capital Action Plan.* Budget 2017 announced the new Venture Capital Catalyst Initiative (VCCI), which is meant to build on VCAP by providing $400 million to BDC as late-stage VC for growth stage companies – with the expectation that it could generate as much as $1.5 billion in total new funding, with private sector participation.

Similarly, a number of provinces also have VC initiatives – like Teralys in Quebec, Alberta Enterprise Corp (AEC) in Alberta, and Ontario's Cleantech Equity Fund – which are funds of funds that stimulate significant investment and attract international capital.

Venture capital investors fill a critical niche in financing the growth of new technologies and firms, particularly because traditional investors are generally reluctant to invest in unfamiliar new technologies with unique risks and opportunities. Venture capitalists specialize in this area; they build expertise on particular sectors and technology groups, and the key players and markets in the field. They use this expertise, combined with skills in business management and growth, to assemble financing for promising technologies and companies. They are sometimes referred to as "smart money" because they bring entrepreneurial expertise, market knowledge, and industry connections alongside their capital. They also send an important signal to the market (for later investment) about which firms and technologies are most viable.

Generally, VCs provide equity investments in companies at different stages of development, ranging from early stage (often called seed stage) through demonstration to scale-up. Few VCs, certainly in Canada, are large enough to finance a company through multiple commercialization stages. The VC makes its returns when the company is sold, merged with another, or goes public and issues shares (also called "exit").†

When it comes to cleantech VC, Canada has a growing pool of resources, but one that remains very small. The Cycle Capital and SDTC study found that over 2010-2016, while the *number* of VC rounds in Canada is comparable to that in the US, round *size* is about half (56%) so that total amount invested is about half as well, relative to the size of the two economies (i.e. Canada has 5.5% as much total VC investment, while its GDP is 9% the size of the US's).[247] As a result, since 2010, only five Canadian cleantech companies have raised more than US$50 million in venture capital, against 183 companies in the U.S.[248]

Further, one of the downsides of the recent successes of a few notable Canadian cleantech companies seems to be a shift in where VC is placing its Canadian cleantech bets. While we have a strength in emerging cleantech, these young Canadian firms are struggling to finance their potential. As the MaRS survey finds, investment is dominated by the top 4% of firms that are leading in growth (i.e. at a later stage of technology development), who received 41% of all capital raised. "In recent years, these later-stage companies have raised increasingly large rounds of venture capital, creating an overall shift away from seed-stage financing to later stage growth financing.

As a result, the imbalance between later and earlier stage funding is more pronounced in cleantech than it is in any other sector."[249] Similarly, the Cleantech Group report finds a decrease in the number of VC deals for early-stage

* Several of our interviews noted an uncertainty – and in some cases a hard skepticism – regarding how beneficial VCAP was particularly for high-capex firms.
† This has to happen within the life of the fund, which can be as little as 7 years. For high-capex cleantech, with its longer project timeframes, this is often not possible.

companies, while later stage companies have seen a recent increase.[250] This is worrisome news for cleantech companies seeking to further test and prove their ideas – venture capital has been their key source of finance but it's shifting away from them.*

Government Support

Because of the extra market failures and barriers facing clean technology, government support plays an important role in leveraging VC investment – both in Canada and globally. Analytica Advisors found that while more than half of equity financing for companies in this stage of development came from VC (which may include government-backed VC such as through VCAP), 21% of total equity financing came from (non-diluting) government grants.[251] Further, the MaRS study found that 53% of cleantech firms that raised money did so with the assistance of federal government programs, suggesting that "government financing acts as an important catalyst for co-investments by venture capital."[252]

Canada has many companies at this stage because it has begun to build solid institutions to support the development and demonstration of clean technologies, particularly over the past 10-15 years (such as SDTC, which has been praised by the OECD[253]). Most provinces and territories have programs to support early stage companies – such as Nova Scotia's Innovacorp's Clean Technology Investment Fund (which makes equity investments in clean technology start-ups), Emissions Reductions Alberta (formerly CCEMC, which makes grants to different projects), British Columbia's Innovative Clean Energy Fund (which funds projects and programs with grants in pre-commercial clean energy technology projects, clean energy vehicles, research and development, and energy efficiency programs) or Ontario's Low Carbon Innovation Fund (see Box 20)†

Federally, a number of programs exist to support early stage technology development and demonstration, including programs administered by NRCan's Office of Energy Research and Development (such as the Budget 2016 Energy Innovation Program or the Budget 2017 Clean Growth in the Natural Resource Sectors Program) among others.

Perhaps the best known federal program is Sustainable Development Technology Canada (SDTC). SDTC helps cleantech companies grow by providing project financing for development and pre-commercial demonstration, along with coaching to help companies bring their innovations to market. To date SDTC has supported more than 300 projects with close to $1 billion ($989M) and leveraged an additional $2.45 billion in funding.[254] SDTC funding has helped to provide 9,437 new direct and indirect jobs in the Canadian cleantech space. In Budget 2017, SDTC was recapitalized with $400 million through its signature SD Tech Fund to support demonstration of innovative clean technologies.‡

"SDTC has a catalysing effect: it brings confidence and raises comfort level of clients." – OECD, 2008[255]

SDTC also recently began to partner with provincial organizations including Alberta Innovates, Emissions Reduction Alberta, Ontario Centres for Excellence, BC's Innovative Clean Energy Fund, Innovacorp, and the Nova Scotia Department of Energy to streamline the application process for applicants proposing their project to multiple funding agencies, with a view to expanding this process to all interested provinces. Providing a

* The challenge is further exacerbated for high capex deals and for those that have elevated working capital needs, as investors increasingly seek only the most capital-efficient, scalable companies, such as those with no hardware.
† For a list of more provincial initiatives, see the report from the Working Group on Clean Technology, Innovation and Jobs (2016).
‡ Budget 2017 also included $229 million to support research, development and demonstration cleantech in the natural resources sectors. This is in addition to the $401 million for clean technology provided in Budget 2016, which concludes in 2017-18.

harmonized one-window application process and putting out joint calls for areas of mutual interest creates synergies for companies and program administrators alike.

While government incentives, often in the form of grants for technology and/or company development play a significant role at early stages, it is important that they leverage private funding.* This is because it brings commercial rigour to the technology screening process, adds assistance with strengthening market knowledge and management development, and engages private investors that are most likely to fund follow-on stages if the results warrant it. SDTC, for example, has achieved, on average, 2:1 leveraging of private capital.[256]

One relatively easy role for government can be to strengthen the role of outreach programs to ensure companies know where to go for government support. For instance, the BC Cleantech survey found that over half of companies access IRAP – a well-respected program that could be used for greater outreach to the cleantech community and leveraged further with cleantech in mind.[257] The federal government's new Clean Growth Hub (funded in Budget 2017) is likely to play an important role in coordinating programs and facilitating companies' experience navigating government support.

Because innovation can be thought of as a series of stages that companies and technologies progress through, it is important to grow the system in a thoughtful way. As we've noted throughout this report, for this early stage public funding (like all funding) to be most effective, governments should seek to concentrate funding more in technologies and firms that show the greatest promise for ultimate success. Doing this requires better coordination among funding programs, within and across governments, and better connecting early stage funding bodies, with both earlier stage (e.g. NSERC, NRC) and later-stage (e.g. BDC, EDC) investment bodies, so that all funding decisions are better aligned with strategies and priorities for ultimate commercial success.†

Box 26: Cap-and-trade in Ontario: Emissions go down, cleantech investment goes up

Funded by proceeds from Ontario's cap-and-trade market, Ontario's new Low Carbon Innovation Fund (LCIF)[258] launched in Fall 2017 with $25.8 million aimed to help researchers, entrepreneurs, and companies create and commercialize new, globally competitive, low-carbon technologies that will help Ontario meet its climate mitigation targets. The first round includes both a technology demonstration stream and a technology validation stream.

5.3 Scale Up and Commercialize

For the companies and technologies that make it through development and demonstration, deployment and diffusion lie ahead. Their challenge now is to scale up and prepare to compete in international markets.

In part because of increased government programs focused on clean energy and cleantech over the past decade leveraging private capital, there is a pool of Canadian companies that have proven their technology, are generating revenue (rarely profit) and now need more capital to grow.[259] According to the Cleantech Group, roughly 45% of the sector is in this stage.[260]

It's perhaps premature to call these growth firms yet, but growth is what they're after. The trajectory for growth differs by market sector and technology and there is a big distinction between the challenges faced by high-capex companies and low-capex companies.

* There may be opportunities for Canada to learn from the experience of other countries in doing this – such as from the US DOE's loan guarantee program or the KfW loans in Germany.
† As the MaRS study notes, the interplay between public and private funding is not always well understood, particularly because government grants may require pre-existing product validation and/or the ability to raise matching funds from the private sector. This could be an area for further exploration, specific to the Canadian context.

High- and Low-capex – Why it matters

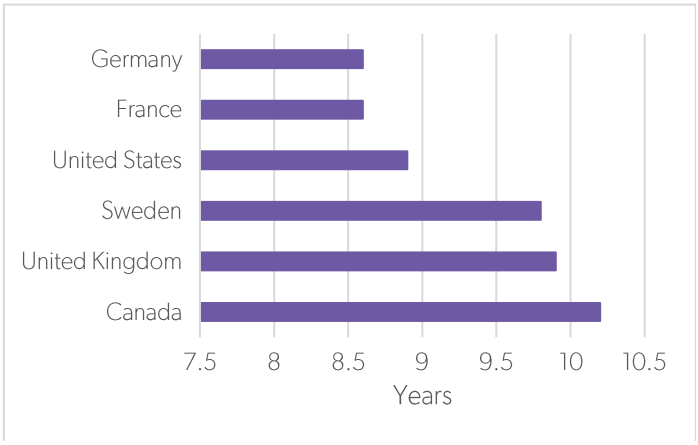
Many new clean technologies involve **high capital costs** (that is, are capital-intensive or **'high-capex'**) because they involve expensive plants or machinery – often requiring a series of three or more stages of increasingly expensive scale-ups before the technology is considered sufficiently proven to attract established, institutional investors. This is sometimes referred to as a "second valley of death". For clean technology, investments often range from $5M to $100+M per scale up, paired with a total timeline of 10 years or more to reach market.[261] While these so-called "high capex" clean technologies may be less attractive for short-term financial returns, many of them will be critical to meeting climate and other environmental goals, and can generate jobs and wealth for the country.* The transition to a clean, low carbon economy will require new energy systems, cleaner fuels, new industrial processes, new forms of water treatment, carbon capture, and new forms of transportation.

At the same time, some clean technologies require relatively small amounts of capital – **capital light or 'low-capex'** – because they are able to scale up and achieve commercial viability fairly quickly. Software-based clean technologies fit this profile. These clean technologies can have the converse problem of high-capex cleantech companies – they require support that is, above all else, quick and nimble because in the world of software and systems, waiting several months for a response to a proposal can mean your competitors will have already secured the market. Programs that target high-capex projects may not meet the needs of these low-capex cleantech companies.† However, because these companies often have a risk and return profile more similar to ICT companies, many of the challenges they face in securing financing are less pronounced than for high capex companies.

Industry evidence tells a somewhat discouraging story of how this financial challenge is affecting companies. While more and more Canadian firms are getting close to the growth stage[263], this is not resulting in growing commercial successes[264] – suggesting many firms are stalled, rather than growing. Canadian firms reaching this stage are older (by 1-2 years) than the average for other countries. This suggests they are facing challenges in achieving commercial success, or at least in a timely way. ‡,[265]

As we know from earlier sections, the lion's share of Canada's public support for clean innovation goes into early stages (research, development and demonstration), with much less going to support growth and scale-up. This is a worrying situation that begs the question, are we setting up companies to fail? Or forcing them to move elsewhere to succeed?

Figure 27: Average Age of Growth-stage Companies[262]



There are many stories of promising Canadian clean technology firms that were successful at the development and demonstration stages, supported by both public and private funds, but were unable to obtain the capital in Canada for scale-up and commercialization. For some, this meant obtaining their main financing elsewhere (usually the US, but increasingly now China), which meant moving control of the company (and often its head office) out of Canada. For others, the company had to sell out to a foreign buyer

* And many of them may deliver higher GHG reductions over longer time periods.
† For instance, some of our interviewees noted that SDTC is generally not designed to meet the needs of these companies.
‡ They average 10.2 years in Canada, but 9.9 years in the United Kingdom, 8.9 years in the United States and 8.6 years in France and Germany. There are likely many reasons behind this, a significant part of which is that Canadian firms are more reliant on capital from international investors because of the smaller Canadian pool of capital – thus taking longer to reach this stage than cleantech companies in other countries.

before it could reap the full returns from its R&D investments – possibly at an undervalued price. Compounding these financing challenges, many companies report that they have an easier time obtaining government procurement contracts for their new technologies abroad than in Canada (as further discussed in PULL).

It appears that Canada incubates promising new technologies, supported in part by public funding, which either cannot secure the financing to achieve commercial success, or end up doing so elsewhere – generating jobs and wealth in other countries.* **We invest a lot of energy in the start of the race, and do fairly well, but not enough in the later stages, where the race gets won.**

Just like the earlier stage technologies, these companies need many things to succeed, and money is probably top of the list. The difference is that they need a different type and scale of financing.

Access to Capital

Financing this stage of commercialization and scale-up is a challenge. The higher capital requirements and longer timelines before the capital investment has been paid back and net returns are generated mean that securing financing is a significant challenge, particularly for high-capex clean technologies.[266] This was consistently identified by both our interviewees and recent industry reports as the biggest challenge facing high-capex clean technologies in Canada. Private capital is hard to secure in Canada (at least at reasonable terms) and public investment programs have traditionally been less focused on this stage. The value proposition of many clean technology companies – particularly the high-capex, more breakthrough technologies that take longer to market - is simply unlikely to be suitably appealing to VC. These companies need a way to bridge the gap from early stage financing to the point where they've shown commercial viability and can attract large scale capital from traditional sources.

This financing challenge is compounded when the end product is one that faces commodity markets with fixed prices.† This is a significant challenge – the output is ultimately undifferentiated from its competitors except by cost.‡ In that case, the new technology must compete with larger, established incumbent technologies – and all their inherent advantages -- without the prospect of price premiums that help to attract investors to new technologies (such as smart phones, new drugs, etc.). For example, bio-fuels must compete with incumbent gas or diesel fuels that have extensive existing production and distribution networks and established customers; and solar power must compete with existing power generation systems (using coal, gas, hydro or nuclear) that have large generating stations (usually publicly funded), existing distribution networks geared to those technologies and often market access rules that favour them. As a low energy price jurisdiction, that is particularly relevant for Canada.

Yet we know that many of these new technologies will be required in order to move to a clean economy and meet global climate and other environmental commitments. **We will not reach our 2050 decarbonization goals without disruptive new technologies – some of which will involve high capital expenditures over a decade or more to develop, scale up and commercialize.[267]**

* That is not to say that being bought out by a foreign company is always a bad thing. In some cases, it can be a useful way to access global value chains and financing, provided that some of the know-how, production and value stays in Canada – which is more likely if the company can negotiate from a position of economic strength.
† Similarly, it can be further compounded when selling into highly regulated markets or into municipal markets (as is the case with many water and wastewater technologies).
‡ Of course as the environmental externality is addressed via PULL policies, this moderates some of the challenge; however, the other disadvantages remain, such as competing with technologies with existing infrastructure.

Fortunately, some of these new clean technologies are becoming increasingly viable as potential 'end game' alternatives to incumbents, as their performance improves and costs come down – like solar power, electric vehicles, bio-chemicals, and advanced building materials. But technological viability is not enough. It is also necessary to generate the substantial financing needed for these cleaner new technologies to scale up and eventually displace dirtier existing ones; that process may take several decades or more if proper financing and capacity can't be brought to bear.

Growing both the amount and kinds of capital in Canada and the capacity to invest it wisely for scale-up and commercialization of clean technology will require a range of financing tools. Different firms require different tools at different stages. While the following analysis is broken down into particular types of financing tools, the key is building Canada's capacity across a range of tools, with the flexibility to use them as needed.

Box 27: Is There Still a Program Gap in the Valley of Death?

Governments have tried to provide support to companies crossing the valley of death. But one comment we heard in our interviews was that there still exists a gap where no/few supports are available.[268] We heard that many companies find themselves graduating from the SDTC SD Tech Fund (grants) but are not yet ready for EDC or BDC's support (debt or equity at commercial rates). In the past, SDTC offered the NextGen Biofuels Fund[269], uniquely for high capex biofuels companies seeking to bridge this gap. It provided funds (up to 40%) that were repayable only once a firm had free cash flow within 10 years (i.e. more forgiving than commercial finance terms). While this fund is now complete, some of our interviewees noted a desire for a program or fund to fill this gap, perhaps one modeled on the NextGen Biofuels Fund but with wider eligibility.

Consistency is as important in funding as it is for policy. For instance, gradually increasing funding over time for SDTC and other early stage clean innovation funding programs (at federal and provincial levels) is more effective than large, short-lived pulses. It makes sense to start with moderate increases, ramping-up over time as the feeder stream of innovative technologies grows. And like we've noted in PUSH and PULL, the amount of funds is in some ways less important than the predictability of their being made available.

When Debt and Equity Both Matter

When companies reach scale-up and commercialization, the balance between debt and equity financing often changes; clean tech firms typically shift from more equity at earlier stages to more debt by the time they are ready for market entry, according to Analytica Advisors.[270] But both are needed.

More debt means less claim on company ownership, but it can be very hard for start-up firms to secure without very high interest rates that may hamper critical cash flow. However, despite the high interest expense of debt it can still be less punitive in certain situations than the dilution impact associated with additional equity investment. And certain types of companies with standalone commercial assets (such as renewable energy, energy storage, waste-to-energy, water treatment, etc.) may seek "off balance sheet" financing. This is known as "project finance" -- when funding for a long-term industrial or infrastructure project is based on the projected cash-flow of the project (rather than on the balance sheet of the company undertaking the project) – in which the equity to debt ratio varies according to the project type and risk.[271]

At the same time, equity remains critically important for technologies at this stage. That presents some challenges. VC is focused on the highest-potential firms – which is good, but there's not enough funding going around to support very many companies. As noted earlier, Canadian VC firms are more active at smaller funding levels and much less active in providing larger funding amounts, particularly when it involves high capital requirements and longer return times.[272] Canadian cleantech companies obtain the bulk of their private financing from foreign sources (the only developed country where this is so).[273]

In other words, a traditional approach to VC investment, while effective for some kinds of clean technologies (such as IT-based ones), is not a good fit for others – particularly the kinds of "high-capex" clean technologies identified as most in need of public support to overcome market barriers.

That does not mean that it cannot be done. There are some existing cleantech VC firms, both in Canada (such as EnerTech Capital, Arctern Ventures, and Cycle Capital) and elsewhere that have been successful at putting together financing for these high capex clean technologies. It isn't common and it isn't easy. It can require identifying and attracting non-traditional investors -- such as large firms with a strategic interest in the technology, or public procurement partners -- who are looking for more than just traditional, short-term investment returns.

Box 28: Want to Put Your Money in Cleantech? Green Bonds and Securitization

How can investors – institutional or individual – get in on the cleantech sector and the rewards it offers? Green bonds are a good option. While individual cleantech investments often come with greater risk than other forms of investment, by compiling a portfolio of cleantech investments, returns can be more predictable and risk can be spread across multiple projects. Through the creation of a portfolio, securities could also be issued – such as green bonds – which could attract investors interested in cleantech, but not in smaller individual projects. Globally, labelled green bonds totaled over US$130 billion in 2017, nearly a 70% increase from 2016's record setting issuance.[274]

To date, green bonds issued in Canada by banks (like TD), governments (like ON and QC, and EDC) and companies (like Telus) have only been available to institutional investors and been used for technology deployment and infrastructure projects. But any Canadian investor can purchase the retail green bonds issued by CoPower, which have primarily supported energy efficiency projects. While the green bonds issued to date in Canada have largely supported projects using existing technologies, green bonds could support earlier cleantech deployment and adoption. These types of products can be appealing to international investors seeking green investment opportunities, as well as to more risk-averse investors such as pension funds. The demand for green bonds is significant – EDC's September 2017 green bond (its 4th, but its first in Canadian currency) saw nearly three times as many orders as there were securities for sale.*

But it does mean that there is a role for public action – smart public investment that draws in private capital by sharing the additional risks of cleantech. As part of the Venture Capital Action Plan (VCAP) in 2013 the government invested $340 million, administered by BDC Capital – a crown corporation with specialized financial expertise. It has since made commitments to 21 new and emerging VC funds, and by leveraging private capital, almost $900 million has been invested.† (And as noted earlier, the new VCCI was announced in Budget 2017).

Beyond VCAP and VCCI, BDC has a significant amount of capital committed to this market segment off of its own balance sheet. For example, BDC is the largest institutional investor in Canadian VC funds that support cleantech, with over $180M of capital committed to funds that have been directly invested in cleantech firms. Furthermore, BDC's Industrial Clean and Energy (ICE) Technology VC fund has allocated $117M to 18 companies in Fund 1 and freshly recapitalized Fund 2 with $135M targeting 15-20 new companies over the next 5 years.

The ICE investment strategy is generally geared towards "low-capex" or capital efficient solutions that create large resource productivity gains through the convergence of hardware, electronics, software and advanced materials

* Smart Prosperity Institute tracks the size of the Canadian green bonds universe every year. See: http://institute.smartprosperity.ca/content/green-bonds-canada-0

† Since the program is considered an investment, it could generate a direct financial return for taxpayers. However, as noted earlier, a number of our interviewees expressed skepticism about VCAP and VCCI's ability to support cleantech, as well as concern that the BC ICE fund did not fund high capex clean technology. It was also noted by interviewees that public VC acts differently than private VC – often more risk averse, despite a need for the opposite.

in industrial systems. The fund actively looks for investments where venture multiples can be realized from an exit within a traditional fund horizon (<10 years). With a few exceptions (e.g. General Fusion, Nexterra) the fund generally does not target companies that require larger amounts of capital and longer timelines to maturity – the very area identified as the key investment gap for building Canada's clean tech sector.

This portfolio mix suggests that BDC has used factors similar to those used by private VC investors to pick sectors and firms to invest in. While this market approach may be sensible for securing timely economic returns and building Canada's VC sector, it may not be optimally suited to growing the long-term clean technology companies that will be needed to transform our economy and meet our environmental commitments. Short-term market returns alone are not always the best metric for picking the clean technologies that have the greatest long-term potential for deep carbon reductions, because of the very market failures and barriers discussed earlier.

Budget 2017 specifically addresses the financing needs of cleantech companies seeking capital – to the tune of nearly $1.4 billion in new financing for BDC and EDC. From this, BDC will provide $950M of new equity and debt capital to help clean technology firms grow and expand. This is in addition to BDC's recent $135M commitment to ICE Fund 2 and an additional $100M already allocated to clean technology firms under BDC's current corporate plan.

This new funding is an opportunity for public equity investments to take a slightly different approach than in the past – one that builds on the solid skills BDC has in equity investing, financing, and advisory services but deliberately takes a longer-term view and considers the environmental returns more explicitly. As many of our interviewees noted, these organizations have to be mandated to take on more risk (to draw private investment into cleantech), to invest with greater patience and to possibly see more failure – a worthwhile approach given the environmental and economic returns possible.

Box 29: Loan Guarantees – the US Department of Energy Experience

Created in 2005, the US Department of Energy's Loan Guarantee Program has committed over US$30 billion to projects that have supported 56,000 jobs and avoided 34.7 million tons of CO_2 emissions while leveraging an additional US$20 billion in private investment.[275] The program de-risks loans to innovative energy firms by committing to repay lenders should the borrowing company default.

The program became a lightning rod for criticism following the 2011 failure of Solyndra to pay back US$ 528 million. However, successes like the US$465 million loan to Tesla are widely forgotten. The program has since recovered previous losses through interest payments and maintains a loss ratio of only 2.22%[276] (to put this in perspective it is less than the write-off allowance for JP Morgan). In fact, 20 of the 25 projects receiving loans through the program are already operating, creating employment, reducing pollution, and paying back the loans with interest.[277]

Loan guarantees for the first 5 utility-scale (>500MW) solar power generation facilities in the US helped launch the industry and develop investor confidence that led to an additional 45 utility-scale projects subsequently financed without loan guarantees.[278]

At the same time that equity is hard to find, debt is hard to come by – at least affordable debt. Canadian cleantech firms generally face particularly high costs to obtain financing.[279] Canada's large lenders (e.g. banks) and investors (e.g. pension funds) are still very hesitant about investing in clean technology -- at least until companies have matured and have proven profitability. Because many clean technologies and their business models are still seen as unproven, as well as being heterogeneous (they cut across sectors), having high capital costs, and additional risks (like policy uncertainty), most companies have difficulty securing support for scale-up

and growth from these major financial players. Further, cleantech is often not recognized as an asset class by some lenders – making it that much harder to secure debt financing.

And while venture capitalists normally take an equity stake in a company, venture debt funds also exist – they look for VC-backed companies and generally lend working capital. Just as Canada lags the US in venture capital, we also lag in venture debt – with roughly as many rounds, but at half the size. Further, 88% of venture debt raised in Canada is concentrated in biofuels and biochemical.[280] In the US, federal institutions have played an active role in venture debt financing, while that has not been the case in Canada to date. In fact, most Canadian venture debt comes from the US.

These problems are not unique to Canada (though they are perhaps more acute here than elsewhere). However, some other countries are doing more to address them: by shoring up market demand for clean innovation (through smart public policies and procurement), and providing public financing to leverage private capital, particularly at later stages. Again, the aim here is to use government action to pull in private funds. Governments can do this by providing loans. Or through guarantees and security (rather than actual loans), which enable private firms to lend more and at affordable rates, with the aim of seeing private action grow over time, allowing public funds to slowly withdraw.

The challenge with these new forms of debt finance is similar to the challenge with public equity finance – governments must find ways to draw-in private finance without acting like private finance. Public funding institutions have to find ways to accept risk, be more patient, and consider not just the financial bottom line, but also the environmental bottom line, if Canadian cleantech is to gain an edge.

Once companies have made it to this stage of maturity, government investment can build on all the private and public investments made through the companies' earlier stages – via debt financing. This can take the form of export security, loan guarantees, performance bonding, project financing and/or working capital. As MaRS points out, "These will likely be more important for cleantech firms than many other emerging technology sectors, given the high level of working capital needed to support project deployment by customers overseas."[282]

As mentioned earlier, BDC will deploy a portion of its $950M allocation in the form of debt to help cleantech firms invest in assets, inventory, talent and market expansion, which established companies may need to fulfill a domestic or international contract. And EDC will administer $450 million for "project finance to enable first-of-its-kind, high-capital-intensive, early commercial-scale clean technology deployment." Additionally, Budget 2017 provides for the creation of the $1.26 billion Strategic Innovation Fund to provide repayable and non-repayable contributions to firms of all sizes, which clean innovation will be able to tap into. The first recipients, announced in early 2018 include investments in chemical and automotive manufacturing (including materials to improve fuel efficiency).[283]

Box 30: Climate-related Disclosures – Information Guiding Investment[281]

Climate change (and the policies to address it) can pose a significant financial risk or opportunity to businesses and investors. While publicly traded companies are obliged to disclose material risks, climate-related risks are not yet widely or consistently included. Created at the behest of G20 Finance Ministers, the Task Force on Climate-related Financial Disclosure led by Michael Bloomberg released a set of recommendations to guide consistent climate-risk disclosure which drew support from more than 100 companies representing US$11 trillion in assets. Mainstreaming and improving the quality and consistency of climate-risk disclosure can allow investors to better consider the sustainability of their portfolio and encourage investment in the innovative companies offering solutions.

5.4 Building Company Capacity – for all growing companies

While money is perhaps the number one item on most cleantech companies' wish lists, assistance with building company capacity can be as important as funding. As their technologies mature, they need to better understand and

reach their markets, evolve their business plans, and work within more complex governance and financial models. As companies grow, often their management teams and governance structures may need to change to bring in the right discipline, competencies and maturity to manage the difficult pivot from being a development-oriented company to a growth-oriented one.* How governments can help nascent companies meet these capacity challenges, and grow their human capital, are further addressed in STRENGTHEN (Section 6).

Given the heterogeneity of the cleantech sector, these middle-stage companies are a diverse mix; they need help meeting their unique challenges and opportunities, and accessing the right supports and services, if they are to quickly ramp up to generating revenues in the hundreds of millions and become commercially competitive. If these companies are not supported soon, Canada could lose an entire cohort of great Canadian cleantech companies.[284] Hopefully, new measures such as those introduced in the 2017 federal budget (including the Clean Growth Hub and Innovation Canada broadly), and in provinces (such as Ontario's new Cleantech Strategy) will help provide these companies with the tailored support they require. Similarly, the increasing cooperation between federal, provincial and territorial governments (as evidence by the Pan-Canadian Framework on Clean Growth and Climate Change) to better support cleantech is encouraging.

Federal and provincial initiatives, various clusters, incubators and networks of expertise, and the other organizations serving cleantech all support building company capacity, yet more could be done. Distinct from project finance, programs could provide small funding amounts, without excessive administration, to companies that need to develop better understanding of their markets, create business plans, or put in place advisory boards whose networks enable greater customer knowledge and access (which is a common feature in American start-ups but is less seen in Canadian companies).

Many of the suggestions we raise in Section 6: STRENGTHEN can help nascent companies find the capacity to grow their human and organizational capacity.

5.5 Reaching export markets (connecting with PULL policies)

The end goal of all the investments and supports made in research, development, demonstration and deployment is for clean innovations ultimately to be implemented. And that means finding markets and making sales.

In PULL, we discussed the importance of domestic markets – and the important role that policy, pollution pricing and procurement play in bolstering Canadian demand for cleantech solutions. International demand matters just as much – if not more. Export markets are critical for cleantech; no matter how important the Canadian market is, it is a fraction the size of the global market – currently $1.15 trillion.[285] **Estimates indicate that exports make up over 50% of revenue for the Canadian cleantech sector.[286]**

Increased trade can enable firms to exploit increased economies of scale and spur innovation through stiffer product market competition and more rapid diffusion of best practices to domestic producers.[287] This is particularly relevant for clean innovation, where the economic opportunity is driven to a large extent by export markets.† The MaRS study found that cleantech firms derive 62% of their sales from outside Canada, which outpaces other sectors like ICT (51%) and advanced health (40%). Just as cleantech as a sector is heterogeneous, so is its export profile. For example, the energy and recycling sectors see more than 80% of their revenue coming from export markets.[288]

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* In some situations, the technical founders may need to recognize that they stand in the way of managing this transition and realizing the longer-term growth potential.

† For this reason, governments and their funding agencies and crown corporations need to understand the value chain to be able to judge the potential success of a clean tech company. If the company is hoping to commercialize its technology or product and the value chain is global – financial agencies must be able to look beyond Canada's borders to assess the opportunities for success.

Tapping into a growing international export market is a tremendous opportunity. But it is also a challenge. Each country has its own policies, programs, and procurement rules – which play a big role in driving the demand for clean tech (as discussed in PULL). Canadian cleantech companies need help to successfully navigate this export challenge – sometimes in the form of financial support, but certainly in the form of connections to local expertise, country- and sector-specific intelligence, and support to build networks and partnerships in the markets of highest promise.*

Canada has built programs and capacity to support export development in general – ranging from government trade missions, to a network of trade commissioners around the globe, to embassies and consulates in key foreign markets. While these are mainly at the federal level, most provinces also have built their own foreign outreach capacity as well. Those resources need to target clean tech as a priority sector for support; up to now that has not been the case, but it seems to be changing.

Box 31: Building Clean Innovation into International Agreements

By being active on international environmental agreements and incorporating stringent environmental standards into trade agreements, Canada can actively encourage foreign markets to spur investment and build foreign demand for clean innovations while lowering the barriers to diffusion.[289] This is particularly important as Canada participates in the renegotiation of NAFTA – the first trade deal to consciously incorporate the environment and labour via side agreements – with the aim of building environmental protections into the main agreement while safeguarding past progress.

International environmental agreements such as the Paris Agreement can help facilitate cleantech investments and diffusion through mechanisms like internationally traded mitigation outcomes (ITMOs). While the precise mechanism is still under negotiation, ITMOs represent an option for a country to receive credit for GHG emissions reductions toward their national commitment by financing mitigation efforts in another jurisdiction.[290] This could provide an avenue for government to encourage domestic innovation, for example by using its power of procurement (see Section 4.3) to demonstrate Canadian innovations and export them around the world.

Federal Budget 2017 included $15 million for Global Affairs Canada to help Canadian cleantech succeed outside our borders and to build the profile of Canadian cleantech abroad, including through the development of a clean technology export strategy and enhanced cleantech capacity in Canada's Trade Commissions. Once this export strategy is built (in coordination with provinces, other departments, and the cleantech sector), it can inform the development of specific additional resources and programs to target cleantech exports.

Certain types of funding support is also important, such as helping small, growing companies (with limited capacity and cash) make initial forays to break into export markets, and also to help with co-financing the particular risks associated with export projects. Canada has both general export support programs (like the CanExport program) and a targeted finance institution (EDC) to help meet these needs. The challenge, again, is to prioritize clean tech in these programs, and build specific expertise to support its needs.

EDC, in particular, has built strong skills and a solid reputation in export finance support. To date, however, it has had mixed success in supporting clean tech. It was one of Canada's first movers on green bonds (starting in 2014, repeated in 2017), successfully raising capital and financing for Canadian clean tech firms. At the same time, several of our interviewees indicated that EDC had experienced real challenges in meeting the particular financing needs of cleantech, which often requires a different approach and risk tolerance than other sectors, and must target both financial and environmental returns to help meet Canada's

* Further, governments and their Crown Corporations need to understand the value chain to be able to judge the potential success of a clean tech company. If the company is hoping to commercialize its technology or product and the value chain is global – financial agencies must be able to look beyond Canada's borders to assess the global opportunities for success.

climate and clean growth goals. These challenges will need to be addressed if EDC is to achieve maximum impact in allocating the $450 million it received in budget 2017 for clean tech finance.

Equally important, Canada has an important global role to play in ensuring other countries make strong climate and other environmental commitments, and act on them with strong policies. Canadian leadership on the international stage through agreements on climate change, biodiversity, and air pollution solves these critical problems and accelerates the shift to a greener global economy. Action on the part of the other countries creates global demand for solutions. And Canada's cleantech companies are keen to provide those solutions.

5.6 Summary of Policy Implications: GROW Policies

When it comes to picking promising clean technologies, the market does not always know best. Because of recognized market failures (such as not pricing pollution) and barriers (such as infrastructure dependence), many clean technologies do not compete on a level economic playing field with existing technologies. Until these market failures and barriers can be corrected – which will take time – governments will need to play a time-limited role in supporting the development of promising clean technologies – as they have done with many other important technologies. By de-risking clean innovation, governments can draw in more private investors, leveraging public funds, with the end goal of creating a strong, privately financed clean innovation ecosystem in Canada.

If we want to be prepared for where the market is going, rather than just where it is today, it will require far-sighted policy leadership from governments – and a little skin in the game. With the right approach to helping commercialize technologies, governments can help cleantech companies GROW to all Canadians' benefit. Policies and programs should be designed with the following considerations in mind:

1. *Smart public investment is essential to de-risk and unleash private investment* in clean technologies, and overcome market barriers. Recent federal and provincial funding commitments go a long way to filling this gap.* In designing and implementing these public investment programs, it is important to ensure that:
    a) Public funds reach the hardest-to-fund technologies and stages, particularly commercialization and scale up of capital intensive clean technologies;
    b) Public funds leverage substantial private funding, particularly from large, patient investors (banks, pension funds, etc.);
    c) Public investment bodies weigh both financial and environmental returns in their investment decisions; and
    d) Public investment bodies at all levels should cooperate closely to promote aligned, coordinated investment strategies and priorities, to ensure they are all pulling in the same direction.

2. Smart public investment requires institutions that are *nimble, risk tolerant, expert and apolitical*. Arm's-length bodies (such as SDTC or BDC) are normally best-suited for this. Department-based funding programs should also include these traits, as far as possible, and have independent expert advisory groups.

3. Governments should signal a *long-term commitment* to public funding programs, to provide the certainty that private firms need to make 10-15 year investments.

4. A major public investment in clean technology is necessary, but should be *transitional in nature*. Over time, as PULL policies ramp-up and build market demand, private capital will increasingly support clean innovations, lessening the need for public support.

* For example: Federal Budget 2017 included $1.8 billion for cleantech financing though BDC, EDC, and SDTC; and the Government of Alberta recently announced $1.4 billion in clean innovation funding

5. Governments should explore new approaches to spur greater private investment in clean technologies, such as:
    - Setting stronger rules for reporting and disclosure of climate-related risks and investments; and
    - Appointing an expert task force to advise on ways to increase climate finance.

6. Grow international markets for Canadian clean technologies by
    - Prioritizing clean technology in trade missions and export support programs (building on the funding in Budget 2017);
    - Leveraging opportunities for Canadian clean technologies that arise from international agreements (e.g. ITMOs) and commitments (e.g. climate finance); and
    - Supporting the development of ambitious climate and environmental agreements that drive the global demand for clean innovation.

6.0 STRENGTHEN: Making the Whole System More Effective and Resilient

6.0 STRENGTHEN: Making the Whole System More Effective and Resilient

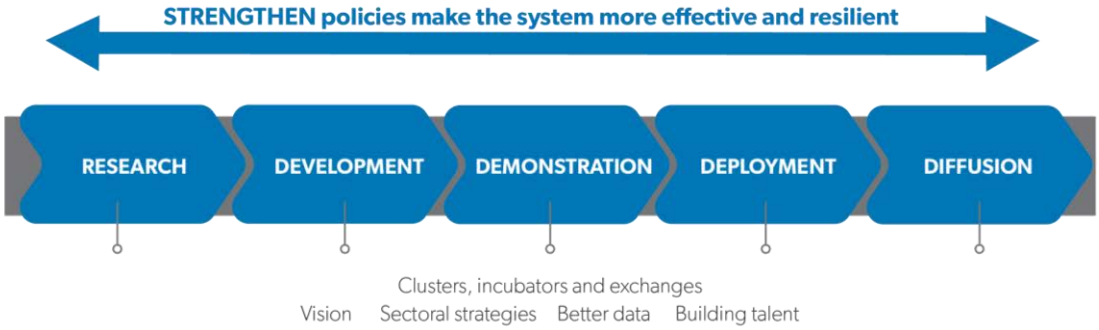
Smart Prosperity Institute's Clean Innovation model shows the broad strokes of the policy ecosystem needed to support clean innovation. Each of the policies explored under PUSH, PULL, and GROW fall into this ecosystem, targeting specific market failures and/or barriers at specific points in the clean innovation process.

There is a group of market barriers, however, that are more distributed throughout the clean innovation process. These are market barriers like "incomplete information", in other words the shortage of data in the nascent cleantech sector which is needed to inform investment decisions, and "policy incongruency", which refers to the mixed or absent policy signals in the clean innovation space. These kinds of market barriers can create negative impacts throughout the clean innovation system.

STRENGTHEN policies fill in the gaps and reinforce the effectiveness of PUSH, PULL and GROW policies by targeting these remaining market barriers. Moreover, by building capacities and amplifying connections they enable this complex system to thrive and grow. As a result, they make the clean innovation ecosystem more effective and more resilient.

The seven key policy tools included in the STRENGTHEN category are: translating vision into strategies; public institutions for clean innovation, networks, connections and clusters; investing in skills for clean innovation; bridging the data gap; bringing the suite of policies together; and ensuring accountability and continuity.

Figure 28: STRENGTHEN Policies and Clean Innovation



The role for public policy to ensure system-wide success is not new or unique to clean innovation. The Jenkins report noted "the responsibility to foster innovation cuts across many functions of government and requires a system-wide perspective." Similarly, the Council of Canadian Academies notes that one of the principal objectives of innovation policy is to "improve the capacity of the innovation ecosystem to support firm-level innovation primarily by aligning and strengthening the connecting links among institutions, policy domains, and jurisdictions." Meanwhile, the experts interviewed for this report, almost without exception, noted a role for public policy to ensure the overall clean innovation system's health.

6.1 Translating Vision into Strategies

Strengthening Canada's clean innovation future must start with a bold and inclusive vision, as explained earlier in this report. Achieving that vision requires an equally bold and inclusive strategy –one that draws on the best existing experience and expertise, buttressed by new research in places.

An effective strategy will not only articulate high-level objectives, priorities and actions, it must also dive deep and articulate potential pathways for different sub-sectors, regions, and technology areas.* It will be important to identify the different challenges and opportunities that each sub-sector faces across the clean innovation system – from R&D, to demonstration, and ultimately to market diffusion – and how public policy can be tailored to help meet these specific needs and unleash private initiative. It's fair to expect that each sub-sector's journey will be different.

It's important to acknowledge the natural tension that exists between a more top-down "sectoral planning" approach and a bottom-up "let-a-thousand-flowers-bloom" approach that supports the clean innovation system broadly but leaves different actors in the system to make their own choices. The ideal approach involves some of both. Most successful new technologies in the past century have, in part, been driven by major government investment (in R&D, finance, procurement, etc.) informed by a larger strategy.[291] But how these public investments ultimately translated into successful commercial innovations has almost always involved unpredictable pathways, driven largely by private entrepreneurship. It is possible, and desirable, to find a middle way – to support clean innovation within sectors with strategic direction and targeted investment, while at the same time enabling experimentation, risk, creativity, and learning-by-doing.

Future research will need to consider this dynamic between promoting diversity and focusing on strategic sectors. Let's take for example the different clean innovation opportunities that different sectors are facing, and consider the different strategies needed to capitalize on those opportunities.

The mining sector has a significant opportunity to be a supplier of key metals and minerals needed for clean technologies, like solar panels.[292] At the same time, all Canadian mining operations can build on the success of initiatives like The Mining Association of Canada's Towards Sustainable Mining program (TSM) to improve their environmental footprint, while also moving towards circular economy models by increasing recycling of products to extract materials for reuse. A strategy for the mining sector might be built around all these (and more) opportunities.

The electricity sector faces a different set of opportunities and challenges. Increased electrification and the phase-out of coal-fired generation come at the same time as growth in generation from renewable sources and a move towards distributed generation, long-distance/interprovincial interties and automation of grids. An electricity sector strategy would consider all these trends, along with energy efficiency and demand-side response more generally.

The opportunity for export of clean and responsibly-sourced mining commodities and electricity will be important inputs into sector development. Just as important will be the export potential of the clean technology solutions developed by and for these sectors.

But while the context in each sector differs, the goal is the same – to build strategies that enable bold and potentially disruptive change. The process to get there will be important. Incumbents may not always be the ones to push for change (and may even resist).

In order to achieve this bold change, it will be important that sector strategies are developed in collaboration with key stakeholders from industry, Indigenous Peoples, all levels of government (and their agencies) and others, both Canadian and global – tailored to each sector. At a minimum, the necessary process will achieve independent, expert, far-sighted advice, at the same time that it ensures engagement and support of key domestic firms and

* See for example the National Advisory Panel on Sustainable Energy Science and Technology (2006) Powerful Connections: Priorities and directions in energy science and technology in Canada, *prepared for Natural Resources Canada.*

stakeholders. This is no small task, and it may result in some friction and differences of opinion, but bold change that enables the action needed to secure the clean innovation advantage is worth the effort.

Federal Budget 2017 announced six sector-specific Economic Strategy Tables – including one for clean technology and one for clean resources. These sector tables will "set ambitious growth targets, identify barriers, and lay out specific strategies to help sectors achieve their targets."[295] Just as important as these two sector strategies for clean technology and clean resources are the other four* (and hopefully more), which should also address clean innovation opportunities and challenges in their formation across the economy.

Box 32: You Can't Win Without a Game Plan

Increasingly, jurisdictions are setting forth strategies to be able to compete in the 21st century clean economy. This can be seen in the UK's *Clean Growth Strategy*, released in 2017, that sets out an ambitious blueprint to decarbonize the economy.[293] Recently, Ontario released a new *Cleantech Strategy* to complement the *Climate Change Action Plan* and accelerate clean innovation.[294]

A key element that will in part define the success of these – and other – strategies for priority sectors will be the degree to which they work across the entire clean innovation system and all stages of clean innovation development. From PUSH efforts, to GROW and PULL, the public policy signals must connect, ensuring programs and policies are aligned and rowing in the same direction. Not only must public policy fill any gaps in the innovation development stages, it must consider how different innovations move through the stages – and be tailored to the uniqueness of each strategic sector.

6.2 Public Institutions for Clean Innovation

Public institutions to support clean innovation perform important roles throughout the innovation process.

For example, public institutions conduct and fund basic and applied research (PUSH policies); enact flexible regulations to induce innovation, bolster markets, and act as a first customer through public procurement (PULL policies); support demonstration, commercialization, market entry, and exports (GROW policies); and facilitate knowledge exchange, set the vision of change, build capacity, and develop structures of implementation (STRENGTHEN policies).[296]

Playing this role effectively requires public institutions to shake off their reputation for being slow, risk-averse, and disconnected from business needs. **In order for governments to be effective at accelerating clean innovation there is a need for public institutions that are nimble, risk-tolerant, smart, and can learn and adjust quickly.**

The two-way interaction between public and private actors helps shape technological development pathways. However, this interaction requires direction and careful design. While it is vital for public institutions to be able to respond to private sector needs, there is also risk of private interests capturing public institutions that fail to maintain mission-orientation toward public interests.

Conversely, government institutions run the risk of being too insular, too locked into their own way of thinking, and without the expertise, connections or responsiveness to effectively catalyze private action. They may be at risk of being disbanded as government agendas change, or they could be maintained despite ineffective performance. In order to explicitly acknowledge such trade-offs, the principles of good institutional design need to be carefully considered in developing institutions to support clean innovation.

* The six Economic Strategy Tables announced in Budget 2017 are for advanced manufacturing, agri-food, clean technology, digital industries, health/bio-sciences and clean resources

Institutional Design Principles

There is a need for public institutions to be responsive and tailored to the particular circumstances of the jurisdiction and the role they perform. Looking at both the academic literature and real-world examples, Haley[297] proposed ten institutional design principles that can be applied across the innovation spectrum:

1. **Comprehensiveness**: Understanding clean innovation as a complex system is necessary to ensure objectives are aligned and unintended consequences are avoided.
2. **Flexibility:** Innovation is a dynamic and uncertain process that requires institutions to be flexible to scale-up successes, quickly discontinue non-performing projects, and adjust to new evidence as it becomes available. Using arm's length bodies can help. While government can be risk-averse and hesitant to close down poor performers, arm's length bodies can be more flexible.
3. **Autonomy from short-term political pressure:** Institutions need room to experiment; failures will occur and institutions need to be risk tolerant and not susceptible to short-term political agendas in pursuing a long-term goal like clean innovation.[298] For this reason public institutions need to emphasize policy "stickiness", which not only protects specific policies (as discussed in Section 4.1)—but the broader innovation strategy as a whole.[299]
4. **Mission-orientation:** Clarity of mission and policy objectives targeted toward specific transformational change for the public good need to be maintained to avoid capture by private interest and to prevent continuation of projects for their ancillary benefits when they fail to attain their primary objectives.[300]
5. **Embeddedness within policy networks:** Consistent and sustained linkages with the private sector are needed to ensure effective two-way flow of information to facilitate mutual learning and build trust and reciprocity to develop the most effective and complementary policies.[301]
6. **Autonomy from private interests** – Any action (or non-action) by government can result in favouring some industries over others, yet public institutions need to be embedded with the private sector to understand the demands of the market. Effective institutions must act in the public interest without being captured by special interests; to avoid this, institutions should house sufficient *competence,* remain *mission-oriented,* and be held *accountable* through transparent evaluation.
7. **Competence:** Public institutions need to have sufficient in-house expertise to maintain their own vision and independence from private interests and earn trust within the sector.
8. **Credibility:** The public institution must have the ability to do what it says it will and act predictably in order for the private sector to have the confidence to invest without fear of sudden policy change.
9. **Stability**: Similarly, clean innovation requires a long-term commitment that must transcend political cycles and changing winds, and provide predictability for business to invest in innovation.
10. **Accountability:** Public institutions require a high degree of transparency, which includes a need for high-quality data and evaluation processes (see Section 6.5) that are open to the public to ensure accountability, support iterative learning, and maintain legitimacy. Ensuring a high-level political leader is accountable for the performance of the institution as well as its champion in government can help ensure innovation issues remain high on the political agenda.

These principles are not mutually exclusive, and a single organization representing all of them may not be desirable, or even possible. Attempting to include all principles may pull policymakers in multiple directions and create conflicting incentives that diminish the ability of an institution to be effective. For example, committing too much to stability and predictability may impede an organization's ability to be flexible and make adjustments as learning occurs. Such trade-offs need to be explicitly recognized in the development and mandate of public institutions and tailored to the specific context and mission of the organization.

Table 2 provides examples of some of the most effective public clean innovation institutions from around the world and how they incorporate these design principles.

Table 2: Examples of innovation institutions around the world

Institution	Role	Description
Advanced Research Projects Agency – Energy (ARPA-e)	Research	US arm's-length mission-driven organization that promotes experimentation in energy innovation. The organization has the *flexibility* to work outside of government hiring procedures which allows it to attract top-tier talent that build institutional *competence* and *credibility* while conducting cutting-edge research. ARPA-e uses an island-bridge model to balance *political autonomy* and *accountability*, by operating "as an island" to allow the *flexibility* to experiment, with a direct "bridge" to the government through the Secretary of Energy who is *accountable* for performance and charged with keeping energy innovation issues high on the agenda.[302]
Fraunhofer Society	Research PPP	The Fraunhofer Society is the leading-edge organization for applied research in Europe that works to bridge the gap between industrial needs and academic research. The society is composed of 69 specialized institutes and research centres (*mission orientation*) that work with universities and focus on rapid commercialization of research through a large number of short-term research projects. Core public funding represents only about 30% of its annual budget (*autonomy*), with contracts from the private and public sectors, as well as licensing from IP composing the majority (*embeddedness*). See more on Fraunhofer in the box below.
Sustainable Development Technology Canada (SDTC)	Finance for demonstration and scale-up	Canadian arm's-length institution (*autonomy*) created in 2001 to help cleantech companies cross the "valley of death" through financing. Over time its mandate has evolved to become more *comprehensive* including business development support to set up follow-on investments, matching technologies to customers, and promoting exports in partnership with Export Development Canada.
Netherlands Front-runner Desk	Throughout	A "frontrunner desk" was created as part of the Netherlands' energy transition approach (*mission-oriented*) for companies to report barriers created by existing policy and regulatory structures to government (*comprehensiveness*). This desk promoted information flow to government to improve policy design and implementation (*embeddedness*), and it helped innovators navigate government processes.[303]
UK Committee on Climate Change (CCC)	Monitoring and enforcement	While not an innovation institution specifically, this *autonomous* body of experts (*competence*) is mandated to advise the UK Government and report to parliament on progress towards achieving emission reduction targets.[304] In particular, the CCC creates 5-year carbon budgets for national emissions that must be approved by parliament and enshrined in law to ensure commitments are *credible* and hold the government *accountable* through a transparent process.

Canada's Innovation Institutions

Canada is home to a wide range of public institutions that support innovation across jurisdictions, sectors, and innovation stages. The federal-provincial Working Group on Clean Technology, Innovation, and Jobs identified dozens of different ministries, agencies, and institutions that oversee more than 180 programs and regulations supporting clean technology across Canada.[305] This decentralization of innovation activities reflects Canada's regional and economic diversity and may allow more freedom and flexibility; however, ensuring innovators can find the right support requires a networked system and effective intermediary institutions.

While examining and evaluating the breadth of Canadian (clean) innovation institutions is beyond the scope of this report, the announcement of new public initiatives to support clean innovation in Canada in Budget 2017 are of particular importance, and the principles outlined above should inform their development.

New Institutions in the Mix

As highlighted in GROW, Budget 2017 recapitalized SDTC to support demonstration of innovative clean technologies, and provided new cleantech specific funding for Business Development Canada (BDC) and Export Development Canada (EDC). One governance challenge for latter two, identified in our interviews, is to build the capacity for mission-oriented cleantech funding, with its unique challenges, in large organizations with more traditional finance expertise and mandates.

Budget 2017 also announced the creation of *new* institutions to support innovation in Canada, and specifically targeted clean innovation.[306]

Innovation Canada
Innovation Canada will be a new platform to coordinate and simplify public support programs for innovators with six sector-specific Economic Strategy Tables, including one for clean technology and one for clean resources. These sector tables have now been launched, and will "set ambitious growth targets, identify barriers, and layout specific strategies to help sectors achieve their targets."[307]

Clean Growth Hub
The Clean Growth Hub, opened in January 2018, is tasked with providing a new single-service window for cleantech firms, to streamline client services, improve federal program coordination, enable tracking and reporting on clean technology results across government, and connect stakeholders to international markets.

Superclusters
As described below in the Networks section, the federal government conducted a competitive process to identify clusters in five areas that – have high potential to become globally competitive, with an injection of almost $1 billion in funding support over 5 years.

Impact Canada Fund
A new mission-oriented fund will provide financial support for "moon-shot" style missions including one to address challenges for Canada's rural and remote communities in transitioning from diesel to renewable and cleaner power sources; and a Smart Cities Challenge to find innovative ways to "improve the quality of life for urban residents".

Effectively implementing an ambitious clean innovation agenda will require public institutions that are able to complement and catalyze private sector initiative. To this end it is important that the ten principles be carefully considered and trade-offs explicitly acknowledged when designing new institutions.

6.3 Networks, Connections and Clusters

The clean innovation system is stronger when public and private researchers, public and private finance, small and large businesses, and customers and solutions providers are connected through various networks. As Lundvall and Borrás point out, **"more and more of the innovation process takes place in networking as opposed to hierarchies and markets… only a small minority of firms and organizations innovate alone, and… most innovations involve a multitude of organizations."**[308]

Networking is defined by the OECD as the systematic establishment and use of internal and external links (communication, interaction, and co-ordination) between people, teams or organizations in order to improve performance. As the OECD points out, "networks may function horizontally – between institutions from the same or different sectors, between firms and research centres, or between competing firms. Or, they may be vertical arrangements between clients and suppliers."[309] They can also include universities, think tanks, standard-setting institutions, consumers and others, all working in a given field.

Hubs, centers of excellence, accelerators, incubators and clusters are all forms of networks. In the clean innovation field, these networks can provide a variety of benefits that counter market barriers such as incomplete information and capital intensity, as well as the spillover and environmental externality market failures.

Clusters

There is a growing body of evidence looking at the importance of clusters in innovation. Michael Porter, who is widely cited as introducing the idea of clusters to the mainstream,* explained a cluster as "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities."[310]

From Bangalore and Silicon Valley (for high-tech) to Boston (for biomedical) to Hollywood (for film and entertainment), to the Greater Toronto Area (for automobile manufacturing), to Montreal (aerospace) there's a long history of cities and regions that host such concentrations of expertise in various fields.

Clusters have a number of positive impacts, including boosting the productivity of the companies in the cluster, driving the pace and direction of innovation, and stimulating new businesses to form (which in turn helps strengthen and expand the cluster). According to Porter, "A cluster allows each member to benefit *as if* it had greater scale or *as if* it had joined with others formally – without requiring it to sacrifice its flexibility."[311] By virtue of being located in close proximity, cluster participants are likely to collaborate on projects, share facilities, attract a greater pool of talent from which to draw, and raise one another's profiles with the public and investors.[312]

A 2015 meta-analysis of clusters finds that clusters do indeed have a positive impact on innovation on average. It also finds a number of factors that are associated with greater innovation in the cluster, such as lower firm concentration, and highly localized/specialized firms in the cluster.[313]

However, as Porter argues, clusters cannot be created from scratch, but instead public support should begin with data and information that identifies pre-existing clusters (which may be obscured in standard industrial categories), or that helps identify where the government may wish to play a role in encouraging a cluster to emerge.

This is a comment we heard often from this report's interviewees – that government support for clusters should not aim to start expertise from scratch but should follow and expand on existing private sector initiatives and strength.

* The very first reference to clusters is generally regarded as Alfred Marshall in his 1890 book Principles of Economics.

Through data and information* about sector specific strengths and opportunities, governments can seek out strategic areas with growth potential. Further, this information can help to pull in the private sector, guide private sector investment, and grow the cluster by showing potential new companies where there is existing expertise to capitalize on. Over time, information can also flow from the cluster back to government, identifying where there may be shortcomings in the existing policy regime and industrial environment.†

The presence of greater knowledge spillover externalities[314] combined with the environmental externality market failure, provide a clear rationale for public policy to support vibrant cleantech clusters. And similar to the finding that in general, firms in clusters outperform their peers, research shows that cleantech businesses in climate innovation hot spots outperform non-cleantech businesses in the same area across several indicators such as employment, wages, and labour productivity.[315]

Box 33: Examples of Clean Innovation Clusters

UK Autodrive[316] is the largest of three UK consortia launched to support the introduction of self-driving vehicles to the UK. It brings together leading technology and automotive businesses, forward-thinking local authorities and academic institutions to deliver a three-year trial of autonomous and connected vehicle technologies (which can reduce congestion and pollution).

Copenhagen's Cleantech Cluster is a climate innovation cluster that has created over 1,000 jobs, helped establish over 120 new businesses and attracted 12 international cleantech companies to Copenhagen. The cluster works with energy, environment, smart city, and has a focus on connecting participating companies with international markets. Denmark was ranked #1 in the 2017 CleanTech Group/WWF ranking.[317]

Canada: Closer to home, both Vancouver and Montreal identify a particular concentration in cleantech. Vancouver claims to be home to 25% of Canada's cleantech companies[318] while Montreal[319] points to its cleantech public research strength and numerous companies.

So how should clusters be formed? A recent discussion paper by the Brookfield Institute and the Institute for Competitiveness and Prosperity argues that a Canadian government cluster strategy – such as the Budget 2017 Innovation Supercluster Initiative[320] – "must build on the existing strengths of the region and lay out targeted initiatives and investments that will be delivered in a coordinated manner over a long time horizon to help overcome market failures." For example, the European Cluster Observatory, a European Commission initiative that studies clusters and cluster policy, evaluates regions by their potential for priority sector clusters based on their strategic profile (see Figure 29 for an example).

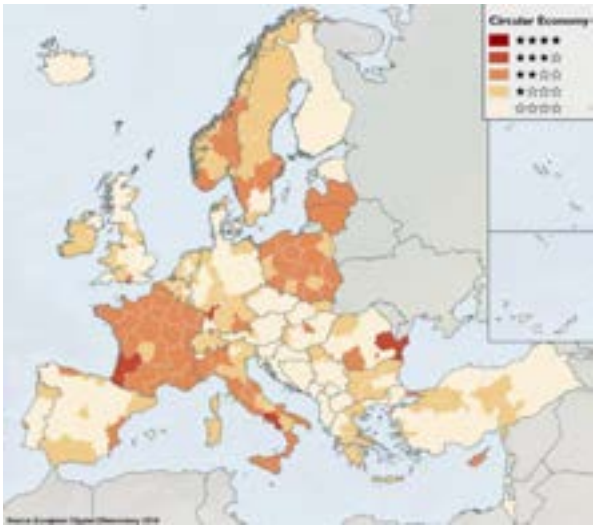
Due to the pace of change in technologies and practices, governments must find ways to ensure their policies remain relevant and are accompanied by plans that extend long term, including beyond current governments' mandates.[321] The authors propose four recommendations in the areas of: ensuring private funding alongside public funding, evaluating cluster goals, ongoing monitoring, and rationalizing cluster support by inking clusters policy with the broader skills and innovation agendas.

* For example, this information could include: the number of small, growing companies, the export potential of the technology group, and the strength of human capital in research and entrepreneurship.
† Porter has also argued that "public policy at the cluster level, in contrast to policy at the industry or firm level, avoids the inefficiencies, moral hazard, potential distortions, and dubious rationale of many narrowly targeted policies such as innovation grants for particular firms, or single industry technical assistance programs. The case for a public role in training, for example, is much stronger at the cluster level than at the industry." Porter, M. (2009) Clusters and Economic Policy: Aligning public policy with the new economics of competition, *ISC White Paper, Harvard Business School.*

A further question is, how clean innovation clusters should be focused? Work undertaken at Imperial College London argues that generally clusters should not be focused on particular technologies, but rather on areas where significant systems change is required – such as in mobility or food. Regarding climate change, the authors argue that "some climate innovation clusters are well positioned to develop climate technology solutions, such as electric vehicles, but these clusters are few… For many regions, a strategy that emphasizes the widespread use of innovations is more realistic than every region aspiring to become the new 'Silicon Valley for cleantech'."[322]

In that vein, the report authors suggest that climate-focused innovation clusters should not just include the solutions producers (like businesses and research institutes), but also "other organizations that are centrally placed in socio-technical systems, such as local authorities, community groups, trade associations, or public transport organizations". And the clusters should focus not just on new technologies, but on other system elements, such as "rolling out essential infrastructure, adapting regulations, training maintenance workers, and changing perceptions about car ownership or range."

Figure 29: Leading Regions in Circular Economy[323]



A recent study by Technopolis Group argues that climate clusters should be formed around where existing industries have needs for solutions, such as in the manufacturing sector where companies are seeing increased demand for lower-polluting, cleaner versions of their products. Similarly, clean innovation should be woven in to cluster strategies for industrial and manufacturing sectors, so as to facilitate these sectors' uptake of climate solutions.[324]

The literature and experience suggests a need for a mix of approaches to facilitate clean innovation networks and connections. There is a role for a more traditional, 'vertical', sector-focused approach of building clean innovation into cluster strategies for specific manufacturing and industrial sectors, to help these existing sectors achieve world class clean performance. But clean innovation solutions may often spring from outside-the-box connections that cross traditional sector lines, for example:

- ICT innovations that help drive solutions for clean transportation (e.g. smart cars) or energy efficiency (e.g. smart meters);
- Clean water solutions that could apply across multiple sectors (e.g. municipal waste, mining, agriculture, oil sands);
- Bio-economy innovations whereby bio-based materials (from agriculture, forestry, food services) help provide clean solutions for advanced chemicals, fuels, or consumer products like cosmetics.

This suggests an additional need for a more 'horizontal' cross-cutting approach to clusters or networks, which links across sectors and regions.[325] These are already forming in Canada. For instance, Evok Innovations is a partnership between the BC Cleantech CEO Alliance, Cenovus Energy and Suncor Energy that accelerates innovation in the oil and gas sector by investing in the commercialization of clean technology.[326]

For these reasons, cluster and networking approaches should combine a mix of approaches, reflecting the differing pathways for clean innovation, including:

- A traditional 'vertical', sector-based approach focused on fostering clean technology solutions for a particular sector(s);
- A 'horizontal', cross-cutting approach that focuses on building novel solutions and connections, across sectors, environmental pressures, regions and technology platforms; and,

- A systems innovation approach, focused on meeting system challenges facing a particular region (transportation, food, etc.) by linking across a broader range of tools (technology, policy, regulatory framework) and actors (like public researchers, companies, regulators and more).

Box 34: Superclusters[327]

Budget 2017 committed $950 million over five years to support the development of "superclusters". Over 50 applicants entered the competition, and in February 2018 the five selected superclusters were announced, representing: digital technology, protein industries, advanced manufacturing, AI-powered supply chains, and ocean industries. While none focuses specifically on clean technology, each has sustainability or cleantech as an element. Building a central role for clean innovation in these clusters will be important, and potentially challenging – since it can be a disruptive force for established players and systems in agriculture, manufacturing and other cluster areas.

6.4 Investing in Skills for Clean Innovation

Seizing the clean innovation opportunity requires human capital. That means preparing Canada's workforce for the jobs that a stronger clean innovation system will both depend on and create. The highest priority areas to invest in include higher education research, building trade and IT skills aligned with emerging clean technologies, and integrating clean innovation knowledge into finance and business development.

Attracting and developing the talent and skills needed to accelerate clean innovation is an area where public policy can play a role.

In general, these clean innovation jobs require skilled workers. On this, Canada begins in a position of strength, ranking first among 34 OECD countries in attainment of tertiary education, including the highest rate of college/vocational training (25%) and 7th highest rate university attainment (28%).[328] This highly educated workforce gives Canada a good foundation to drive clean innovation and adapt to shifts in industry demands.

Cleantech is hiring

On cleantech specifically, Canadian employment has seen growth in recent years; according to Analytica Advisors, employment in the cleantech sector currently accounts for over 55,000 jobs.[330] These tend to be high-skilled and high-wage jobs, and more are becoming available. For example, a survey of the cleantech industry in British Columbia found the average salary to be $84,000, and 85% of respondents anticipated hiring in the next 12 months.[331] Young workers in particular are finding roles in the emerging cleantech industry, representing 23% of the sector.[332]

Identifying and building the required skills

While 23% of Canadians entering the industry come with a background in engineering, the sector's needs are diverse.[333] Research points to the need for technical skills in science, operations management, engineering and skilled trades as high future demand areas for the clean economy.[334] While not specific to cleantech, one estimate suggests the skills gap in Ontario alone (in areas like science, engineering, and technology, and business and finance – which are key to clean innovation) costs the province as much as $24.3 billion in lost GDP annually.[335]

Box 35: Founding Fathers

While growing cleantech companies is key, so is growing cleantech company leadership. According to the MaRS survey, just under 80% of the surveyed companies were founded by all-male teams and only 17% had at least one woman among their founders. As MaRS points out, this gender skew may be because cleantech founders are often engineers, a profession that is still heavily male dominated. "Canada has a long way to go before it achieves anything close to gender balance in cleantech."[329] The story of visible minority representation is similar. Without greater diversity in cleantech leadership, Canada's cleantech sector will miss the opportunity to draw upon the diverse skills and perspectives of women and minorities.

While most discussions around skills for the low-carbon economy focus on the technical skills required, the business skills required for supporting innovation and company growth are also essential. In order for clean technology companies to commercialize, scale, and compete internationally, the development of strong business leadership skills in clean technologies are needed, including international business development, sales, and capital-raising.

Another recurrent theme from the cleantech sector is that Canadian banks and finance institutions need to develop the skills to provide innovative financial solutions that meet the unique needs of the cleantech sector[337] (see GROW).

Box 36: Sustainability at Canadian Colleges and Institutes[336]

The Colleges and Institutes of Canada, representing 130 educational organizations across the country have signed on to the *Pan-Canadian Protocol for Sustainability* committing to incorporating measures of sustainability into their own organizational practices, but also to "integrate the principles of sustainability within curriculum to enable students and communities to develop competencies and commitment to contribute to a sustainable future."

Industry surveys and interviews have identified some general skills needs for clean innovation, however data about current and future skills demand are limited.

The Labour Market Information Council for Canada was created in 2015 with a mandate to "to improve the timeliness, reliability, and accessibility of LMI to facilitate decision making by students, workers, job seekers, employers, and policy makers, in support of a flexible, efficient labour market." [338] Such an initiative has potential to help meet the current information gaps, however it will be essential to be forward looking and include a vision of the low-carbon economy of the future to ensure skills and training initiatives are 'skating to where the puck is going'.

Collecting detailed labour market information and information on the skills profile that employers anticipate needing can help identify where there are mismatches between the workforce and the economy's needs – thus pointing out the gaps where efforts to improve training and education are needed.

Box 37: Skills Gaps as a Barrier to Adoption of Clean Innovations

Skills gaps not only threaten our ability to create clean innovations, but also to effectively adopt and integrate them into business practices –an integral element for clean innovation to be successful. A survey by DEEP Centre identifies a lack of in-house skills (i.e., within the existing staff) as a major barrier to adoption of clean technologies.[339] Another recent survey of Canadian businesses identified challenges related to employee skills and training as 4 of the top 5 obstacles to adopting advanced green technologies behind only return on investment.[340]

Aligning government resources, industry knowledge and needs, and the training capacity of institutions will not only allow new graduates to develop the skills profiles that organizations are seeking but also provide upskilling opportunities to workers in industries that are changing.

Skills misalignment can also be spatial, if qualified workers are not where industry needs them.[341] Migration, both domestic and international, can help get skilled workers to the industries where they are in demand. For this reason the Canadian Government recently announced a Global Skills strategy to accelerate the administrative process for bringing highly skilled workers into the country.[342] As the Canadian population continues to age, migration will continue to be a key talent source to fill skills gaps.

In order to meet the skills demand for accelerating clean innovation, adequate opportunities and incentives for training and skill upgrades should be made available to workers. Not only does this ensure the workforce that employers need, it can help position more workers to benefit from the growing low carbon economy. Further, while a greener economy brings enormous benefits, it can come with disruption. Some workers may require additional support to effectively navigate the transition, such as training workers in declining sectors will be able to

adapt their skills for new opportunities in growing sectors. In some cases, only small amounts of training are required, for example many of the skills used in the oil sector such as welding, surface treatment, and outfitting are in high demand in the emerging wind turbine industry.[343] In particular, there is a need for support for low-skilled and marginalized workers with fewer opportunities for formal education or on the job training and who may face additional barriers to "upskilling".[344]

Box 38: Building Skills for a Clean, Inclusive Economy

BUILD (Building Urban Industries for Local Development) is an Aboriginal-run non-profit in Winnipeg that conducts water efficiency retrofits and installs insulation in low-income housing while providing jobs and training for people facing barriers to employment. In 2011, BUILD was awarded the Scotiabank eco-living prize for business leadership.[345]

Similarly, FortisBC, the natural gas distributor in BC's lower mainland, sponsors a training program called Residential Energy and Efficiency Works (REnEW) to help those who have faced barriers to employment gain the necessary skills and certifications to enter the workforce. Since its inception in 2010, the program has trained 140 individuals.[346]

Recent Policy Progress

The government announced a wide ranging 'Innovation and Skills Plan' in Budget 2017 that includes measures to support the migration of skilled workers, extend financial support to post-secondary students with families, extend Employment Insurance support for those upgrading their skills, and invest in work-integrated placements for students. Notably, the Budget also announces the creation of a new organization to "support skills development and measurement in Canada."[347] Budget 2018 built upon these commitments with new training programs for under-represented groups in the skilled trades and science, technology, engineering, and mathematics.[348]

6.5 Bridging the Data Gap

Information is power, but when it comes to Canada's clean innovation system there is too little of it readily available. Information, such as the amount of revenue generated by companies selling cleantech, their levels of employment, their exports and their level of investment from venture capital and other sources of private investment, is generally missing for researchers, policymakers, and investors. Bridging the data gap is critical to overcoming barriers from incomplete information and accelerating clean innovation.

No single source of data is able to tell a complete story. The following sources of data could contribute to more informed stakeholders and a more efficient clean innovation system:

- *Industry data,* such as revenues, employment, and exports to show industry trends and areas of emerging strength
- *Public program data,* also known as *administrative data,* including information on how organizations are using government programs and their successes/failures will help inform evaluation and future program design
- *Jobs data,* to help inform the skills agenda and allow educational institutions to align their offerings with market demand (see Section 6.4)
- *Firm level data*, including tracking companies as they progress through the innovation system, to improve understanding of the system as a whole, and help identify strengths and weaknesses

Industry data

Statistics Canada collects data on cleantech business services, their revenue and the percentage of revenue that comes from exports. In general, it uses a combination of surveys and sampling to gather that information.

Information gathering in the cleantech sector by Statistics Canada began with the Environmental Industry Survey and was bolstered with the Survey of Environmental Goods and Services (SEGS) to collect data on companies

specializing in clean technologies. SEGS has recently been expanded to include a broader range of environmental services with new data released in Fall 2017.[349]

Statistics Canada is also piloting a new "satellite account" for environmental and clean technology (meaning it is part of the System of National Accounts and can be analyzed with broader economic accounts). This allows StatsCan to identify and extract clean technology activities from within the economy and present this information in a coherent form – creating a "big picture" of the upstream and downstream economic impact of cleantech sectors. As a satellite account the measurement conforms to the Canadian System of National Accounts principles so that it can be examined along with broader economic accounts.

While the initial accounting casts a wide net (for instance scrap metal exports is Canada's #2 cleantech export), the account provides new insight into the size of the environmental and cleantech product market, estimating it to represent 3.1% of GDP and 274,000 jobs.[350]

This first-of-its-kind program to measure the environmental and clean technology sector's economic impacts, in addition to Canada's established expertise in natural resource accounting, will position Canada among the world leaders in economic and environmental accounting for the cleantech sector. As Canada forges ahead in this area, it will be important to monitor, and align Canada's approach with international best practices (as they evolve) to be able to share Canada's developed expertise and make accurate international comparisons of performance and progress.

Private Data Gathering Exercises

There are a number of private organizations that gather key company level data. For example, Analytica Advisors collects data from a sample of the more than 800 companies specializing in clean technologies.[351] Analytica's analysis is based on comprehensive and detailed data, going beyond company revenues to the levels and source of investment at the various stages of technology development.

Other companies have private data sets, including the Cleantech Group, as well as a number of large international data gathering companies like Pitchbook and Bloomberg. These private data sets provide a wealth of detailed data. However, confidentiality concerns and/or paywalls limit data availability.

As demand for information on the cleantech sector has grown, more initiatives have stepped in to meet this information need. This includes recent reports that profile the state and needs of the cleantech sector, such as KPMG's survey of the British Columbia cleantech sector, and MaRS Discovery District's report using data from the cleantech companies they work with (see Box 22).[352]

Information on Government Programming

There is also a need for consistent, accessible information about government funding and programs in order to inform the public and industry, and evaluate the performance of programs, and maintain transparency. This data is often referred to as "administrative" data, and is collected by dozens of departments, agencies and programs, across federal and provincial governments.

In general, the existing firm-level data collected in public program applications is not made public (due to confidentiality concerns) but rather used solely for government decision-making purposes.

Information on the amount of funding allocated to companies is generally made available, however it remains housed in separate silos of government with no single repository for federal information, let alone for information from across jurisdictions. This information, is collected by SDTC, BDC, EDC, IRAP and other institutions providing research support, grants, loans, or support services to cleantech companies.

Government research labs, such as NRC and CanMET, are another important storehouse of information. The extent to which government labs such as these are working on clean innovation, the projects they are exploring and their successes and failures could help inform research agendas, promote collaboration and avoid redundancy. The same is true for federal and provincial research granting councils such as NSERC. While some research data must remain confidential, information from these bodies can help in understanding, for example, where Canada's research energies are being directed, and how to best align research funding with broader public and private sector strategic priorities.

Notably, recent funding in Budget 2018 to support data collection on innovation programming by Statistics Canada and program evaluation by the Treasury Board provide a strong opportunity to improve in this area.[353]

All this data – subject to confidentiality restrictions – should be accessible via a single window, ideally including both federal and provincial programming. This would allow the public, academics, think tanks and investors to easily see where public effort is assisting companies working on clean innovation, and to evaluate results. Further, maintaining data on projects and companies that applied but did not receive support would allow for better understanding of the impacts of such programs. This will help policymakers to understand the effectiveness of various programs, learn from other organizations' experiences, and make adjustments as required.

Standardization of data collection and collaboration can reduce the data collection burden and help streamline processes for firms progressing through the suite of government programs. Tracking firms' performance as they progress through programs at different stages will help to better understand the innovation system as a whole and identify where programs are not living up to their investments and gaps where more support is needed.

Additional data needs

An area where data collection remains particularly challenging is around the adoption of clean technologies. Data on clean technology sales and exports from StatsCan's new satellite account can help inform this area, however this also requires comparable international data to understand the degree to which Canadians and firms are purchasing foreign-made clean innovations. Gaining a better understanding of where and how clean technologies are being purchased and used remains an important area for further data development.

Further, environmental performance data on clean innovations to accompany economic performance data would be useful to measure the magnitude of improvements. In particular, there is a need for better information on environmental impacts beyond GHG emissions. Understanding the environmental impacts of technologies and production practices and being able to quantify degrees of improvement can help inform baseline setting in regulations that have to keep up with rapidly changing technology. Additionally, improving the amount and accuracy of environmental performance data on products and processes will allow for better informed decision making by consumers.

Additional data needs have been highlighted throughout earlier sections of the report, including better data around skills, public procurement, and financing, including mergers and acquisitions, VC funding, and loans.

Current and Future Data Gathering Options

Recognizing the importance of good data, the Pan-Canadian Framework on Clean Growth and Climate Change set out to create a Clean Technology Data Strategy, which was funded by the federal government in Budget 2017. The strategy aims to establish a statistical framework for evaluating the performance and economic contribution of the cleantech sector.

One innovative means of gathering future data would be to crowdsource it. There are a large number of actors, from private companies to cluster organizations to government programs that are gathering data. Standardizing and streamlining the methodology as well as creating a central repository could enable detailed data to be easily and publically accessible. It would also democratize access to information and provide more specific data than StatsCan's current survey and sampling methodology allows.

Accurate and accessible data is necessary to ensure clean innovation is receiving the support it needs, where it needs it, and for the sector to grow and compete globally in the decades to come. The Clean Technology Data Strategy is a promising opportunity for Canada to build on its world-leading statistical capability and help pioneer this important area. Improved data is needed with regard to industry (employment, revenues, exports), public programs (quantifying their effectiveness), jobs, and firm-level data (to track firms as they progress through the system), as well as financing and public procurement, amongst others. For such a significant undertaking to be successful, it will require coordination across regions, jurisdictions, sectors, government departments, and private actors in order to build a comprehensive picture of the clean innovation system.

6.6 Bringing the Suite of Policies Together

As outlined throughout this report, effectively addressing the double market failure and additional barriers that impede clean innovation requires a suite of policies. These policies transcend innovation policy and include environmental policy (as demonstrated in PULL), finance and trade policy (GROW), IP, science, and technology policy (PUSH), and even education, labour and immigration policy (STRENGTHEN).

Therefore, looking at the impacts of PUSH, PULL, GROW, and STRENGTHEN policies in isolation is necessary but not sufficient, there is a need to recognize how they interact in the clean innovation system and consider the wider policy, regulatory, and political context in which they occur. [354] Evidence shows that the combination of innovation and environmental policy instruments can be more effective in supporting clean innovation than either in isolation, a view that is now widely accepted by innovation researchers,[355] political scientists,[356] as well as economists.[357] For example, Fischer and Newell (2008)[358] look at PUSH and PULL and find that a combination of emissions pricing, R&D subsidies, and learning can lead to the reduction of emissions at a significantly lower cost than any single policy instrument alone (with emissions pricing being the most efficient single instrument).

Additionally, combining policies effectively can help compensate for negative impacts and unintended consequences of clean innovation policies. For example, aligning PUSH, GROW, and PULL policies can help prevent carbon leakage (from strong climate policies) by fostering research, development, and deployment of technologies that allow firms to boost productivity and reduce emissions and energy use at lower cost.

The role and impact of policy instruments differ depending on the type of innovation, its maturity, level of disruptiveness, as well as the capacity of actors targeted by the policy. It is therefore important to build a portfolio of clean innovation policies that target the weakest points in the system. It is also essential to ensure gaps are minimized and firms can smoothly transition between programs to continue to progress through the innovation system. This can be aided by strengthening communication and handoffs between programs.

One critical element to building an effective policy mix is policy coherence. As highlighted earlier, lack of policy coherence represents a barrier that undermines clean innovation performance; when policies aren't pulling in the same direction the result will inevitably be an underperforming system. One common example of this is the presence of subsidies for oil and gas producers in Canada, estimated by some at over $3 billion annually.[359] While Canada has committed to phasing-out fossil fuel subsidies along with the rest of the G20, the presence of these subsidies encourages the very polluting activities the country is trying to reduce – with public policies, incentives, and investments – and undermines attempts to internalize the environmental externality market failure.

Designing an effective, coherent policy mix is a complex and challenging process, characterized by an increasingly crowded policy landscape attempting to achieve a variety of goals with limited coordination between multiple agencies and jurisdictions. It is therefore important to take a systemic view and consider the policy mix at all stages, from individual policy and portfolio design through to monitoring and evaluation.[360] Some suggest that 'policy patching' – the gradual implementation and targeted updating of policies – may be more effective than attempting to design a comprehensive policy package that spans the entire system at one time.[361]

6.7 Ensuring Accountability and Continuity

Clean innovation requires a long-term commitment that must endure beyond political cycles. How can governments create the "stickiness" required to sustain not only specific policies (as discussed in PULL) but a broader clean innovation direction and strategy as a whole? How can they ensure results are measured and achieved? We've noted several times that policy signals require certainty and predictability, while investment programs require long-term commitment (both for R&D and commercialization).

By designing and funding programs with a trajectory over 5-10 year periods (or more), governments create more long-term certainty; this predictability will do better at drawing in private capital to co-invest. Policies and programs that signal a safe environment for private investment (in research, demonstration, commercialization or adoption) help build the business case for clean technologies.

One of the ways in which governments can do this is via the creation of processes and institutions to provide oversight, give expert advice and ensure accountability. The Jenkins report called for an external advisory committee for this very reason: "Effective implementation of our action plan will depend on an oversight structure that ensures the timely achievement of desired outcomes." It envisioned "a body with a whole-of-government focus that would oversee the realization of our proposed action plan, as well as serve as a permanent mechanism to promote the refinement and improvement of the government's business innovation programs going forward."[362]

Box 39: The Science, Technology and Innovation Council[363]

The Science, Technology and Innovation Council (STIC) is an expert body established in 2007 to advise the federal government in the areas of science, technology, and innovation. STIC produces biennial reports that benchmark Canada's progress and performance relative to other nations and provides an evidence base for government decision making.

Independent, expert reviews are one way in which accountability can be embedded by design. The Pan-Canadian Framework on Clean Growth and Climate Change includes a commitment to develop a process to review implementation, as well as review carbon pricing, to be completed by early 2022.

A further option is the creation of independent, expert bodies. The UK Committee on Climate Change (see Box 17) is one such example. It embodies many of the features of institutions we describe in Section 6.2. In Canada, the National Roundtable on the Environment and the Economy played a similar, broader role for over 25 years, until it was disbanded in 2013, leaving Canada without a national advisory body in the area of environment-economy-sustainability (as are found in many developed nations).[364]

Canada should consider options to guide the development and implementation of policies and programs for clean innovation, including: (a) establishing independent, expert advisory processes and committees, and (b) creating an independent commission or council, with sufficient staff and resources to provide ongoing expert advice. Possibilities include a stand-alone commission on clean innovation, or embedding this as a key function in a broader commission, focused (for example) on overall innovation or clean growth.

6.8 Summary of Policy Implications: STRENGTHEN Policies

There are certain aspects of clean innovation that permeate the entire system: translating vision into strategies; well-designed public institutions ; networks, connections and clusters; investing in skills; bridging the data gap; bringing the suit of policies together; and ensuring accountability and continuity. Ensuring these elements are effectively designed and aligned is essential to the success of the system as a whole.

1. Governments should develop *clean innovation strategies,* informed by expert advisers, in collaboration with key actors (business, research, investor, community).* These strategies should:
    - Identify goals, priority areas, and key actions to advance clean innovation, based on Canada's strengths and comparative advantages;
    - Address different sectors, regions and technology areas, considering both short- and long-term opportunities; and
    - Inform and align all government research, investment, resource allocation and policy-making across the clean innovation system.

    Federal sector strategy tables, by prioritizing clean growth, could partly meet this need.

2. To catalyze clean innovation, governments themselves must be more innovative. They must encourage more experimentation, risk-taking, learning and adjusting (fast) from successes and failures. Public institutions supporting clean innovation must be designed to embody these traits (see 'ten institutional design principles' in Section 6.2)

3. Prioritize clean innovation in clusters and networks that combine a mix of the following approaches:
    - A traditional 'vertical' approach focused on a particular sector(s)
    - A 'horizontal', cross-cutting approach focused on building novel solutions and connections across sectors, environmental pressures and technology platforms
    - A 'systems' innovation approach, focused on meeting systemic challenges (food, transportation, northern energy) by linking across a range of actors and tools (investment, infrastructure, policy)

    The federal superclusters program offers an important opportunity to grow large-scale strategic clusters, they embed clean innovation as a priority. It is also important to prioritize clean innovation in *network* support programs (e.g. NCE, tri-council, OCE).

4. Support regional incubators and hubs, to build capacity and connections with an emphasis on clean innovation.

5. Identify and close skills gaps for clean innovation by supporting training initiatives, education programs, and re-training or upskilling opportunities in changing sectors, with a particular focus on affected workers and under-represented communities.

6. Improve clean innovation-related data, including as it relates to industry (revenues, exports), public programs (their effectiveness) and jobs, as well as financing and public procurement. This data should be coordinated across jurisdictions, sectors and departments, and be available to researchers to enable better evidence based policy-making and investment. (The Clean Technology Data Strategy is a promising opportunity for Canada to build on its world-leading statistical capability and help pioneer this important area.)

7. Ensure that the overall mix of PUSH, PULL, GROW and STRENGTHEN policies are aligned, comprehensive and reaching intended goals. This requires better policy and program coordination,

* This could be nested within a larger clean *growth* strategy (or strategies).

measurement and evaluation across governments. (Institutions like the new Clean Growth Hub can help to meet this need.)

8. Establish an independent clean innovation advisory council or institute, with sufficient staff and resources to provide ongoing expert advice to guide the development and implementation of policies and programs. This is important to provide 'stickiness' and drive continued momentum for clean innovation initiatives.

7.0 Overall Implications for Policy Makers

From climate change, to water scarcity, to biodiversity loss – the world is facing a new imperative for clean, low-pollution, resource-efficient economic growth and development. All sectors of the Canadian economy have an opportunity to build on our unique strengths to provide these solutions to the world. Doing so will require a new vision and framework for aggressively adopting the best clean technologies the world has to offer, while simultaneously getting Made-in-Canada clean innovations to scale and to market.

In addition to the specific policy implication identified in each section, several high level lessons emerge from this report:

- Accelerating clean innovation is not just about solar panels and electric cars; it offers tremendous opportunities across all economic sectors and regions of Canada. Clean innovations lower costs. They meet an increasing market demand for environmental solutions that will only surge in value in the years ahead. And they both open and strengthen global market avenues for Canadian firms in every sector. While it is impossible to fully predict the business horizons that will come with solving the world's most pressing environmental challenges, policy-makers should not underestimate the role clean innovation will play as a major global economic driver in the years ahead.
- Canada – its governments, firms, and other institutions – must go farther than today's best efforts to move to the front of the clean innovation pack. The double market failure – and in particular, the environmental externality – suggests that the best public policy response will be not one policy, but a suite of coordinated policy initiatives that address different needs in different parts of the clean innovation ecosystem.
- While public policy has a role in all stages of clean innovation, it is particularly important as innovations move closer to market – the point where leadership is needed to overcome market failures and stimulate demand. Efforts to nurture clean innovation at earlier stages will be much less effective unless there is strong, sustained market demand for the ultimate products and services. If governments can help to strengthen demand – through smart policies (pricing, standards and incentives) and green procurement – over time there will be a decreasing need for public finance in the later stages of the system, as market signals increasingly draw in private investors and drive demand.
- Ultimately, governments' job is to help position our economies for long-term success. They can invest more patiently with longer horizons than the private sector and can design policies to 'crowd-in' private investment so that Canada's scale of effort matches our scale of ambition. At the same time, only governments can fix market failures and provide the policy certainty that will unleash clean innovation. This argues for governments setting a bold vision for Canada's clean innovation performance, and matching that vision with policy ambition.
- Governments must also approach risk differently. Innovation is a fast-moving, dynamic process that often follows hard-to-predict pathways. To effectively support innovation, governments and public institutions must be nimble, risk-tolerant, smart, and able to learn – sometimes fail – and adjust quickly. Those traits are not ones that come easily to governments, for some understandable reasons. Yet, like the private sector, they must rise to the challenge if Canada is to succeed in the global clean innovation race.

Capturing the fast-growing opportunities that clean innovation offers requires a strong, healthy, and integrated system of researchers, entrepreneurs, investors, businesses and regulators all functioning together. Each has a role to play. In government's case, it is to remove barriers, provide incentives, build public infrastructure, and make policies that provide sustained ambition and direction to achieve Canada's economic and environmental goals. Through smart, bold, far-sighted action, governments can help to unleash the private investment, invention and initiative that will accelerate clean innovation across Canada's economy.

Appendix I: Experts Interviewed

The authors would like to thank the following individuals for participating in interviews to help inform this report. Note: Interviewees participated in their individual capacities, not as representatives of their organizations.*

Anne Waddell	BioAmber Inc.
Alison Nankivell	Business Development Bank of Canada
Andrea Moffat	Ivey Foundation
Andreé Lise Methot	Cycle Capital Management
Andrew Heintzmann	InvestEco Capital Corp.
Annette Verschuren	NRStor
Bob Masterson	Chemistry Industry Association of Canada
Bruce Dudley	Delphi Group
Carolyn Cahill	Statistics Canada
Celine Bak	Analytica Advisors
Chris Boivin	Sustainable Development Technology Canada
Dan Wicklum	Canada's Oil Sands Innovation Alliance
David Hone	Shell Canada
David Paterson	General Motors of Canada
David Rozin	Royal Bank of Canada
Dean Haslip	CanmetENERGY
Denise Chang-Yen	Shell Canada
Derek Burleton	TD Bank Financial Group
Geoff Munroe	Natural Resources Canada
Gilles Duruflé	Independent Venture Capital Consultant
Jane Kearns	MaRS Cleantech
Jean Simard	Aluminum Association of Canada
Jeanette Pattell	General Electric
JP Gladu	Canadian Council for Aboriginal Business
Judy Fairburn	Cenovus Energy Inc.
Julie Sunday	Natural Resources Canada
Marie D'Iorio	National Research Council
Marie-Hélène Labrie	Enerkem
Marty Reed	Evok Innovations
Matt Rogers	McKinsey & Company
Nick Johnstone	Organisation for Economic Co-operation and Development
Paul Manias	Ontario Municipal Employees Retirement System (OMERS)
Peter Nicholson	Innovation expert (formerly with Council of Canadian Academies)
Ralph Torrie	Torrie Smith Associates
Rod Lever	Cowater International (formerly with EDC)
Sara Hastings-Simon	Pembina Institute
Tessa Hebb	Carleton University
Toby Heaps	Corporate Knights
Todd Allmendinger	Enovation Partners
Tom Corr	Ontario Centres for Excellence
Tony van Bommel	Business Development Bank of Canada
Troy Ault	The Cleantech Group
Vicky Sharpe	Cleantech finance expert (formerly with SDTC)
Yiota Kokkinos	Natural Resources Canada
Zoltan Tompa	Business Development Bank of Canada

* This list reflects the interviewees' organizations at the time of their interview. Some have changed organizations since then.

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