The state of Canadian climate innovation

EXECUTIVE SUMMARY

Carbon dioxide emissions continue to rise. In 2022, emissions increased 0.9 percent, releasing 36.8 gigatonnes into the atmosphere. At 419 parts per million, the carbon levels in the Earth's atmosphere are higher than they have been at any other time in the last 800,000 years, and a whopping 150 percent higher than they were at the beginning of the industrial age.

Canadian atmospheric scientist Katharine Hayhoe puts it bluntly: "We need solutions at every single level, because what is at stake, is quite literally us — we humans, and many of the other living things that share this home with us."

In this report we dive into emerging technologies that can help tackle the climate crisis from all angles.

Energy:

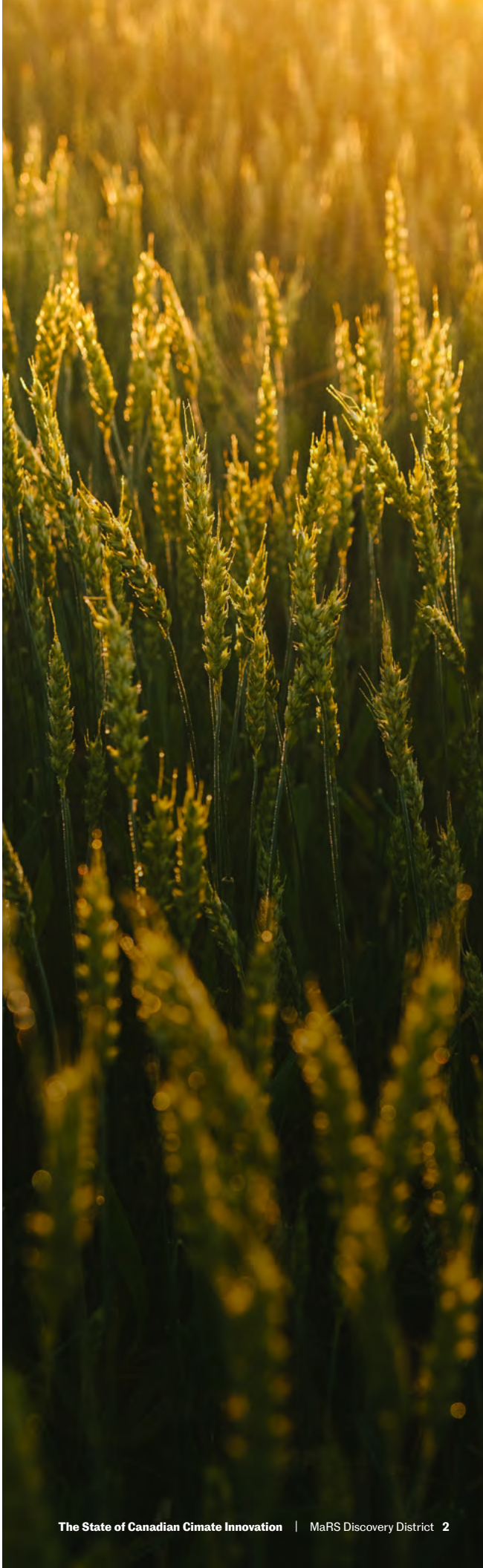
- Energy storage will play an essential role in doubling or tripling our supply by 2050, ensuring reliable service that can mitigate the intermittent power generation of renewables.
- Decentralized power sources offer flexibility in remote and rural areas, and can provide options for managing industrial energy needs in house.
- Solar energy is becoming more efficient and effective through the development of bifacial panels and the use of solar ink.
- Small modular nuclear reactors offer consistent sources of clean energy. And scientists are moving closer to realizing the promise of nuclear fusion.
- Hydrogen's potential to provide clean energy is being explored in three key areas: aviation, marine shipping and steel production

Transportation:

- Fleet management is helping companies lower their emissions through predictive maintenance and optimization.
- Next-generation mass transit options are ramping up.
- Innovators are finessing the range, efficiency and charging speed of electric batteries, and are coming up with novel ways to maximize their resources through second-life applications.

Carbon solutions:

- New innovations could make direct air capture cheaper and less energy intensive.
- Industry players are exploring new ways of transforming carbon dioxide into rock, sequestering it in the ocean and creating more sustainable building materials.
- As the carbon market matures, there is a growing demand for technology that monitors and measures both emissions and sequestration.



EXECUTIVE SUMMARY

Sustainable cities:

- More municipalities are relying on data collection and analysis to help inform policy. Notably, digital twins are helping planners prepare for everything from increased electrical demand to climate emergencies.
- Smart tools, like AI platforms involved in optimizing HVACs or prioritizing retrofits, help building managers reduce carbon emissions.
- Planners are boosting resilience in communities through tree canopy management and designing urban infrastructure that can absorb and withstand climate impacts.

Sustainable materials:

- Biochar is emerging as a way to help the steel industry decarbonize.
- Cement that is infused with carbon dioxide presents a double benefit: it effectively sequesters the gas and results in concrete that is 40 percent stronger.
- Plant-based plastics offer industry players a plug-and-play alternative to petrochemicals.
- Animal-free leather and plant-based foam are garnering attention as more sustainable for vehicle upholstery.

Sustainable mining:

- Entrepreneurs are developing new approaches to extract lithium using a fraction of the resources involved in conventional processes.
- Mine tailings are being transformed into carbon sinks.
- Digital solutions are helping the mining industry decarbonize, whether through data collection for more efficient extraction or automation to reduce energy consumption.

AgTech:

- Precision agriculture helps increase crop yields with fewer inputs.
- Food producers are looking to scale up alternate forms of protein — from insect farming to cell-based agriculture.
- Innovations along the supply chain are working to reduce the amount of food waste produced.

Clean water and oceans:

- New companies are working to extract value from the ocean while also preserving the health of the marine ecosystem.
- Digital sensors, drone vessels and trackers in the ocean are being used to optimize shipping routes, protect coastlines and monitor marine life.
- Technologies that improve the efficiency of waste water treatments plants are attracting large investments.

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Clean shift: Tech innovations for a sustainable future

The time for change is now. Earlier this year, the Intergovernmental Panel on Climate Change issued an unequivocal call to action: If there is any hope of meeting the goal set by the 2015 Paris Agreement — that is, of preventing the Earth's temperature from rising more than 1.5 degrees Celsius above the pre-industrial average, a benchmark for sustained human survival — it is imperative that we as a global community take immediate, significant steps to change the status quo.

If those terms seem abstract, the urgency can be felt in the messages conveyed by nature itself. The effects of climate change are evident all around us: torrential floods, protracted droughts, decimated crops, uncontrollable wildfires. In addition to causing environmental and human devastation, these disasters have significant economic impacts. When the derecho swept through the Quebec-Windsor corridor in the spring of 2022, it left $1 billion in insured damages in its wake; Hurricane Fiona, which hit Atlantic and Eastern Canada a few months later, wreaked havoc to the tune of more than $846 million. And the thick smoke that cloaked a large portion of the continent during the summer of 2023 disrupted air travel and had marked effects on productivity. According to a report from the Canadian Climate Institute, by 2025, climate-related repercussions could cause the country's economic growth to lag by $25 billion (or half of the projected annual GDP) per year.

Investment update

While Canada is strong on research and development, we have a ways to go. Compared to other countries and regions, local business and capital communities are relatively risk averse. That said, the good news is that investment in climate tech is on an upward trajectory: Last year, $82 billion was invested, a 19.4 percent year-over-year increase. While the overall deals are down, mega-rounds totalled $53 billion in 2002, indicating a growing maturity of the ecosystem.

Debt financing was up

60%

Grant financing grew

128%

Equity investment grew

11%

Mega-rounds totalled

$53B

Add to that the growing concerns about energy security in the context of the ongoing war in Ukraine and consumer worries about affordability, and the need to scale up promising solutions is clear.

Fortunately, this country is home to brilliant, forward-thinking innovators who are dedicating time and resources to developing new technologies that benefit the planet. For each of the past five years, at least 10 Canadian companies have appeared on the annual top Global Cleantech 100 companies list — including 12 different ventures in 2023, second only to the United States. And while these novel ideas are a key first step, funding and scalability are crucial to ensure they are implemented in meaningful ways. Which, in a global landscape, requires a different kind of collaboration, as Leah Perry, the senior manager of cleantech at MaRS, points out: "Canadian innovators are well known on the international stage, but innovation is not enough. We need to ensure they receive adequate capital and engage corporate adopters to make real progress toward our net-zero journey."

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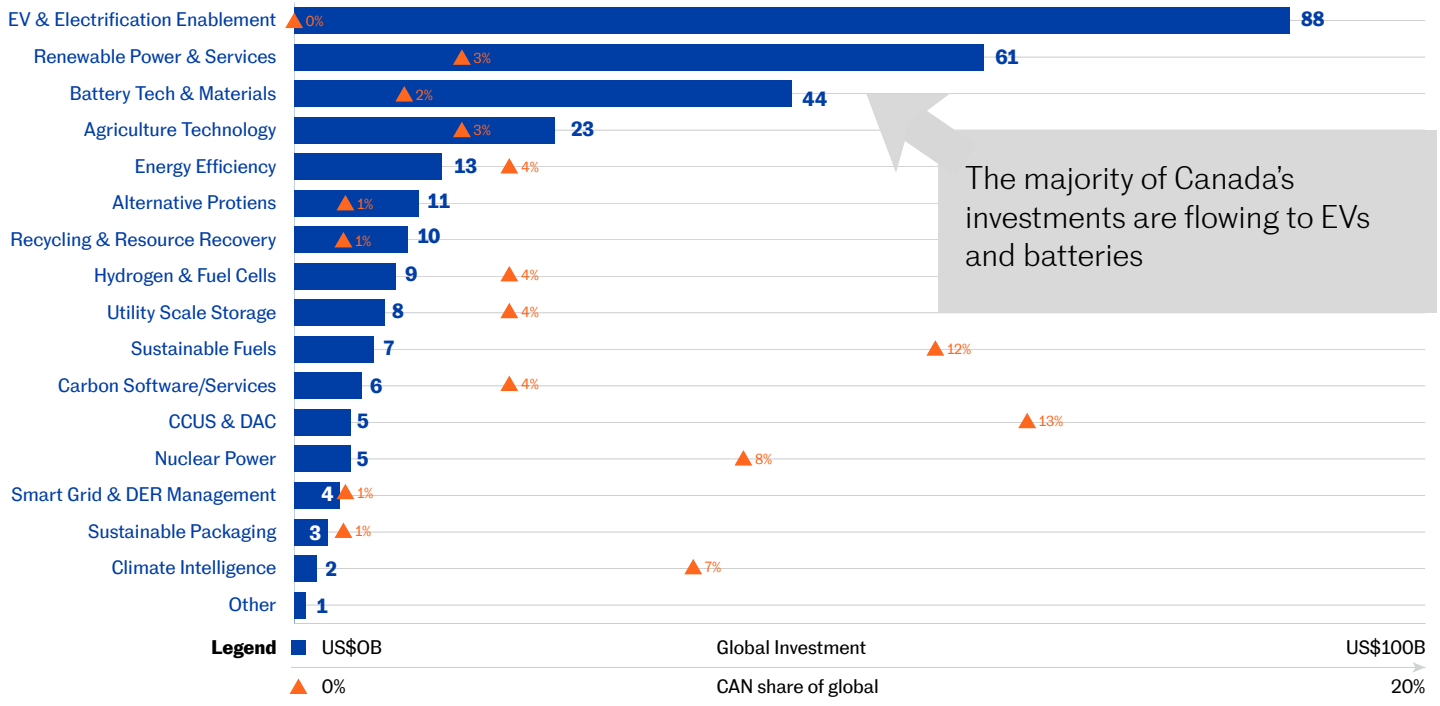
Canadian innovators seizing impressive early position in select emerging sectors

Climate tech private investment 2017 – 2022 (US$)



Analysis based on climate tech startups funded since 2017, does not include corporate R&D. 35% of investment data undisclosed. Climate tech investments include traditional VC, PE, corporate VC, plus other equity and debt financing (including project finance)

Note: Other include tech spaces <1SB global investment (methane, flare & leak management, heat pumps & HVAC, and low-carbon building materials)
Sources Netflase Quid, BCG Green Tech Poetal, EGG's Center for Growth and Innovation Analytics

Source: BCG

The future of energy: Supercharging clean electricity

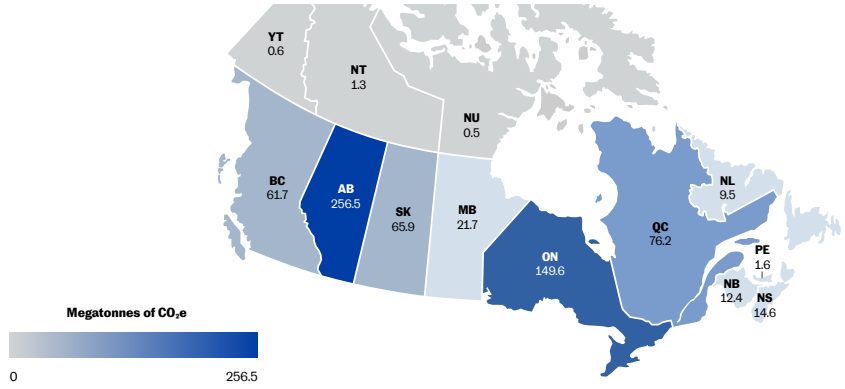
Innovators are forging novel pathways toward a net-zero system.

The big picture: Doing more with less

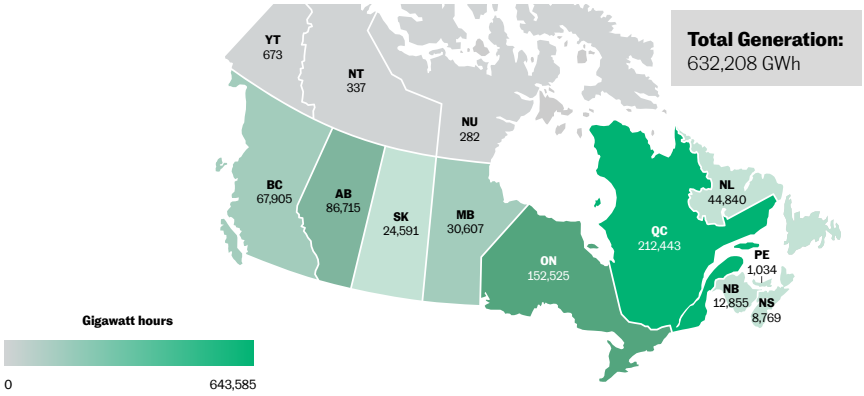
As we speed toward 2050, Canada is faced with a two-pronged challenge: getting more electricity and making it cleaner. The federal government estimates our electricity requirements will double within the next 25 years with the increased adoption of EVs, heat pumps and other technologies that rely on the grid for power. In line with forecasts from the International Energy Agency and the Canadian Climate Institute, the government has also suggested that to meet said demand, we will have to increase capacity by up to 3.4 times our current volume.

Reaching net zero while more than doubling capacity is a complex endeavour. And while our country has one of the cleanest grids in the world, with 82 percent of our supply coming from low- and non-emitting sources, we have less than three decades to hit 100 percent. In short, it's a big leap from here to net zero — we'll need strong policies and immediate action to get there.

Greenhouse gas emissions across the country (2020)



How much electricity was generated in 2019



Source: Canada Energy Regulator. Canada's Energy Future Data Appendices. DOI

Meeting these ambitious goals requires buy-in from various levels of government, Indigenous Nations, investors, regulators andothers. Although our electrical grid is largely emissions-free, three provinces and two territories — Nova Scotia, Saskatchewan, Alberta, Northwest Territories and Nunavut — operate electricity systems with higher proportions of GHG-emitting electricity than countries such as Russia and China. The federal government has launched several initiatives to support the necessary shifts in this process, including regulations to reduce GHGs produced in the generation of electricity and a cap on emissions from the oil and gas sector.

This process also requires that we scale up storage solutions and increase efforts to diversify where we get power and how we use it. Traditional sources of energy are no longer viable. As Pierre Fitzgibbon, Quebec's minister of economy, innovation and energy, said this past May, reflecting on Hydro-Québec's supply, "our surpluses have melted like glaciers under the sun of climate change."

Major developments

There were 65 venture capital, private equity and M&A deals made in Canada's renewable energy sector worth approximately **$2.1 billion**

5 deals
~$47M
Wind Power

13 deals
~$34.1M
Solar Power

There were 26 deals made in the hydrogen production sector, worth approximately **$4.6 billion**

- The largest deal involved Project Nujio'qonik in the Bay of St. George, Nfld., which received $4.5 billion to form a joint venture with World Energy GH2 and SK Ecoplant

the largest hydrogen production deal
$4.5B
Project Nujio'qonik

There were 6 deals made in the nuclear sector worth approximately **$30 million**

- The largest deal involved Vancouver's General Fusion receiving $25 million in Series F funding

the largest nuclear deal
$25M
Project Nujio'qonik

There were 11 deals made in the energy storage sector worth approximately **$382 million**

- The largest deal was the acquisition of Oneida Energy Storage in Haldimand County, Ont., for $369.63 million

the largest energy storage deal
$369.63M
Oneida Energy Storage

While energy innovation is happening in a range of technologies, a few areas stand out.

1. Smart, sustainable storage

If the aim is to double or even triple our supply capacity by 2050, it follows that we'll also need to support long-duration energy storage. Storage is a crucial part of ensuring reliable service that can mitigate the peaks and valleys of the intermittent power generation associated with renewable energies such as wind and solar. Whether in the form of mobile batteries or facilities that can hold more than eight hours' worth of energy, long-duration storage will help power everything from EVs and heat pumps to remote communities that have had to rely on diesel generators.

At the moment, there are 61 energy-storage firms operating in Canada. As James Larsen, CEO of e-Zinc, says, "the demand is already there." His company — which creates recyclable and rechargeable long-duration batteries using zinc as the energy carrier — has raised more than $70 million and has broken ground on a 50,000 square-foot manufacturing facility in Mississauga. Meanwhile, Toronto's NRSTOR is collaborating with the Six Nations of the Grand River Corporation to build a plant using lithium-ion batteries for energy storage, in Haldimand County, Ont. The facility, known as Oneida, is the largest such project in Canada. Once it's up and running, Oneida is projected to prevent the production of 4.1 million tonnes of GHG emissions over the next two decades — while also providing ongoing job opportunities for members of the Six Nations community. For its part, Toronto-based Hydrostor uses off-peak electricity to compress and heat air, which it then stores and draws on to produce energy. This past January, the company announced a 25-year power purchase agreement with California-based Central Coast Community Energy to provide long-duration storage.

Whether in the form of mobile batteries or facilities that can hold more than eight hours' worth of energy, long-duration storage will help power everything from EVs and heat pumps to remote communities that have had to rely on diesel generators.

2. Power moves

Shifting away from a consolidated central power source has historically allowed for more sustainable, efficient, reliable and affordable alternatives, especially in rural areas. Energy decentralization has expanded beyond micro-grids; industry partners, for instance, may want to manage energy needs in-house via small modular nuclear reactors. To adequately handle current and future demands, alternatives to the traditional one-way grid — such as a digitized, interconnected and automated system that can cycle power back into the system — are crucial.

A number of ventures have developed technologies that allow more flexibility than a conventional grid. For instance, Moment Energy provides grid storage from an unlikely source: spent EV batteries. According to a report from the National Renewable Energy Laboratory, even at the end of an EV's life, the battery inside can retain up to 70 percent of its capacity. Turns out that's plenty of juice left — up to a decade or more — for other second-life applications. (See more on page 16)

3. Next-generation renewables

Renewables continue to be deployed in countries around the world, prompting companies to invest in technologies to improve just how efficient renewable energy generation can be.

A number of Canadian companies are harnessing the power of the sun and helping to meet net-zero goals in the process. Toronto-based Morgan Solar designs solar panels, blinds and building facades that convert sunlight into electricity. The thermal load on the building is controlled by an intelligent shading system that uses sensors to provide data in real time. Another Toronto company, Enersion, converts solar radiation into electricity, heating and refrigerant-free cooling in one on-site system.

Sunny outlook

Solar energy is now less expensive than natural gas in most jurisdictions and is expected to double in capacity by 2025. Canadian breakthroughs are helping the panels become thinner, cheaper and more efficient.

Capturing the full spectrum

Most solar panels use silicon, but it captures only a fraction of the available solar radiation. Perovskite is emerging as a more affordable and effective alternative. In its panels, QDSolar combines this material with quantum dots to capture more of the sun's spectrum, including infrared, ultraviolet and visible light.

Placing panels everywhere

Solaires, in Langford, B.C., has created a solar "ink" that can be used to coat surfaces and create electricity in a more versatile and affordable way than conventional silicon solar cells. "Another beautiful part of this technology," says Solaires CEO Sahar Sam, "is that perovskite can generate electricity from low-intensity light in our homes."

Measuring the impact

By 2050, it's estimated that bifacial photovoltaic technology will be supplying more than 16 percent of the global energy demand. Enurgen's software is able to measure and model production on both sides of the panels — the first commercial software to do so.

4. Nuclear options

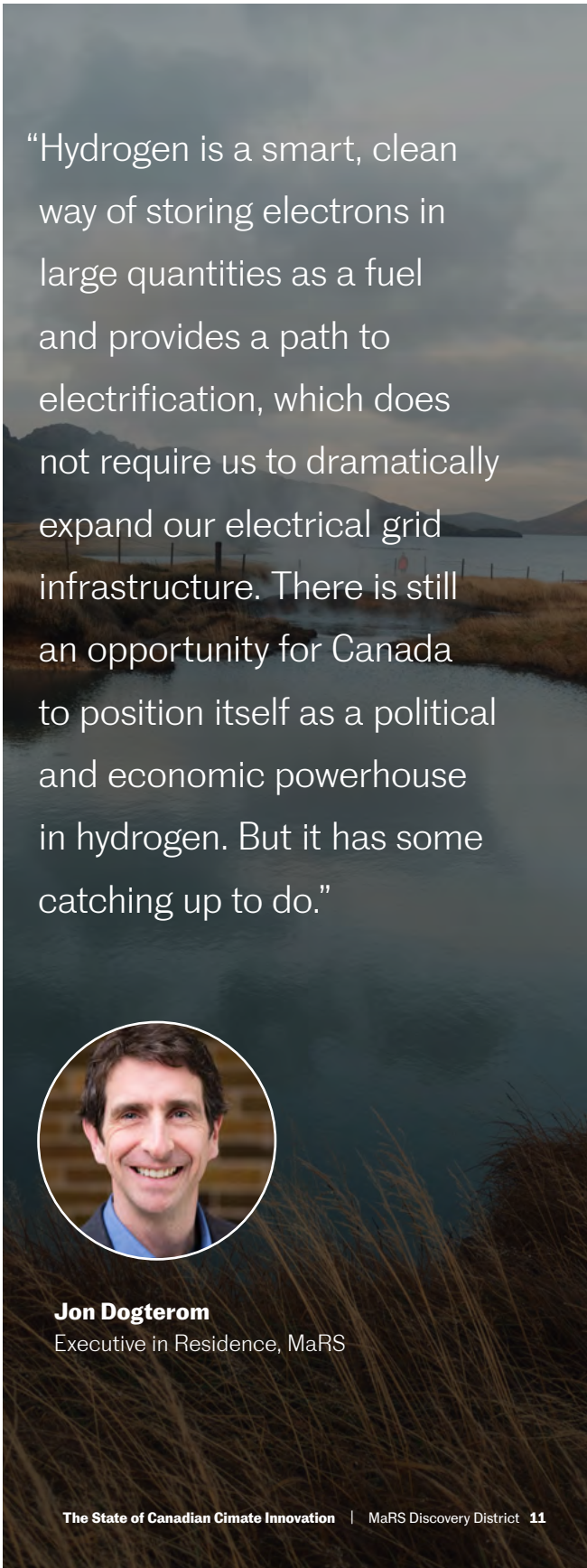
Delivering on its reputation as a long-time proponent of nuclear energy, Canada has laid out a plan to refurbish existing reactors and invest in small modular reactors. By 2050, it is projected that nuclear energy will cover roughly 40 percent of Ontario's power needs. The province's plans to increase its nuclear power generating capacity include nearly doubling production at Bruce Power (already the largest nuclear generation station in the world), adding three small modular reactors to the existing project slated for the Darlington Nuclear Generating Station and potentially refurbishing the Pickering site, which holds the status of being the country's oldest operating nuclear power plant.

In recent years, the potential of harnessing green, virtually limitless nuclear fusion as an energy source has attracted a number of startups, including B.C.–based General Fusion. It's planning to build a magnetized target fusion machine in Richmond to demonstrate their proof of concept by 2026 — the company's aim is to illustrate that it is possible to create the necessary conditions to achieve nuclear fusion that can be scaled commercially. Fusion is a clean, safe, abundant and on-demand form of energy that, when harnessed, could provide a nearly unlimited source of power with zero CO2 emissions.

5. Gas routes

Although hydrogen is the most common molecule in the universe, it is only relatively recently that we have come to understand how abundant the gas is in its natural form — and recognize its potential viability as a source of green energy. Unlike hydrogen fuel derived from water (which requires electricity) or fossil fuels (which emit carbon dioxide), renewable natural hydrogen is a ready-to-go gas that doesn't require energy-intensive production methods, making it a climate-friendly option. According to Alberta's Hydrogen Roadmap plan, hydrogen could provide up to 24 percent of global energy demand by 2050, growing to almost 700 million tonnes per year (an almost eight-fold increase from the global consumption of 90 million tonnes in 2020).

As part of the overarching shift mapped out in Canada's Hydrogen Strategy, the government has been implementing carbon-capture technology to reduce emissions related to production. Such efforts could help the country secure a significant portion of the U.S.$60 trillion hydrogen market by 2030.



"Hydrogen is a smart, clean way of storing electrons in large quantities as a fuel and provides a path to electrification, which does not require us to dramatically expand our electrical grid infrastructure. There is still an opportunity for Canada to position itself as a political and economic powerhouse in hydrogen. But it has some catching up to do."

Jon Dogterom
Executive in Residence, MaRS

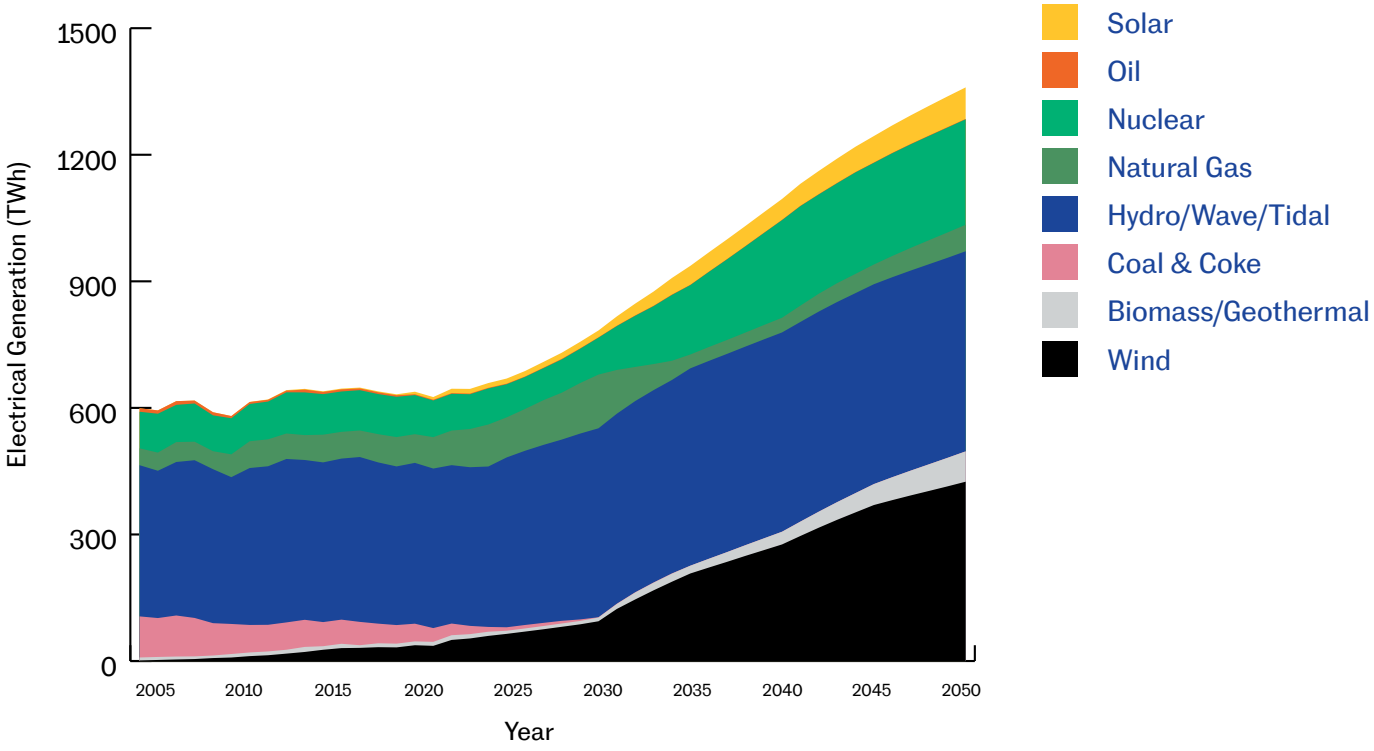
Early applications for hydrogen over the next decade will include heavy-duty transport in cases where battery electrification is a) too heavy to accommodate distance and carry capacity demands; b) requires excessive charging time; and c) necessitates dramatic changes to electrical infrastructure. As well, there is an interest in blending hydrogen with natural gas to offset residential and commercial heat loads. Industry watchers predict that by 2050, the largest uses of hydrogen will be clustered in aviation, shipping and steel production.

In the absence of a centralized hydrogen infrastructure, many early-stage producers are creating innovative solutions in close proximity to the site of use. Alberta's Aurora Hydrogen is planning a pilot project in Edmonton to assess whether it can produce 200 kilograms a day of turquoise hydrogen. This method, which uses 80 percent less electricity than electrolysis, doesn't require water as a feedstock, which means the company is able to produce hydrogen for end-users located in land-locked provinces. CleanInnoGen has adopted a similar distributed approach, using waste heat to produce hydrogen and oxygen on-site with an aim of helping heavy industry.

Facilitating change

In early November, TES Canada announced it will build a $4-billion hydrogen project north of Montreal. Once online, it plans to produce 70,000 tonnes of hydrogen a year using electricity.

Potential electricity generation



In this model, electricity generation grows about 40 percent by 2050 from 2019 levels, with much of this new generation coming from wind and solar.

Source: Canada Energy Regulator

The road ahead

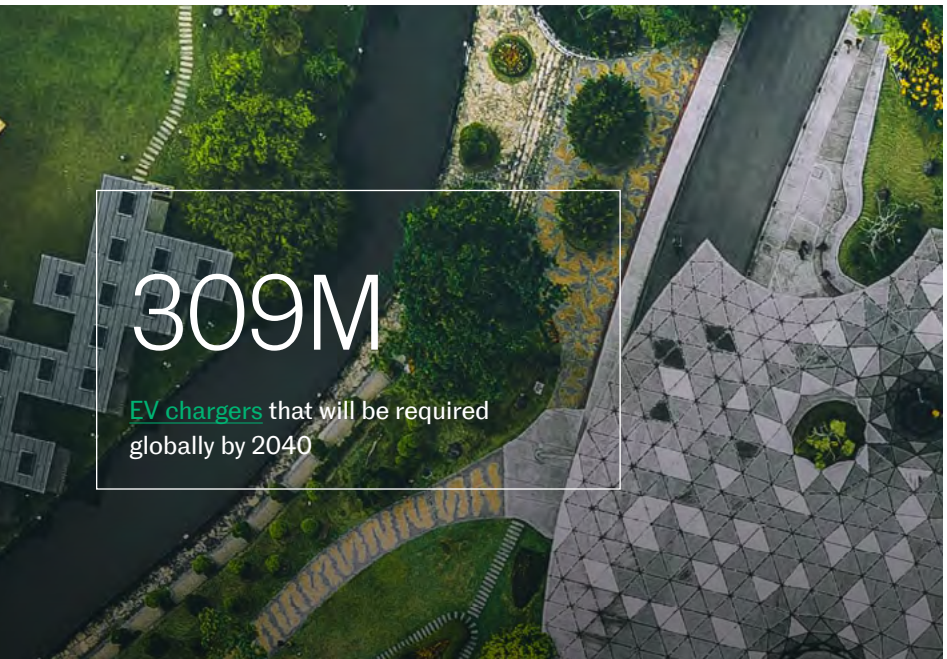
Solutions to help build a clean mobility network.

The big picture: Better, faster, cleaner, smarter

Reaching our net-zero goals by 2050 requires a full-scale transformation of how we move from point A to B (and everywhere in between). This will entail a broad swath of changes, including decarbonizing heavy-duty vehicles, improving public transit, building high-speed rail lines, optimizing fleets and scaling up lower-carbon alternatives to jet fuel.

On a personal level, getting around is getting greener, thanks to a marked uptick in the number of hybrid electric vehicles and battery electric vehicles on the road. While nearly 95 percent of the 24.1 million registered light-duty vehicles on Canadian roads in 2021 still used gasoline, the number of plug-in hybrid electric vehicles jumped 24 percent and the number of battery electric vehicles jumped 48 percent from the previous year.

But those numbers could — and arguably should — be higher, what with $1.7 billion in consumer purchase incentives, a federal mandate for all new vehicle sales to be zero emission by 2035, and the fact that the transportation industry is a major contributor to climate change. Canada — already a major player in the automotive manufacturing sector — is actively striving to bump up those numbers, making headway in several lanes with an aim of securing a leading position in the production of EVs. A domestic battery supply is a clear priority: The government of Ontario and the federal government have invested billions of dollars in EV battery factories in St. Thomas and Windsor and in a battery parts plant near Kingston and in a project near Maple Ridge, B.C., which is slated to be the largest high-performance battery manufacturing facility in the country.



Significant Deals

Since January 1, 2023:

- Approximately $110 million (29 percent) of all VC, private equity and M&A deals in Canada have involved companies that are working on building the EV charging infrastructure. This is 2.28 times the amount of investment that occurred in 2022 (less than 1 percent of all investments were made in charging infrastructure in 2022).

- Approximately $57 million (16 percent) has gone to companies that are mining metals to build EV batteries. The remaining deals include investments in companies that are building EV components. Although this is a 12 percent drop from the amount invested in 2022, the proportion of funding allocated toward mining EV battery metals has doubled.

Overall, 48 deals were completed in 2023. Some notable ones include:

- ChargeLab raised $30 million in Series A
- Cyclic Materials raised $27 million in Series A
- Hexagon Purus received in $48.8 million in PIPE (private investment in public equity)

There have been massive investments by various levels of government in the EV battery supply chain, including:

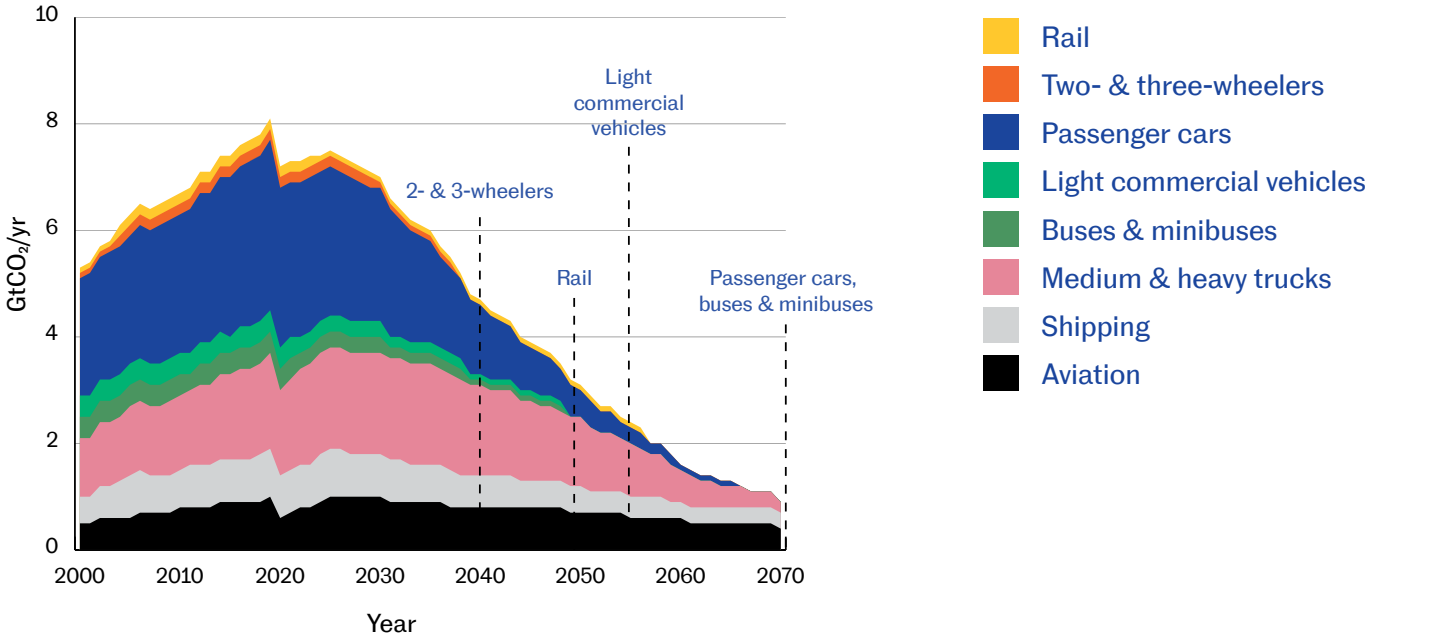
$4 million for FBT Inc., a family-owned advanced manufacturer of precision machine components and parts used in EVs as well as semiconductors and power generation.

There are many challenges on the road to electrification, however. Manitoba Hydro has warned that demand for power in the province will more than double in the next two decades. And in Ontario, demand for electricity is forecasted to grow by 2 percent every year for the next 20 years. Some industry watchers have warned that it could be a challenge to support the growing demand for EV charging, which will be competing against heat pumps and industrial processes for every clean electron produced. This speaks to the need to scale up mass transit options: Every trip that moves from a passenger to a bike, walking, train or bus, means one fewer trip we need to electrify.

Sustainable transportation means adopting non-emitting, energy-efficient and affordable modes of travel, but it also means supporting the innovation and infrastructure that will make that possible.

- $15 billion in performance incentives on the future output of the Stellantic-LG plant in Windsor.
- $2.7 billion to establish a new battery factory in Loyalist Township, Ont.
- Ten transit organizations in Quebec are banding together to procure up to 1,229 Nova Bus electric buses for $2.1 billion. This is the largest deal in North America.
- Joint federal and provincial funding — $395.5 million — will support BC Transit's zero-emission bus transition, allowing BC Transit to purchase 115 electric buses and 134 charging points.

Transportation's estimated global carbon dioxide emissions



Notes: Dotted lines indicate the year in which various transport modes have largely stopped consuming fossil fuels and hence no longer contribute to direct emissions of CO_2 from fossil fuel combustion. Residual emissions in transport are compensated by negative emissions technologies, such as BECCS and DAC, in the power and other energy transformation sectors.

Source: IEA

Within sustainable transportation, several key trends stand out.

1. Revamping existing vehicles

Overhauling how we get around doesn't happen overnight, and it doesn't mean reinventing our wheels. Re-envisioning how we use our existing fleets of trucks and buses, and how we can improve on those forms of transport, is an important part of reaching net zero.

Two bus-focused companies are doing just that. Girardin, a school-bus manufacturer in Quebec, is focusing on fully electric fleets, with expanded charging networks through its EV-infrastructure subsidiary, Polara, and has a partnership with Lithion to recover and recycle end-of-life lithium-ion batteries used in school buses. The Toronto firm Pantonium has developed an AI platform to optimize bus routes, which helps cut down on emissions while also boosting ridership. Montreal-based Effenco, which was recently acquired by Canadian auto parts manufacturer Martinrea, is working with industrial customers and municipalities to electrify heavy-duty fleet vehicles such as waste collection trucks, using fast-charging ultracapacitor-based power modules. Meanwhile, Hamilton, Ont.–based Preteckt, is leaning into fleet management, offering diagnostics and repairs through AI. Quantuity Analytics Inc. works with the commercial trucking industry, using intelligent AI IoT smart sensor technology and 5G cellular connectivity to allow for real-time tracking and monitoring of fleet vehicles, with a goal of optimizing pre-trip inspections and enhancing safety. Its AI smart centres help reduce brake inspection time down to 30 seconds from 40 minutes, improving both vehicle and driver safety. And Lafarge Canada is starting to electrify its fleet with two Vicinity Motor trucks.

2. Go your own way

In Canada, the transportation sector is responsible for 27 percent of GHGs, with passenger vehicles (cars, SUVs, light-duty trucks) accounting for almost half of that total. Reducing our national emissions means creating efficient and convenient public transit that is a viable enough alternative to attract users. Toronto's TransPod is developing ultra-fast and fossil fuel–free commercial and passenger tube transportation. The company's hyperloop train uses vacuum technology that is compatible with renewable power sources to travel at speeds of 1,000 kilometres an hour. TransPod anticipates its vehicles could reduce travel time between Calgary and Edmonton (its first hyperloop line) from three-plus hours to just 45 minutes. The company is aiming to start construction on a 10-km test track in Edmonton in 2024.

3. Recharging the battery life cycle

The time required to charge an EV battery and the distance that fully charged battery will travel have long been chief concerns for would-be EV adopters. There has been significant activity — in the realms of both innovation and policy incentives — to address those issues, whether by amping up battery production in Canada via the funding of battery manufacturing plants, making plans to keep hazardous battery waste out of landfills or using AI to improve the charging speed and range of batteries.

Aluma Power in Sarnia, Ont., has created a galvanic generator that extends a vehicle's range by charging the car while you drive. The generator runs on scrap aluminum, which is easier and cheaper to procure than the lithium used in conventional batteries. Ottawa-based GBatteries is working to charge an EV as fast as filling a tank of gas by using AI to manage power flow and protect batteries from the degradation that is a common side effect of accelerated charging. Toronto's eLeapPower is using an integrated inverter and wireless charger that can charge directly from renewable energy sources like solar and wind, and also direct power back to the grid. And for performance-enhancement-oriented EV users, Toronto's Inmotive is working with Suzuki Motor Corporation (one of its investors) to commercialize a form of automatic transmission that improves acceleration, speed and range.

Charging infrastructure and technology is also poised to explode into a massive global market that will reward both first movers and technology innovators. In 2022, the federal government allocated an additional $900 million to zero-emission vehicle infrastructure, including deployment of 50,000 additional EV chargers by 2027. But it's not as simple as installing one and hooking it up to the grid. While we have enough energy production to meet the demand, "we don't have it where we need it," says Carmine Pizzurro, president of fast-charging company eCAMION. Areas with older grid infrastructure, such as the Trans-Canada Highway, will be challenging. To help with that challenge, Pizzurro and his team have developed an energy-storage unit that collects power during off-peak hours and then delivers it to cars through the company's Jule fast chargers. The firm says its chargers can deliver 150 kW of charge with only 30 kW from the grid. Toronto-based SWTCH is focusing its efforts in multi-tenant dwellings, and Etobicoke-based ChargeLab has developed open software that works with most chargers and optimizes the vehicles' charging for grid capacity and cost-effectiveness.

Extracting new value

Recycling spent batteries is non-negotiable if we're to achieve net zero. Last year, Li-Cycle announced a $200-million partnership with Glencore, a Swiss materials company to recover valuable minerals and metals from spent batteries — a smart move given research out of the University of California that found recycled materials could supply more than half of the lithium, nickel and cobalt in new EV batteries by 2040. Vancouver's Moment Energy is taking end-of-life EV batteries with enough power left to meet lower-energy demands and repurposing them in off-grid locations, or in buildings where energy can be stored for use during high-cost peak hours. Toronto's Cyclic Materials, meanwhile, focuses on recycling rare earth elements — metallic components found in many high-tech devices, including EVs — reducing the need to open new mines.

4. High hopes for hydrogen

Hydrogen, which, according to Alberta's Hydrogen Roadmap plan, could provide up to 24 percent of global energy demand by 2050, holds some interest in a clean mobility context. EVs have dominated the conversation thus far, but hydrogen fuel-cell vehicles could play a pivotal role in decarbonizing parts of the transportation sector, namely through their ability to refuel quickly, cover long ranges and carry heavy cargo — particularly in shipping and aviation. One significant hindrance to the widespread adoption of hydrogen in vehicles, however, is the lack of hydrogen fuelling stations: At present, there are only 11 such facilities in Canada, the bulk of which are on the west coast.

Alberta has seen a number of significant developments in hydrogen. The Edmonton airport, for instance, has introduced a fleet of 100 Toyota hydrogen fuel cell EVs. And the Alberta Zero Emission Hydrogen Transit (AZEHT) initiative is testing out two hydrogen buses in real world conditions. In other advances, Canada's first hydrogen train started taking passengers from Quebec City to Baie-Saint-Paul this summer, and Universal Hydrogen passed a major milestone with the flight of their hydrogen-powered aircraft between two regional airports.

Scaling new hydrogen solutions

Ayrton Energy, an early-stage startup, is working on a solution that straddles both hydrogen and electric charging. The Calgary-based company is finessing a system for EV charging that supports distributed hydrogen generation and allows the gas to be stored at an optimal density. Meanwhile, StormFisher Hydrogen, based in London, Ont., uses electrolysis to produce hydrogen for the marine sector. The company's green hydrogen is then used to make zero-carbon methane (methanol), an alternative fuel source.

The carbon conversation: Beyond net zero

Market innovations are key to a sustainable future.

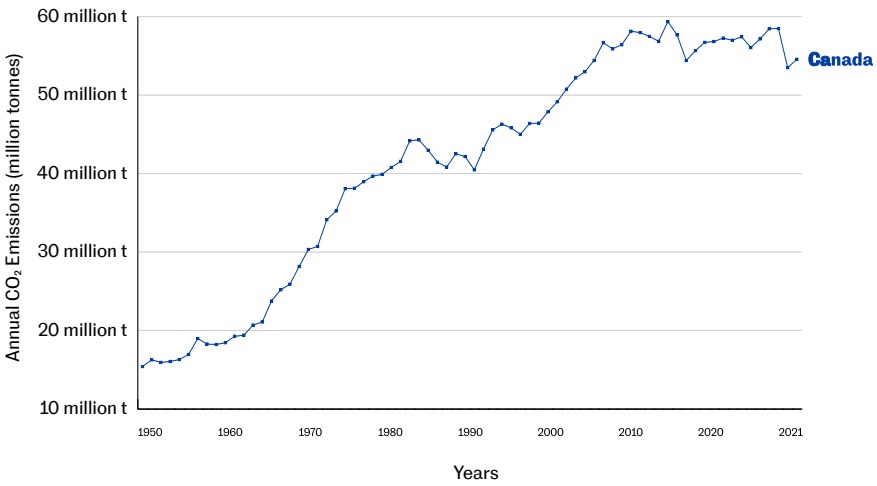
The big picture: Atmospheric reset

If we want to move forward, we have to rewind. That's the sobering takeaway from current climate-change assessments, based on the increasingly devastating impacts of global warming — and the atmospheric effects that have led us to this place. Even if we were to achieve net-zero emissions by 2050, existing GHGs in the atmosphere will propel the earth's temperature steadily upward. Simply put: We are not on track to keep global warming within the 1.5 degree Celsius limit that is essential to preserve the health of the planet. Models indicate that if carbon emissions are not drastically reduced, we will likely blow past that crucial target by the end of this decade. Which is why the best-case scenario involves not just dialing down our emissions, but proactively taking carbon out of the atmosphere.

"We need to go beyond net zero and reach negative emissions," says Andy Lam, senior manager of climate programs at MaRS. This will help bring the planet back to where it was decades ago, he adds. "We need as many tools as possible to get us there before the damage becomes irreversible."

Advancements in both policy and investment (the IEA estimates that about U.S.$1.7 trillion will be allocated globally to deploying climate tech this year — a record high) are paving the way for a greater variety of tools. The ambitious Inflation Reduction Act in the United States has spurred investment in this space, and many are calling for further support here at home. Meanwhile, businesses across the globe are recognizing that GHG-reduction initiatives can benefit both the environment and their bottom line. Even within industries where emissions mitigation poses challenges, corporate leaders are realizing that carbon capture can be a vehicle for profitable byproducts.

Canada's annual carbon dioxide emissions



Source: Our World in Data

3.8 gigatonnes

The estimated amount of carbon dioxide that will be produced globally by the concrete industry between now and 2050 if current standard practices

Major developments

In Canada's carbon capture and removal space, there were 43 venture capital and private equity deals so far in 2023, worth more than $685 million. But the biggest headline was the U.S$1.1 billion acquisition of Squamish, B.C. startup Carbon Engineering by Occidental Petroleum. "It showed there's an opportunity for big industry to help play a major role in scaling up this innovation," says Tyler Hamilton, senior director of climate at MaRS. "It's clear there's going to be a lot more demand."

As outlined in the IPCC's 2022 report, a range of carbon capture, utilization and storage (CCUS) approaches (such as reforestation, direct air capture and ocean carbon sequestration) are crucial to keep global warming within a relatively stable range of 1.5 to 2 degrees Celsius. From a market standpoint, these decarbonization strategies can be broken down into three key categories.

1. Carbon dioxide cleanup

In some ways, it's basic math: If we want fewer carbon dioxide molecules turning our planet into a de facto greenhouse, we need effective methods to trap and store those molecules. Biological and geological processes have cycled carbon into and out of the atmosphere for billions of years, maintaining the right balance for a stable climate. If we want to pull enough carbon dioxide out of the atmosphere to avoid climate breakdown, we need to deploy effective methods to augment these natural carbon cycles.

To that end, there have been exciting advancements and robust investment in both carbon capture (implementing technologies adjacent to oil and gas fields or manufacturing facilities to collect emissions on site) and direct air capture (or DAC, where fan-equipped plants use chemicals to extract carbon dioxide from the air and convert it into a form that can be more easily contained or used).

These methods can be very energy intensive, which poses a challenge in terms of meeting net-zero goals. But Canadian innovators are working on approaches that mitigate energy consumption by taking advantage of existing conditions. Gaia Refinery, which is currently building its pilot facility, uses acetic acid (the compound found in white vinegar) as a bio-based alternative to processes that involve excessive energy or heat. And Ottawa-based DAC company TerraFixing relies on zeolites, highly absorptive minerals that perform best in low temperatures, which means its technology is well suited to sub-zero climates and has been an effective tool to help capture emissions near northern mines.

Recycling carbon

Startups, such as Hyperion Global Energy, are helping heavy industrial plants decarbonize. Its modular units can be retrofitted into existing manufacturing plants to capture carbon dioxide from the exhaust gas and transform it into precipitated calcium carbonate, a non-toxic mineral used in many everyday products, including toothpaste, pharmaceuticals and construction materials. "We call it carbon recycling because we are turning carbon dioxide into a new material," says co-founder Heather Ward.

Genny Shaw
Co-founder, Gaia Refinery

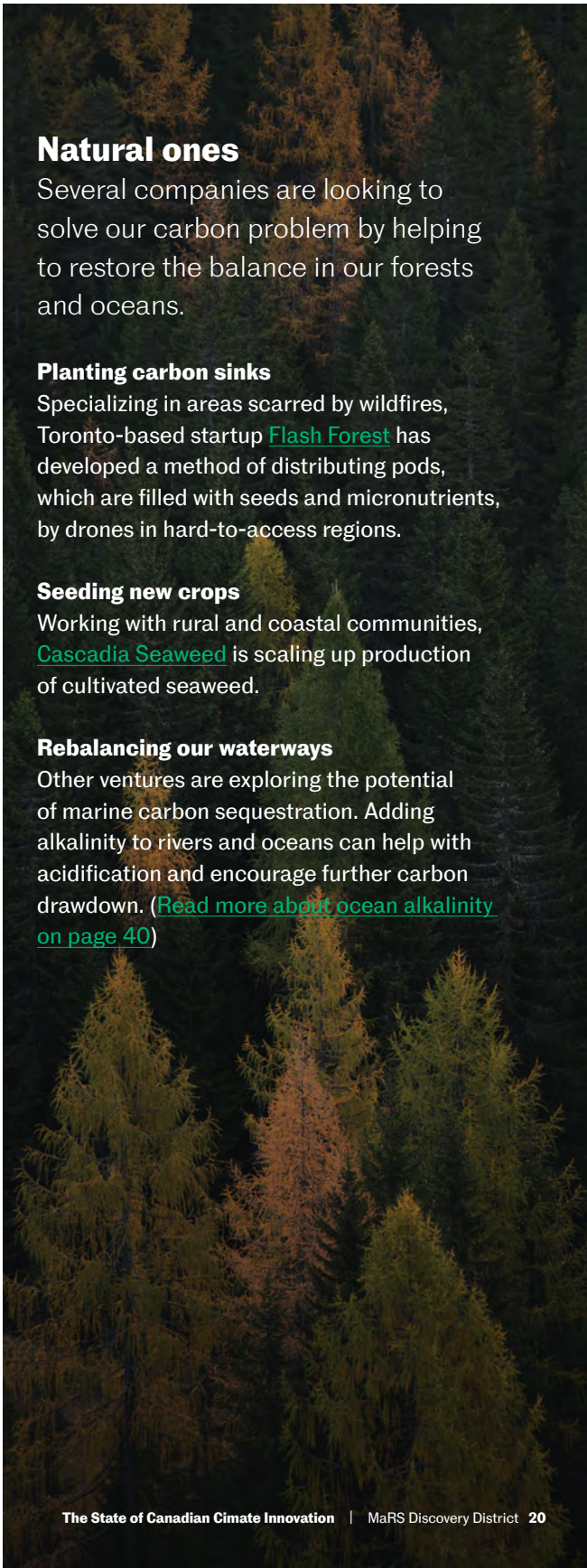
"It's almost like recycling right from the atmosphere into the products the current economy wants and uses. There are a lot of pathways and that will continue as this circular carbon economy develops."

2. Storage solutions

As heavy-emitting industries work to decarbonize, sector leaders are exploring new ways their assets can be instrumentalized to help capture, utilize or store carbon onsite. They are refining methods of transforming carbon dioxide into rock, sequestering it in the ocean or creating more sustainable building materials. In Iceland, for instance, carbon dioxide from a nearby power plant is being mixed with water and then injected into the basalt rock below where it mineralizes. And mining companies are looking at the potential sequestration of carbon dioxide through the natural weathering processes using tailings.

Concrete production is garnering a lot of attention as a promising use case. The process requires cement, a binding agent derived from ground limestone, which accounts for nearly 8 percent of all carbon dioxide emissions globally. But injecting carbon dioxide directly into cement is an effective way of storing carbon and results in stronger concrete. Given the prevalence of concrete in construction — approximately 30 billion tonnes are poured each year — there are great opportunities in terms of both scale and the volume of carbon that can potentially be contained.

Based in Halifax, CarbonCure offers a range of sustainable concrete options, from ready-made mixes to design resources. This past February, the company undertook a first-of-its-kind pilot project in a California plant that involved injecting DAC-collected CO2 directly into fresh concrete. And in some cases, a carbon-storage strategy solves several problems at once. Quebec company Carbicrete takes slag, a byproduct of rendering steel, and uses it in a slurry to produce calcium carbonate, which can in turn be incorporated into other building materials — including a low-carbon or "negative-carbon concrete," as co-founder and CEO Chris Stern explains. (See more about sustainable material page 27).



Natural ones

Several companies are looking to solve our carbon problem by helping to restore the balance in our forests and oceans.

Planting carbon sinks
Specializing in areas scarred by wildfires, Toronto-based startup Flash Forest has developed a method of distributing pods, which are filled with seeds and micronutrients, by drones in hard-to-access regions.

Seeding new crops
Working with rural and coastal communities, Cascadia Seaweed is scaling up production of cultivated seaweed.

Rebalancing our waterways
Other ventures are exploring the potential of marine carbon sequestration. Adding alkalinity to rivers and oceans can help with acidification and encourage further carbon drawdown. (Read more about ocean alkalinity on page 40)

3. The monitoring market

With mounting pressure on corporations to reduce their climate impact, carbon markets have emerged as a powerful mechanism to orient entire economies to the urgency of the climate crisis. But because we can't monitor and measure — and monetize — what we don't track, there has been rapid growth in the development of digital strategies that can assess carbon-related data and provide robust accounting around emissions and exchanges. A World Bank report from May of this year found that at least 23 percent of greenhouse emissions are subject to a carbon tax or an ETS — more than triple the 7 percent that fell under regulatory oversight in 2013. The global carbon data market has grown significantly even since 2022, when it was valued at U.S.$13 billion. Private companies are under increased pressure from customers to reduce emissions, a phenomenon that Carbonhound CEO Sanders Lazier describes as "trickle down carbonomics."

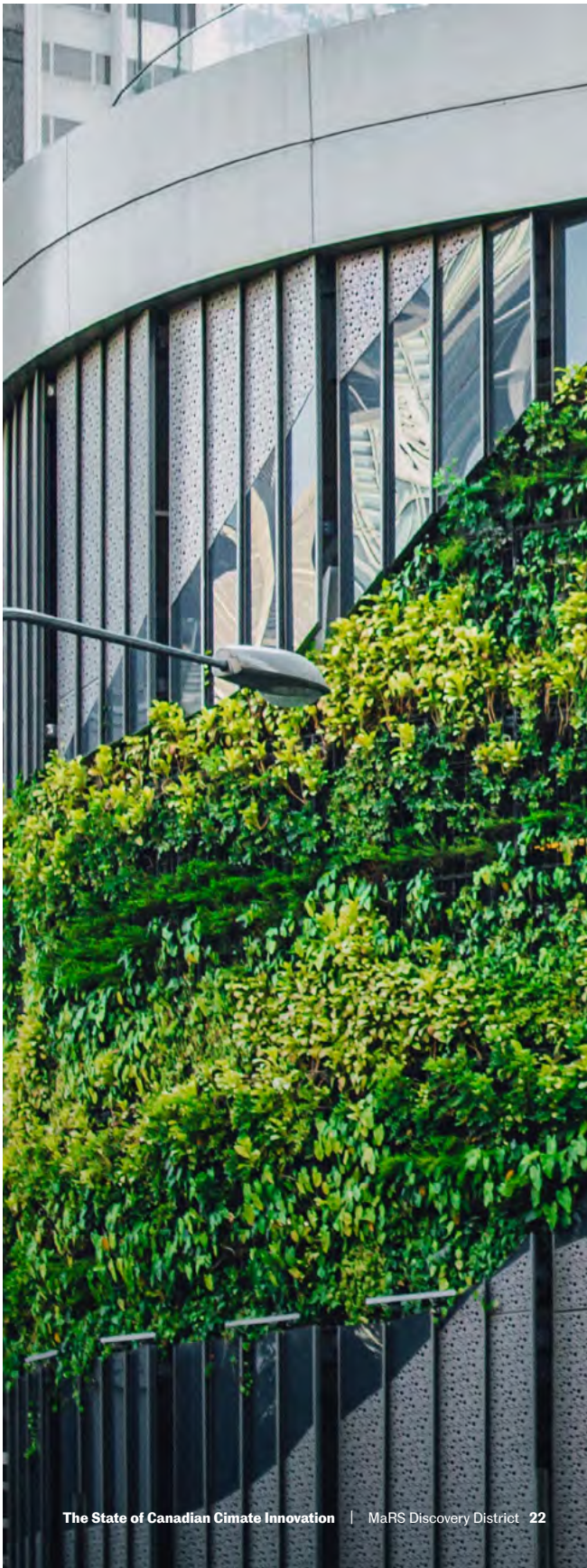
Of course, taking action is contingent on accessing accurate carbon-related data (from HVAC systems, vehicles, utilities, solid waste, methane leaks and other pollutants), information that can be gleaned from both macro and micro approaches. Carbonhound's platform helps corporations more efficiently and effectively track their own emissions on a granular level. Meanwhile, Montreal-based GHGSat deploys hi-res sensor-equipped satellites to remotely monitor (and identify) different kinds of emissions. Its technology can effectively determine whether an area of excess GHGs has been caused by industrial pollution or natural processes. In September 2023, the company had snagged $59 million to launch additional satellites, and in November, GHGSat made further strides with the successful launch of its new carbon dioxide–detecting satellite, which is aimed at helping commercial clients in heavy-emitting industries.

"We have some great innovation coming out of the Canadian ecosystem and we're working with a lot of early-stage companies who have very good carbon removal solutions. A big part of our work at MaRS is to help them scale up and become bigger players in the global marketplace."

Tyler Hamilton
Senior Director, Climate, MaRS

Street smart: Tech solutions for more resilient cities

From temperature-regulating buildings to flood-thwarting curbs, smart innovations are helping municipalities become more sustainable and less susceptible to environmental extremes.



The big picture: Climate change hits us where we live

This summer's wildfires and floods proved just how vulnerable our cities and citizens are to climate change and its ramifications. The economic impact is significant, too. It's estimated that the severity and frequency of climate disasters could slow Canada's economy by $25 billion a year. According to the Canadian Climate Institute, our GDP is expected to fall by roughly 12 percent by the end of the century as a result of climate-related concerns, which will have a disproportionate effect on lower-income households, worsening existing inequality.

Proactive strategies, especially on the municipal level, can help mitigate these effects and foster resilient communities. Businesses, for example, face multiple risks: climate-related damage can force closures, supply-chain disruptions can affect inventory, and the challenges of trying to draw new talent to a vulnerable city can result in loss of income. Developing increasingly sustainable cities can take many forms, and there are several key areas in which tech solutions can be crucial, from sensor-equipped AI that helps maximize efficiency to smart buildings that regulate their own temperature to design features that are engineered to contend with environmental extremes.

Municipalities have limited budgets and long procurement processes, which means achieving net-zero emissions with agility and speed can be challenging, if not near impossible. To help Canadian cities reach their climate goals, MaRS and Social Venture Connexion launched Climate Action Accelerator to Net Zero, known as CAANZero. "Canada will need to spend about $400 billion over the next 20 years to retrofit infrastructure to meet its climate goals and more than half of that infrastructure falls within cities," says Tyler Hamilton, senior director of climate at MaRS. To help ease that burden, CAANZero will assist small and medium-sized cities in securing, financing and selecting which innovative climate mitigation projects to focus on — making it simpler and faster for communities to adopt effective solutions.

New technology can play a critical role in creating "smarter" cities. By leveraging data, communities are better able to understand the risks they face, plan for different outcomes and design for better functionality, while also tackling climate change.

1. Optimization through data

For municipal planners, data is essential in assessing risk, anticipating outcomes and planning for the future. A dearth of accurate information "has always been a challenge in moving city solutions forward," says Ana Gonzalez Guerrero, the senior manager for climate and cities at MaRS. Planners need real-time access to knowledge in order to respond quickly to the changing environment; more importantly, they require complete, unbiased data to prevent the amplification of inequities.

Considering the varied effects of both strategic solutions and catastrophic events on diverse communities is central to the mission of RUNWITHIT Synthetics. The Toronto firm uses AI to create digital civic twins — essentially, virtual models of cities (think SimCity, but with more verisimilitude) that share characteristics (i.e., infrastructure, transportation, demographics) with their real-world counterparts — so that decision-makers can conceptualize how various scenarios might play out in real life and adapt their plans accordingly. Halifax-based Liveable Cities, on the other hand, installs tiny sensors on existing urban infrastructure (such as lampposts), enabling clients to collect traffic and pedestrian data that can inform everything from energy use to street architecture.

Track changes

Other startups are developing ways to help asset managers assess building and portfolio carbon exposure. For instance, Audette Analytics tracks such metrics as carbon emissions, GHG intensity and projected tax risk due to increases in carbon pricing.

2. Smarter buildings

According to the International Energy Agency, buildings and building operations (electricity, HVAC, etc.) are responsible for approximately 30 percent of the world's energy use and just over a quarter of emissions. Factor in construction activities, and that percentage climbs to 40 percent of all global emissions. Globally, debris from demolition and related processes accounts for more than 25 percent of total waste. That means that any net-zero strategy needs to emphasize greener practices in new builds and — given the likelihood that 70 percent of all existing structures will still be in use in 2050 — involve a robust plan to retrofit current inventory.

For building managers aiming to tackle inefficiencies within their properties, trying to determine what to prioritize can be less like looking for a needle in a haystack than like searching for the most essential needle in a pile of needles. The tools developed by Markham, Ontario's QEA Tech can help streamline this process. It offers a fleet of thermal sensor–equipped drones that are able to assess structures for hot spots; that data illuminates which areas are especially susceptible to energy loss.

And for developers looking to leverage more sustainable construction practices, Toronto-based Adaptis draws on AI to help bolster decarbonization and circular processes. Its platform, which develops salvage-value and life-cycle assessments, can also be applied to retrofits. These assessments have helped its clients reduce carbon emissions by as much as 60 percent.

Energy saver

Montreal's BrainBox AI uses AI to track emissions and optimize HVAC settings, with a big-picture aim of aggregating and controlling the electrical load of buildings across cities to help keep the grid optimized and always in balance. This is increasingly important as more intermittent renewable energy generation, like wind and solar, is added to the grid. The company is developing a demand-based service that could coordinate the flow of energy out of the system. Meanwhile, its platform, which optimizes HVAC systems, has already been deployed in hundreds of multi-site real estate locations. For instance, Sleep Country has installed it in 214 stores across Canada. On average, BrainBox AI has helped retail clients decrease carbon emissions by 28 percent.

3. The built environment

Based on the standards proposed by the World Green Building Council in 2019, any net-zero plan requires all building and infrastructure projects to reduce carbon output by 40 percent by 2030. Individual municipalities have different strategies for achieving this target, which can aid in overarching goals around improving air quality, preserving and expanding the inner-city tree canopy and effectively managing the effects of extreme weather.

To that end, planners around the world are assessing strategies that can take a kind of grassroots approach to infrastructure — sometimes in a literal sense. So-called "sponge cities" involve the deliberate incorporation of intentional wetlands and other green spaces that absorb and reroute excess rainwater. And while creating new parks is not always a practical option, rethinking the materials that are used in hardscape areas can be revolutionary. In 2021, an early-stage Toronto startup called Curb the Rain, founded by four sustainable management classmates at U of T, earned first prize at a climate-oriented student competition with a deceptively simple concept: curbs made of porous concrete that can help soak up stormwater.

"The environment doesn't care if you pollute the south or north; it's going to affect everyone. We need to look at how these solutions will disproportionately affect different groups."

Ana Gonzalez Guerrero
Senior Manager for Climate and Cities, MaRS

Reuse, recycle and rethink

Developing new and unexpected innovations for resource production.

The big picture: Making the most with minimal impact

Since 1970, the total mass of materials that were extracted from the earth has increased by more than 250 percent — and that figure is on track to double by 2050, if production continues at current rates. Transforming the way we extract, transform and consume materials is of vital importance in the race to meet emissions targets. With material production in the industrial sector accounting for more than half of GHG emissions, the importance of overhauling our approach to resource-intensive materials is clear.

Cement, lime and plaster (in construction), iron and steel (in manufacturing), chemicals as well as rubber, plastics and fabricated metals are some of the most carbon-intensive substances out there. In addition to finding lower-impact, sustainable ways to produce new quantities of materials, corporations must take a circular approach to optimize the use and reuse of the ones that are already out there, from sourcing to end of life.

So-called advanced materials are specifically designed to have optimized technical properties or a gentler environmental impact. According to the World Economic Forum, such innovations will play a critical role as an alternative to the emission-intensive status quo. It is impossible to overstate the critical need for scalable substitutes, and for solutions that can be integrated into existing processes and facilities. Having to replace machinery or build new facilities is a significant barrier that can be sidestepped with plug-and-play technologies.

Significant Deals

- Erthos raised $39 million of venture funding in a deal led by Capricorn Investment Group
- Evoco raised $8.76 million in Series B funding
- CHAR Technologies received $6.6 million of development capital from ArcelorMittal
- Carbon Upcycling raised $26.11 million in Series A funding
- CarbonCure raised $80 million in Series F

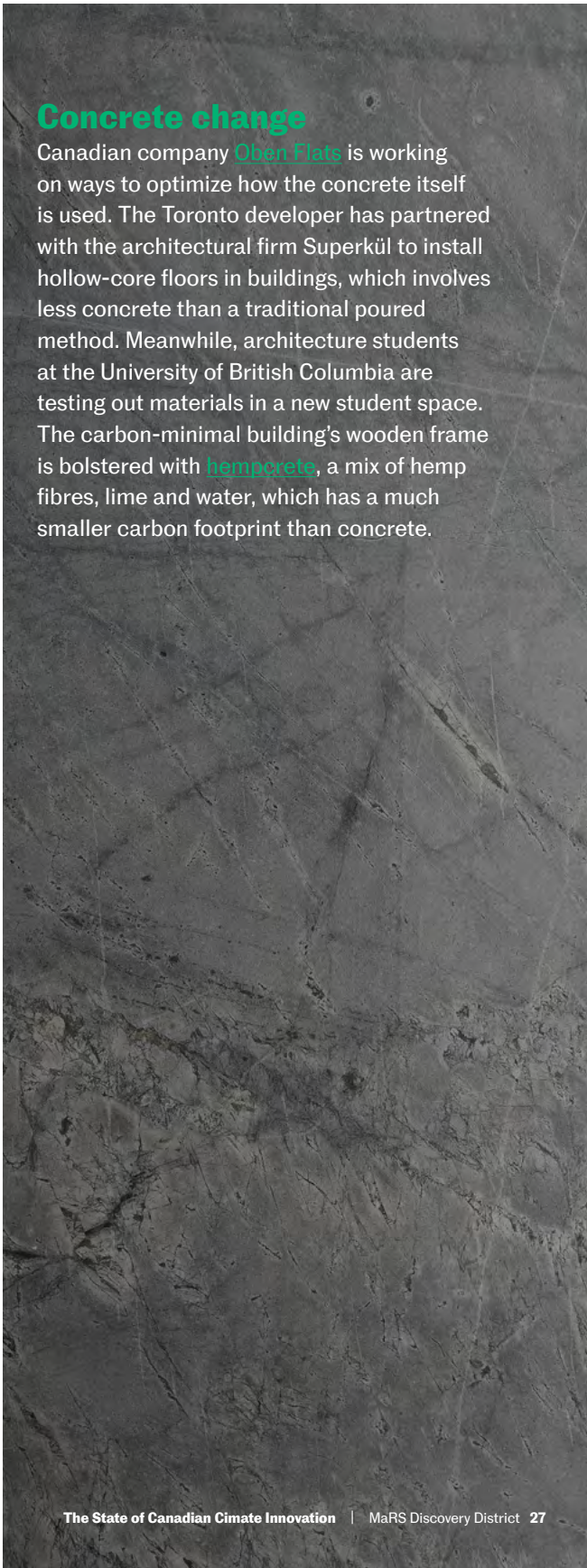
Innovators are exploring a host of options.

1. Steel made with biochar

One of the most common materials on earth, steel is a pillar of the construction and automotive industries. It is also a big pollutant, in part because it is traditionally produced with the use of coal. Cleaning up these processes without sacrificing strength is top of mind for one of the world's biggest steel producers and miners, ArcelorMittal Dofasco. It has invested $6.6 million in CHAR Technologies, a Mississauga-based company that transforms wood waste products into sustainable energy sources. CHAR's biochar, of which Dofasco has purchased 5,000 tonnes for use in its plants, is a significant step toward helping the manufacturer decarbonize steel production.

2. Carbon-packed concrete

Concrete, which can be found just about anywhere on the planet, contains cement — a major contributor of GHG that could be responsible for releasing 3.8 gigatons of carbon dioxide into the atmosphere by 2050. According to a 2021 study published in Nature, the use of concrete is rising more steeply than materials like steel or wood, meaning the global building industry will need to drastically scale up technologies to slow the rapid growth of emissions. But there are solid indicators of progress: Heirloom, a California startup, and CarbonCure, a Nova Scotia firm, have been working on solutions: the former company captures carbon dioxide from the air and the latter adds it to wastewater then injects the water (infused with the mineralized carbon) to make fresh concrete. Companies such as Montreal's Carbicrete and Calgary's Carbon Upcycling are also working on ways of infusing carbon-containing substances into concrete as it is being mixed. The carbon dioxide creates calcium carbonate, a non-toxic mineral found in limestone that enhances density and strength — its addition makes concrete 40 percent stronger. And this method also helps sequester the carbon to prevent it from being released into the atmosphere. (See more on page 20.)



Concrete change

Canadian company Oben Flats is working on ways to optimize how the concrete itself is used. The Toronto developer has partnered with the architectural firm Superkül to install hollow-core floors in buildings, which involves less concrete than a traditional poured method. Meanwhile, architecture students at the University of British Columbia are testing out materials in a new student space. The carbon-minimal building's wooden frame is bolstered with hempcrete, a mix of hemp fibres, lime and water, which has a much smaller carbon footprint than concrete.

3. Plant-based plastics

Plastics aren't going anywhere anytime soon — the global trade hit a record $1.2 trillion in 2021. But the need for sustainable alternatives is evident, especially as bans on conventional single-use plastic bags, stir sticks, straws and their ilk take effect in Canada and around the world. The Mississauga-based startup Erthos is focused on biodegradable, plant-based plastics that use food by-products and waste from agricultural sources. The company's proprietary resin is scalable — and fully compatible with existing manufacturing technology. According to co-founder Kritika Tyagi, people would ask if they should focus on recyclables, reusables or compostables. Her answer: "The problem is so huge and the amount of plastic waste so vast, we need all three solutions to work together."

4. Animal-free leathers

Reducing the environmental damage caused by the fashion industry — which, in 2019, produced 10 percent of the world's carbon emissions — is a global concern. A major step in tackling this issue is finding alternatives to leather, a significant pollutant. Case in point: North Americans' desire for leather seats in their SUVs is contributing to the destruction of Brazil's rainforest. With vegan leather expected to bring in U.S.$1,200 million by 2030, there's a huge market in upholstery, whether for personal vehicles or airplane fleets.

MycoFutures North Atlantic is one of a few ventures scaling up production of alternative leather. The company's version is a pliable substance that feels like, well, leather, but is made from mycelium (the root system of fungi). It grows quickly on sawdust and doesn't require high heat or intense light, making it a promising alternative to bovine leather, which contributes to deforestation and GHG emissions, as well as faux leather made from PVC, a petroleum product.

5. Foam alternatives

Petroleum (which is more or less a euphemism for crude oil) has a tendency to turn up where you least expect it. Foam is among the products that make ample use of this fossil fuel. Used in car seats, furniture, insulation, shoe soles and countless other products, polyurethane foam is anything but sustainable. Toronto's Evoco eschews that option, using agricultural by-products and cellulose to make its eco foam, which is being used by such footwear companies as Timberland, Vans and Keen. The company, which recently raised $12 million in funding, plans to expand into leather, 3-D printing and other solutions and expand into cushioning and upholstery.

"I would like to see a future where we move away from petrochemical materials. There are so many plant-based materials that can be used to stop the waste that's produced and also address the fundamental issues of the materials that we are currently using. I'm hoping that we get to a net zero by 2030 or 2040 by using a lot of these new materials."

Natalie Ashdown
Co-founder and COO, Evoco

Rich deposits: Developing novel technologies to help reach net zero

Finding methods that are lighter on the Earth.

The big picture: Getting more with less impact

Globally, mining accounts for between 4 and 7 percent of GHG emissions. According to MiningWatch Canada, this sector also generates 30 times more solid waste per year than is generated by people, municipalities and other industries combined. Mining is energy intensive and requires stable and substantial amounts of electricity; even just the ball mills used to crush and grind ore consume almost 1.8 percent of the world's electricity. Put another way, mining must make big moves toward renewable energy and electrification to have any hope of meeting decarbonization goals.

While the challenges are significant, there is nevertheless a clear way forward. An array of clean technologies rely on critical minerals. With the expansion of electricity networks, it's estimated that copper demand will nearly double to 50 million tonnes by 2035, while demand for lithium, cobalt, rare earth elements, nickel and graphite will increase 20- to 40-fold over the next two decades. The energy transition that these technologies enable should, in turn, radically transform mining — provided the sector gets on board.

Critical minerals, such as copper, lithium, nickel cobalt, graphite and rare earth elements, are used in a wide array of clean technologies — including EV batteries, wind turbines, solar panels and energy-storage devices. Figuring out how the mining industry can extract them sustainably and manage waste in innovative ways is also a key part of reaching net zero. Over the next decade, according to the World Economic Forum, smart mining technologies may generate more than U.S.$425 billion of value for society, the industry and the environment in the form of reduced carbon dioxide emissions.

Significant Developments

The Canadian mining sector consists of 9,518 companies. In 2023, 305 VC, private equity and M&A deals were made worth $36.42 billion.
The largest deals include:

- Teck Resources was spun out of Teck Metals. The transaction was worth $4.89 billion
- Yamana Gold was acquired by Agnico Eagle Mines and Pan American Silver for $4.8 billion
- Total E&P Canada was acquired by Suncor Energy for $4.52 billion
- The Point Rousse Project of Signal Gold was acquired by Maritime Resources for $3 billion
- In Canada, the Mining Innovation Commercialization Accelerator (MICA) has assembled a $40-million investment fund to support sustainable-mining startups. Elsewhere in the Canadian mining space, B.C.-based Teck Resources is part of an industry-academic consortium that is investigating novel approaches to tailings treatment, such as the use of genetically engineered microbes that can break down toxins. Other companies are exploring metallurgical techniques for stabilizing tailings for re-use as construction materials.

- Summit Nanotech is working toward the development of a commercial-scale module that will cost about $40 million. Following on the heels of a U.S.$14 million Series A last fall, in January the company completed a U.S.$50 million Series A2 round led by Evok Innovations and the BDC Capital climate tech fund. (Hall expects to go back to capital markets next year for a Series B worth about $150 to $200 million.)

In addition, over the past few years, the Canadian government has made several major announcements to help bolster the supply chain for electric vehicles.

- Last December, the federal government released its strategy for critical minerals, earmarking $79.2 million in geoscience and exploration and offering a 30 percent tax rebate for companies exploring critical minerals.
- It is contributing $5 million to help establish the facility to process rare earth minerals in Saskatoon.
- Through the Strategic Innovation Fund, it's planning to invest up to $222 million to help Rio Tinto Fer et Titane increase its production of critical minerals.

Here are three trends to watch.

1. Sustainable extraction

Well over 90 percent of the material removed in the process of extracting the world's most sought-after minerals ends up as waste — much of which can be toxic or carbon-heavy.

Calgary's Summit Nanotech has developed a new approach for sourcing lithium, a key material for EVs that is mined using substantial amounts of water. The company's proprietary nanomaterial can be used to build large-scale filters that require less water and that absorb the mineral in the brine pumped out of lithium reserves, eliminating the possibility of an environmentally harmful residue. Also in Calgary, Litus is working on extracting lithium directly from aqueous sources (salt lake brine, underground brine, seawater) using nanotechnology, making the process faster, more efficient and greener. Novamera, in Oakville, Ont., focuses on precision drilling small-scale and narrow vein mineral deposits using conventional equipment in conjunction with data-driven hardware and software. The company's goal: a minimally invasive method that is significantly less wasteful than traditional open-pit and underground mining.

2. Capturing carbon in mining waste

The circular economy is vital in reaching net zero — and it's also profitable: the World Economic Forum has estimated that this sector will be worth U.S.$4.5 trillion by 2030. Companies are developing technologies that use waste materials such as construction debris, end-of-life textiles and, yes, mine tailings. Innovators are also developing circular-economy processes for everything from bioplastics to clean energy.

As part of its ocean alkalinization/carbon-capture approach, Halifax-based Planetary Technologies has developed processes that convert mining waste into marketable minerals, hydrogen and an alkaline substance that can be infused into the ocean to sequester carbon through basic chemical reactions. (See more on page 40). Vancouver's Arca, meanwhile, has chosen land over sea, trapping excess atmospheric carbon dioxide inside rocks. The company uses ultramafic mine tailings, a by-product of critical metal mining, which is rich in magnesium and naturally reacts with carbon dioxide, allowing the substance to be captured and stored.

3. Automation and digitization

Automation, digitization and software solutions are helping the mining industry decarbonize, whether through data collection for more efficient extraction or automation to reduce energy consumption.

Symbioticware, based in Sudbury, Ont., has created a platform whereby IoT devices are installed on heavy-duty vehicles, such as the large trucks on mine sites, to gather information that can be processed by the company's software to provide insights and analytics on improved performance and energy-consumption variables, such as driver behaviour, tire pressure, tailpipe emissions and idling time. "Eight percent of the annual fuel consumption in the fleet goes toward idling," says CEO Ash Agarwal. "It's not insignificant. We help our operators identify those incidents so that they can take action and change those behaviours."

Meanwhile, RockMass Technologies allows geologists to develop a much more accurate assessment of the extent and yield of a particular seam by using a device that generates a 3D model to provide precise data about the body of ore — which decision-makers can draw on to make real-time decisions. "Right now, it's a handheld device that a user takes underground," explains CEO Shelby Yee. "But in the future, that's going to be completely remotely operated."

Mining's next frontier

NASA is exploring the makeup of several promisingly metal-rich asteroids (the first mission launched in October 2023) and the potential financial boon is attracting private enterprise. Though the barriers to extracting nickel and iron from an asteroid are high — Earth's tenacious gravity; a commute of hundreds of million kilometres — mining in space is an inevitable step in establishing a human presence on the moon and beyond, according to Canadian Space Mining Corporations CEO Daniel Sax, "If we solve these big problems in space, we'll derive a lot of solutions for life on Earth." Indeed, this new frontier holds great allure: in November, Next Generation Manufacturing Canada (NGen) unveiled Moonshot 4 Mining, Minerals and Manufacturing, a $5.5-million project (backed by the Canadian Space Agency) to explore lunar extraction opportunities.

"Mining has to change how it does business. And to do that, novel technologies need to be tried out."

Charles Nyabeze
Vice President Business Development
Centre of Excellence in Mining Innovation

Feeding the planet: The need to eat smarter

Novel solutions are cropping up throughout the food chain

The big picture: Food's outsized footprint

It's enough to turn your stomach. We need to eat in order to survive, but what we eat — or more accurately, the foods we choose and the way that food is produced — is endangering the long-term survival of our species. To put it bluntly: Our food system is a major contributor to climate change. According to the IPCC's 2020 Special Report on Climate Change and Land, 23 percent of greenhouse gas emissions per year come from agriculture, forestry and related industries. Cows, pigs, chickens and other farmed creatures take a particularly heavy toll on the environment — livestock is the world's biggest source of methane released by human activities.

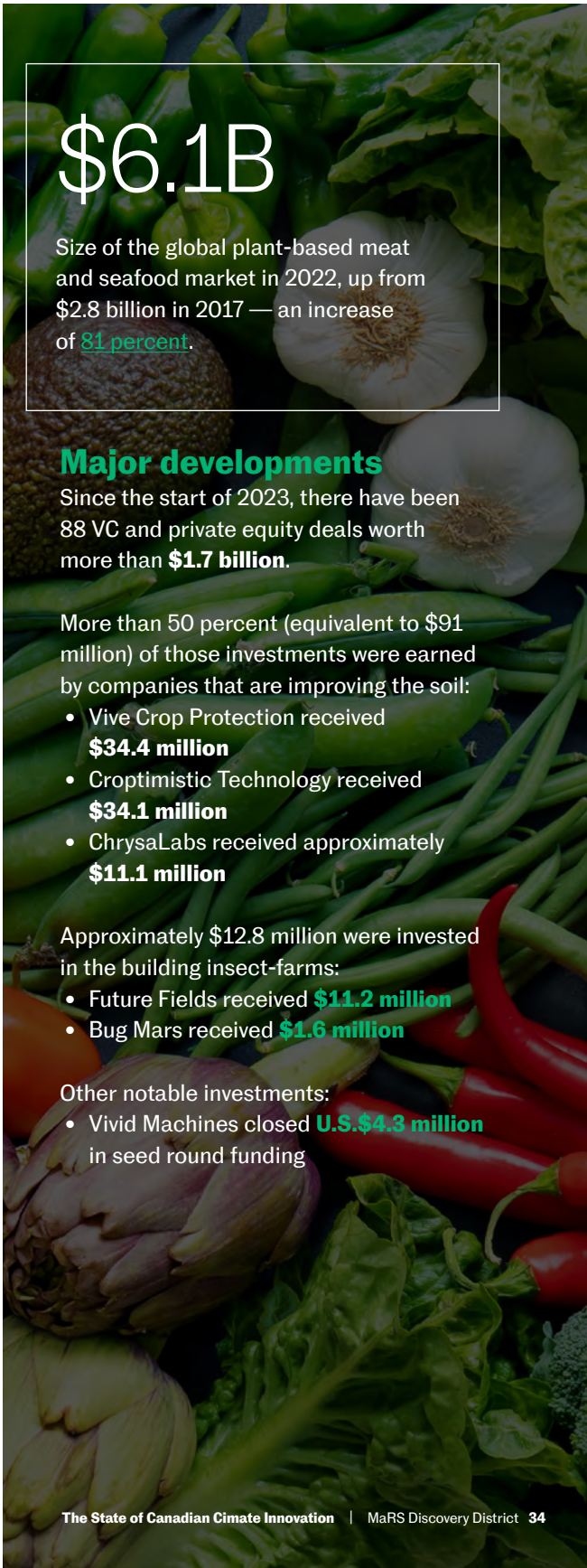
The temperature increases generated by the GHG from the food industry have serious repercussions: a jump of even 1.5 degrees Celsius would put more pressure on arable land, which will need to provide up to 77 percent more food per acre within the next three decades. Plus, half of all habitable land is already used for agriculture, and further deforestation would only exacerbate environmental stressors. Factor in rapid population growth — the planet will be home to 9.7 billion people by 2050 — and it's clear that the status quo is not a viable option.

"When we come up against these existential problems, technical solutions can happen," says Phil De Luna, chief carbon scientist at Deep Sky. "Can we feed 10 billion people? Yes. But I think it's going to require some sacrifice or massive technological advancement."

The development of new technologies is a crucial factor in both mitigating the planetary impact of agriculture and bolstering food security around the world. Although the farming sector can be characteristically conservative when it comes to the prospective costs (both labour and financial) of investing in new modes of production, there is considerable potential for growth. Experts anticipate up to 123,000 job vacancies in agriculture by 2029, with an urgent need for workers who have experience in tech-related areas (such as drones, AI, and automation).

The industry is on the brink of a major shift in terms of labour and leadership. "We're very interested in creating a resilient food system," says Mary Dimou, a Toronto-based entrepreneur and biochemist who co-launched Nàdarra Ventures, a $20-million fund focusing on sustainable agtech, earlier this year.

"We're extremely excited about technology that helps reduce and repurpose food waste, but anything that can drive food safety and security is a priority. When we think about social and environmental sustainability, the potential for improvement is huge."



$6.1B

Size of the global plant-based meat and seafood market in 2022, up from $2.8 billion in 2017 — an increase of 81 percent.

Major developments

Since the start of 2023, there have been 88 VC and private equity deals worth more than **$1.7 billion**.

More than 50 percent (equivalent to $91 million) of those investments were earned by companies that are improving the soil:

- Vive Crop Protection received **$34.4 million**
- Croptimistic Technology received **$34.1 million**
- ChrysaLabs received approximately **$11.1 million**

Approximately $12.8 million were invested in the building insect-farms:

- Future Fields received **$11.2 million**
- Bug Mars received **$1.6 million**

Other notable investments:

- Vivid Machines closed **U.S.$4.3 million** in seed round funding

Under the umbrella of agtech innovation, three key areas stand out.

1. Optimizing how we grow

Since the advent of agriculture, humans have been finessing the means and the methods of how food is grown. Major innovations (the emergence of tractors in the early 19th century, the advent of milking machines in the1890s and the more recent arrival of robotic milking systems) have had marked effects on the productivity of farms. The latest revolutionary tools involve harnessing the power of computers to enhance the precision and sustainability of cultivation.

For instance, Toronto-based Ukko Agro's AI-equipped sensors can collect and analyze data that allows farmers to tailor everything from irrigation to pest control based on what their crops need. At Area X.O, an R&D facility near Ottawa, innovators are exploring agricultural applications of everything from drones to self-driving vehicles to a state-of-the-art weather tracking system. Preliminary results from a pilot collaboration between Area X.O and researchers at the Ottawa Smart Farm suggest that using sensor-equipped tractors as part of a targeted cultivation strategy can reduce greenhouse gas emissions while also increasing crop yields by up to 30 percent. As climate change alters growing conditions, collecting and analyzing data will be crucial in helping growers predict and plan. That added information can also identify the areas of a field that might require additional moisture and nutrients — to make the most of every acre.

Smart growth

Startups and scale-ups in this space are working to optimize yields.

Targeted support

Vive Crop Protection has developed pesticides and fungicides using a nanoscale system that helps cut down on water required. In spring 2023, Health Canada approved the sale of one of its fungicides to help potato farmers combat soil-borne diseases.

Added insights

Nectar's AI remote monitoring platform helps commercial beekeepers to keep tabs on the health of their hives, while reducing operational expenses. Similarly, Wittaya's software platform collects data and provides recommendations, but for a different kind of food producer: aquaculture operators. With insights on feeding and growth, aquaculture farmers are able to reduce food costs and waste by up to 10 percent.

Local production

Nearly one-fifth of carbon emissions in the food system come from transportation. To help communities grow produce year-round, Ottawa startup Growcer fabricates hydroponic farms in custom-built containers. And to boost production at vertical farms and greenhouses, Sollum Technologies has developed smart LED lighting solutions that recreates the full spectrum of the sun's rays.

2. Changing what we eat

It takes some 15,000 litres of water and 25 kilograms of feed to produce one kilogram of meat. Given the need to maximize land productivity and make the most of available resources, finding alternatives to animal protein is key. Companies such as Bug Mars and Entomo have focused efforts low on the food chain, cultivating insects to be consumed by both humans and animals.

Other disruptors have honed in on even tinier targets, eschewing fields for labs and drawing on genomics and biochemistry to develop additives that can enhance the flavour and composition of plant-based options, or perfecting cruelty-free meat that can be grown from single cells. Last year, Kitchener-Waterloo-based Evolved Meats raised $2 million in seed funding from investors (including Maple Leaf Foods) who were intrigued by the company's strides in producing cultivated meat products. This year, German bioengineering firm The Cultivated B opened a 130,000-square-foot facility in Burlington, Ont. In partnership with Ontario Genomics and Genome Canada, the company's $50-million investment will help scale up production. Meanwhile, Protein Industries Canada is looking to harness the potential of AI for plant-based innovation — the organization recently issued a $10-million call for projects. Indeed, cellular agriculture holds tremendous potential for the Canadian economy: One recent report suggested that by 2030, the sector could be worth as much as $7.5 billion per year and could employ as many as 86,000 people.

The rise of alternatives

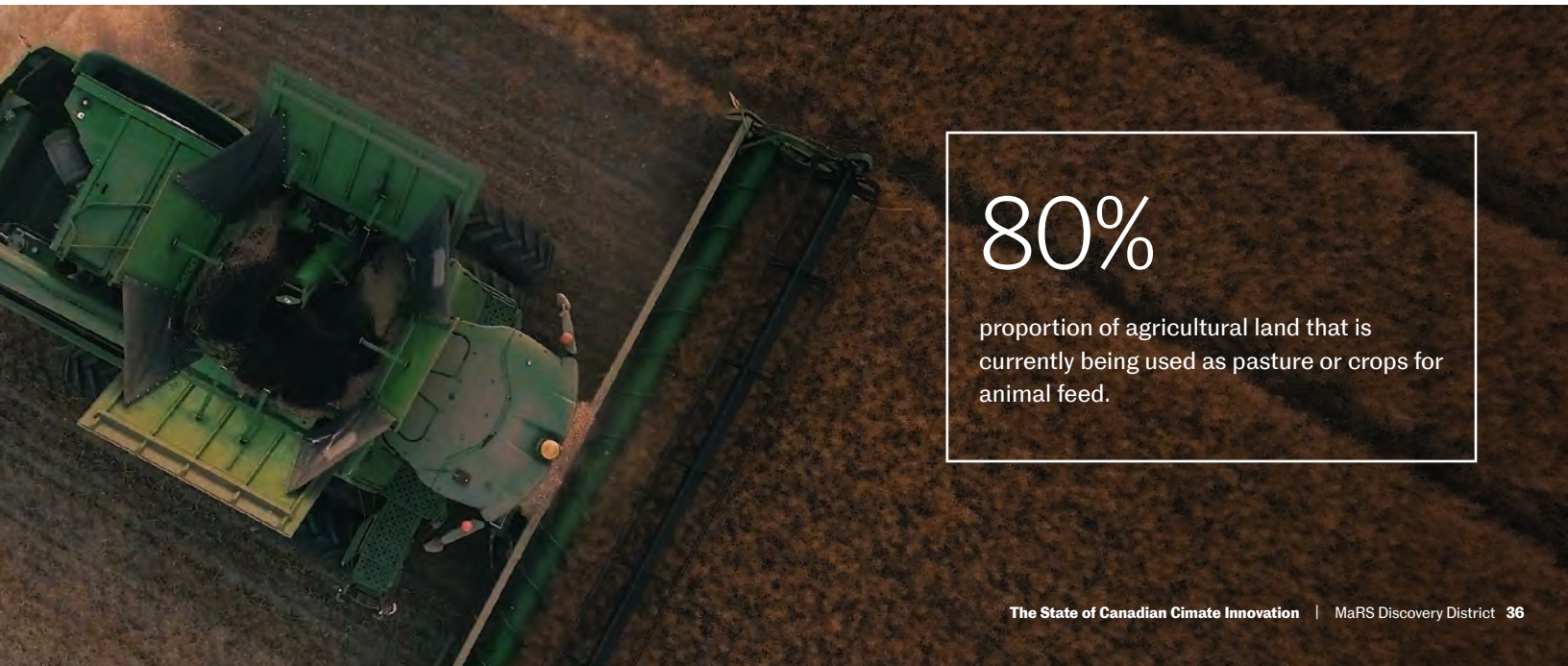
Innovators are ushering in a revolution in how we produce our food.

In vitro vittles

Startups are working on producing ingredients far removed from a barn. Early-stage startup Opalia creates its dairy in a bioreactor using genetically engineered bovine mammary cells. And Genuine Taste is growing cultivated fat from stem cells.

Plant power

Precision fermentation — a method that has been used for centuries to produce beer — is gaining interest as a way to create plant-based protein. For instance, Liven Proteins upcycles byproducts of food manufacturing. It uses pea starch, which typically ends up in landfills or is used in animal feed, to create animal-free collagen to improve the nutritional value and texture of plant-based products. And New School Foods has developed plant-based fish fillets that are high in protein and Omega 3s.



80%

proportion of agricultural land that is currently being used as pasture or crops for animal feed.

3. Doing more with less

Any discussion about sustainable agtech needs to be anchored in a solid understanding of waste, access and equitable distribution. In Canada, we waste close to 60 percent of all food produced each year. That's the equivalent of 11.2 million metric tonnes, or about $49.5 billion.

By putting energy into innovative strategies for preserving food, cultivating ingredients in unconventional environments and streamlining channels of distribution, more people can effectively be fed using fewer resources. Grimsby, Ontario-based Bluicity, for instance, deploys sensors to track the status of food throughout the supply chain, using algorithms to help optimize freshness based on environmental factors.

Treasure from trash

Other startups are focusing on making the most of food waste that is unavoidable, transforming byproducts and scraps into valuable products. Toronto-based Genecis is turning organic waste into biodegradable plastic. With more than $20 million in funding raised, the company plans to launch a collection of consumer products — their aim is to make everything from kitchenware to clothing to sunglasses. Meanwhile, Aruna Health is repurposing food waste, creating fibres for its compostable menstrual pads. And food waste is a key input for ALT TEX's alternative to polyester.

"Food waste occurs from farm to fork. And that means a huge percentage of the food system is falling through the cracks. We're losing a third of the possible food. We have sustainability goals that we have to hit by 2030, and corporations and countries are accountable for trying to hit those goals. It comes down to these critical things like saving our planet, and saving our people."

Mary Dimou
General Partner, Nàdarra Ventures

Liquid assets: Protecting one of the world's most important resources

Innovators are scaling up technologies to help solve our microplastics issue, treat our wastewater more efficiently and use bodies of water to help tackle climate change.

The big picture: Water, water everywhere

Much like the air that we breathe, water is something that is easily taken for granted in this country: There's a seemingly endless, reliable, potable supply on tap. Indeed, Canada is a heavy hitter when it comes to H2O — the country boasts more kilometres of coastline (200,000) than any other, and is home to 7 percent of global freshwater stores. But that abundance hangs in a complex and precarious balance.

Within the past half-decade, contaminated drinking water has been an issue for one in 10 Canadian households. As of March 2023, 28 First Nations communities were still contending with long-term boil-water advisories. That such a resource-rich nation is grappling with issues around access underscores how precious water is, and illuminates the need for solutions to improve our supply.

Rising ocean temperatures, stressed ecosystems, more frequent droughts and flooding — water reflects the very real impact of global warming. And yet only 3 percent of the funds allocated for climate solutions are directed toward water. This lack of proactive investment can have significant financial repercussions. In fact, a recent report from multinational firm GHD estimates that floods, droughts and storms could cost Canada's economy U.S.$108 billion over the next 30 years, with mounting damage to power, manufacturing and transportation infrastructure. By tackling these issues as soon as possible, potential crises can be averted before they head downstream.

Indeed, innovators are developing technologies that create efficiencies in desalination and wastewater treatment, protect ecosystems and even utilize our waterways as a place to store additional carbon. Ocean carbon sequestration is drawing particular interest from hard-to-abate industries as a way of lowering emissions overall. Oceans are the planet's largest natural carbon sink — they currently absorb and store around a third of the global carbon emissions. "So they offer a significant opportunity to expedite our journey to net zero," notes Serena Nguyen, innovation lead at MaRS. "It's imperative to invest in ocean sequestration to provide the necessary time to address climate change holistically."

Major developments

This year, in Canada's wastewater sector there were 15 venture capital, private equity, and mergers and acquisition deals worth $403.31 million.

- The largest deal was the acquisition of H2O Innovation by Ember Infrastructure Management, Investissement Québec and Caisse de dépôt et placement du Québec for $395 million.
- ASLAN Technologies was acquired by Amiad Water systems for $4.39 million.
- Axine raised $1.7 million while Roshan Water Solutions raised $650,000.

And there have been a number of important announcements in the blue economy.

- ISED invested $950 million into the Ocean Supercluster.
- Dalhousie University received a $154-million investment to study the ocean's potential role in tackling climate change.
- The federal government invested more than $8.1 million to support the development of ocean technology and clean energy on Vancouver Island.

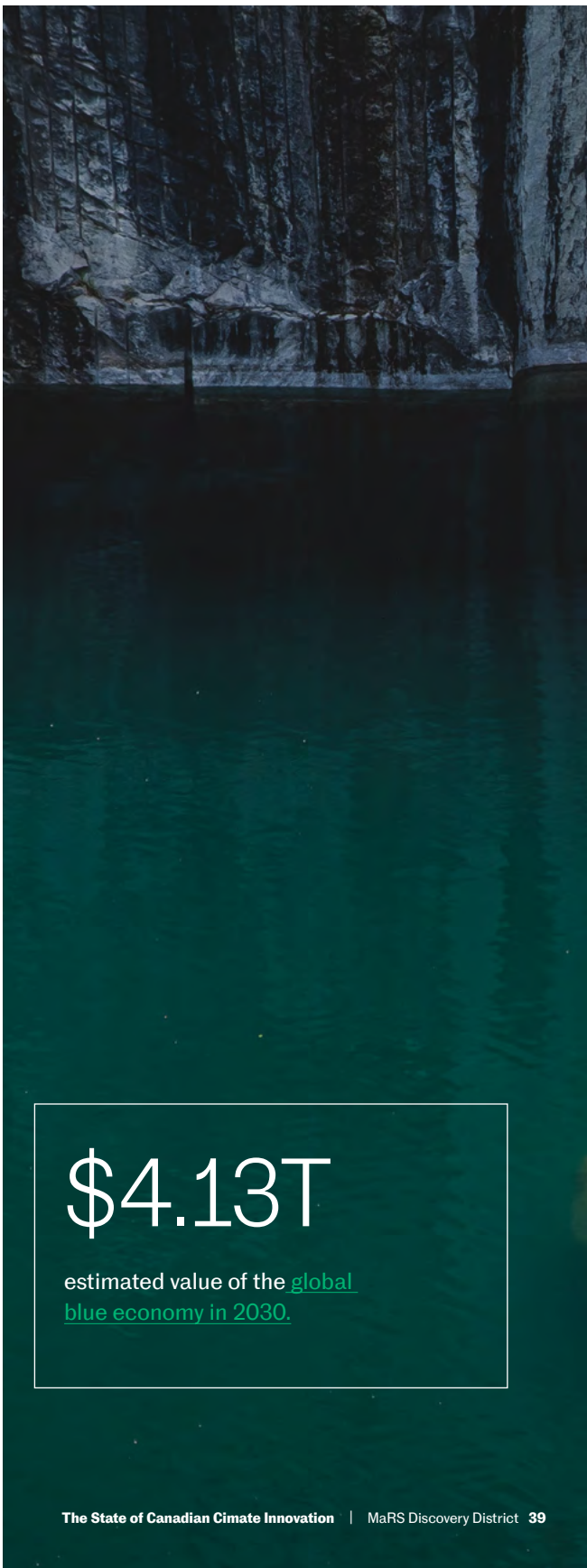
Within the realm of water tech, three areas stand out.

1. The blue wave

The blue economy aims to promote the sustainable use of ocean resources for economic growth while also preserving the health of the marine ecosystem. The value of marine ecosystem services is enormous, with an annual worldwide value of more than U.S.$1.5 trillion a year; in Canada alone, it's responsible for 1.6 percent of the GDP. The expansion of the blue economy has been fuelled by robust growth within a number of areas, including next-generation aquaculture; harnessing tidal energy; desalination; interventions to clean up both shorelines and bodies of water; and ocean-based carbon sequestration through the introduction of alkaline enhancements.

Technologies that augment the ocean's ability to absorb carbon is garnering interest from the business community. Meta's former CTO and a group of other business leaders have committed U.S.$50 million to research and develop carbon sequestration techniques. In October 2023, Montreal-based developer Deep Sky announced plans to partner with U.S. startup Equatic to test seawater-based carbon removal processes that also makes hydrogen at its Quebec facility. And this fall CarbonRun, which uses alkalinity to restore river ecosystems (see more in sidebar page 40), secured a U.S.$500,000 market commitment from Frontier Climate with such members as Shopify, Meta and Stripe.

When it comes to ocean cleanups, one of the largest issues is also one of the tiniest: microplastics are accumulating in waves and on our beaches, making up no small fraction of what experts estimate will be a staggering 150 million tons of plastic debris by 2025. While there's no such thing as good pollution, microplastics are particularly problematic — they're present in our drinking water, which means they can build up in our bodies; worse, they can have severely detrimental effects on marine organisms, which in turn poses major risks to the overall ecosystem. The good news is that a number of companies have come up with ways to tackle this big little problem. Quebec City–based Hoola One, for example, uses innovative vacuum technology to effectively sift through sand and collect microplastics from beaches so that they can be recycled. Meanwhile, Viridis Research is tackling the issue close to the source. Its electrochemical filters help remove microplastics and dyes from textile manufacturing and commercial washing machines, as well as in household washers and the homecare products market.



$4.13T

estimated value of the global blue economy in 2030.

According to the U.N., in 2020, 2.6 billion people worldwide didn't have access to safely-managed drinking water, and, by 2050, up to half the global urban population will experience water scarcity. Given these concerns — and the relative surplus of salt water on the planet — there is also significant interest in desalination, or solutions that can help convert the latter into the former. (Think of it as the Conundrum of the Ancient Mariner.) The market for such technologies is robust — current projections put it at U.S $47.9 billion by 2033 — but even so, desalination strategies can be cost-prohibitive, in part because of how much energy the process requires. But one company, Sherbrooke, Que.'s Oneka Technologies, one of the ocean ventures supported by Novarium, has developed a remarkable workaround. It harnesses the power of the waves and the sun to drive ocean-based devices that take the salt out of seawater. Each of the zero-emission units can serve up to 1,500 people per day.

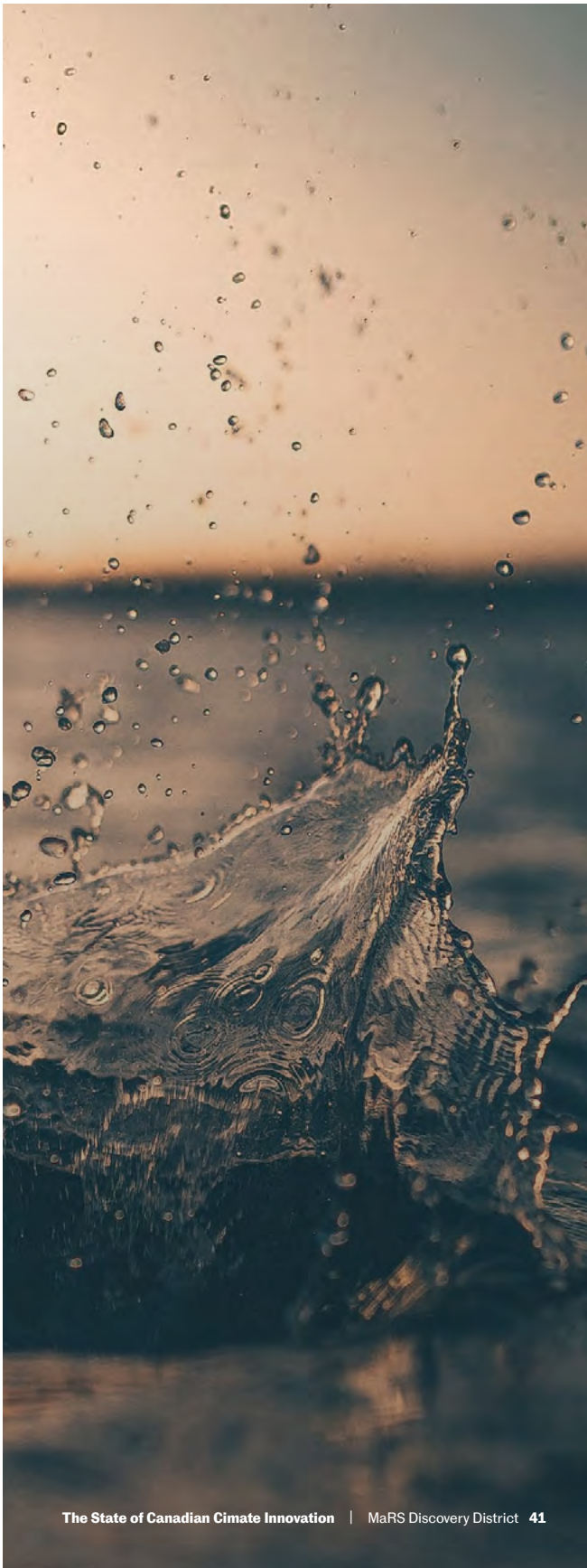
An antacid for our waterways

Two startups in Halifax are working to improve the health of our waterways and oceans, while also sequestering carbon — by using chemistry. When alkaline substances are added to water, it not only helps restore the pH balance, it also encourages the absorption of more carbon dioxide. "You get this double win," explains Will Burt, chief ocean scientist at Planetary Technologies. The company teamed up with researchers from Dalhousie University to study the effects of added alkalinity in the Halifax Harbour. Further upstream, CarbonRun is focusing its efforts on using alkalinity to restore river ecosystems. It found that by deacidifying rivers, the number of fish that were able to reproduce tripled.

2. A digital ocean

Oceans generate 50 percent of the world's oxygen, absorb nearly a third of our CO2 emissions and buffer a staggering 90 percent of greenhouse effect–generated heat — and yet there is so much about these regions that remains unknown: more than three-quarters of all oceans worldwide have yet to be explored and/or documented in map form. New strides in the size and mechanics of observation technologies — miniaturization and automation chief among them — have helped catalyze advancements in this field.

Digital sensors and trackers hold tremendous potential to aid navigation, shed light on marine life and demystify the shadowy depths of the oceans themselves. Quebec's Whale Seeker, for one, draws on both AI and satellites to provide insights into the movements and activities of whales — information that can aid marine biologists and also head off potential collisions with shipping vessels. And the autonomous robot boats developed by B.C.–based startup Open Ocean Robotics can measure water turbidity, depth, wave height, temperature and oxygen levels. The vessels, which can be deployed for up to six months at a time, are also able to identify marine mammals as they map and monitor stretches of water.



3. Waste watch

Most of us would prefer not to think about what we flush down the toilet and wash down the drain. But unfortunately, we have little time to waste in this realm. A disconcerting 80 percent of all wastewater worldwide is sent back into our rivers, lakes, oceans and streams — and ultimately into our bodies — without ever being treated. And even when it is cleaned up, that runoff winds up causing further harm to the planet — wastewater treatment generates 5 percent of GHG emissions.

There are major incentives to put time, money and effort into this area: chemicals that can affect our endocrine systems, the residue from prescription medications, detritus from heavy manufacturing — all these contaminants wind up in our waterways, says Patrick Kiely, the founder of Sentry Water Tech. Kiely's firm, which is based in PEI, develops nuanced systems that allow municipalities and industry partners to monitor the quality and composition of a host of water systems, from drinking water reservoirs to treatment plants.

Treatment options

MaRS supports a number of ventures working on water treatment. Vancouver-based Axine Water Technologies tackles toxic organic pollutants in manufacturing wastewater for clients in the pharmaceutical and chemical industries. Swirtex has developed a filtration system that separates contaminants from clean water using an innovative application of buoyancy. Meanwhile, Aclarus uses ozone in its treatment systems. And Pani, which uses AI to optimize desalination and treatment plants, was one of 12 Canadian ventures named to the global Cleantech 100 this year.

"Canada is uniquely positioned to lead and catalyze significant momentum in blue economy innovation. This enables us to adopt a holistic approach, considering the interconnectedness of land- and ocean-based solutions to drive comprehensive climate solutions."

Serena Nguyen
Innovation Services Lead, MaRS

CONCLUSION

What's next

To reach net zero, we need to move quickly.

Grappling with climate change can seem like an abstract — and daunting — concept. On a granular level, however, sustainable adaptation is embedded in most aspects of everyday life: how we construct buildings; how we power our homes and businesses; how we get around in the world; what we eat, wear and grow. Small changes and intentional decisions are part of the puzzle to protect the future of our planet. But the meaningful shifts that are necessary to get us back on track to meet targets around emissions, global warming and other environmental goals require big-picture investments, in the areas of both policy and finance.

What does this mean? Strategic commitments are key, now more than ever. A recent report from the Federation of Municipalities pegged the costs of necessary climate adaptations at $5.3 billion annually, split between federal, provincial and municipal governments. While this is a significant financial outlay, failing to bolster infrastructure and implement sustainable practices will result in far more severe economic consequences.

Funding models exist to spur development: In the 2022 budget, the federal government announced $28 billion in incentives for climate action and clean growth — a 65 percent increase over the previous year's plan. National Resources Canada recently issued a call — open to non-profit organizations — for adaptation proposals, where successful candidates can receive up to 60 percent in funding for projects with budgets over $150,000. And although Canada already punches above its weight when it comes to R&D and innovation, to reach net zero by 2050, we need to ensure that new technologies can be commercially scaled and widely adopted.

What is crucial now is to accelerate that process — through targeted investment, strategic partnerships and a commitment to collaboration. Close to half of the emission reduction required to reach net zero comes from climate tech that is currently in the demonstration or prototype stage. To move climate solutions from the lab to mainstream implementation as quickly as possible, development times must shrink dramatically.

Tackling the climate crisis isn't easy — and it won't happen overnight — but by joining forces, it is possible to change course and envision a brighter, cleaner future.

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