Deloitte.

Scaling solutions

Accelerating the commercialization of made-in-Canada clean technology

Preface

Canada has committed to reducing greenhouse gas (GHG) emissions by 40% to 45% below 2005 levels by 2030 as part of our nationally determined contribution (NDC) under the Paris Agreement and has further pledged to be net-zero by 2050. Much has been written about the ambition and feasibility of the plan, its targets, and the investment required to meet those targets. One piece missing from the analysis to date: the degree to which made-in-Canada clean technology is deployed domestically toward our 2030 and 2050 goals.

Are the companies in Canada's clean technology industry ready to commercialize at industrial scale? To answer that, Deloitte developed a commercial readiness framework that extends the concept of readiness beyond technical performance to include market viability, supportive policy frameworks, and the capacity of the company itself. It provides a structure to assess innovation in reference to desired commercial objectives and identify the missing or immature elements of a coherent commercial ecosystem. These readiness indicators measure and forecast the conditions that may support—or restrain—the deployment of a climate solution that displaces the high-carbon status quo.

This framework can be used to inform or guide an investment decision, highlight bottlenecks, and identify priority action areas. It also provides a consistent language to evaluate the degree of readiness across technical, market, policy, and company capacity requirements. It addresses gaps in the understanding of Canada's clean technology solutions inventory and helps determine the commercial readiness of those solutions.

Experience has shown that it takes between 12 to 15 years to commercialize innovative ideas in Canada, and even longer for them to become profitable. Continued fiscal support for innovation is critical, but investment alone does not address the more difficult challenge to commercialization: the time it takes to develop, pilot, secure industry buy-in, and then deploy market-ready technology.

Thirteen Canadian companies cracked the prestigious 2022 Global Cleantech 100 list, which recognizes privately held cleantech companies considered most likely to have significant market impact.[1] This reinforces the need for a specific clean technology industrial strategy for commercial success, global market share, economic impact, job creation, environmental benefits, realization of climate goals, Indigenous reconciliation, and social prosperity.

Canada is in a good position to implement a clean technology strategy with ambitious targets: 2% global market share; a top-five export sector; a US$100 billion contribution to GDP; increased private sector investment; achievement of NDC emissions reduction targets; new jobs across the country; clean energy and water for remote, rural, and Indigenous communities; and an industrial policy that can support growth, innovation, and successful companies in a way that delivers economic, social, and environmental value throughout the country.[2]

But we won't realize any of those transformative benefits if we are unable to commercialize homegrown clean technology solutions, most of which are already successfully deployed in markets around the world. Canada stands to lose public investment, talent, intellectual property, and other intangible assets if our leading companies are acquired or relocate to more attractive markets.

Our ambition must be greater than scaling a technology or scaling a company. We must scale climate solutions.

Executive summary

Clean technology enables economic growth, global competitiveness, decarbonization, reconciliation, and new employment opportunities in a net-zero economy—potential that few other sectors have to advance Canada's environmental, social, and economic imperatives at the same time. It represents an opportunity not only by driving change in traditional industries, but also as an industry in and of itself.[3]

Canada's 2030 Emissions Reduction Plan identifies targets for seven economic sectors and calls for a 40% to 45% emissions reduction from 2005 levels. In numbers, that means dropping from 730 megatonnes (in 2019, when the plan was introduced) to 443 megatonnes in 2030. Much has been written about the ambition and feasibility of the plan, its targets, and the $128 billion federal government investment required to meet those targets.[4] One piece missing from the analysis is the degree to which made-in-Canada clean technology is deployed domestically as part of the country's 2030 emissions reduction target and net-zero 2050 goal.

To facilitate the commercial deployment of any technology into a productive innovation system, its readiness must be evaluated against the necessary technology, market, and policy enablers as well as the capabilities of the company itself. While scale is often used as a proxy, we define commercialization as technology performance proven through successful in-use operations and available for immediate production based on placed orders.

Building coherent commercial ecosystems requires an assessment of four key areas:

- **Technical readiness** gauges the technology's in-use performance and maturity, cost competitiveness in markets unwilling to pay a premium, and the degree to which it delivers quantifiable, verifiable, and material greenhouse gas (GHG) emissions reductions.
- **Market readiness** determines the external commercial ecosystem and the structures required for the deployment and use of the technology.
- **Policy readiness** refers to those public and private sector policies that facilitate an organization's ability to adopt a new technology and the creation of niche or commercial-scale markets.
- **Organizational readiness** ensures the dynamic capabilities of the clean technology company itself to commercialize its technology. Those that have a high capacity to allocate resources, capabilities, and competencies in environments of technological and regulatory uncertainty through responsive business models that can constantly adapt to market challenges are the ones that have been successful to date.

For each of the seven economic sectors outlined in the federal emissions reduction plan—oil and gas, transport, buildings, heavy industry, agriculture, electricity, and waste/others—we identified both the challenges to commercialization and the conditions that could accelerate market expansion. Because the deployment of clean technology occurs within a highly interdependent and coherent commercial ecosystem, each sector will need to find a net-zero path that's consistent with global technological and market dynamics and policy in its industry.

Such a sectoral view highlights the complexity of adopting and commercializing technology. While targets are established and the cost-effective solutions to reducing emissions are widely consistent, the best way for clean technology to scale successfully to market in each industry is far from clear. Even successful demonstrations face a steep uphill climb to commercial success, and many interdependent climate technologies will need to gain commercial traction at once.

New models of collaboration, stakeholder mobilization, and networks are needed to facilitate the connections and commercial ecosystems to accelerate the transition to green energy. To that end, we conclude this paper with a call to action for the private sector, the public sector, and the clean technology organizations themselves to start building the foundations for

coherent commercial ecosystems and new markets and marketplaces.

Canada's 2016 Advisory Council on Economic Growth identified clean technology as one of six sectors set to have an outsized impact on the nation's economic growth potential. But to date, the only publicly stated and consistently referenced goal for it is $20 billion in exports by 2025, as noted in the Report from Canada's Economic Strategy Tables.[5] Given that 2020 exports were only $7.1 billion, an annual growth rate of more than 30% will be required to hit this target.[6]

If Canada is to rely on its clean technology sector to compete in a decarbonizing world, what would a globally competitive industry that delivers economic, social, and environmental value to Canada and Canadians look like? It would have:

- Entrepreneurs who can consistently orchestrate the opportunities that emerge from new technologies, consumer needs, market niches, and competitors.[57]
- A productive and thriving commercial ecosystem, with companies of all sizes and an industrial base of anchor companies that can be dominant players in the global marketplace.[7]
- A business environment that supports startups: mid-size and large independent and multinational anchor companies that are organically growing, innovating, and acquiring startups to expand their technology portfolio.[8]
- Enhanced collaboration across all levels of government to build low-emission industries through regional as well as national economic growth strategies.
- A parallel, coordinated commercial effort to embed clean technology in global value chains, identify promising niches, fund product development, and facilitate the sale of Canadian cleantech in every industrial supply chain.
- Policies, governance structures, and implementation mechanisms that successfully use public dollars to attract private capital for clean technology development and deployment.
- A reduced dependency on globalized supply chains, favouring domestic industry for domestic markets.

Achieving net-zero emissions will require Canada to undergo an economic and industrial transformation. This paradigm shift will be enabled by the technology, market, and policy conditions that accelerate the deployment of low-emission technologies at commercial scale into economically viable and de-risked markets, underpinned by policies and regulations that facilitate and incentivize decarbonization. It will also be made possible by clean technology companies with the capacity to allocate resources, capabilities, and competencies in a commercial environment of technological and regulatory uncertainty.[9]

And there is no time to proceed slowly. The longer action is delayed, the more expensive decarbonization becomes. Building on a platform of strong fiscal support, leaders can transition cleantech companies into an industrial base of players that can become globally competitive and dominant. But this only happens with an intentional focus on the development of coherent commercial ecosystems and the technology, market, policy, and company readiness conditions that accelerate deployment at industrial scale.

The state of Canada's clean technology industry

What is clean technology?

Any of the tools, technologies, products, and services that deliver GHG emissions reductions, lead to more circular economies through the recycling, regeneration, and reuse of resources, and promote well-being for people, communities, and nature through sustainable agriculture, clean air and water, resilient communities and cities, and the preservation and regeneration of natural ecosystems.[10]

Across Canada today, there are roughly 1,100 clean technology, or cleantech, companies. They represent about 3.1% of GDP, $7.1 billion in exports in 2020, and more than 210,000 jobs.[11] Almost a hundred of them (97) are publicly traded companies in the cleantech and renewable energy sector. As of July 31, 2022, the 39 companies traded on the Toronto Stock Exchange (TSX) had a total market cap of $73.1 billion, or 2% of the TSX, while the 58 traded on the TSX Venture Exchange (TSXV) had a total market cap of $2.4 billion, or 3% of the TSXV.[12]

The industry comprises a diverse set of organizations and technologies, at varying levels of maturity, that have cross-industrial applications related to energy, water, agriculture, heavy industry, waste management, the built environment, and adapted goods, such as energy-efficient equipment and sustainable mobility.[13]

The rapid pace of digital innovation in clean technology—including advancements in on-demand travel services, big-data assisted logistics, newly automated and decentralized electricity systems, 3D printing, and machine learning—has spurred new clean technology markets, industries, and companies.[14] And the expansion of environmental, social, and governance (ESG) reporting and increasing investor demands for the disclosure of the material impacts of organizational performance have been enabled by software-based climate technology that uses data to derive operational insights, optimize processes, and provide precision measurements of the environmental impact of complex industrial activities.

The cleantech industry is almost entirely composed of small and medium-sized enterprises (SMEs) facing the challenges of growth capital, market access, commercialization talent, and limited agency to inform policy and regulation. The fact technologies can be deployed across economic sectors further complicates go-to-market strategies, partnership acquisition, and the market intelligence needed to disrupt, compete with, or partner with much larger companies that are also investing in net-zero solutions. The companies may have weak ties to industry and their operational needs but they're expected to provide transformative solutions to industrial customers who have "zero-to-ready" technology performance expectations and little patience for prototypes.

"There is codependence and interconnection between a broad range of obstacles to successful technological development and commercialization rather than a discrete set of barriers."[15]

Nicola Dee et al.
University of Cambridge

"People who are adapting are thriving. There is no chill on the overall market. The chill is on last year's business plan."[19]

Jigar Shah
Director of the Loan Programs Office of the US Department of Energy

To operate successfully, clean technology solutions require a highly interdependent and coherent commercial ecosystem. Many technologies are viable only if other ones are implemented at the same level of facility, company, region, or value chain. Stakeholders must therefore coordinate and collaborate to facilitate a the connections and frameworks that can accelerate the energy transition.

With a bear market and a recession looming, a downturn may be in store for cleantech startups that would disproportionately affect them depending on their sector, growth stage, and risk level.[16] Venture capital (VC) investment for cleantech, however, has remained relatively healthy through the first half of the year. According to Pitchbook, cleantech companies worldwide raised US$10.1 billion in venture capital in the second quarter of 2022, 2% higher than the first quarter. In Canada, VC funding for cleantech grew to US$342.4 million, 21.6% more than in the first quarter and a 223% increase year over year.[17]

Clean technology is an enabler of economic growth, global competitiveness, decarbonization, reconciliation with Indigenous peoples, and new employment opportunities in a net-zero economy. Few other sectors can advance environmental, social, and economic imperatives at the same time. Cleantech represents an economic opportunity through its impact on traditional industries as well as being an industry in and of itself.[18]

Building coherent commercial ecosystems

A technology is considered commercial when its performance has been proven through successful in-use operations and is available for immediate production based on placed orders.[20] In this section, we'll look at how the key components of a commercial ecosystem—not only the technology itself but also the company that provides it, the market, and the policy framework—can be assessed for readiness.

Innovation systems analysis

Technologies do not replace technologies; systems replace systems. To facilitate the commercial deployment of any technology into a productive innovation system, we must evaluate the system's readiness against the technology, market, and policy enablers as well as the capabilities of the company itself.[21] Readiness is a matter of degree. It does not imply a direct outcome but should still target a particular outcome.

Any new technology has traditionally been assigned a technology readiness level (TRL) on a standardized and widely understood scale. While helpful as a scientific objective, a TRL is not a commercial objective. Innovation systems analysis (ISA) theory extends the concept of readiness beyond technical performance to market viability, supportive policy frameworks, and the capacity of the company itself. ISA provides a structure to assess innovation in reference to desired commercial objectives and helps to identify the missing or immature elements of the commercialization ecosystem. These readiness indicators reveal, measure, and forecast the conditions that may support—or restrain—the deployment of a climate solution that displaces the high-carbon status quo.

Net-zero requires economic and industrial transformation. This paradigm shift will be enabled by technology, market, and policy conditions that accelerate the deployment of low-emission technologies at commercial scale into economically viable and de-risked markets. It will be underpinned by policies and regulations that facilitate and incentivize decarbonization. And it will be deployed, at the front lines, by clean technology companies with the capacity to allocate resources, capabilities, and competencies in a commercial environment of technological and regulatory uncertainty.[22]

Innovation systems analysis offers an approach to make sure these innovation stories can happen.

Commercial readiness assessment

To realize transformative environmental and sustainability benefits, we need first to commercialize clean technology. The following assumptions guided our thinking on commercial readiness:

- Scale-up capital to reach commercialization remains available and accessible for market-competitive clean technology.
- Market needs and market fit are determined by external partners and/or customers.
- Even successful demonstrations face a steep uphill climb for commercial success.
- Many interdependent climate technologies will need to gain commercial traction at once.
- While targets are established and the cost-effective solutions to reducing emissions are widely consistent, there is a high degree of uncertainty about the best technological path for all sectors to pursue.
- Companies must be able to operate effectively in an environment of technological and regulatory uncertainty.

We're excited about the potential for technology leaps and moonshot innovations, but we have not assumed any.

Technical readiness

A technology's in-use performance and maturity, its cost-competitiveness in markets that are unwilling to pay a premium, and the degree to which it delivers quantifiable, verifiable, and material GHG-emissions reductions are the measures of its technical readiness.

	Technology readiness	Cost-competitiveness	Abatement potential
5	The low-emission technology is available within a highly competitive commercial environment	The low-emission technology is lower-cost than an incumbent in a market unwilling to pay a premium	Quantifiable, verifiable, material GHG emissions reductions are aligned to 2030 and 2050 targets
4	The technology is commercially available in key markets	The technology is cost-competitive with an incumbent in a market unwilling to pay a premium	Quantifiable, verifiable, material GHG emissions reductions are not aligned with either 2030 or 2050 targets
3	The technology has been successfully demonstrated in commercial operating environment	The technology is cost-prohibitive in a market willing to pay a premium	Estimated, unverfiied GHG emissions reductions are not aligned with 2030 or 2050 targets
2	The technology has been successfully prototyped at scale	The technology is cost-prohibitive and the market is unwilling to pay a premium	GHG emissions reductions are not estimated or projected
1	The technology is at the concept or early prototype stage	The technology is cost-prohibitive at any/all TRLs	The technology does not deliver GHG emissions reductions

Technology readiness level (TRL)
Ability to score well on a common framework to estimate and enable consistent and uniform discussions of technical maturity across different technology types.

Commercial competitiveness
Cost-competitive with the incumbent technology through its value chain. Costs drop with economies of scale, knowledge spillovers, market experience, and improvement in reliability, durability, and performance.

Abatement potential
Ability to deliver transformative environmental benefit and verified GHG emissions reductions.

Market readiness

This refers to the external commercial ecosystem and the structures required to support the deployment and use of technologies.

	Value chain	Infrastructure	Supply chain capability	Market/customer familiarity
5	All elements reach maturity by the time the full value chain needs to be deployed	The infrastructure required to enable deployment and market share is ubiquitious and accessible	Low-emission technology is available within a highly competitive commercial market	Low-emission technology is a product of choice
4	Key elements reach commercial maturity by the time the full value chain needs to be deployed	The infrastructure required to enable deployment and market share is widely established in key markets	Competition is increasing to supply low-emission technology in a commercial market	The majority of customers have familiarity and/or market experience with low-emission technology
3	Key elements reach sufficient commercial maturity by the time the full value chain needs to be deployed	The infrastructure required to enable deployment and market share is partially established	Experienced, specialized providers of low-emission technology are available and market competition is emerging	Early adopters have familiarity and/or market experience with low-emission technology
2	Some elements reach sufficient maturity by the time the full value chain needs to be deployed	The infrastructure required to enable deployment and market share is emerging	Few and relatively new commercial suppliers of low-emission technology exist	Innovators have some familiarity and/or market experience with low-emission technology
1	No element of the value chain is mature enough	The infrastructure required to enable deployment needs to be developed entirely	No commercial suppliers of low-emission technology exist	There is no market awareness of the low-emission technology

Value chain
Access to the full range of market activities needed to deploy a product or service.

Infrastructure
Possesses the physical and operational ecosystem required for deployment, typically impacted by capital investment and rate of build-out or expansion.

Supply chain capability
Ability of commercial suppliers to make the innovative components, or other requirements of a new clean technology available at a market-competitive price.

Market and customer familiarity
Ability to bring disruptive technology successfully to prototype, early adoption, and maturity stages. Market share increases as more customers become familiar with the performance and proven value proposition against the incumbent.

Policy readiness

Public and private sector policies facilitate the ability of an organization to adopt a new technology and foster the creation of niche or commercial-scale markets.

	Policy	Regulations	Codes and standards
5	Policy frameworks prioritize low-emission technology and disadvantage/penalize incumbents	Regulations and regulators create a market where the low-emission technologies must be deployed	Codes and standards are designed and adopted to promote the use of low-emission technologies
4	Policy frameworks incentivize the deployment of low-emission technology	Regulations and regulators incentivize and facilitate the deployment of low-emission technologies	Codes and standards exist to support the deployment of low-emission technologies
3	Policy frameworks are technology-neutral, outcomes-driven, and forward-looking	Regulations and regulators are technology-neutral and permit experimentation with low-emission technologies	A limited number of codes and standards exist to support deployment of low-emission technologies
2	Policy frameworks support incumbent technologies but do not disadvantage/penalize low-emission technologies	Regulations and regulators support incumbent technologies but do not disadvantage/penalize low-emission technologies	No codes and standards exist to support the deployment of low-emission technologies
1	Policy frameworks support incumbent technologies and disadvantage/penalize low-emission technologies	Regulations and regulators limit experimentation and the adoption of low-emission technologies	Existing codes and standards prohibit the deployment of low-emission technologies

Policy
The presence of a comprehensive suite of government tools and/or private sector commitments that can assist the deployment and adoption of a technology.

Regulations
Reflecting societal values through their stated outcomes, regulations that can accelerate, incentivize, limit, or penalize the introduction and adoption of new technologies.

Codes and standards
The presence of the evidence-based testing that's necessary to ensure the reliable, efficient, and safe industrial operations of a new technology. Those codes and standards that are compatible across jurisdictions enable market expansion.

Organizational readiness

Ultimately, the cleantech company itself must be able to allocate resources, capabilities, and competencies in environments of technological and regulatory uncertainty through responsive business models that can address the constant adaptation to market challenges.[23]

	Partnership strategy	Management capability	Intellectual property	Business models
5	Strategic partnerships enable deployment at industrial scale	Demonstrated management ability and experience with deployment at an industrial scale	IP portfolio is strategically managed to monetize assets, IP strategy is business strategy	Tested business model enables deployment at scale and cannot be replicated
4	Commercial partners lend credibility and legitimacy to new market entrants	Demonstrated management ability and experience with product commercialization	IP strategy optimizes the approach to intangible assets and is flexible to the stage of the innovation cycle	Sustainable business model that is responsive to market demands and cannot be replicated
3	Commercial partners validate market need	Management and technical teams with capabilities to commercialize the technology	IP strategy is centred on acquisition of legal rights, IP defence, and alignment with business strategy	Business model is adaptable to product innovation cycle and difficult to replicate
2	Partners are identified but the partner acquisition strategy is undefined	Inexperienced management and technical teams with no track record of commercialization	Intellectual property has not been protected	Business model is untested and easy to replicate by competitors
1	Technology solutions are developed with no tie to industry or partner needs	Inexperienced technical team focused primarily on techology development	Intellectual property has not been created/understood/identified	Business model is undefined

Partnership strategy
Degree to which partnership and customer development occur alongside product and technology development. Commercial partners provide a path to market.

Management capability
The organization's core capabilities drive competitive advantage. The culture of commercialization is very different from that of invention.

Intellectual property
Success at protecting and leveraging intangible assets to drive competitive advantage and sustainable growth.

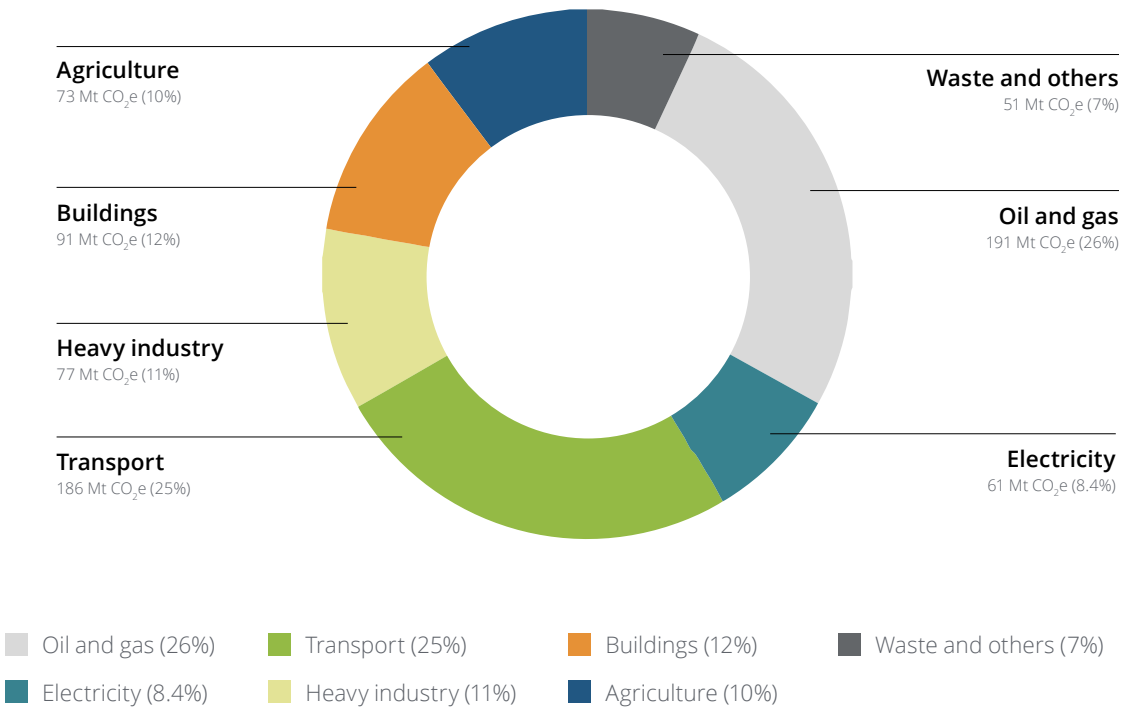
Business models
Application of a model that enables ongoing investment in technology development, manufacturing, and operations. Deployment of market strategies that efficiently and effectively connect solutions providers and customers in a commercial ecosystem.

The emissions-reduction challenge by sector

"Factors like the pace and scale of clean technology adoption, additional actions from other governments, and emerging market opportunities will all influence Canada's emissions trajectory to 2030—but, it is unclear at this point how these factors will evolve over time."[24]

Environment and Climate Change Canada

Figure 1: Breakdown of Canada's GHG emissions by economic sector (2019)

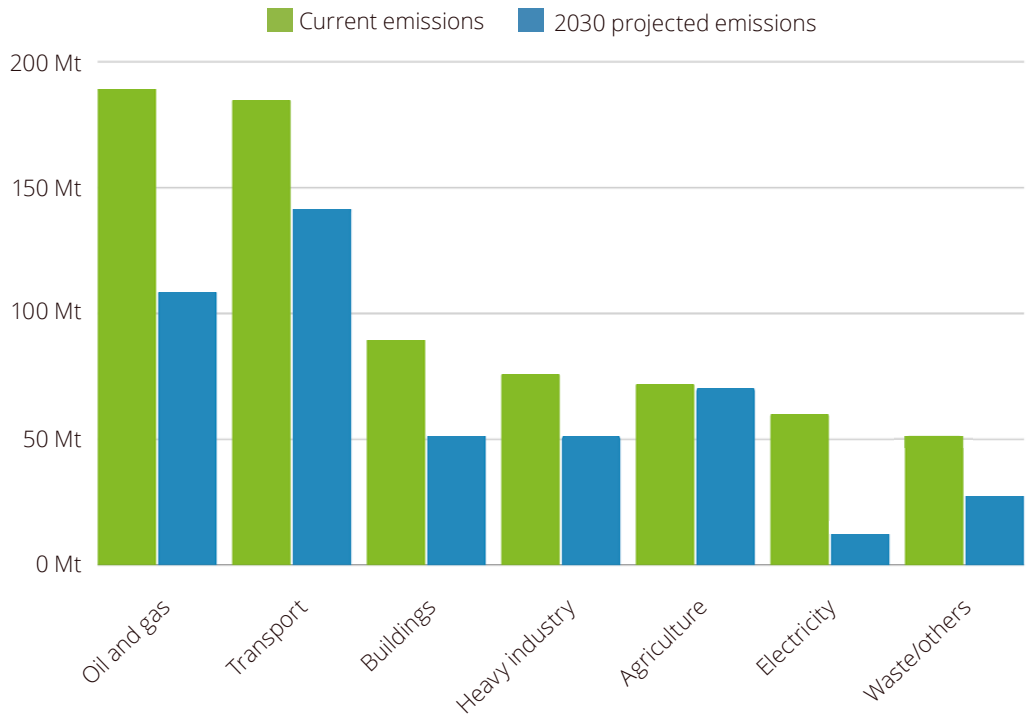


Source: Environment and Climate Change Canada (2022) "2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy"

Canada's 2030 Emissions Reduction Plan sets targets for seven economic sectors and calls for a 40% to 45% emissions reduction from 2005 levels (in hard numbers, from 730 megatonnes in 2019 to 443 megatonnes in 2030).

Much has been written about the ambition and feasibility of the plan, its targets, and the $128 billion in federal government investment required to meet those targets. One missing piece from the analysis is the degree to which made-in-Canada clean technology is deployed domestically for our 2030 emissions-reduction target and net-zero 2050 goal.

Figure 2: Sectoral GHG emissions reduction projections for 2030



Source: Environment and Climate Change Canada (2022) "2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy"

Sectoral snapshots

Each industry in Canada will need to find its own path, one that's in line with global technological and market dynamics and policy in its sector.

Oil and gas

In 2019, the oil and gas sector produced 26% of Canada's national emissions. While their intensity has been reduced 20% since 2005 levels, overall emissions have climbed due to significant growth in production.[26] The sector is facing a major economic transformation—and with it, the opportunity to unlock energy value in a manner consistent with the country's climate objectives. In addition to reframing their own business models, oil and gas companies are being called upon to rebuild the world's energy infrastructure while helping to drive down value-chain emissions.

But the sector also faces challenges independent of any of our national choices. And it's vulnerable to larger global and market forces around climate policy and capital markets.

Commercial challenges	Potential market accelerants
• Infrastructure bottlenecks and permitting delays are increasing uncertainty and cost • Risk aversion to loss of production from technology downtime • Acute financing gaps between the piloting stage and the realization of first sales[27] • Policy signals may not incentivize technology investments • Uncertainty of carbon markets and commodity price volatility contributes to complexity of business case	• Global demands for secure, reliable, and affordable energy • Opportunity to distinguish industry based on ESG performance and leadership • Market synergies that enable reductions in emissions intensity from existing technologies and carbon intensity per barrel • Technically viable and cost-effective scaling of engineered negative-emissions solutions and next-generation carbon capture, utilization, and storage (CCUS)

Transport

Transportation—on-road, off-road, rail, air, and marine—is the second-largest source of GHG emissions in Canada, accounting for 25% of total emissions. It's the highest source for most provinces and territories. More than 93% of the energy consumed in transport is the gasoline and diesel used in internal combustion engines.[28] It's a fragmented market that's facing significant disruptions from digitalization, electrification, and autonomous technology.

Except for light-duty passenger cars and trucks and niche commercial markets like public transit and refuse collection, the decarbonization of the high-emitting, heavy-duty transport segments will require technologies and fuels that hold significant promise but tend to be in very early stages of development.

Commercial challenges

- Commercial transportation ecosystem must replicate established sales, support, service, and warranty functions
- Uncertainty of residual value in the secondary market
- Regulatory frameworks that provide model-year certainty for original equipment manufacturers (OEMs) gate the introduction of new technologies into the development cycle
- Long sales cycles, involving lead generation, conversion rates, and supply lead times
- Value chain elements for zero-emission vehicles are not maturing at pace

Potential market accelerants

- Stringent emissions regulations and policies that support zero-emission vehicle (ZEV) sales goals
- Go-to-market strategy with an OEM partner or tier-one or tier-two supplier
- Concurrent build-out of charging or fuelling infrastructure
- Expanded vehicle choice for demanding commercial-duty cycles
- Second-generation, low-carbon biofuels that enable ongoing use of internal combustion engines in current vehicle parc

Buildings

In 2019, buildings accounted for 12% of Canada's direct GHG emissions. When indirect emissions from offsite electricity generation are included, that rises to 17%.[27] Heating, ventilation, and air conditioning (HVAC) systems are the largest source, followed by lighting, inefficient utilization of space, and design limitations.[29]

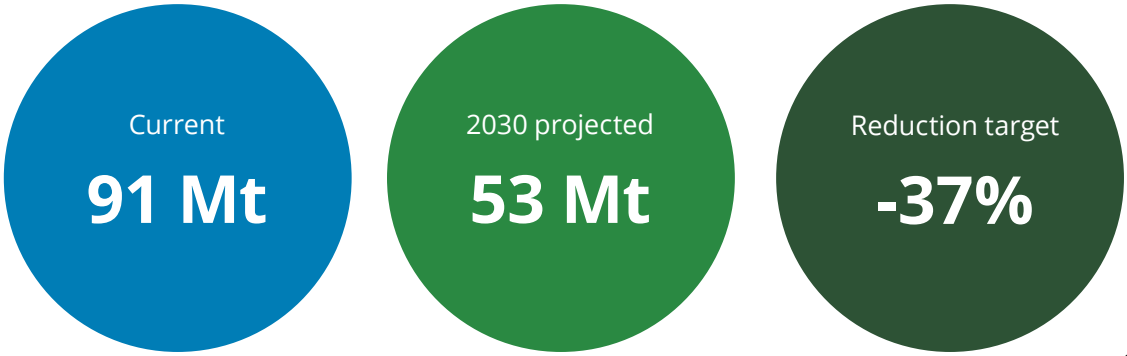
While new stock is built to net-zero performance requirements, about 80% of the country's current buildings will still be utilized in 2030. That means there's a lot of work to be done to bring existing buildings in line with climate objectives. The building sector could reach net-zero without relying on negative-emissions technology or solutions still in the early stages of development, but that will require sufficiently stringent and coordinated policies.[30] Emissions reductions will be made possible by the integration of buildings with energy systems, policy that supports the decarbonization of steel and cement manufacturing, and investment that accelerates the deployment of commercial solutions at scale.

Commercial challenges

- Having to devise a complex go-to-market strategy, as those paying for energy or end-use goods and services are often different from those making decisions about new-building efficiency and equipment stock
- Renovations and retrofits of existing and old infrastructure are often cost-prohibitive, with a long return on investment
- Grids, grid operations, and complementary on-demand power all need to significantly evolve to accommodate projected growth
- Lack of coordinated advocacy across the construction chain to align contractors, designers, manufacturers, and others to ensure new standards and features work together

Potential market accelerants

- Ability to decarbonize without increasing household energy costs
- Increasingly stringent and coordinated policy to foster development of new zero-emission technologies
- Expanding collaboration of technology along material and energy value chains
- Shifting focus from proprietary technology to open-source design, from concept through to construction



Heavy industry

Canada's heavy industry encompasses mining and the manufacturing of industrial and commercial products such as metals, chemicals and fertilizers, cement, and pulp and paper. As one of the sectors that's most difficult to abate, there are limited market-ready, zero- or near-zero emissions technologies that can replace the industrial processes that rely heavily on fossil fuels and generate process emissions.[31] The challenge is compounded by projected growth in forestry, mining, chemicals, steel, cement, hydrogen, and metals.

The coordination and collaboration of heavy industry stakeholders across government and industrial sectors and other entities will be needed to accelerate innovation timelines for the technology solutions that are key to reaching Canada's 2050 targets. That same coordination and collaboration will be required to foster the deployment of commercially available material and energy-efficient technologies that deliver incremental emissions reductions for 2030.

Commercial challenges

- High costs associated with retiring capital-intensive assets with a long operating life to make room for lower-emissions technologies
- Prioritization of sequencing and pacing of investments for incremental improvements for high-emitting facilities in the near term versus the need to shift to zero-emission production in the medium term
- Misalignment in how decision-makers manage and introduce technology into long integration cycles

Potential market accelerants

- Availability of negative-emission solutions to offset emissions that are costly to reduce or capture at source
- The alignment of investment cycles with net-zero targets to avoid "locked-in" emissions and create markets for new technology
- Robust policy frameworks that both decarbonize and maintain industrial competitiveness
- New global partnerships that share the financial and technological risks inherent in transitioning to new technologies and accelerate demand

Agriculture

Emissions from Canada's agriculture sector were 73 megatonnes in 2019, accounting for 10% of total emissions.[32] It's also one of the largest sources of methane emissions, contributing almost one-third of the country's total. Agriculture has been one of the last industries to digitalize, but artificial intelligence (AI) platforms are now driving precision irrigation, crop management and protection, advanced aerial analytics, and genetic breeding optimization.

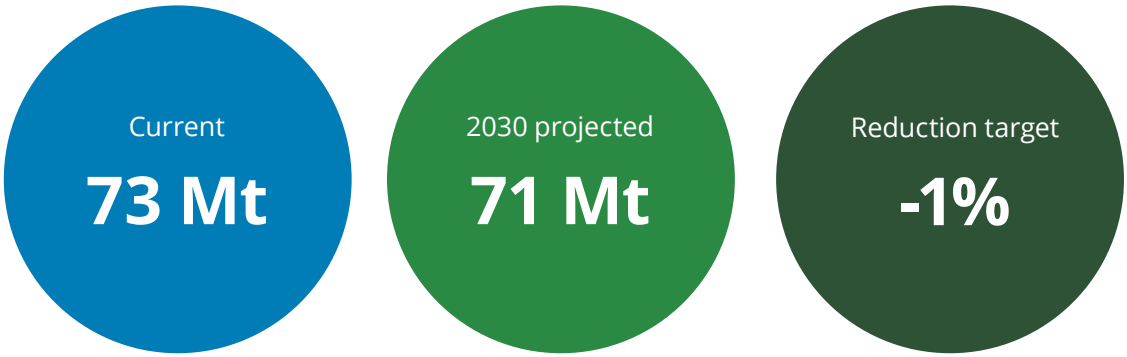
Despite being a major source of emissions, agriculture has been absent from international climate discussions, including the Conference of the Parties (COP). Ambitious action is needed to make progress on reducing emissions in this sector and to maximize the potential of agricultural soils to sequester carbon.

Commercial challenges

- An established, conservative market that's reluctant to introduce unproven technology given already significant weather and market risk
- Lengthy integration cycles, with time required to implement, install, and commission equipment
- Long regulatory cycles compared to those of larger international markets
- Buying decisions and buying cycles across a highly fragmented market need to be well understood

Potential market accelerants

- Expanded and improved digital connectivity in rural Canada
- Enabling technologies like AI, automation, aerial imagery, and others are converging
- Deploying a demonstrable technology that builds trust and credibility with ecosystem partners
- Nature-based solutions and alternative farming practices offer potential for emissions reductions and other benefits, such as enhanced biodiversity and flood risk reduction



Electricity

Electricity emissions have declined more than any other sector in Canada since 2005; in fact, 82% of the country's current electricity sources don't generate any emissions.[33] The mix of sources varies widely across regions and includes hydro, nuclear, solar, and wind energy, along with investments in carbon capture, utilization, and storage (CCUS). Hydrogen power, second-generation biofuels, and the expansion of CCUS need significant advancement in technologies that are not yet commercially viable or scalable.[34]

Achieving a net-zero electricity grid is complex given jurisdictional responsibilities, the regional variability of the energy mix, and the need for reliable and affordable energy sources. Its nationwide decarbonization would encourage emissions reductions in the heavy industry, building, and transportation sectors, but it would also lead to a significant increase in demand for non-emitting electricity and the infrastructure to support increased electrification, such as for all-electric vehicles.

Electrification will transform power systems around the world. This is an opportunity for Canada to open new export market revenue streams for low- and non-emitting technologies, enhancing its international economic competitiveness.

Commercial challenges

- Path to market involves projects with complex environmental assessments and consultations, and a precise sequencing of regulations and permitting
- Capital-intensive investments with long-term investment horizons
- Grid reliability is paramount; there's reluctance to introduce unproven technology without third-party confirmation of its reliability
- Permitting and power purchase agreements for offtake are not in place
- Highly competitive space due to constant price pressure

Potential market accelerants

- Aligned sequencing of regulations and permitting
- High degree of stakeholder coordination and alignment (investors, regulators, utilities, end users) in the deployment ecosystem
- Transition will advance reconciliation, Indigenous-led climate action, and local economic development, since more than 200 Indigenous and rural communities lack necessary infrastructure and rely heavily on diesel

Waste and others

About 4% of Canada's total emissions (29 megatonnes) is generated by the waste sector,[35] which includes coal production, light manufacturing, construction, and forest resources.

The circular economy—loosely defined as conserving materials and avoiding waste by closing material flows—is integral to the waste sector's emissions reduction strategy. Value retention processes (VRPs) aim to retain the economic value of a product and encompass production-related activities that ensure at least the completion of and potentially extend a product's service life beyond what would traditionally be expected.[36] These processes include direct reuse, repair, refurbishment, and remanufacturing. A circular economy may also increase the value of waste emissions by using them to transform raw materials into end-use products or renewable energy.

Commercial challenges	Potential market accelerants
• Long investment horizon and long sales cycles for new capital equipment • Technology must compete on price, not sustainability or circular economy objectives • Highly fragmented sector with site- and system-specific operating environments that each require a pilot and demonstration to prove performance to prospective customers, partners, and investors • Public sector procurement is risk-averse and prioritizes cost, capacity, compliance, and reliability • Absent or overly prescriptive regulatory frameworks	• Digital transformation is accelerating the replacement of legacy systems • Accepted ESG and circular economy objectives to redefine value and encourage innovation • New and evolving business models related to circular supplies, product as a service, product life extension, sharing platforms, and resource recovery[37]

Scaling commercial solutions: calls to action

"The problem with breakthrough technologies is not our shortage of ideas, but the very long time required to take a laboratory-scale idea through the technical and commercial development cycle before it can begin to capture a substantial share of the global market."[38]

Julian Allwood
UK FIRES

For many decarbonization requirements, no technology has yet prevailed because the path to commercialization is too complex and does not yield short-term successes. This will make it challenging to meet Canada's emissions-reduction target. Action is urgently needed to accelerate the use of commercially available technologies for 2030, to advance the development of those solutions necessary to achieve the 2050 net-zero goal, and to initiate, intensify, and accelerate the investments and other actions to shape Canada's long-term emissions trajectory.

New models, new networks, and new mechanisms of trust and collaboration are needed.

Call to action: private sector

There is space for government to step in, but it requires government to be well-versed in the complexities of clean technology, industrial sectors, and climate change. Private sector leadership remains critical.

Create markets and marketplaces

- Be the first (or second) domestic customer to adopt made-in-Canada commercial clean technology. Boosting investment and expenditure within the country will facilitate scale to increase prospects for export-market penetration by individual companies.[39]
- Offer not just a pilot and demonstration site for a new technology, but also a path to market and a commercial sale.
- Develop enhanced mechanisms of market pull and decarbonization roadmaps to diffuse the required technological innovation through industry.

Initiate new models of collaboration

- Given the interdependence of climate technologies, cooperate to develop better models of collaboration and alignment across demand, production, infrastructure, investment, and knowledge to build new value chains and commercial ecosystems. Such models have the potential to disrupt existing industrial networks.
- Technology developed in one industry has the potential to support decarbonization in another: that makes it vital to strengthen commercial ecosystems. Build sectoral collaboration platforms that can create and sustain markets and avoid duplicative efforts.
- Focus net-zero efforts on a sectoral or application-specific basis, such as better systems to heat buildings or low-carbon steel, and not just at the level of an individual technology.

Take a leadership position

- Commit to net-zero plans aligned with the Science Based Targets initiative (SBTi) and operationalize net-zero strategies, investing appropriately to adopt clean technologies.
- Assume a sectoral leadership position for transformative innovation. Organize or join ecosystems to help new technology gain market acceptance.
- Environmental, social, and governance (ESG) is not a climate strategy, it's a capital markets risk-management framework. For ESG reporting, use data-enabled clean technology: it offers precision measurement on environmental performance for enhanced disclosures of emissions reductions and technology investments.

Call to action: public sector

"Canada's political culture favours showcasing individual announcements... The country badly needs a broader dialogue and debate about its strategic innovation and technology interests."[40]

Navdeep Bains and John Knubley
Public Policy Forum

Commit to the demand side

- Consistent and sustained signals of support for demand-side intervention are required to accelerate diffusion, adoption, and market creation for clean technology, along with demand-pull innovation policies that coordinate with or incentivize the private sector.[42]
- Facilitate industrial decarbonization by ensuring that first movers are not penalized if they invest in low-carbon technologies.[43]
- De-risk technology adoption through a "fund customers, not companies" strategy and/or introduce tax incentives to mobilize private sector investment.
- Regulations and regulators must keep pace with technical advances and new clean technology that delivers quantified and verified emissions reductions. Expand the Clean Technology Regulatory Review, a process designed to identify regulatory challenges and barriers to adoption.[44]
- Consider the success of the United States in setting aside public procurement budgets for SMEs and requiring that major government vendors develop supplier relationships with smaller companies,[45] which has resulted in large organizations establishing innovative supplier agreements with clean energy and clean technology innovators.[46]

Develop new models of collaboration

- Accelerate the national rollout of the Regional Energy and Resource Tables, which are designed to identify, prioritize, and pursue opportunities for economic growth through aligned investment and regulations. Ensure that industry-government collaboration is evidence-based.
- Effectively supporting innovation requires knowledge of the factors critical to effective commercialization and how policy and regulations either support or hinder favourable outcomes in cleantech.[47]
- Identify strategic priorities for cleantech and support an evolving portfolio of competing designs and companies at different stages of maturity.[48]

"Innovation policy and energy policy need to be considered together, and... clean technology innovation should be seen as a core element in energy policy decision-making."[41]

International Energy Agency

Call to action: cleantech companies

> The dynamic capabilities of clean technology firms refer to a high capacity to allocate resources, capabilities, and competencies in environments of technological and regulatory uncertainty as well as responsive business models that can constantly adapt to market challenges.[49]
>
> **Matheus Soares de Noronha et al.**
> **Innovation and Management Review**

Create markets and marketplaces

- Customer solutions are brought to the market, not specific technologies. Consider opportunities with early-reference customers as a launch pad for domestic adoption and global export, as well as offer a critical voice on the customer experience.
- Constantly orchestrate—identify, learn, coordinate, and reconfigure—the opportunities that emerge from new technologies, customer needs, market niches, and competitors in highly uncertain environments.[50]
- Be able to deliver quantifiable and verifiable emissions reductions and/or transformative environmental benefit.
- Encourage customers, government, investors, partners, and the public to move faster. Solutions need to be deployed at a pace and scale that is aligned with climate action.

Build a culture of commercialization

- Develop defined strategies for recruiting commercialization specialists in manufacturing, partnerships, business development, customer support, and financing.
- Help derive enhanced ecosystem intelligence to reveal the enabling commercial conditions and policy/regulatory frameworks that will advance adoption and deployment.

Engage early and often

- Develop an engagement strategy focused on co-creation and compliance to build a collaborative relationship with government. Leaders must engage in the regulatory process ahead of market penetration and build capacity to advocate and/or influence as required.
- Plan to engage constructively with proposed standards and regulations and prepare for evidence-based consultations.
- Public sector procurement of clean technology in an integrated marketplace is challenging. Procurement professionals are data-driven and assume performance claims are not true until proven, so cleantech entrepreneurs must be prepared to demonstrate a tested, in-use value proposition.

Enabling Canada's global competitiveness

"The next 1,000 unicorns won't be search engines or social media companies, they'll be sustainable, scalable innovators—startups that help the world decarbonize and make the energy transition affordable for all consumers."[51]

Larry Fink
CEO of BlackRock

The disconnect in Canada's innovation ecosystem is well documented. Productivity and economic growth have stalled despite the fact that we lead in educational attainment and our pace of science and ideas is comparable to that of our economic peers. Private-sector investment in research and development as well as technology adoption are well below the Organisation for Economic Co-operation and Development average. We have been able to create but not retain innovative high-growth companies. Canada doesn't have a startup problem; we have a scale-up problem. Our "low innovation equilibrium" is deep and persistent.[52]

The 2016 Advisory Council on Economic Growth identified clean technology as one of six sectors set to have an outsized impact on the country's economic growth potential. But to date, the only publicly stated and consistently referenced goal on clean technology is $20 billion in exports by 2025, as found in the Report from Canada's Economic Strategy Tables.[53] Given that 2020 exports were only $7.1 billion, we need an annual growth rate of more than 30% to hit the target.[54]

If Canada intends to rely on its cleantech sector to compete in a decarbonizing world, what would a globally competitive industry need to look like?

It would need to have:

- Entrepreneurs who can constantly orchestrate opportunities that emerge from new technologies, consumer needs, market niches, and competitors.[55]
- A productive and thriving commercial ecosystem with companies of all sizes and an industrial base of anchor firms that can be globally competitive and dominant players.[56]
- A business environment that supports startups: mid-sized and large independent and multinational anchor companies that are organically growing, innovating, and acquiring startups to expand their technology portfolio.[57]
- Enhanced collaboration across all levels of government to build low-emission industries through regional as well as national economic-growth strategies.
- A coordinated parallel commercial effort to embed cleantech in global value chains, identify promising niches, fund product development, and facilitate the sale of Canadian cleantech in every industrial supply chain.
- Policies, governance structures, and implementation mechanisms that successfully use public dollars to attract private capital for cleantech development and deployment.
- A reduced dependency on globalized supply chains, favouring domestic industry for domestic markets.

Ultimately, competitive advantage must be measured against commercial and market metrics, but it should also track progress against a set of comprehensive climate, economic, and social indicators that drive inclusive growth.[58] Canada already invests public money, shapes markets, and makes industrial policy decisions in explicit and implicit ways, but these activities must be better aligned with broader policy goals.

The 2022 federal budget included an array of cleantech investments and supports, such as direct subsidies and tax credits along with the creation of a $15-billion Canada Growth Fund to attract private sector investment, and a market-oriented $1-billion Innovation and Investment Agency to target the challenge of low business investment in innovation. The federal government's fall economic statement promises more details as to how the fund will use public dollars to attract private-sector investment in clean technology.

In the United States, the recent passage of the Inflation Reduction Act, which provides US$370 billion in spending measures to transition to a low-carbon economy, should accelerate urgency on this side of the border toward commercialization at industrial scale.[59] With a carbon price in place and a steady pace of public-sector investments, Canadian companies have some wind under their wings to support the emerging technology solutions that can deliver low-cost emissions reductions for 2030.

Decarbonization becomes more expensive the longer action is delayed. Building on a platform of strong fiscal support, we can transition the firms in the cleantech sector to an industrial base of companies that can become globally competitive, dominant players. But this can only happen with the intentional, strategic development of coherent commercial ecosystems and the technology, market, policy, and organizational readiness conditions that accelerate deployment at industrial scale.

Endnotes

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