

Clean Innova- tion

Why it Matters & How to
Accelerate it Across the
Canadian Economy

March 2018



ABOUT THE SMART PROSPERITY LEADERS' INITIATIVE

The Smart Prosperity Leaders' Initiative was launched by respected Canadian leaders from business, think tanks, labour, Indigenous Peoples, youth, and NGO communities. Our purpose: To harness new thinking to accelerate Canada's transition to a stronger, cleaner economy.

The Initiative is supported by Smart Prosperity Institute. Smart Prosperity Institute (formerly Sustainable Prosperity) is a national research network and policy think tank based at the University of Ottawa.



LEADERS' STATEMENT

Canada's Moment is Now

Speaking recently at the World Economic Forum in Davos, economist and forum founder Klaus Schwab hailed technological innovation for its potential “to lift humanity into a new collective consciousness based on a shared sense of destiny”. As Leaders of the Smart Prosperity Initiative, the same *shared sense of destiny* has brought us together to advance a vision for a bold new wave of innovation here in Canada.

A global shift to a cleaner, more innovative economy is underway. It is driven by the realization that we face unprecedented and growing environmental challenges — none more urgent than climate change — and by the accelerating pace of technological breakthroughs to help meet these challenges. We believe this is a crucial moment — a once-in-a-generation opportunity for Canada to set a course to prosper in the emerging low-carbon economy, while boosting its environmental performance.

Clean innovation is the key to capturing this economic and environmental opportunity. And it's one that crosses every sector of the Canadian economy, from burgeoning new cleantech industries to established sectors like resource development, energy, farming and manufacturing. Low-carbon and resource-efficient solutions are in growing demand in every field, and a booming global market awaits.

But we must act now — from civil society and universities, to corporate boardrooms and the halls of government at every level — to secure our place among the emerging leaders in this new wave of clean innovation. The world will build a low-pollution economy with or without us. It's our intention as Smart Prosperity Leaders to do all we can to ensure that Canada opts in.

The primary engines to drive clean innovation across the Canadian economy are private investment and initiative. But the magnitude of the opportunity, its importance to society, and the array of market barriers facing clean innovators means that government also has a critical role to play.

Based on the findings of an in-depth new research report, we recommend that governments at all levels act to accelerate clean innovation across Canada in the following six ways:

1. **Unleash private investment in clean innovation.** By co-investing in promising clean technologies, governments can de-risk and catalyze the large amounts of private investment needed to grow these inventions into market successes. Public support should target priority areas where Canada has comparative advantages — with particular focus on hard-to-finance stages and technologies.

- 2. Set world-class environmental standards and innovation incentives.** Adopting stringent environmental policies — particularly pollution pricing and other flexible tools — will spur demand for clean innovation, position Canadian businesses as environmental performance leaders, and send the long-term signals needed to drive private initiative and investment. Well-designed policies that reduce barriers to innovation, paired with targeted incentives, can strengthen Canada’s economy-wide competitiveness.
- 3. Open export markets.** Prioritizing clean innovation in Canada’s trade missions and programs, while also supporting ambitious international climate and environmental agreements, will help boost global demand for made-in-Canada clean technology solutions.
- 4. Lead by example through green procurement and infrastructure.** By leveraging their own purchasing power as Canada’s biggest buyer, governments can grow the market for clean innovation, build the infrastructure to prepare us for a low-carbon economy, and provide a testbed and showcase for Canadian clean technologies.
- 5. Strengthen Canada’s clean innovation ecosystem.** Nurturing clusters and incubators, generating better data (to inform investments and policies), and investing in skills, capacity building, and developing young entrepreneurs can help grow a stronger, more connected innovation system for a 21st century clean economy.
- 6. Create a Clean Innovation Strategy.** Bringing key players together to map out Canada’s comparative advantages and priorities in the global clean innovation race will ensure that everyone is pulling in the same direction in making investment, infrastructure, research, and resource allocation decisions.

Encompassing all of these recommendations is the need for governments to be more nimble, risk tolerant, and open to experimentation; to be the dynamic partners that private innovators need.

The good news is, Canadian governments are already making progress on many of these fronts. From a landmark First Ministers’ Agreement on Clean Growth and Climate Change to major budgetary investments in clean innovation and infrastructure, and from provincial carbon pricing policies to federal superclusters and sector strategies, Canada has started down the path. Now we must turn commitments into action, while ramping up our clean innovation focus and ambition. We pledge to do all we can, working within our own organizations and networks to help lead this change.

Ultimately, this is about positioning Canada not only for clean growth, but inclusive growth. All Canadians want and deserve the chance to do meaningful work in thriving businesses that will not just weather but prosper in the global transition to a low-carbon economy. That transition has already started. If we want to grasp its promise, and achieve our potential, we must make clean innovation a national priority... starting today.

Canada's success in the years and decades to come will be defined by the choices we make today. Join us in choosing the path to our brightest future — the path of clean innovation.

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#CLEANINNOVATION STORY

Turning trash into green gold

Imagine a Canadian technology replacing landfills all over the world, transforming non-recyclable garbage into valuable renewable fuels. Montreal-based Enerkem can do just that. Its clean technology is installed at Edmonton's municipal waste management centre and will produce 40 million liters of ethanol every year. The company also recently signed a \$125M agreement to expand into China. A growing Canadian clean innovation success.

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INTRODUCTION

Welcome to the New Economy

There is a new Industrial Revolution underway — and it's being driven by a global boom in clean innovation. If the term seems unfamiliar, that's perhaps because the boom has emerged so quickly and in such diverse industries, spread across far-flung locales.

Clean innovation is Germany's extraordinary solar power growth and the sudden proliferation of wind turbines in breezy West Texas. Clean innovation is a global race to lead the electric vehicle market with visionary entrepreneur Elon Musk of Tesla Motors and state-driven production by Chinese firms like BYD as frontrunners. Clean innovation is a new factory in Sarnia, Ontario, where a chemical company called BioAmber makes plastic feedstock from agricultural waste. And it is a new facility in Fort Saskatchewan, Alberta, where Shell Canada removes a million tonnes of carbon dioxide from its oil sands upgrading operations each year. Clean innovation is research at the University of Toronto spawning a start-up firm called CircuitMeter to re-invent energy efficiency measurement for companies like Wal-Mart. And it is a laboratory breakthrough in capturing carbon dioxide from the air at the University of Calgary giving rise to a new company called Carbon Engineering that attracts millions in investment from the likes of Bill Gates.

Clean innovation is an emerging economic imperative to find new ways of generating economic growth that lighten environmental impacts. This new paradigm is urgently needed. The world today is facing unprecedented and growing environmental challenges. At the same time, the pace of technological change to address these challenges is accelerating, inspiring a wave of clean innovation that offers both environmental solutions and economic opportunities.

The market trends have never been clearer. Clean innovation taps a fast-growing global market estimated to be worth \$2.5 trillion by 2022 (more than Canada's annual GDP). Five of the World Economic Forum's top ten emerging technologies are in the clean innovation sector. Solar installations grew worldwide by more than 40 percent per year since 2010, and electric vehicle sales are up 8 times over the same period. Beyond the new cleantech sector, the clean innovation market opportunity is even bigger for established industries like mining, forestry, manufacturing, energy and agriculture that can produce existing products more efficiently and create altogether new products. Clean innovation is the through-line connecting and driving the major business trends of the twenty-first century, and it represents the greatest economic opportunity of our age.

Box 1

Two varieties of clean

Clean innovations are new technologies, products, processes and business practices that improve environmental performance in any sector of the economy

Clean technology —cleantech— is the sector of the economy focused exclusively on developing next-generation green innovations such as energy production and storage, biochemicals, and electric vehicle batteries

This is indeed an enormous opportunity — and we must seize it. Clean innovation is a twenty-first century necessity, driven by environmental and economic risks we can't afford to take — the risk of failing future generations, and the risk of falling behind the leading wave of this new industrial revolution.

The mounting environmental risks we face are now well understood. We have entered a period of unprecedented pressure on the planet's vital resources, and scientists warn that we may be approaching critical environmental tipping points. Thankfully, governments worldwide have begun to address these challenges head-on. The Paris Agreement of 2015 is an unprecedented global commitment to tackle climate change, joining pivotal agreements that have already begun to address biodiversity loss, water security, air quality, and more.

Clean innovation is the toolkit required to surmount these challenges and to turn them into opportunities — to build a new economy that harnesses market ingenuity to help solve environmental problems like climate change. Already in more than 35 countries and several Canadian provinces greenhouse gas emissions have been dropping since 2005 while GDP has continued to grow. The decoupling of economic growth from environmental harm is already underway.

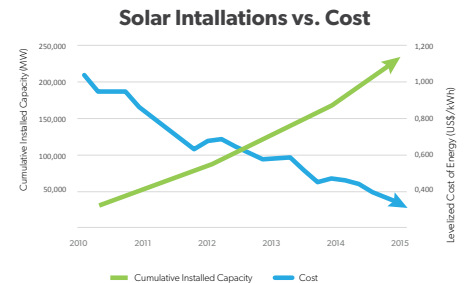
Canada has all of the components to become a clean innovation powerhouse, and there is no bigger opportunity this century to channel the nation's greatest strengths into producing the solutions that the global market is now demanding. "Now is the time to accelerate our efforts to prepare Canada for success in a changing global economy," explains Dominic Barton, Worldwide Managing Director, McKinsey & Company, and chair of Canada's Advisory Council on Economic Growth. "Canada has never been in a better position to be a global leader."

This new industrial revolution, driven by clean innovation, is well underway in Canada and around the world. The cleantech sector alone already employs more than 55,000 Canadians, and the potential for growth is enormous. But despite Canada's many strengths in this field, its share of the global clean technology market has fallen by 12 percent since 2008. Governments have begun to address this slide, and recent global reports confirm that our clean innovation performance and prospects are improving. Canada needs to continue to ramp up its efforts at every level of government and in every business sector to remain part of the leading wave.

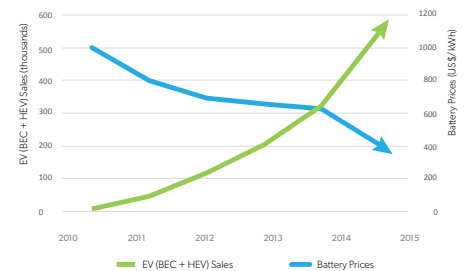
These efforts also need to be targeted at Canada's comparative advantages — the things we're already good at. With our world-leading expertise in agriculture, energy, manufacturing and mining, among others, we have a head start in these industries for advancing the clean solutions the world needs.

Box 2

As costs come down, adoption goes up



Electric Vehicle Sales and Battery Prices



Box 3

Clean Innovation by the Numbers

US\$80 billion: Estimated size of the energy-efficient vehicle market by 2020

US\$55.4 billion: Estimated global market for water treatment technologies by 2020

US\$221 billion: Estimated global investment in energy efficiency in 2015

30%: Estimated growth in the market for smart homes and buildings by 2020

C\$3.6 trillion: Estimated investment in boosting resource efficiency and innovation in resource-based sectors worldwide by 2030

2600%: Estimated growth in demand for rare earth elements by 2025 that will benefit Canada's mining sector

The clean innovation opportunity will not wait, and Canada cannot afford to fall behind. Numerous reports and studies (including Smart Prosperity’s own) show that while Canada does fairly well at clean innovation’s early research and development stages, it stumbles at commercialization and deployment — the stages where most of the wealth and jobs are created. Canada’s progress, though improving, has been hindered by uncertain government policies, lack of funding, and two fundamental market failures. Canadians have the strengths and skills to succeed, but we are not making the most of them.

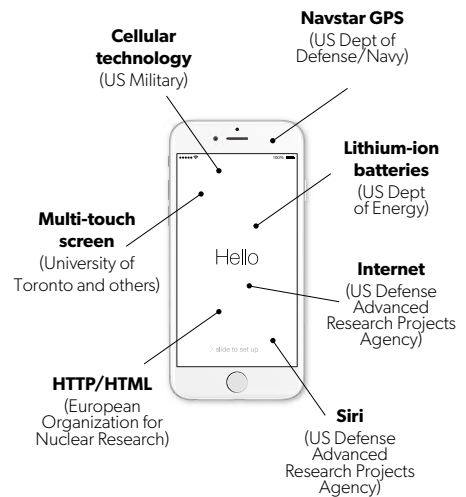
This is a critical moment for governments and private investors, working together, to step up and supercharge the clean innovation economy. While governments are understandably wary of picking winners, they do need to take risks and intervene to remove barriers and correct market failures where they exist. Using smart, flexible policies and targeted funding, governments can unleash the powerful forces of private capital and entrepreneurship that drive innovation in the marketplace. This is a role the public sector has frequently played in commercial technology development — and often to enormous success. Scratch under the surface of a smartphone or probe the backstory of the canola harvest or the oil sands boom, and you’ll find that the private investment and entrepreneurship that drove the innovation into the marketplace was amply backed by government research and public money.

This government role is especially crucial for clean innovation. Technological breakthroughs that reduce environmental harm face unique barriers and market failures that stifle investment (more on that later). By fixing these market failures, governments can unleash private investment in clean technologies, allowing markets to do their job.

The clean innovation opportunity will not wait. As the world deepens its embrace of low-carbon, resource-efficient, and pollution-reducing solutions, Canada must move swiftly to boost its own clean innovation performance. A new economy awaits, and it follows a prosperous path to our brightest future. Let’s move on to how to blaze that trail.

Box 4

Government Support Behind the Smart Phone





#CLEANINNOVATION STORY

Successfully storing CO₂ in the ground

In 2016, the Scotford oil refinery near Fort Saskatchewan, Alberta, successfully captured and stored its first 1 million tonnes of CO₂. It's a feat that it will now repeat every single year – the equivalent of taking 250,000 cars off the road annually. The carbon-capture-and-storage (CCS) project was led by Shell Canada and is the first of its kind in the oil sands, and one of only 17 large-scale operational CCS projects in the world. That makes Canada a global expert in a clean technology that the International Energy Agency says will need to account for one sixth of all greenhouse gas reductions by 2050.

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The Four Pillars of Accelerating Clean Innovation

Building the Clean Innovation System

Innovation, especially in the technology world, calls to mind images of solo inventors working feverishly in laboratories and whiz kids launching world-beating companies from suburban garages. But in truth, innovation is a *system* that weaves together an interdependent web of scientists, business people, bankers, and public officials to marshal a new idea from lab research and product development to commercial deployment and global diffusion. By the time a technological breakthrough reaches mainstream markets and achieves widespread success, it has often spent years or even decades relying on this system's varied actors and supports.

Canada's overall innovation system has a mixed track record. Canada has always done well at fundamental research and generating bright ideas, and we have produced a steady stream of innovative companies. But many Canadian businesses have succeeded without having to become leaders in innovation, for a range of reasons — from abundant natural resources to a “branch plant” economic development history. This mediocre record won't be enough to stay competitive in the twenty-first century — and it will fall short in particular when it comes to *clean* innovation.

Boosting clean innovation is critical for Canada, but it isn't simple. That's because there are two distinct market failures that hamper clean innovation in the marketplace — one that limits new ideas, and the other that particularly impedes environmental solutions. The first of these is the “knowledge spillover” failure, which occurs when researchers make one of those big breakthroughs. The knowledge they create is generally available to anyone, spilling over to benefit other researchers or firms, so the original researchers fail to capture the full value of their discoveries. This is a widely recognized problem for all types of innovation, and dampens the incentive to invent.

Clean innovation, however, faces an additional market failure — the “externality” failure. Pollution imposes very real costs on human health, the planet’s ecology, and the economy, but market prices do not reflect this harm. No one gets a bill for pollution. This is a massive and systemic market distortion — an unpaid toll estimated at tens of billions of dollars each year in Canada alone.

The upshot? We habitually under-invest in pollution-reducing innovations. A company that invents a better smartphone or develops drought-resistant wheat can readily find investors who see profits on the horizon and customers ready to pay top dollar for their innovations. But finding investors for clean innovation is often hard, because we don’t pay for pollution, so there is normally little to no economic reward for inventions that reduce it. This externality failure must be fixed — a task only governments can perform — or else markets will go on failing to deliver the environmental solutions we need.

This double market failure is why governments have such a vital role to play in accelerating clean innovation. Doing that job efficiently means identifying the right places to intervene and designing smart policies that correct market failures and remove barriers. This is what’s needed to unleash the private investment and initiative necessary to build an advanced twenty-first century economy.

Accelerating clean innovation requires a clear understanding of how clean innovation happens: what drives the search for new ideas? How do these ideas transform into commercially viable products? And where is government help most effective in catalyzing the clean innovation system as a whole?

Innovation systems are driven by three main forces: a *push* force, where both public and private research and development (R&D) generate new ideas and inventions; a *grow* force, where these inventions are developed into viable technologies and often spawn new firms; and a *pull* force, where markets and consumers determine which of those inventions have enough value to achieve broader diffusion into domestic and export markets.

In most innovation systems, governments play a larger role in boosting push forces, in order to address the well-known “knowledge spillover” problem. But for clean innovation, because of the additional market failure of environmental externalities, governments must play a more active role in stimulating grow and pull forces as well.

The double market failure is why governments have such a vital role to play in accelerating clean innovation.

What’s more, for clean innovation to succeed, those three forces must work together as part of a dynamic, integrated system that rewards experimentation and risk-taking. Government interventions are required to *strengthen* this overall system — by providing training and skills, building infrastructure, collecting data, removing barriers, and fostering the connections that enable a bright idea to become a market success.

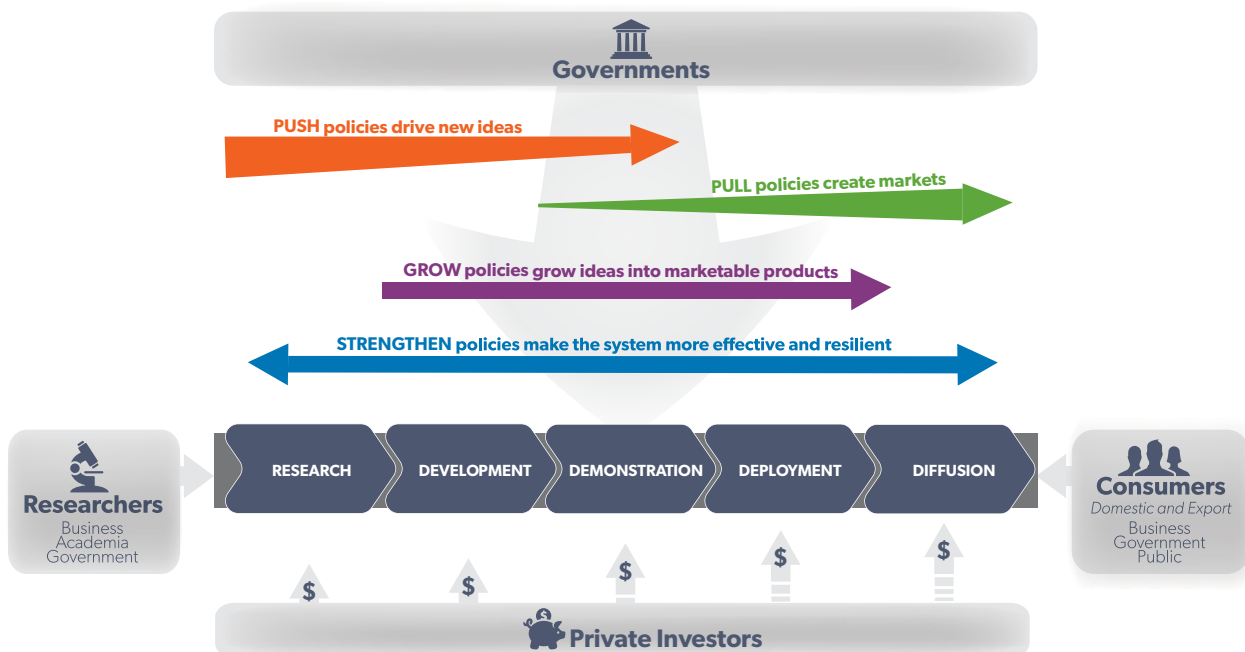
These, then, are the four areas where governments can be most effective at unleashing private enterprise to accelerate clean innovation in Canada:

- (1) PUSH policies that move a clean innovation from idea to product;
- (2) GROW policies to bridge the gap between product and market entry;
- (3) PULL policies that help spur demand and take clean innovations from market entry to mass production; and
- (4) STRENGTHEN policies that make the system as a whole more effective, connected and resilient, transforming clean innovations from fledgling market into economic engine.

In short, clean innovation is a public-private partnership: one in which governments help to spur invention, remove barriers, and provide incentives that unleash the private initiative and investment needed to carry new environmental solutions through to market success.

Box 5

The Clean Innovation System at Work





#CLEANINNOVATION STORY

Mining without burning fossil fuels

A Canadian mine will be the first in North America to go all electric. The Borden Gold mine, northwest of Sudbury, Ontario, is switching its vehicles and equipment entirely from diesel to electric. This not only eliminates emissions from vehicles and equipment, but also slashes the ventilation needs of the mine – an energy and emissions hog in its own right. It's clean innovation expertise that the company can then market globally.

Read more Clean Innovation Stories at:
[smartprosperity.ca](https://www.smartprosperity.ca)

PUSH: From Idea to Product

Ideas are the fuel of innovation, the spark that fires the engine. But breakthroughs and inventions do not make their way from the laboratory to the marketplace entirely on the strength of their novelty and brilliance. The barriers along the path from idea to product are many, and they loom large in the early stages of the innovation process, when success and profitability can be many risky and uncertain years away.

In particular, every innovation system suffers from the “knowledge spillover” market failure, in which the creators of new ideas are not able to fully capture the value of those inventions. This market failure also discourages private investment in the early-stage research that generates innovative ideas. And clean innovation is even more prone to this spillover effect, since its breakthroughs often have broad applicability to a multitude of sectors, driving economic growth and environmental benefits far beyond the realm of the innovation itself.

All of this points to why government intervention is so essential to overcome the spillover failure. This is the core focus of PUSH policies. They provide vital support to basic research and development — through funding, grants and tax incentives — to support new ideas and inventions whose path to the marketplace could stretch ten years or longer. PUSH policies can either incentivize private research through tools like tax credits and intellectual property rights, or they can fund public research directly through government labs and universities. These interventions help feed the innovation pipeline with a steady stream of new ideas.

Axine Water Technologies, a start-up company based in Vancouver, is a textbook example of PUSH policies at work in the clean innovation sphere. Its breakthrough technology – an electrochemical process that destroys the toxic pollutants in industrial wastewater – originated in a classic basement workshop. But converting that research into an actual product turned on some key inputs. Next to the right talent, a strong management team and committed early investors, government help was critical. “Axine secured a combination of grants, loans and tax credits from the federal and BC governments, including the Industrial Research Assistance Program, that helped put us on the path to success”, says CEO Jonathan Rhone. As a result, Axine has commercialized its technology and now regularly cracks the annual Global Cleantech 100 index of companies “best positioned to solve tomorrow’s clean technology challenges”.

At the early stages, the timelines are often long, and the uncharted waters that clean innovation must navigate are rife with uncertainties and risks that often scare off private investors. Even relatively modest injections of capital and support from government at this stage can mean the difference between success and failure. For CircuitMeter, a Toronto-area start-up with a revolutionary approach to monitoring and improving energy efficiency in buildings, a \$250,000 loan from the Ontario government gave the fledgling company the lift it needed to take its data-crunching from lab-scale to its own

PUSH policies provide vital support to spur research and development, and overcome ‘knowledge spillovers’.

offices as an entrepreneurial start-up. In the case of Novonix Battery Testing Services of Dartmouth, Nova Scotia, \$500,000 from the Atlantic Canada Opportunities Agency allowed the company to leave its laboratory birthplace at Dalhousie University and chart a course for the global marketplace. Now it is working with clients like Apple and Tesla Motors on improving lithium-ion battery longevity — a critical element of the booming electric vehicles market.

In other instances PUSH policies mounted at more ambitious scale can help provide the incentive to introduce clean innovation into established industrial sectors. This was the case for Quest, the carbon capture and storage (CCS) facility installed at Shell Canada's oil sands upgrader in Fort Saskatchewan, Alberta. Designing and building the first-ever CCS project for the oil sands — and one of only 17 large-scale CCS projects operating globally — was too big a risk for the private sector to undertake on its own. It required hundreds of millions of dollars in coordinated funding from both the provincial and federal governments, as well as an industry partner willing to sink a similar amount of its own funds into operating the facility for decades. Now Quest is pulling more than a million tonnes of carbon dioxide from Shell's operations each year, and has positioned Canada as a global expert for a technology that the International Energy Agency says could account for one sixth of all carbon emission reductions by 2050. That is exactly the kind of long-term bet that PUSH policies aim to inspire.

One of the biggest, riskiest innovation bets ever laid was the American government's Apollo project — its mammoth PUSH-style investment into unproven technology to land a man on the moon in a decade. There is a moonshot quality to clean innovation today — a similar sense of urgency, a comparable scale of risk and opportunity. Governments around the world have begun making big bets on specific clean technologies — from next-generation batteries and biofuels to advanced solar and auto manufacturing — pairing with private investors in an effort to claim the largest shares in the growing global clean innovation market. If the process is sufficiently rigorous and credible, such big bets are well worth the investment, to secure a place at the table of the new economy and its attending job growth.

Consider Carbon Engineering, a start-up firm that has set up shop at the experimental science-fiction edge of clean innovation. The level of risk — and sometimes controversy — is high in this realm, and Carbon Engineering's technology is no exception. It emerged from lab research led by physicist David Keith at the University of Calgary in the young field of geoengineering — the investigation of ways to intervene in the atmosphere at planetary scale in order to reverse the impacts of greenhouse gas emissions. Carbon Engineering's cleantech breakthrough seeks to capture carbon dioxide directly from the air, and turn it into transportation fuels and other useful products.

Box 6

How Canadian Research Ranks

5th: Canada's university ranking on the 2017 Global Innovation Index

17th: Canada's global rank for scientific and technical articles

22nd: Canada's rank on university-industry research collaboration

3.4%: Canada's share of global cleantech publications

0.7%: Canada's share of global academic cleantech patents

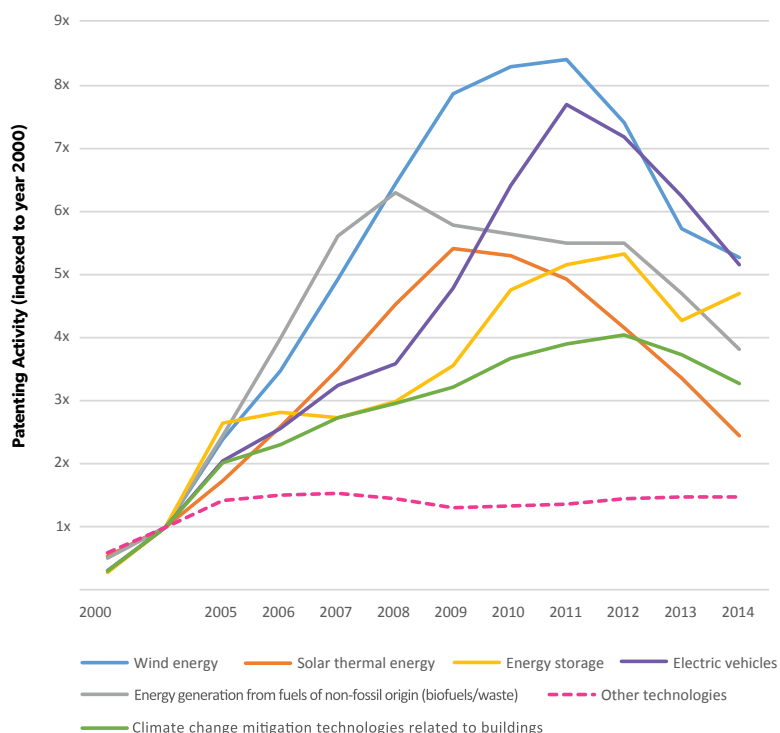
The company has already made use of a range of PUSH policies — fellowships from Alberta Innovates, research grants from several government programs, funding from the federal government’s Sustainable Development Technology Canada program — to transition from campus to private sector to pilot project. If the company’s technology can work safely and efficiently, it could give rise to a global-scale industrial sector all its own and become a vital tool in the climate change fight. What’s more, the company’s work builds on a well-established Canadian strength in synthetic fuel engineering. The PUSH stage is about seeding new ideas like this one that could lead to major breakthroughs, while recognizing that their risks and uncertainties will need to be addressed as they grow. “Make no mistake, it’s a race,” says Jean-Francois Beland of Carbon Engineering. “The expertise around this topic is going to coalesce somewhere. We want it to be Canada.”

Canada has long performed well in the earliest stages of innovation — its overall performance on the research front ranks highly, due in large measure to the strength of its government labs and universities. But governments need to do a better job of directing this considerable research muscle towards clean innovation — focusing on areas where we have comparative advantages to develop commercialized clean technologies. And Canada must also enhance its efforts to stimulate private research and development — business expenditure on R&D (BERD) has been dropping steadily in Canada for 15 years, and lags well behind the rest of the OECD.

To make smart bets and inspire many more early sparks of clean innovation, governments must prioritize clean innovation in their public and private research funding programs; increase support for major public-private research partnerships to pursue breakthrough innovation in areas of comparative advantage; and lock in that support — sometimes for a decade or more — to give inventors and investors the certainty they need to dive in. The pace of change in the clean innovation economy is accelerating, and Canada needs to sharpen its PUSH policies to kickstart the next-generation inventions that will position us for success in the clean economy of the 21st century.

Box 7

Cleantech patents outpace other technologies



A large, dark steel lattice tower stands in a field of yellow wildflowers under a sunset sky. In the background, several high-voltage power line towers are visible against the orange and pinkish light of the setting sun. The tower in the foreground is a complex structure of interconnected beams, forming a lattice. The ground is covered in a dense field of yellow wildflowers.

#CLEANINNOVATION STORY

Storing electricity for when it's needed

Imagine a Canadian technology unlocking a mega-sized renewable energy future. That's what Temporal Power is setting out to do with its flywheel energy storage technology. Flywheel storage works at the grid scale, meaning that it gets used by the people managing our electricity systems behind the scenes, helping them store renewable energy when it's not needed and dispatch it to our homes and businesses when it is. It's a missing puzzle piece that could also unlock worldwide profits.

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GROW: From Product to Market Entry

A great idea can't just leap to the marketplace all on its own. As it emerges from the research lab, it must transform into prototypes and demonstrations, eventually achieving production on a scale where it can successfully enter the open marketplace and meet large-scale consumer demand. Getting through these steps takes a lot of money, mostly courtesy of private investors. Clean innovations often face big barriers to investment at this stage. They often have higher capital requirements, longer payback periods, and many other market barriers. Even clean innovations with great long-term prospects for success in a low-carbon economy can struggle to attract financing. This is where GROW policies come in — to help bridge the so-called “Valley of Death” between early-stage research and market-ready company.

Consider NSolv, a Calgary company that has developed a promising technology for use in the oil sands that allows bitumen to be pumped using no water, resulting in a far smaller carbon footprint. With the financial support of government programs like Sustainable Development Technology Canada and Alberta Emissions Reduction, NSolv has been able to attract significant private investment. But even after a successful three-year field test with Suncor, the company finds itself stalled at the edge of a financial cliff, with full commercial-scale operation far on the other side of a broad gap that can only be bridged by capital investment. This is the Valley of Death, and it yawns particularly wide for clean innovations, whose path to commercialization is often much longer and more capital-intensive than other technology firms.

“We’re now at the biggest chasm that there is,” says NSolv CEO Joe Kuhach. “We’re technically proven and ready to go from a commercial standpoint, but getting over that barrier to commercialization, that’s the biggest cost investment and that’s arguably where you need the most help. That’s where lots of technologies die. At some point you’ve got to start betting on the winners.”

Most clean innovations encounter the Valley of Death at some point in their journey from bright idea to market entry. It could be at the early stages, when young companies need more capital and technical capacity to get on their feet. Or it could be at the scale-up stage, when they need to expand to reach markets. These are crucial junctures when many firms need large capital injections. Yet banks, pension funds, corporations and other major private investors are often deterred from providing this capital by the unfamiliar barriers and risks facing clean innovation. This is where GROW policies can make a real difference. With well-targeted public support — through grants, equity, loans, guarantees, performance bonds, or other financial tools — governments can reduce the risk presented by clean innovation opportunities. This in turn can unleash the private investment needed to bridge the gap to commercial success.

With well-targeted support, governments can reduce the risk presented by clean innovation opportunities and unleash private investment.

The fossil-fuel-free biochemical company BioAmber is a case in point. The company built its first commercial plant in Sarnia, Ontario, at a cost of \$160 million, using a combination of low-interest loans and grants from the provincial and federal governments, which then leveraged larger amounts of private capital. They've now proven their technology works and secured initial customers. But to succeed as it enters the fast-growing global marketplace, BioAmber needs to build a new plant at four times the scale and more than three times the cost of their Sarnia plant — a scale and degree of risk that stretches the current capacity of Canada's capital markets.

BioAmber's innovation is just one example of the suite of capital-intensive new technologies that will be needed to build the energy, transportation and industrial systems for a successful low-carbon economy. Finding ways to finance the scale-up and growth of these crucial emerging technologies and firms is a challenge, but one that offers big rewards (and jobs) for countries that succeed.

There are many examples over the years where smart public investment in Canada and elsewhere has helped spur commercially successful technologies and products in different fields. But in the cleantech sector, Canada far too often incubates promising new technologies that either fail to secure the financing needed to achieve commercial success or end up finding it elsewhere — bringing jobs and economic gains to other countries. That is one reason why Canada's share of the global cleantech market is small (1.4%) and has been falling. Reversing that trend requires aggressive GROW policies.

The best economic opportunities for clean innovation are often found in export markets — more than 60 percent of Canadian cleantech revenues already come from international customers — and so GROW policies that support increased trade and help create economies of scale are vital to seize those opportunities.

Temporal Power of Mississauga, Ontario, for example, developed an innovative energy storage system using flywheels — a critical component of low-carbon energy systems — and demonstrated its technology at a power plant in southwestern Ontario. But Temporal's founders understood that the real opportunities waited in the international marketplace. By working with Export Development Canada to design a custom-made bond solution, Temporal secured the financing needed to reassure its first export customers that it could deliver on its international orders. As a result, a Temporal flywheel system is now operating on the Caribbean island of Aruba, and more overseas customers beckon.

Clean innovation's deep uncertainties and long time horizons also present a major barrier. For example, at their pilot plant in Squamish, British Columbia, Carbon Engineering is beginning to showcase its carbon capture technology,

Box 8:

The 'Valleys of Death'

Clean innovators face major and sometimes fatal challenges in securing financing. These challenges are so recurring that the two main points in the clean innovation process where they happen most often are known as the Valleys of Death. The 'technological valley of death' happens at the development stage, when innovators need financing to turn a promising research concept into a prototype or pilot plant. The second is the 'commercialization valley of death', when innovators need major financing to scale up to commercial production.

synthesizing small quantities of gasoline and diesel fuels from air and water. The company is already attracting international capital (Bill Gates is an investor) and serious interest from global clients, and the synthetic fuels they produce from captured carbon dioxide are expected to be a valuable commodity in the years to come. But Carbon Engineering's executives know they will need hundreds of millions of dollars and several years at minimum to scale up to a commercially viable facility. "We're staring straight into the Valley of Death now," says company vice-president Jean-Francois Beland.

For Canadian clean innovators standing at the precipice of the Valley of Death, it's about the money first and foremost — about securing the right investments at the right time. That's what will make the difference between a market success and another bright idea that withers on the vine. To unleash that investment, Canadian clean innovators need well-designed GROW policies that use public capital to reduce the risk and draw in large private investors who can carry the firms through to market.

Governments in Canada have begun to act, with over \$2 billion in new federal money and renewed mandates for institutions like the Business Development Bank of Canada and Sustainable Development Technology Canada, plus major provincial financial commitments such as in Emissions Reduction Alberta and Ontario's new Low Carbon Innovation Fund. This funding is critical. Now the key is to turn it into results, through far-sighted public investment decisions that leverage far greater amounts of private capital, and grow a cohort of Canadian cleantech firms ready to compete with the world's pacesetters.

The race to the marketplace is on, and Canada's competitors are gearing up to claim their share of the growing global market for cleaner technologies, resources and products. We must keep pace. The opportunity won't wait.

The race to the marketplace is on, and Canada's competitors are gearing up to claim their share.



#CLEANINNOVATION STORY

Fabricating metals the carbon neutral way

Meet a small plant that saved its business by virtually eliminating all greenhouse gas emissions. That's how Veriform owner Paul Rak puts it. Beginning in 2006, Veriform re-invented its metal fabrication business in Cambridge, Ontario, to be more energy efficient. New equipment and improved practices helped cut the company's greenhouse gas emissions by more than 70% while also earning it \$1.42 million in energy savings over 10 years. That has made it more competitive against its international counterparts.

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PULL: From Market Entry to Mass Production

As they emerge from the lab and scale-up, most other types of technological innovation find established markets ready and waiting (whether to be served or disrupted). From the consumer wizardry of the smartphone to the everyday pantry utility of canola oil, these breakthroughs hit the marketplace as products and services whose value is already recognized. People are ready to pay a price for them.

A clean innovation, however, encounters a unique hurdle en route to the marketplace. Firms and households alike don't pay the true costs of pollution and environmental damage, and so there is little market reward for developing innovations to fix these problems. In almost every case, a clean innovation addresses problems that are outside of established markets — *externalities* that are the symptom of a critical market failure.

The role of PULL policies, simply put, is to rectify this fundamental market failure. By introducing PULL policies — in particular by putting prices on pollution to reflect its real cost, enacting world class environmental regulations, and removing regulatory impediments to innovation — governments not only help stimulate the market for clean innovations but also signal to entrepreneurs, investors, and researchers that there is profit to be gained from clean products and services. What's more, as the largest buyer in Canada, governments can serve as important market drivers. Through green procurement, governments provide test beds and showcases for Canadian clean technologies. And by investing in clean infrastructure, governments build the platforms for next generation innovation.

PUSH policies can help turn a laboratory discovery into a new product or process. But clean innovations need effective PULL policies to tap the full power of the marketplace.

On the banks of the North Saskatchewan River outside Edmonton, there stands a sort of monument to the importance of PULL policies in clean innovation. There, at the Edmonton Waste Management Centre, a biorefinery built by the Montreal-based firm Enerkem turns the city's municipal waste into ethanol.

The value of Enerkem's facility might seem obvious. At full capacity it will divert 30 percent of the City of Edmonton's non-recyclable and non-compostable waste from landfill, transforming it instead into 40 million liters of biofuels every year. But even though governments (through a range of PUSH measures) had joined with private investors to provide Enerkem with the support it needed to scale its innovation, it took PULL policies for it to get to commercial scale with the Edmonton plant. First among these was the City of Edmonton's own waste diversion regulations, which led to the building of the state-of-the-art Waste Management Centre and sent the city looking for

PULL policies fix a fundamental market failure and stimulate the market for clean innovations.



#CLEANINNOVATION STORY

Making chemicals out of plant-based sugars

Everyday items from furniture to clothing to cosmetics depend on fossil fuels for their chemical building blocks. That is until Canadian company BioAmber Sarnia began producing the same chemical building blocks using plant-based sugars. The company continues to scale up its first commercial plant in Sarnia, Ontario. But with over 70 customers in 17 different countries, BioAmber is already going toe to toe with its big petroleum-based competitors, giving it a clear edge in the projected \$10-billion bio-chemicals market.

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vendors to help divert more of its garbage from landfill – showing leadership through green procurement. Equally crucial, though, was the federal and Alberta governments’ renewable fuel standards, which obliged commercial fuel suppliers to add renewable fuels like Enerkem’s ethanol to their products. The fuel standard not only provided a market for Enerkem’s ethanol – which now provides ten percent of Alberta’s mandated biofuel supply – it also sent a clear signal to investors that Enerkem’s technology had a bright and stable future.

“The Renewable Fuel Standard demonstrated the government’s commitment to a greener and more diversified transportation fuel market,” says Marie-Helene Labrie of Enerkem. “It opened the marketplace. Private investors then felt more comfortable to take those financial risks.” And that Alberta success has laid the foundation for international contracts, including a recent \$125 million investment for Enerkem to expand into China.

This is how PULL policies perform best, working in concert with PUSH and GROW policies to take technologies from the R&D phase, scale them up, and encourage their wider adoption. By establishing world-class environmental standards, governments at all levels can successfully drive market demand for clean innovation.

There is no better policy tool for doing this than pollution pricing. In a market where pollution bears a price, clean innovation takes on real economic value. This means firms that reduce pollution reap rewards for doing so while also providing valuable services to society at large. What’s more, pricing schemes — unlike prescriptive regulations — allow businesses and households to make their own choices about how to cut pollution, a level of flexibility that further spurs innovation. For example, after Europe brought in carbon pricing in 2005, the number of new patents for low carbon technologies more than doubled in four years. And well-designed pollution pricing has upsides for both the environment and the economy. Since British Columbia brought in its carbon tax in 2008, the province has outpaced the rest of Canada in both emission reductions and GDP growth.

Similar successes are beginning to emerge in Alberta, where the province’s new PULL policies — a carbon price and oil sands emissions cap — have provided a powerful economic incentive for clean innovators. These policies, for example, boost the market case for NSolv, the Alberta company noted earlier whose breakthrough technology was field-tested recently at a Suncor oil sands facility, where it promises to significantly reduce greenhouse gas emissions.

As vital as pollution pricing is, there are some challenges that also require more targeted interventions. Smart regulations, tailored to particular products or industry sectors, also play a crucial role in accelerating clean innovation.

“There is no better policy tool than pollution pricing for driving market demand for clean innovation.”

Consider INCO, the Canadian mining giant, whose nickel smelter in Sudbury, Ontario, was the single largest source of sulphur dioxide emissions on the planet when acid rain was identified as an environmental crisis in the 1980s. INCO initially resisted regulation, but Ontario eventually brought in stringent standards to curb sulphur dioxide pollution. INCO was forced to innovate — and it did so successfully, reducing its emissions by 90 percent while also finding markets for its new waste byproducts, which reduced plant costs by \$70 million per year.

A generation later, the Ontario government's more stringent water treatment regulations, introduced in response to the E. coli bacteria outbreak in Walkerton, gave rise to a wave of clean water innovation across the province. Trojan Technologies of London, Ontario, for example, found a welcome market for its water treatment technology in Ontario as a result of these new regulations, and it has since built an impressive list of global customers.

Smart environmental policies like these can drive clean innovation in every sector of the economy. And Canada is making progress on this front. The federal government is bringing in a nationwide, rising floor price on carbon — building on the successful pricing schemes in the four largest provinces. Federal and provincial governments have also committed themselves to an ambitious suite of new climate policies — for cleaner energy, vehicles, buildings, and more — all aimed at meeting Canada's global climate commitments by 2030 (as part of the Pan-Canadian Framework on Clean Growth and Climate Change — more on that later). To be effective, these new policies will need to combine *stringency* (to drive best-in-class performance), *flexibility* (to encourage novel approaches), and *predictability* (to inspire investor confidence over the long term).

Designed well, environment policies like these can spur innovation without driving up the overall cost of doing business. For example, if governments use carbon price revenues to cut income taxes (as British Columbia does) or provide incentives for clean technology investment and adoption (as Alberta and Ontario do), they can bolster competitiveness at the same time.

And it isn't just domestic environmental regulations that matter. By pursuing strong international agreements — such as the Paris Climate Accord — Canadian governments can help to build the global market for made-in-Canada environmental solutions. They can also help Canadian companies reach those markets by prioritizing clean technologies in trade missions and export support programs.

Beyond prices and regulations, there is another crucial role for PULL policies to play — they can establish governments in the role of early and major customers for clean technologies. Governments are the largest purchasers of goods and services in Canada, and they can serve as powerful market drivers while creating low-risk spaces in which to test clean innovations.

Box 9:

Carbon Pricing Drives Innovation

A price on carbon helps stimulate demand for innovative low-carbon technologies and practices. Building on the existing systems in four provinces, the Pan-Canadian Framework on Clean Growth and Climate Change (2016) mandates that every province and territory must have an economy-wide price on carbon by the end of 2018.

**Designed well,
environment
policies can spur
innovation without
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doing business.**

This was certainly the case for BluTip Power Technologies, which developed a breakthrough system for monitoring and improving efficiency in high-horsepower motors like the ones used in most large-scale mining operations. BluTip received a contract under the Build in Canada Program, designed to make the federal government the first customer for innovative technologies. With that vital toehold in the marketplace, BluTip's technology has now been installed on four continents.

BluTip's success notwithstanding, many Canadian companies have found it easier to sell promising innovations to governments *outside* Canada than to make sales here at home. That needs to change. And new programs like Innovative Solutions Canada and Ontario's Green Focus on Innovation and Technology (GreenFIT) program are doing just that. By targeting procurement of clean technologies, programs like these are beginning to provide vital first contracts — and a much-needed leg up — for Canada's eco innovators.

Government leadership is equally important when it comes to infrastructure, which provides the physical platforms — energy, transportation and water systems — that many types of clean innovation need to reach the marketplace. Canadian governments will be making once-in-a-generation investments in infrastructure over the next decade (including \$21.9 billion in green infrastructure), and they must ensure that they build infrastructure that prepares us for the clean economy of the next generation.

Leadership in clean infrastructure procurement will yield other benefits as well. The global infrastructure market will be worth an estimated US\$90 trillion from now until 2030, and we can position Canadian firms to secure significant shares of this massive investment, building on existing strengths in areas like construction and engineering.

The demand for clean innovation is mounting, and Canadian businesses are keen to meet it. The right PULL initiatives today — from procurement to pollution pricing — can blow wind into the sails of investors and entrepreneurs, and put Canada on the path to a leading role in this emerging economy.

Box 10:

Government Procurement

\$236 billion: The amount that governments in Canada spent on goods, services and infrastructure in 2015, representing more than 13% of GDP.



#CLEANINNOVATION STORY

Making industrial wastewater clean again

Cleaning up industrial wastewater costs North American companies \$30 billion every year. Enter Vancouver-based Axine Technologies with its modular solution that destroys the toxic pollutants in wastewater. It treats the water on-site, saving plant owners the costs of trucking it offsite. And doing it chemical-free with zero waste by-products means less environmental harm. That's why Axine now regularly cracks the Global Cleantech 100 index of "companies best positioned to solve tomorrow's clean technology challenges".

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STRENGTHEN: From Fledgling Market to Economic Engine

Clean innovation is a new economic ecosystem: a broad wave of new technologies and processes being advanced by a diverse cohort of inventors, entrepreneurs, investors, skilled workers, businesses, and many more. Like natural ecosystems, clean innovation can only grow and thrive if all of the individual parts of the system are healthy and working in tandem. Mature industrial sectors have had the time to establish this kind of dynamic, but the clean innovation ecosystem needs help to build its own ecosystem on the fly.

That's why STRENGTHEN policies — interventions that weed out remaining market barriers, fortify weak links, and support the ecosystem as a whole — are so important. And these policies are especially important for clean innovation, because the companies and markets involved operate in emerging spaces high in uncertainty and risk, underfed gardens often lacking in the information, expertise, connections and resources to thrive.

Clean innovation needs investment in skills development across a wide swath of the labour market. Training in the building trades, IT, science and engineering must be aligned with emerging clean technologies; business students require specific education in clean innovation finance and management; and immigration programs can be targeted to attract workers with the right skills for clean innovation. Programs are needed as well to support emerging innovators as well as existing workers as they upgrade or retool skills for clean economy jobs.

Clean innovation is also aching for better data and metrics. There is not yet a universally recognized definition of what the cleantech sector is, let alone metrics to track and compare success. Different studies take different approaches, and there are big gaps in the data itself — it doesn't reside with a single agency, and often it isn't even accessible to the public. Reliable information on everything from clean technology investment and revenues to employment and export levels is needed to inform both investors and policymakers, and to create trust in these new markets. Statistics Canada's new environmental and clean technology satellite account is a positive step in this direction, helping position Canada as a world leader in the nascent field of economic and environmental accounting for the cleantech sector.

And clean innovation must build a broader web of business connections and enhance its business capacity. Young companies require links with knowledgeable investors. They need help building the finance, marketing, and management capacity that will enable them to grow, and assistance building the contact networks that will allow them to reach vital export markets. These challenges arise for most emerging technologies, but they are particularly acute for clean innovation because it cuts across sectors and regions and faces additional market barriers. Governments can help to overcome them by supporting incubators, clusters, hubs, and networks.

Clean innovation can only grow and thrive if all of the individual parts of the system are healthy and working in tandem.

Canadian governments have already begun to create the STRENGTHEN tools to reinforce and expand Canada's clean innovation sector. The MaRS Discovery District in Toronto is a textbook model. The facility, established with a multimillion-dollar low-interest loan from the Ontario government, serves as incubator, partner and networking hub for fledgling clean innovations. CircuitMeter's groundbreaking energy monitoring system, for example, arrived at MaRS as a raw technology. MaRS incubated the newborn company, helped build its business plan and find a business-oriented CEO, and then found CircuitMeter the venture capital it needed to make it to market and the first big customer that allowed it to find its own footing at commercial scale. "We very much followed the script of what MaRS is supposed to do," says CircuitMeter CEO Paul Mertes.

Networks and institutions driven by STRENGTHEN policies also stand behind many other Canadian clean innovation successes. Axine Water is a member of the B.C. Cleantech CEO Alliance, which both helped Axine's executives connect with the sales, marketing and investor networks they needed to get market-ready and also worked with the federal government to develop funding programs finely tuned to the needs of companies like Axine. The Sustainability Co-Lab, an Ontario clean innovation network, has nurtured companies like Veriform, a small metal fabricator in Cambridge that drew on the Co-Lab's expertise to slash its greenhouse gas emissions by more than 70 percent through energy efficiency retrofits and innovations in business practices. And Ecotech Quebec, a provincial-based cluster, supports innovators like Energex, a wood pellet manufacturer based in Lac-Mégantic that recently expanded into the US.

Last but not least, beyond these targeted initiatives, the Canadian economy requires a clean innovation strategy to coordinate this epochal transformation — to ensure that everyone is pulling in the same direction as they set research, investment, procurement and policy priorities. This strategy should draw on the expertise and experience of leaders in both the government and business sectors to map out Canada's comparative advantages in this growing global marketplace. The goal is a long-term commitment to the clean economy that can survive changing political cycles, supported by arm's length agencies and independent reviews.

Some pieces of the puzzle are already in place or taking shape. The Pan-Canadian Framework on Clean Growth and Climate Change, signed by the Prime Minister and most provincial and territorial leaders, marks an important step. The framework establishes a coordinated, nationwide plan to meet Canada's climate goals and boost clean innovation, building on ambitious action plans in provinces such as Quebec, Ontario, Manitoba, Alberta and BC. The National Innovation Agenda, meanwhile, charts the course for federal action, supported by the 2017 budget, alongside parallel efforts in many provinces, such as Ontario's recent Cleantech Strategy. Looking ahead, Ottawa has committed \$1 billion to fund new innovation superclusters and create growth strategies for six major sectors — including cleantech and clean resources — while the new Clean Growth Hub will co-ordinate all federal programs and provide a single access point for clean innovators.

Across the country on many fronts, work is underway on building the blueprint for Canada's clean innovation economy.

The Canadian economy requires a clean innovation strategy to coordinate this epochal transformation.

A tall building under construction with a crane lifting a concrete bucket. The building has a grid of concrete and steel beams, with yellow safety railings on the balconies. The crane is yellow and is lifting a concrete bucket from the top of the building. The sky is clear blue.

#CLEANINNOVATION STORY

Turning Waste CO₂ into Stronger Concrete

Too much carbon dioxide is bad for the atmosphere, but turns out it's like steroids for concrete. That's the secret behind Halifax-based CarbonCure's technology, which recycles captured carbon emissions from industrial emitters and puts them to work for concrete producers. Fewer emissions, more durable product. That clean innovation has now been picked up by almost 100 plants across North America, including for the construction of California's famous High-Speed Rail project. Where will we find CarbonCure's technology next?

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#CLEANINNOVATION STORY

Fuelling next-generation air travel

The aviation industry accounts for roughly 2 percent of global greenhouse gas emissions. Watch for that figure to start dropping, thanks to Canadian company Agrisoma. From its base in Gatineau, Quebec, Agrisoma takes the oil of the Carinata mustard seed and turns it into a powerful biofuel, which then gets mixed with regular jet fuel to cut its overall GHG emissions by as much as 77%. In 2018, Agrisoma made history by partnering with Qantas International to fuel the first ever transpacific biofuel-based flight.

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CONCLUSION

The Race is On.

From start-up water technology firms to big bio-chemical plants, and from small energy efficiency pioneers to international oil giants, Canada's clean innovation economy is on the rise. And there is no time to waste — clean innovation is the centerpiece of a new, low-carbon industrial order in leading economies worldwide, all racing to become global players in this dynamic, fast-growing market.

The urgency is not just economic but environmental. From climate change to water stress to biodiversity loss — the world is facing a new imperative for low-pollution, resource-efficient economic growth. Every sector of the Canadian economy can seize a piece of this opportunity to build on our unique strengths and 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.

Accelerating clean innovation offers a once-in-a-generation economic opportunity. 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 economic sector.

Clean innovation is the key to building a greener, stronger, more inclusive Canadian economy. It will produce the next generation of good jobs nationwide, harnessing a skilled workforce and emerging entrepreneurs to solve environmental problems. It promises more sustainable development of our lands and resources, in partnership with Indigenous Peoples. And, if done right, it can ensure that all Canadians — including vulnerable populations and affected workers — will benefit from this historic transition.

Canada is making progress: with new public policies and investments aimed at leveraging private funds and unleashing entrepreneurs, we are moving up the global rankings. Now we must build on these efforts — turning commitments into action — and go even further if we want to keep pace with global leaders in this clean innovation race.



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What next?



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New Thinking Is Good for the Environment and the Economy.

