On the cleantech frontier:

HOW AI IS IMPACTING INNOVATION

EDC Economics
Prerna Sharma

Canada

EDC
TAKE ON THE WORLD

Contents

Executive summary

The integration of artificial intelligence (AI) in the clean technology (cleantech) industry has the potential to change the way we create, distribute and consume energy. From emissions reductions and grid optimization to scientific discovery and climate modelling, AI's use case in cleantech is abundantly diverse.

As a result, innovations and investments into AI-enabled cleantech and deep technology (deep tech) have been growing at breakneck pace (totalling US$28.5 billion between 2018 and 2023). But, AI's use in cleantech has environmental implications, including the high energy and water demands of AI data centres. This pushes the pace at which we would need to build out clean energy infrastructure and clean electricity sources that are required to fuel the AI boom.

While not AI-enabled cleantech, there are other novel technologies that hold much promise. We focus on three here:

- Carbon capture, utilization and storage (CCUS)
- Hydrogen and other alternative fuels
- Energy storage with a focus on long-duration energy storage (LDES).

Many of these technologies are critical for global decarbonization and energy transition efforts. In Canada, we find significant opportunities and competitive advantages for these technologies. We also highlight the potential for small modular reactors to rapidly scale nuclear energy and use cases for AI in the sector.

Given the urgency to decarbonize and to meet global net zero commitments, cleantech venture investments have surged since 2020. But a slowing economy, high interest rates and a looming recession resulted in a drop in global cleantech investments in 2023 (US$41 billion). Canadian venture capital (VC) investment remained resilient, noting no changes since 2022, settling at $1.2 billion in 2023.

The environmental and clean technologies (ECT) sector also remains an important contributor to Canadian gross domestic product (GDP) and exports. In 2022, the sector contributed $80 billion or 3.5% to Canadian gross domestic product (GDP) and Canadian ECT exports amounted to $20.9 billion (2.2% of exports). While progress is being made, on average, exports have grown at a compound annual growth rate of 0.6% in the last decade. There was also a significant rise in Canadian clean electricity exports in 2022, which speaks to the rising prominence of clean energy in Canada's export mix.

As the drive towards decarbonization pushes countries to convert early cleantech innovation into competitive advantages, in this report, Prerna Sharma, Export Development Canada's (EDC) senior economist, explores how AI is ushering in a new era for cleantech. For AI-enabled cleantech, the more fundamental the problem AI helps solve, the more exportable products or services might be. Like all innovative technologies, a combination of factors will determine success—favourable policies, private sector investment support, skilled workforce and dynamic startup ecosystem will all help fuel growth. For the other novel technologies, research and development (R&D), critical funding and commercialization, will help the development of markets and export opportunities. The synergy between AI and cleantech, if implemented at scale, has tremendous potential to accelerate net zero and decarbonization efforts—both domestically and globally—and Canada is well-positioned to be a leader in this space.

Since 2012, EDC has supported nearly $41 billion in cleantech exports and is a leading financier of Canada's cleantech industry. We provide support for businesses across all subsectors, including renewable power generation, biofuels, energy efficiency and green buildings. We have helped Canadian cleantech companies of all sizes achieve success on the global stage.

"EDC is proud to support the cleantech sector in Canada. With a dedicated focus since 2012, our financing, risk mitigation, knowledge, and connections programming have supported hundreds of cleantech companies on their growth journeys and net zero goals," says Jeff Keats, EDC's national ecosystem cleantech lead.

In 2022, EDC set a goal of providing $10 billion in support for cleantech businesses by 2025. As of Dec. 31, 2023, we exceeded our target by providing more than $12 billion in financing and insurance solutions to more than 440 cleantech businesses—up from $8.8 billion and 392 companies in 2022.

"For the past seven years, we've hosted our annual Cleantech Export Summit. I hope you can attend this year's hybrid event entitled, Towards net zero: Global opportunities for Canadian cleantech, on Oct. 29. Our team looks forward to uniting innovators and adopters from the cleantech ecosystem, discussing sector trends, creating opportunities to connect companies with investors and financiers and—most importantly—come together unified by a shared goal towards net zero carbon emissions," Keats says.

Introduction

Close to 10,000 satellites currently peer down at us from the sky. On Earth, sensor technologies track the movements of water as it permeates our planet's soils and ecosystems.

This new generation of technologies is backed by millions of algorithms feeding into sophisticated, large language models (LLMs) running climate simulations, driving efficiency and discovering new materials. These new data technologies and physical models present uncharted territories, begging the question: How can we use artificial intelligence (AI) to address the needs of our planet?

By some estimates, AI-enabled cleantech could help mitigate up to 10% of global greenhouse gas (GHG) emissions by 2030.[1] And in the realm of climate change, AI has a vast range of applications. Many differ from the more popularly known use cases stemming from generative AI[2], though some of the applications can have elements of generative AI in them.

Currently, cleantech innovators are integrating AI capabilities across various facets of their operations. This has led to innovations and efficiencies in how we address emission reductions, grid usage, land management, water security and decarbonization. By understanding complex systems that drive climate-related outcomes through the amalgamation and processing of massive data sets, AI can reveal patterns that can accelerate the pace at which we decarbonize. It can also enable operational optimization, monitor progress towards net zero goals and enhance the discovery of materials.

This is, by no means, trivial. Studies suggest that using AI in addressing climate problems could help reduce 2.6 to 5.3 gigatonnes (Gt) of GHG emissions and could provide between US$1 trillion and US$3 trillion in value additions toward corporate sustainability by 2030.[3]

But AI does have an energy problem. It can help address carbon emissions, but to do so, it must leverage current carbon-intensive infrastructure. Data centres such as those used to supply cloud computing have in the past decade accounted for 1%–2% of global energy demand. Generative AI, specifically, changes the scale of the energy required to meet their uses. Training a single model, for example, uses more electricity than 120 U.S. homes consume in an entire year or emit as many emissions as 110 U.S. cars emit in an entire year.[4]

1 Accelerating Climate Action with AI, Dannouni et al (2023), Boston Consulting Group: bcg-accelerating-climate-action-with-ai-nov-2023-rev.pdf

2 The main difference between traditional AI and generative AI lies in their capabilities and application. Traditional AI systems are primarily used to analyze data and make predictions, while generative AI goes a step further by creating new data similar to the data it was trained on.

3 Reduce Carbon and Costs with the Power of AI | BCG

4 Why AI and energy are the new power couple – Analysis - IEA

Foundational LLMs are expected to put more strain on energy grids. A simple search on an AI chatbot with natural language processing (NLP) is set to consume 10 times the electricity consumption of a simple Google search. The International Energy Agency (IEA) predicts that by 2026, data centres alone could use twice as much energy as they consumed two years ago—the size of the electricity consumption of a country the size of Japan.[5] In fact, data centres are expected to account for one-third of all new electricity demand in America[6] over the next two years. Coupled with the rise of electric vehicles (EVs), utility companies don't currently have the capabilities to build new renewable capacity as quickly as the market demands.

The current macroeconomic environment and high interest rates further add to the upward pressure on the price of wind and solar projects. Given all this, the shortage of renewable energy and current grid constraints means utilities aren't ready to deal with the scale at which electricity will need to be deployed to fuel the AI boom. But there's a silver lining in this: Could AI itself help solve some of these problems? Many are willing to place this bet. By monitoring, predicting and reducing emissions using AI algorithms, AI can help us decarbonize more effectively and efficiently. To this end, how far can "green intelligence" take us?

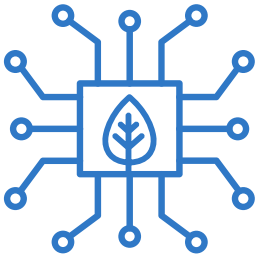
A suite of other products along the clean technology frontier is also offering novel solutions to fundamental climate problems, including the carbon-intensive energy consumption problems of AI. A key commitment towards net zero, including those made at the 2023 United Nations Climate Change Conference (COP28), is the agreement across countries to transition away from fossil fuels, triple renewable capacity and double energy efficiency by 2030.

While the transition to cleaner sources of energy is imperative, building out that infrastructure is going to take time. And while these commitments are crutial to meet climate goals as we look to 2050, other frontier technologies will be key to getting us there. While there are several solutions, we'll focus on three critical and promising ones:

- Carbon capture utilization and storage (CCUS)
- Hydrogen and other alternative fuels
- Energy storage with a focus on long-duration energy storage (LDES)

These technologies, in our view, have adaptations across a range of crucial economic sectors, especially those that have been traditionally hard to abate. While these technologies will be deployed in varying capacities in the decades to come, for now, their potential seems massive—from diversifying the economy and strengthening energy security to fostering innovation.

This report also offers insights into venture investment data for AI-enabled cleantech and the global and Canadian cleantech sectors. We provide an overview of cleantech and environment goods and services exports for Canada and an outlook for AI-enabled cleantech and other frontier technologies exports, focusing on opportunities for Canada.



Studies suggest that using AI in addressing climate problems could help reduce 2.6 to 5.3 gigatonnes (Gt) of GHG emissions and could provide between US$1 trillion and US$3 trillion in value additions toward corporate sustainability by 2030.

5 Electricity 2024: Analysis and forecast to 2026 (iea.blob.core.windows.net)

6 International Energy Agency (IEA), see more here: Data centres & networks—IEA

What is AI-enabled cleantech?

AI-enabled cleantech covers a suite of products and services that use elements of AI in their offerings. This includes core software applications (e.g., a large language model (LLM) that can learn from emissions data and offers grid optimization solutions), or the integration of AI software into hardware components (e.g., sensors, vision systems, robotics) that control full processes, or enhance a part or all of the technology.

AI-enabled cleantech solutions could range from upstream approaches such as those with large algorithm sophistication to cutting-edge solutions that capture new forms of data.

Regardless of the use, AI-enabled cleantech is expected to add value across the entire clean energy and technology supply chain, including:

- AI and large language models can deepen our understanding of climate data, leveraging it to fill gaps and forecast future trends.
- AI can optimize design for existing and new cleantech solutions, including hardware such as electrolyzers, small modular reactors, etc.
- AI can enhance performance by analyzing data in a time and cost-effective manner and help reduce time-to-market for technologies or products.
- AI can provide analytical insights to users further optimizing usage through real-time analytics.
- AI can be used for product and scientific discovery (e.g., cathodes, materials, catalysts) and development.
- AI can help regions, citizens and businesses forecast climate-related hazards and respond in real time to crises.

Table 1: AI technology & climate-related applications

AI technology	Climate-related example
Advanced analytics Using advanced mathematical techniques to develop insights from data.	**Energy use optimization** Optimizing a building's carbon footprint by changing heating, cooling and lighting using advanced analytics from sensors and weather forecasts.
Machine learning Training computers to make predictions from historical data.	**Predicting wildfires** Machine learning models can analyze satellite imagery and weather data and predict the likelihood of wildfires.
Deep learning A form of machine learning that uses artificial neural networks to generate insights from diverse data sets, including images, audio and text. These specialized models can recognize patterns and features within data.	**Predicting extreme weather events** Deep learning models capable of analyzing troves of historical and real-time meteorological and satellite data to predict hurricanes, tornadoes and typhoons.
Large language models Advanced AI models that are trained on troves of text data and can leverage sophisticated probabilistic-based models to generate human-like text as output for generative AI use cases.	**Cleantech innovation** LLMs are capable of accelerating innovation by conducting hyper-quick literature reviews of scientific papers and patent applications to identify knowledge gaps. This can have massive implications for new and novel clean technologies, bolstering the pace at which products or tech come to market. They can also help companies automate processes, troubleshoot hardware issues and enhance efficiency of manufacturing processes, reducing carbon footprints and promoting effective emissions mitigation.

Source: Boston Consulting Group (BCG), EDC Economics

Infographic 2: AI's value-add in clean technology subsectors.

AI value-add	Agriculture & food	Energy & power	Materials & chemicals	Resources & environment	Transportation & logistics
Resource allocation	Indoor farming	Grid management	Catalyst & materials discovery	Waste sorting	Management of energy assets
Discovery & demand prediction	Prediction of breeding	Predictive analytics & maintenance		Climate-risk modelling	EV-charging stations
Process efficiency	Applications of agro-chemicals	Battery production	Optimization of steel & iron	Wastewater operations	Route & transportation optimization
Data analysis & monitoring	Agriculture commodity grading	Market optimization	Optimization of chemical process	Carbon emissions tracking	Traffic management

Source: Cleantech Group, 2024, EDC Economics

Contrary to what some might believe, the value proposition of AI in cleantech is multi-dimensional. It goes beyond pure-play software (a computer-based product that focuses only on producing goods for a single industry and selling those products on the internet to customers in that sector) to include applications into hardware and the integration of AI solutions to capture new data and apply industry-specific solutions. AI's role in the cleantech market could very well be observable in every industry group.

Box 3: AI's use in climate-risk[7,8]

AI and climate scenario modelling enables climate risks to be identified, measured and priced. In some cases, the models might also be able to provide adaptation actions, which help companies and regions build resilience strategies. As the field of mandatory climate-risk disclosures and climate data-informed underwriting in insurance develops, conducting such scenarios might become regulatory requirements for certain companies and industries. Key AI-enabled climate deals in the climate-risk space in 2023 include:

ClimateAi — Raised US$22 million in a Series B round in 2023, expanding their footprint to India, Japan and other countries in the Global South, which are adversely impacted by climate risk. It's an enterprise-level, climate resilience technology platform.

PANO — Raised US$17 million in growth funding; it operates at the intersection of geospatial data analysis and AI-enabled wildfire intelligence.

LeapFrog Investments — Raised US$600 million for a new fund focused on climate adaptation in 2023.

Source: Cleantech Group 2024, EDC Economics

7 Climate-related disclosures are expected to be required across 40% of the global economy, including requirements in the U.S., Europe and Canada.

8 See more here: Additional insights on mandatory climate disclosures around the world, specifically in the U.S. (Final rule: The Enhancement and Standardization of Climate-Related Disclosures for Investors (sec.gov)), Europe (Corporate sustainability reporting - European Commission (europa.eu) & Canada (Office of the Superintendent of Financial Institutions (osfi-bsif.gc.ca) This includes investment in nuclear energy by key market players in the technology and AI space, see more here: Artificial Intelligence Is Fueling A 'Nuclear Renaissance,' Bill Gates and Jeff Bezos Are In On It. | Investor's Business Daily (investors.com) and AI's energy needs may boost a small modular reactor startup (axios.com)

AI & nuclear energy

The nuclear energy and power industry is specifically poised to benefit from AI in areas such as automation, design optimization, data analytics, prediction and insights extraction. Machine learning applications in the nuclear industry have existed for some time now, with operators leveraging machine learning algorithms for real-time monitoring and predictive maintenance. While the technology isn't at a stage of replacing human analysis, it can deliver fast, accurate results, enhancing precision, reducing costs and optimizing human oversight where necessary. More recently, AI applications in small modular and microreactors have gained significant momentum.

While existing nuclear reactors take multiple years to construct, they also rely on analog systems that limit how much AI can benefit their operation. Small modular reactors have digital gauges and sensors that allow for seamless AI integration for data collection and design and performance enhancement. This has led to much interest and enthusiasm in the venture capital (VC), corporate and government space with nuclear energy powered by small modular reactors as a possible provider of future energy requirements (including those of AI models).

Box 4: Nuclear energy and small modular reactors (SMRs) in Canada

Canada has an established and safe nuclear industry with more than six decades of engagement and exports of technology to other countries. Saskatchewan also has the largest high-grade uranium in the world. Canada was the world's second-largest producer and exporter of uranium in 2022. Today, five nuclear power plants, in three Canadian provinces, provide about 15% of Canada's electricity—totalling 84.6 million megawatts per hour (MWh). Currently, all nuclear power plants in Canada are CANDU (Canadian deuterium uranium) reactors, a highly safe and reliable reactor technology.

Nuclear power offers a clean source of energy that provides emission-free power generation. New innovations, including the advancement of new reactor designs, offer a new frontier in nuclear technology. One such application includes the small modular reactor, a tried-and-tested technology in Canada. SMRs are more adaptable versions of existing large-scale nuclear reactors. While currently not commercialized, SMRs are touted to accelerate nuclear project timelines, lower costs and bring nuclear energy to geographies with small grids. Canada is a world leader in SMR technology, with several announced projects close to demonstration stages. Once presented, Canada's SMR market could capture a crucial first-mover advantage at the global stage, representing a large potential export opportunity for Canada. AI technologies also offer great promise for applications in CANDU-style nuclear power plants, offering potential solutions to enhance safety, efficiency and reliability.

The energy-thirsty AI industry is expected to lift the nuclear and small modular reactor (SMR) space as needs for reliable and clean sources of power rise.[9] In fact, according to the Nuclear Energy Institute (NEI), nuclear plant operators in the U.S. are expecting to double their output over the next 30 years with the bulk of this energy coming from new small modular reactors.[10]

According to the Canadian Energy Regulator (CER), Canada could save 41 megatonnes of emissions, on average, annually between 2030 and 2050 through SMRs relative to unabated natural gas generation.[11]

9 This includes investment in nuclear energy by key market players in the technology and AI space, see more here: Artificial Intelligence Is Fueling A 'Nuclear Renaissance.' Bill Gates and Jeff Bezos Are In On It. | Investor's Business Daily (investors.com) and AI's energy needs may boost a small modular reactor startup (axios.com)

10 From the U.S. nuclear trade association, Nuclear industry hopes to expand output with new reactors | AP News

11 Canada's Energy Future, Canada Energy Regulator, 2023: cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/canada-energy-futures-2023.pdf

The global cleantech and AI-enabled cleantech market

World energy investment is projected to surpass US$3 trillion in 2024, with US$2 trillion allocated to clean energy technologies and infrastructure, according to International Energy Agency's *World Energy Investment 2024* report.[12]

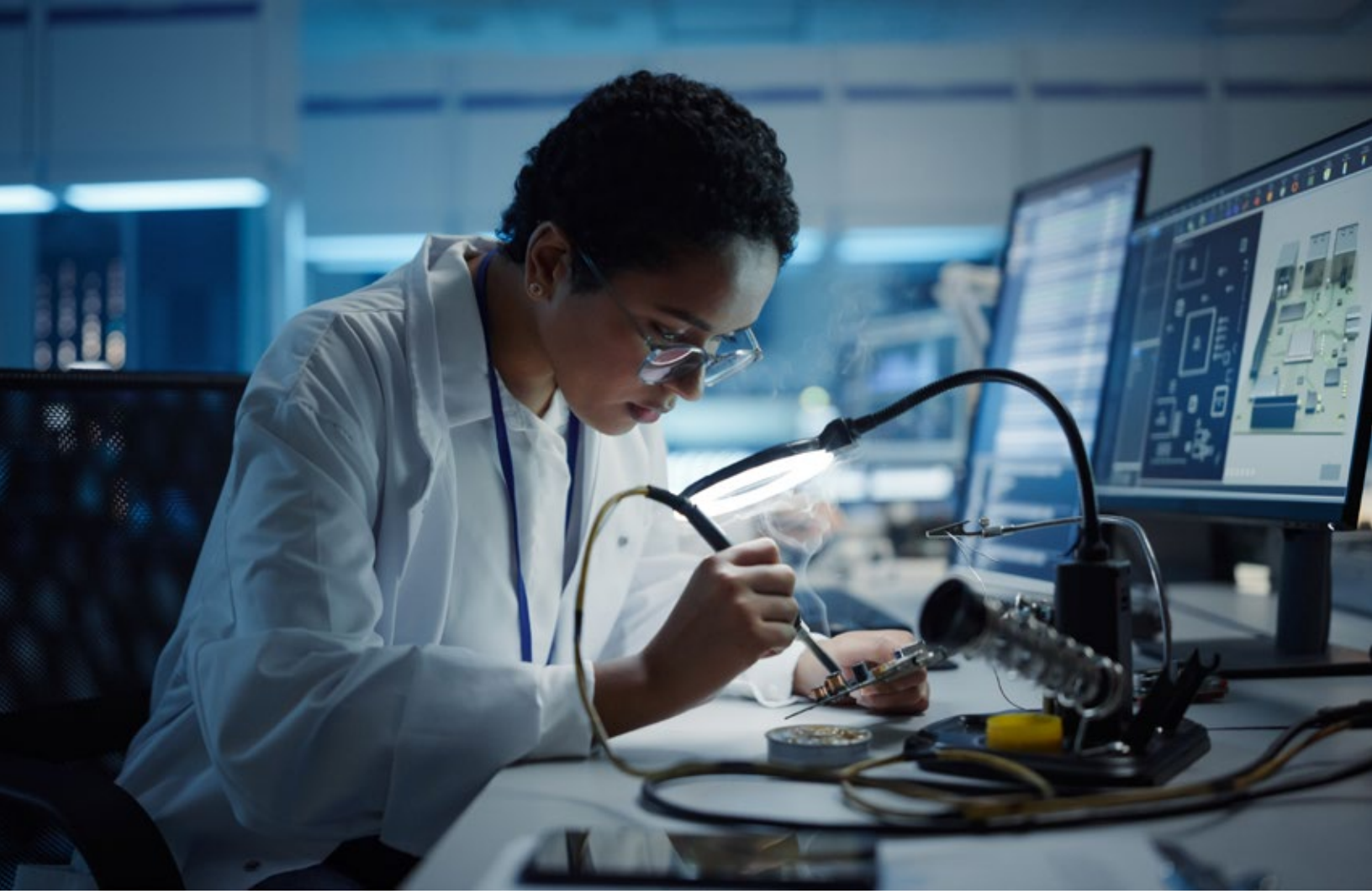
While clean energy investment has surged since 2020, a slowing economy, high interest rates and a looming recession resulted in a year-on-year (YOY) fall in global venture capital (VC) investment activity in 2023. Global cleantech attracted US$41 billion in venture investment in 2023,[13] a notable US$10 billion decline since 2022. (See Chart 4 and for a detailed look at sector highlights from global cleantech venture investment, see Appendix).

A crucial development in the cleantech sector in 2023 was the further growth of innovation and investments in the "deep tech" space—at the intersection of digital and physical technologies. Deep tech includes productivity improvements in core hardware elements in the new generation of sustainable products and clean technologies. Most of this has been spurred by the use of AI and machine learning across cleantech frontiers.

According to calculations by the Cleantech Group, 13% of all cleantech investments in 2023 were in deep tech products or services, including fuel cells, electrolyzers, battery materials (electrodes and electrolytes), lithium batteries, crop inputs and green cement and concrete. The introduction of AI in the tech development and deployment process has further blurred the dichotomy of pure-play software versus hardware, pushing innovations that are improving efficiencies and are taking hardware to the next level.

12 World Energy Investment 2024 (iea.blob.core.windows.net)

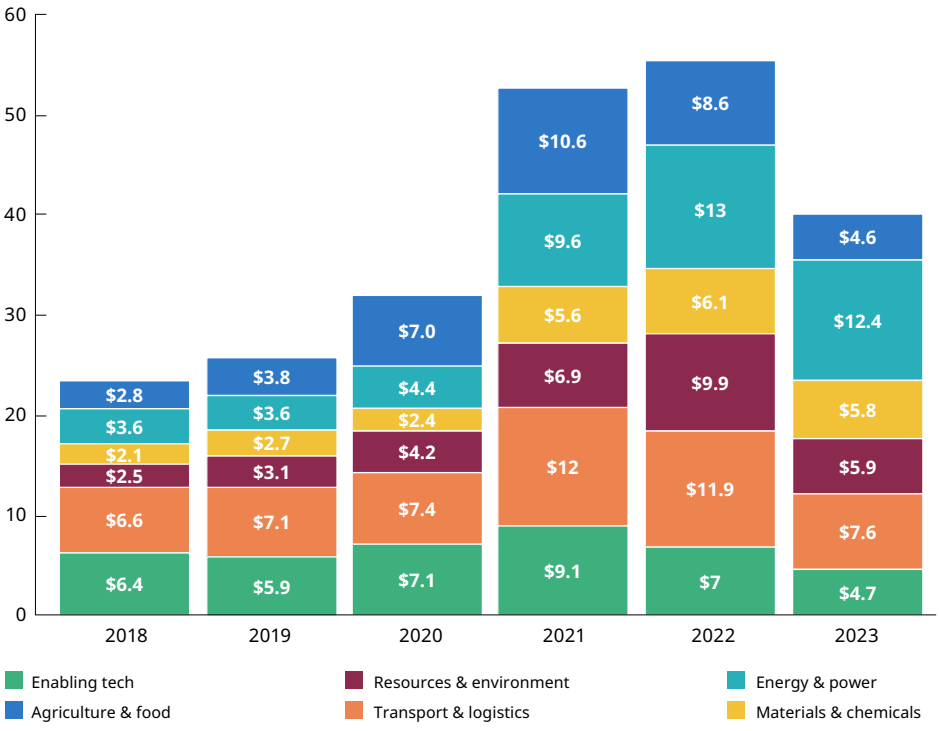
13 Cleantech Group 2024



These developments aren't just making manufacturing processes more efficient, or forecasting energy demand through computer models, but they're striving to push hardware innovation over the edge. These innovations are expected to transform building management systems, improve construction methods through automation and assembly, create and discover new materials and improve recycling and waste systems. The impacts and benefits of AI at the research and development (R&D) stages have the potential to be massive.

Innovators who integrate specialized AI in their businesses and processes are likely to end up on the better end of the curve as the intellectual property and proprietary nature of their hardware and software products become lucrative over time.

Chart 4: Total cleantech investment by sector (US$ billions), 2018-2023



Source: Cleantech Group, 2024, EDC Economics

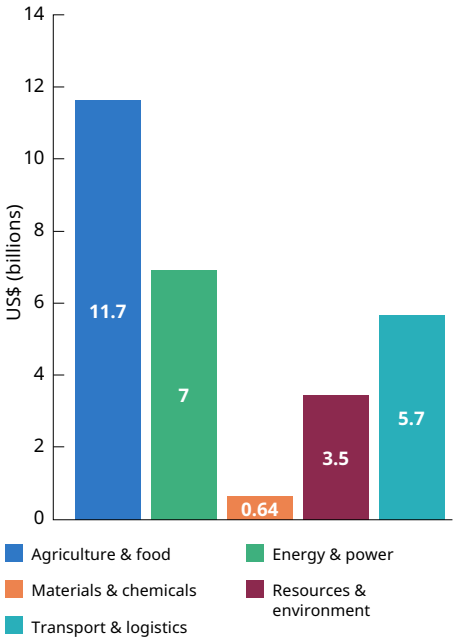
AI-enabled cleantech venture investment estimates

Investment in early-stage cleantech AI is on the rise despite a slowing global venture capital environment. According to the Cleantech Group, in the last five years (2018-2023), AI-enabled cleantech investment totalled US$28.5 billion[14] or 12% of total global cleantech investment. Notably, between 2018 and 2023, 10 deals were more than US$350 million for five companies in the growth equity and Series B stage. These deals aren't included in the total investment number, but they cumulatively raised US$86 billion in the last five years.

This US$28.5 billion invested in AI-enabled cleantech was spread across slightly less than 2,000 deals with a majority focused on growth equity. Between 2018 and 2023, seed and Series A funding grew 160%, which bodes well for new entrants and startups in the field. Seed and Series A funding for AI-enabled cleantech also grew significantly over the past five years—from 26% of total investment in 2018 to 38% in 2023. This growth showcases the importance the investment community places on early-stage innovators as AI's significance grows in the cleantech sector.

A surge of risk capital from public sector investments and support of AI accelerator programs (some with a focus on climate-AI) have helped fuel further growth of AI-enabled cleantech. Between 2018 and 2023, risk capital in AI-enabled cleantech innovators totalled more than US$6.9 billion.[15] The Top 5 accelerators and incubators supported 97 AI-enabled cleantech deals between 2018-2023.[16]

Chart 5: Total AI-enabled cleantech investment by sector (US$ billions), 2018-2023*

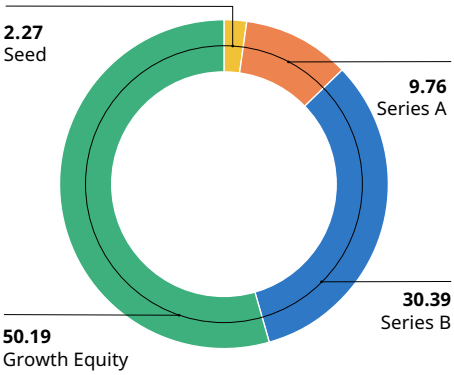


*Excludes outlier deals > US$350 million
Source: Cleantech Group, 2024, EDC Economics

Strong public policy support has also massively contributed to the development in the field, including multiple AI-enabled cleantech deals by the U.S. Department of Energy (DOE), Sustainable Development Technology Canada (SDTC), Singapore's Temasek Holdings, Bpifrance, Innovate UK and The European Innovation Council.

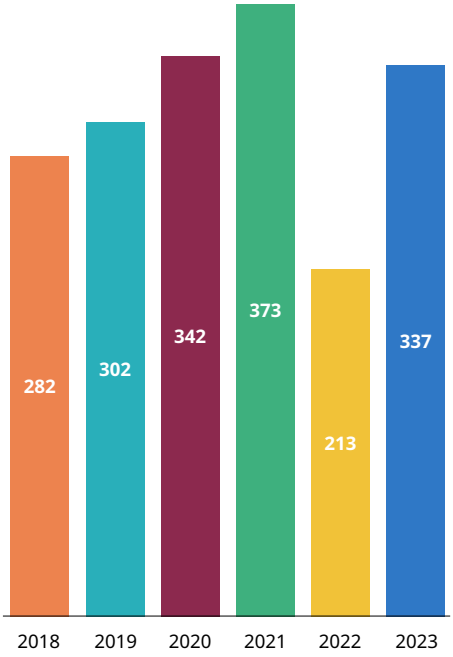
Early-stage investors play the most active and critical role in supporting AI-enabled cleantech solutions. Though these deals remain small in dollar values, they spur critical activity in the sector. Various universities, research institutes and incubators also serve as sources of innovation—supporting R&D and providing ecosystem services, driving the growth of startups and big data research.

Chart 6: Average deal size and investment rounds (US$ billions), 2018-2023



Source: Cleantech Group, 2024, EDC Economics

Chart 7: Number of AI-enabled cleantech deals, 2018-2023



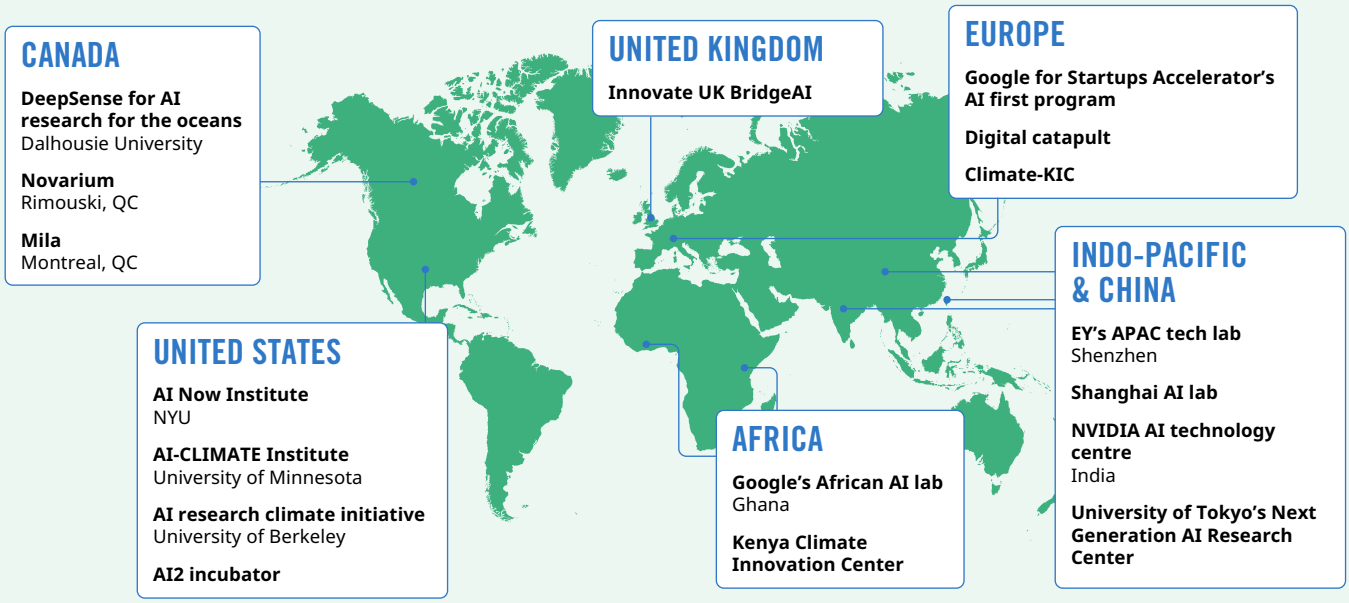
Source: Cleantech Group, 2024, EDC Economics

14 This includes only venture and growth investment data such as seed, Series A, Series B and growth equity deals. It excludes all outlier deals more than US$350 million.

15 This includes investments by Insight Partners, Breakthrough Energy Ventures, Google Ventures, S2G Ventures, Lower carbon Capital, BDC Capital, Congruent Ventures, Blue Bear Capital, LocalGlobe, AgFunder, Shell Ventures, Future Energy Ventures. Source: Cleantech Group

16 This includes Rockstart, Plug and Play, Y Combinator, Techstars and EIT InnoEnergy. Source: Cleantech Group

Infographic 8: Snapshot of geographical distribution of AI-enabled cleantech innovators



Source: Cleantech Group, 2024, EDC Economics

While these figures account for a tiny fraction of what's currently employed in AI investment globally[17], AI's value in cleantech spans industries—from the pure-play software to hardware integration spectrum. Given this, capital deployment in AI-enabled cleantech innovation is expected to grow fivefold in the next six years, with US$138 billion expected to be deployed between 2024 and 2029 (see Table 9, below).

Mitigating challenges and risks for AI-enabled cleantech innovation

Despite strong investment momentum, a key headwind that risks the growth of the sector is the dichotomy between high energy consumption needs of AI technologies, while addressing the critical rare metals and materials strain these technologies impose.

This requires strong mitigation efforts to minimize the environmental impact of AI and AI-enabled cleantech. So, while AI requires high energy consumption by data centres, greening data centres—while investing in sustainable procurement and recycling options for hardware—offer possible ways in which these challenges can be addressed. Geographic load balancing and building use cases for AI to deliver and distribute load efficiently will also help reduce the high energy requirements that come with AI use. In 2022, global data centre electricity consumption accounted for 1%–1.3% of global electricity demand.[19] While small, as processing powers of AI develop and the innovation and adoption curves expand, electricity usage and GHG emissions are expected to increase.

Table 9: Capital deployment in AI-enabled cleantech, projections 2024-2029 (USD)[18]

	Early stage	Late stage
Capital deployed, 2018-2023	$7 billion	$21.5 billion
Base case projections: Capital supply, 2024-2029	$1 billion	$58 billion
Accelerated growth projections: Capital supply, 2024-2029	$22 billion	$116 billion

Source: Cleantech Group, 2024, EDC Economics

17 While there's no consensus, as per the World Economic forum total venture capital investment in the U.S. alone has totalled US$290 billion over the last five years. As per Stanford University, funding for generative AI octupled from 2022, reaching US$25.2 billion in 2023. AI Index Report 2024: Artificial Intelligence Index (stanford.edu)

18 Calculations and projections are based on Cleantech Group's 2024 estimates. These are based on the National Venture Capital Association demand to supply ratio model using PitchBook-NVCA Venture Monitor, summer 2023 data.

19 International Energy Agency, Data centres & networks, IEA

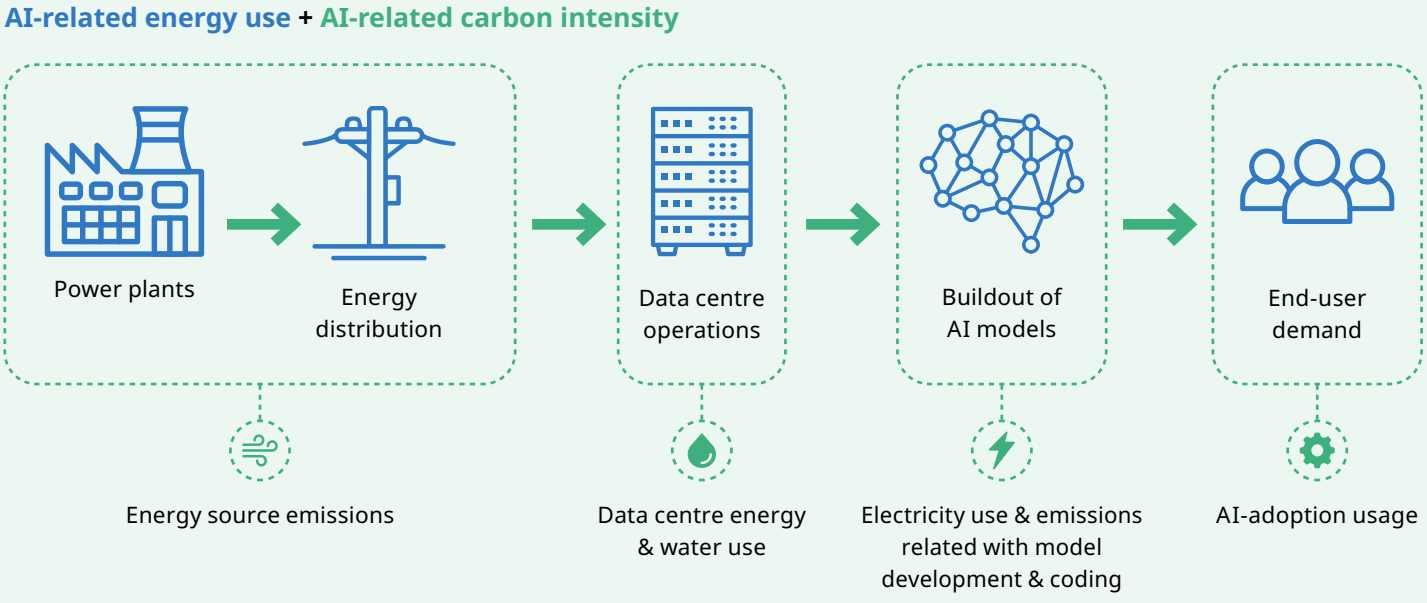
AI also requires high water consumption for cooling data centres. In general, data centre water use isn't widely reported, and actual volumes vary greatly based on the centre's size, location, use of infrastructure and weather conditions of the location. According to the U.S. Department of Energy estimates from 2016, data centre water consumption was 626 billion litres in 2014.[20] This accounts to 1.7 billion litres of water usage a day, of which 0.3 billion litres/day is used on site for cooling.

Here, use cases for advanced cooling technologies, direct-to-chip cooling and implementing water recycling systems to minimize freshwater demand offer solutions to meet AI's water needs for cooling.

Probably one of the most critical challenges for AI technologies' use and adoption is the demand for graphics processing units (GPU) and specialized chip supply.

Rare materials supply chains (rare earth metals) are heavily concentrated in geography and processing alongside sustainability, habitat and community damage concerns. Beyond AI use, the criticality of many net zero and clean technologies depends on global supply chains that are susceptible to potential choke points. A small number of countries control a large share of critical mineral reserves, and processing and manufacturing. Most of the minerals are indispensable for renewable technologies and are difficult to substitute. Mitigation efforts on the technology side include designing AI hardware with longer lifespans, optimizing software for more efficiency in GPUs and recycling solutions for chip and hardware components. In general, circularity, recycling and reuse will help solve many of AI's e-waste challenges.

Infographic 10: AI's energy use & emissions



Source: BCG, EDC Economics

20 United States Data Center Energy Usage Report (technical report) | OSTI.GOV

Other notable clean technologies

Some sectors such as transportation and power have already developed commercial, scalable technologies that are accelerating the pace at which they're decarbonizing. As a result, these sectors have made significant strides in reducing emissions. This includes technological improvements in electric vehicles (EVs) in the transport sector and the commercialization of solar and wind power in the energy sector. Energy storage remains critically important where significant technological progress is yet to be made. Many traditional sectors that are also hard to abate have met with challenges in reducing emissions and decarbonizing effectively and efficiently.

Achieving decarbonization requires a combination of measures and suite of technologies. New tools, technologies and processes that accelerate the reduction of emissions, while also meeting set net zero targets, won't be restricted to climate use cases of AI. While a host of technologies can be included in this list, in this report, we focus on three:

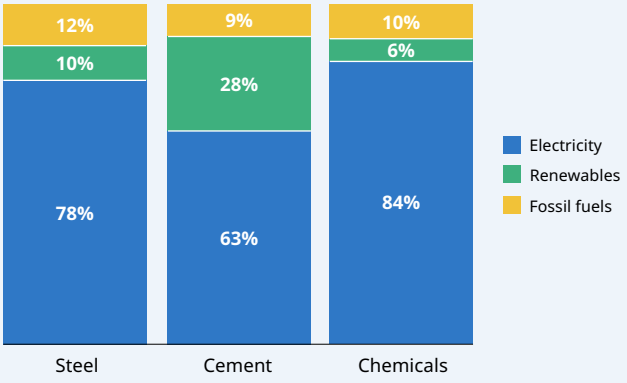
- Carbon capture, utilization and storage (CCUS)
- Hydrogen and alternative fuels
- Energy storage with a focus on long-duration energy storage (LDES)

These technologies are critical in decarbonizing crucial aspects of our economy, especially hard-to-abate traditional industries and may well hold solutions to solving the energy problems of AI itself. Many of these technologies are, in no means, new such as CCUS and hydrogen that has been produced, or utilized in Canada in varying degrees for many years, but they hold much promise and are farther along the technology frontier.

Box 11: Decarbonization of heavy industry

Emissions from heavy industries such as those from chemical, metals and cement production account for about a fourth (24%) of all global GHG emissions. Steel, for example, produces 2.75 pounds of carbon dioxide (CO_2) for every pound of steel produced, with most of the emissions coming from energy use during heating. Cement's emissions come not only from energy consumption, but also from the chemical processes required to create cement. The complexity involved in industrial manufacturing makes these emissions notoriously hard and expensive to eliminate. All climate scenarios call for more than half of industrial energy to come from clean electricity by 2050, critically requiring these industries to transition away from fossil fuels and building the use case for energy storage solutions, which help deal with intermittencies in renewable energy.

Chart 11: Carbon dioxide emissions from heavy industries

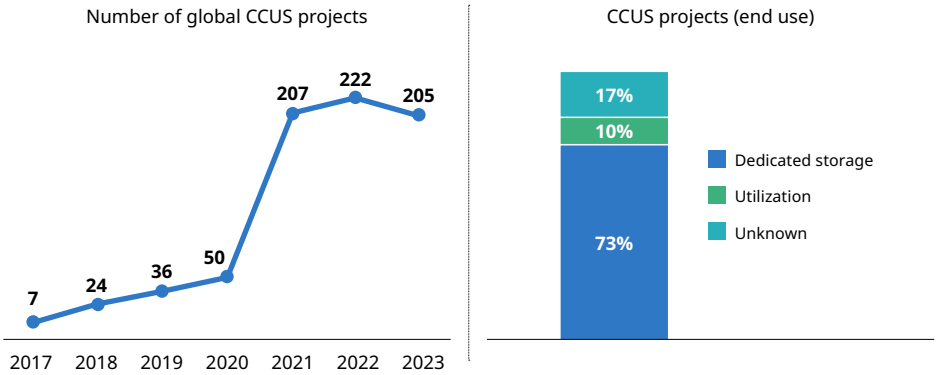


Source: IEA, 2024 & EDC Economics

Carbon capture, utilization and sequestration (CCUS)

CCUS technologies involve the capture and removal of carbon dioxide (CO_2) from large point emissions sources for on-site usage, transportation, or injection into deep geological formations. The role of CCUS in clean energy transitions is critical—from retrofitting existing power and industrial plants tackling emissions in hard-to-abate sectors to removing (CO_2) from the atmosphere to balance unavoidable emissions. Currently, CCUS facilities capture more than 50 megatonnes (Mt) of CO_2 annually. But estimates suggest that CCUS technologies have the potential to eliminate 230 metric tonnes of CO_2 ($MtCO_2$) emissions by 2030 in the U.S. alone.[21] While buoyed by significant policy support globally—especially in the U.S. (such as the 45Q tax credit for carbon capture projects)—Canada's investment tax credits (ITCs) and in Europe—the technology remains at a nascent stage.

Chart 12: Global CCUS project (left, graph) announcements by end use (right, graph).



Source: The International Energy Agency, 2023[25] & EDC Economics

Concerns around the accuracy of avoidance credits, which are notoriously hard to verify, have further spurred market demand for high-quality carbon sequestration products and technologies. Announced CCUS projects are expected to add 1.1 Gt of carbon removal capacity per year by 2030, which is lower than what's needed under the net zero emissions path. Though most planned projects are currently in carbon storage, there's significant innovation happening in the market, supported mostly by venture capital-backed technology companies experimenting with novel uses for carbon and carbon capture, including innovations in direct air capture technologies[22] and point source carbon capture.[23] Promising technological innovations are also in demonstration stages around the world, including some that are expected to reduce CCUS costs in the power generation sector.[24]

21 Cleantech: Can the U.S. raise its game? | McKinsey

22 Direct air capture technologies extract carbon dioxide directly from the atmosphere at any location unlike carbon capture, which is generally carried out at the point of emissions. Currently, this is the most expensive application of carbon capture.

23 Point source carbon capture is when carbon is captured at a large emission source (e.g., an industrial facility). It's usually when the emission source itself is equipped with technology that allows the capture and, in some cases, storage of CO_2, preventing it from being emitted at source.

24 IEA: Carbon Capture, Utilization and Storage: Energy System—IEA

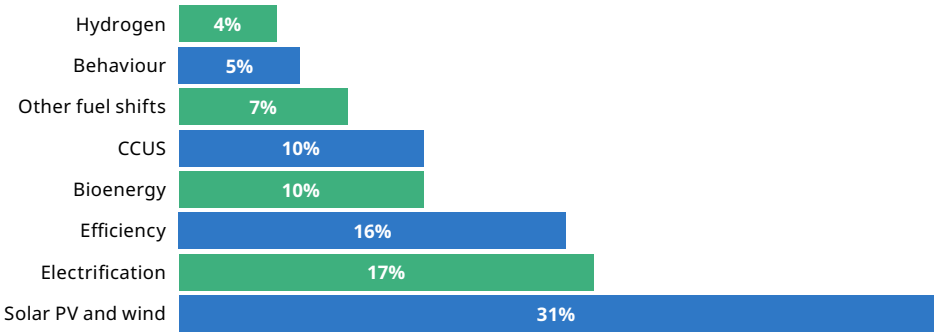
25 Net zero by 2050. Analysis: IEA

New energy commodities: Hydrogen & other alternative fuels

A versatile energy carrier, hydrogen holds much promise to tackle many critical energy challenges. Clean hydrogen produced with renewable or nuclear energy, or fossil fuels using carbon capture, is expected to decarbonize multiple sectors and industries. This includes hard-to-abate sectors such as iron and steel production, chemicals, refining, cargo ships and long-haul trucking. Experts estimate the global hydrogen market to be anywhere between US$500 million and $1.23 trillion a year by 2050.[26] According to most industry forecasts, hydrogen is one of the six clean energy technologies, which cumulatively hold the potential to unlock around 50% of emissions reductions to 2050.[27]

The hydrogen market is heavily supported by the *Inflation Reduction Act* (IRA) in the U.S. and other policy instruments in Canada (such as the Clean Fuels Fund, Net Zero Accelerator and the national Hydrogen Strategy), Europe and Asia. This has rallied sufficient private funding and financing at the global stage. The most notable funding push in 2023 and 2024 has been in low- to no-carbon hydrogen, with technologies leapfrogging towards manufacturing lines in 2024.

Chart 13: Cumulative emissions reductions by clean technology & drivers



Source: IEA, 2023, EDC Economics

Breakthroughs in hydrogen technology and financing are expected to have compounded impacts on downstream innovation, including in the advancement of fuel cell technology and sustainable aviation fuels (SAF) for jets. But the cost-efficient scaling of clean hydrogen technologies (green hydrogen, for example) depends on the availability of cheap renewable electricity and the global supply of electrolyzers. The scale of blue hydrogen[28] currently hinges on the development of CCUS technologies. Current cost structures also remain a hinderance to industrial consumers of hydrogen, who are unwillingly to take on projects without supply certainty and competitive pricing. This is visible in the low uptake of new offtake agreements.[29]

Canadian fuel cell manufacturers are global technology leaders and Canada is a global Top 10 producer of hydrogen.

Alternative fuels include biofuels that can be used as drop-in fuels in conventional internal combustion engines (ICE), fostering emissions abatement in the transportation sector and supporting the decarbonization of existing fleets. These include ethanol, hydrotreated vegetable oil (HVO), or synthetic fuels such as ammonia. Even in a world with an expansive electric vehicles (EV) uptake, meeting GHG emissions reduction targets for transportation will require significant contribution from sustainable fuels in existing fleets with ICE engines.

26 Cleantech: Can the U.S. raise its game? | McKinsey

27 IEA's Energy Technology Perspective 2023 and as per IEA's Net Zero Emission (NZE) scenario.

28 Grey, blue and green are colours representing different hydrogen production methods. Grey hydrogen is produced from natural gas, blue from natural gas with capture and green from renewable energy. There are other hydrogen production methods, including thermal splitting of natural gas, coal gasification and biomass gasification.

29 Clean hydrogen has a serious demand problem | Canary Media

Beyond vehicle segments, sustainable aviation fuels also offer decarbonization potential to limit emissions, as well as applications in the maritime and shipping sectors and buildings, and industry as an alternative energy source to replace fossil fuels. As of 2023, more than US$150 billion of clean fuel production capacity investments have been announced globally.[30] Currently, the alternative fuel landscape is highly complex, with multiple fuel types, technology pathways and feedstock considerations. Most alternative fuels are derived from feedstocks such as edible sugars and oils, which account for 60%-80% of production costs.[31] This means that the use and utilization of alternative fuels is heavily dependent on the availability of advanced feedstocks. This complexity has made it challenging for market participants to fully understand and reap the benefits from the technology.

Long-duration energy storage (LDES)

Responsible for one-third of global greenhouse gas emissions, the power sector has a critical role to play in the energy transition. The rise of renewables in the energy mix has exposed structural flaws in existing power generation, transmission and distribution lines, highlighting the need for long-term technologies that help address the inherent invariabilities of renewable power supply, including intermittency. This has led to the development of the long-duration energy storage field—encompassing novel thermal, chemical, mechanical and electrochemical (battery) technologies that can store energy for prolonged periods of time (from several hours to days).

Examples of these technologies include pumped hydro electric storage, battery storage, thermal storage, or compressed air storage.

LDES technologies aim to provide grid flexibility—absorbing and managing demand and supply fluctuations by storing energy at times of surpluses and releasing energy when the need arises. While at different levels of maturity and market readiness, LDES technologies are attracting significant interest from government, utilities and transmission operators, given the multiple use cases the technology offers in balancing power systems and making them more efficient.

30 Global Energy Perspective 2023: Sustainable fuels outlook | McKinsey

31 Global Energy Perspective 2023: Sustainable fuels outlook | McKinsey

The Canadian cleantech market

Canada is home to a vibrant cleantech ecosystem. Touted as the birthplace of modern AI and deep learning breakthroughs, Canada stands to significantly benefit from the AI and AI-enabled cleantech sector.

Canadian innovation, a vibrant startup community and the support of public and private programs have led to the establishment of a significant marketplace for the cleantech and AI-enabled cleantech space. According to the Cleantech Group, Canada is third globally for risk capital deployed in the AI-enabled cleantech innovation space.

Based on the Cleantech Group's annual list of the Top 100 most innovative global cleantech firms, 13 Canadian companies were featured in the 2024 rankings.[32] The companies were in a wide range of sectors—from the resources and environment space, materials and chemicals to the energy and power sector.

Canadian market and investment patterns

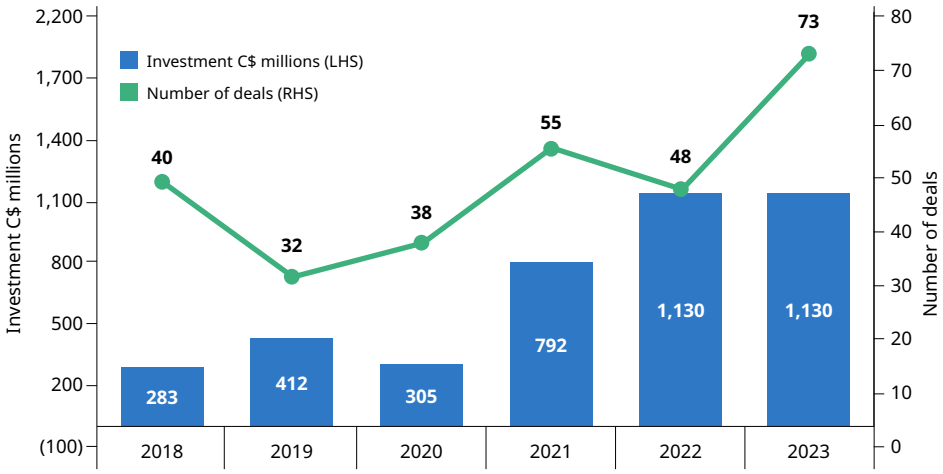
Canadian cleantech venture capital (VC) activity in 2023 was recorded at $1.2 billion across 73 deals.[33] Total investment numbers remained unchanged from 2022, but across 73 deals, the highest number of deals record in the past five years.

Notably, this led to a smaller average deal size compared to 2022 ($15.5 million on average in 2023 versus $26 million in 2022, which was the highest average deal size on record). While muted, Canadian VC activity in the cleantech sector didn't reduce in value in 2023 (as was the case in some other sectors). Much of this has been driven by the capitalization of emerging opportunities in the life sciences and AI space, which has boded well for the AI-enabled cleantech sector. In the first quarter of 2024, $164 million worth of investments has already been made across 11 deals.

32 See more here: The Global Cleantech 100 | Cleantech Group

33 Canadian Venture Capital & Private Equity Association; Canadian cleantech sector gains momentum with record... | CVCA Central

Chart 16: Canadian cleantech investment activity (2018-2023)



Source: Canadian Venture Capital & Private Equity Association, EDC Economics

Contribution of environmental and clean technologies to Canadian GDP

In 2022, the environmental and clean technologies (ECT) contributed[34] $80 billion to GDP, or 3.5% of GDP.[35] More than half of this contribution was attributed to the cleantech goods and services subsector (53.1%) and the remaining 46.9% attributed to the environmental goods and services subsector.

Cleantech trade flows

Exports

In 2022, Canadian ECT exports amounted to $20.9 billion, or 2.2% of total Canadian exports. This was an increase of $3 billion from 2021, a 17% year-on-year (YOY) rise. ECT exports have consistently trended upwards since 2012 (including the COVID-19 years) and hit the highest level on record in 2022, growing at a compound annual growth rate (CAGR) of 0.6% in the last decade. Within the subcategories, environmental product exports were $11 billion, compared to $9.8 billion in cleantech exports.[36] Cleantech goods have accounted for a higher share of ECT exports in most years (eight out of the 10 years analyzed).

Following the trend from 2020, environmental product exports increased 26% YOY, mainly driven by a whopping 73% YOY growth in exports of clean electricity and a modest 4% YOY rise in waste and scrap goods. Notably, all Canadian electricity exports are to the United States and, in 2022, exports were supported by favourable weather conditions and increases in renewable capacity— particularly, more wind and solar plants coming online. According to Natural Resources Canada, wind energy and solar photovoltaic (PV) are the fastest-growing sources of electricity of Canada.[37]

Notably, waste and scrap goods have historically been a substantial portion of Canadian environmental goods' exports (close to 50% every year), but the importance of clean electricity exports has been consistently rising, which bodes well for Canadian exports and cleantech, in general. In contrast, cleantech product exports rose 15% YOY between 2020 and 2021. (Chart 17).

Most Canadian ECT exports are cleantech manufactured goods (38%), or waste and scrap goods (24%). But the rising importance of clean electricity exports (growing to account for 21% of total cleantech exports in 2022, from being 16% of total ECT exports in 2012) is a welcome sign and speaks to the rising prominence of clean energy in Canada's export mix. Exports of clean electricity also bode well for Canadian exporters, due to the benefits of cross-border integration of electricity grids with the U.S.

34 Statistics Canada categorizes the environmental and clean technology (ECT) products sector in two broad product and process categories:
- Environmental goods and services that include clean electricity from renewables and nuclear power generation, biofuels and primary goods, and waste management and remediation services.
- Clean technology goods and services include manufactured goods, scientific and research and development services, construction services, and support services. Examples of clean technology goods and services include solar panels and the construction of energy-efficient buildings.

The environmental and clean technology products economic account (ECTPEA) from Statistics Canada measures the economic contribution of the sector in terms of output, gross domestic product (GDP), value-added and other economic variables. Per this definition, ECT's contribution to Canadian GDP is defined as "any process, product or service that reduces environmental impacts through any of the following three strategies: Environmental protection activities that prevent, reduce or eliminate pollution, or any other degradation of the environment; resource management activities that result in the more efficient use of natural resources, which safeguard against their depletion; the use of goods that have been adapted to be significantly less energy or resource intensive than the industry standard. See Statistics Canada for the definition.

35 GDP is at current market prices. In 2022, it was estimated at $2.5 trillion by Statistics Canada, see https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610022201

36 Note: Any changes from last year's data are due to the statistical revision of the time series by Statistics Canada.

37 About renewable energy in Canada, Natural Resources Canada

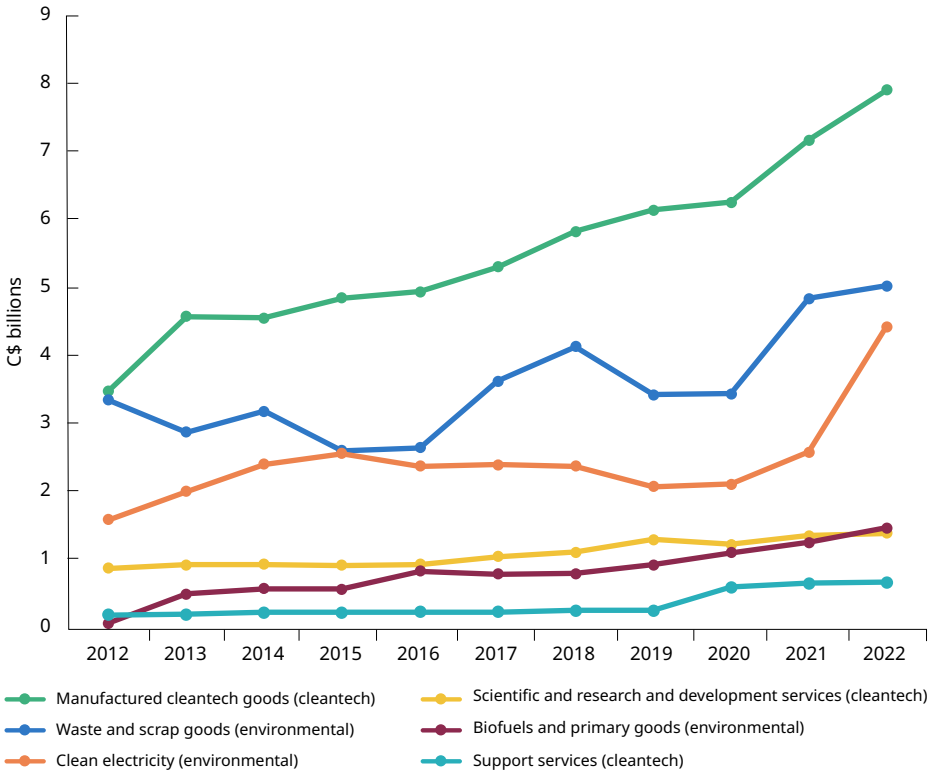
Box 17: Canadian low-carbon exports[38, 39]

In the last decade, Canada's basket of low-carbon exports has outpaced the growth of all other exports. Between 2013 and 2023, Canada's low-carbon exports more than doubled in value from $15.8 billion to $38.7 billion last year. Beyond outperforming overall export growth in the last decade, Canada's low-carbon exports also outperformed oil and gas exports.

Geographic destination of exports

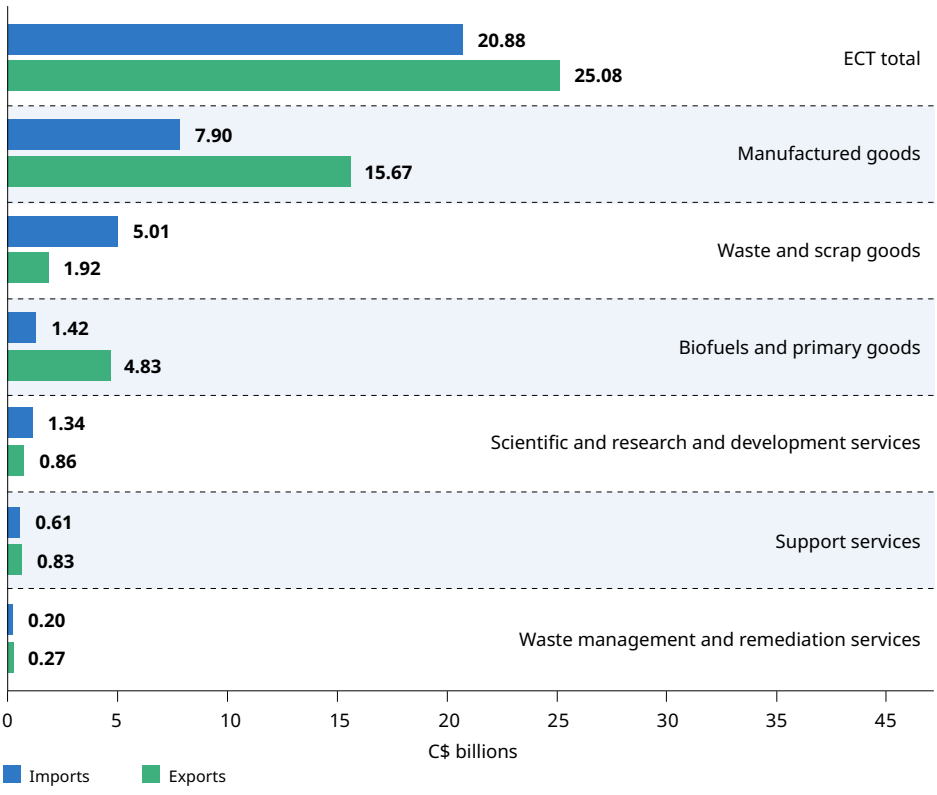
Most Canadian ECT exports go to the U.S., which accounted for 77.7% of total Canadian ECT exports in 2022.[40] Of total ECT exports to the U.S., environmental goods account for more than half (53.4%), followed by cleantech manufactured goods (38.6%) and cleantech services (8%). After the U.S., Europe was Canada's second-largest export partner receiving $2.2 billion of Canadian ECT exports. Three European countries—the United Kingdom (18.1%), the Netherlands (16.6%) and Norway (15.5%)—received slightly more than half of all Canadian exports to Europe. Canada also exported $413.5 million of ECT products to China, followed by India at $348.4 million in 2022.

Chart 17: ECT exports by environment and cleantech products, 2012-2022



Source: Statistics Canada, EDC Economics

Chart 18: ECT imports and exports, 2022



Source: Statistics Canada, EDC Economics

38 These calculations are from the Canadian Climate Institute, see more here: Canada's low-carbon exports are growing nearly twice as fast as other exports (440megatonnes.ca).

39 The list of low-carbon export products includes 141 individual low-carbon commodities from a diverse set of industries across different industrial classifications, including mining, alternative fuels, clean industry, clean electricity and power equipment, etc. See more here: Canada's clean-energy gazelles are outperforming fossil fuels (irpp.org)

40 See The Daily—International trade in environmental and clean technology products by origin and destination, 2022 (statcan.gc.ca)

EDC's cleantech support

In 2022, Export Development Canada (EDC) set the goal of providing $10 billion in support for cleantech businesses by 2025. As of Dec. 31, 2023, EDC had exceeded our target by providing more than $12 billion in financing and insurance solutions to more than 440 cleantech businesses—up from $8.8 billion and 392 companies in 2022. Since 2012, EDC has supported nearly $41 billion in cleantech exports and is a leading financier of Canada's cleantech industry.

As one of Canada's largest financiers of cleantech, EDC provides support for businesses across all subsectors, including renewable power generation, biofuels, energy efficiency and green buildings. We've helped Canadian cleantech companies of all sizes achieve success on the global stage.

Imports

In 2022, imports of ECT products reached $25 billion, representing 2.6% of total Canadian imports. Environmental product imports totalled $7.7 billion in 2021, compared to $17.4 billion in cleantech imports. Historically, cleantech imports have had an outsize share (more than 70% of total ECT imports in the last decade) in Canada's total ECT imports compared to environmental goods imports.

Net trade flows

Due to a reliance on ECT imports, Canada's trade balance has experienced a consistent deficit since 2012. In 2022, Canada's ECT trade balance was $4.2 billion, larger than the trade deficit of the entire Canadian economy, which stood at $3.7 billion. Notably, this deficit has been entirely driven by the cleantech subsector. Barring 2013—when the trade deficit was $551 million—environmental products' trade balance has been consistently positive, or in a surplus. (on previous page)

At a subsector level, the main contributor to Canada's ECT trade deficit is its imports of manufactured clean technology goods, vis-à-vis clean technology services. Cleantech goods imports have constituted, on average, 89% of total cleantech imports since 2012. More positively, waste and scrap products and clean electricity have shown continued trade surpluses. But primary environmental goods, including biofuels, have consistent deficits. The growing importance of clean electricity in Canada's export mix is a positive sign and offers massive opportunities given cross-border integration of grids with the U.S. and the growing importance of energy security and renewable energy across the world.

The frontiers of cleantech: Opportunities and exports

Increased volatility in energy markets, coupled with a drive towards decarbonization, will see countries and regions looking to convert early cleantech innovation into competitive positions on the global stage.

Countries that accelerate domestic deployment of climate technologies and race toward developing cleantech supply chains are expected to capture more value from the new developing green economy. How countries act will also lay the foundation for long-term value-add in promising nascent technologies and their applications, including AI-enabled cleantech, hydrogen, carbon capture, utilization and storage (CCUS), etc.

Policy instruments such as U.S. President Joe Biden's *Inflation Reduction Act* (IRA), Canadian cleantech investment tax credits and the REPowerEU, the European Union's plan to reduce Europe's dependence on fossil fuel and accelerate the transition to green energy, have, in part, been put in place to build meaningful momentum toward advancing these goals.

Specifically for AI-enabled cleantech, the more fundamental the problem AI helps solve, the more exportable the product or service will be. In this view, the more traditional the industry, the more applications for AI-enabled cleantech. Like all innovative technologies, early entrants will also reap the most benefits. Given current developments, North America—where most notable AI innovation is advancing—is advantageously positioned, alongside slow, but significant momentum across China, Japan and Singapore. While pockets in Europe have technology centres, data protection and privacy laws have made it historically difficult for data, or AI-driven companies to thrive.

Canada has historically been a leader in AI innovation, touted as a global trailblazer in both cleantech innovation and AI.

Strong government support—including the Pan-Canadian AI Strategy, investment tax credits for clean technologies and multiple grants and opportunities for funding—and a vibrant startup space and well-educated workforce position Canada well for deep AI and cleantech integration. The development of these novel technologies, including risk capital, will be critical in securing Canada's future AI-enabled cleantech advantages. In building these ecosystems, improvements in the provision and access of AI infrastructure, alongside affordable access to computing power that's needed for these AI models, will be essential. Our clean electricity grid, extensive access to renewable energy, abundant water sources and critical minerals, offer numerous opportunities for the country to develop computing infrastructure. If Canada is to strengthen its AI advantage, the private sector will need to rally around and support companies to grow, scale and establish this key infrastructure.

When it comes to novel technologies, accelerated domestic deployment of mature climate technologies (e.g., solar and wind) is expected to enable the production of new exportable downstream products, including the production of new energy commodities such as hydrogen and sustainable fuels.

These energy commodities have the ability to reduce the emission's intensity of end-products and support infrastructure as it transitions to be greener. Countries that focus on capturing portions of these new markets for domestic use, as well as exports to countries with limited access to renewable electricity, will stand to make substantial gains. In areas where Canada already has a competitive advantage—such as nuclear power, hydrogen and CCUS—markets will need to be developed and nurtured, including building companies, capacity and technological know-how, and creating export opportunities along new energy commodity value chains.

The advent of AI and its powerful computing and data analysis capabilities is also expected to radically revolutionize nuclear technology, including drastically reducing costs and transforming reactor designs.

A safe and thriving nuclear power industry and the announcement of two SMR projects offer substantial benefits for Canada. Nuclear power plants have been producing electricity commercially and safely in Canada since the early 1960s. Recognizing the critical role sustainable and alternative fuels play in the energy transition and future energy mix, Canada's government has announced the clean fuel standard (CFS)[41], increases to the federal carbon pollution price, and the Hydrogen Strategy for Canada[42].

CCUS technologies offer many advantages to countries that have concentrated industrial emissions sites with access to sequestration areas. Canada is considered a world leader in CCUS technologies.

Canada has historically been a leader in AI innovation, touted as a global trailblazer in both cleantech innovation and AI.

The federal and provincial carbon pricing system has historically led to the trading of carbon credits, which has encouraged innovation in carbon-capturing techniques. Vast sequestration sites with close access to renewable energy and world-class geological engineering R&D also offer resource advantages for CCUS in Canada. Given Canada's access to high-quality renewable resources, high sequestration potential and geological and engineering expertise, direct air capture also stands out as an area of potential opportunities for Canada in the global carbon removal market.

The energy storage market is also poised for substantial growth in Canada. Long-duration energy storage (LDES), in particular, offers substantial opportunities for the suite of exportable clean technologies in which Canada has a competitive advantage. LDES is expected to protect against potential development risks and vulnerabilities, while optimizing the performance of small modular reactors (SMRs), grid-scale nuclear, blue and green hydrogen assets, and other emerging resources in Canada. Canada also has a long history with LDES, with Ontario's Power Generation (OPG) pumped hydro storage in Niagara Falls. But widespread usage is still limited as Canada's current installed national capacity for energy storage is less than one gigawatt (GW).[43]

41 Clean Fuel Regulations—Canada.ca

42 The Hydrogen Strategy—Canada.ca

43 A snapshot of Canada's energy storage market in 2023, A snapshot of Canada's energy storage market in 2023—Energy-Storage News

CONCLUSION

Efforts to unlock the potential of emerging climate technologies will hinge on a region or country's ability to build competitive advantages that will go beyond pure innovation. A favourable policy mix, intellectual property, infrastructure, access to critical minerals, skilled labour and sufficient financial capital will be the backbone of the new green economy. Maintaining the innovation edge requires constantly improving the position and providing ample opportunities for novel technologies to scale and mature, while simultaneously improving operational efficiency—a problem that AI and deep data-driven learning can help solve.

As climate-related use cases for AI rise and novel technologies evolve offering decarbonization and transition solutions, the next frontier of green growth and clean technologies offers much promise.

Appendix

Sector highlights of global cleantech venture investment from 2023

Transportation and logistics

Total investment in 2023:
US$7.59 (down 43% from 2022)

Key innovations to watch in 2024:
EV-charging innovation, on-road vehicles (including commercial heavy-duty vehicles and innovations in micromobility[44]) and fleet electrification and management solutions

Focus on: Charging and energy management solutions to stabilize grids and meet growing consumer power demands from electrification of fleets

Energy and power

Total investment in 2023:
US$12.37 billion (down 1% from 2022)

Key innovations to watch in 2024:
Hydrogen and electrolysis technologies, energy storage innovation (in both the EV battery and long-duration storage), digital and hardware innovations in buildings (such as sensors for smart buildings and utilities, and system operators, as well as heat pumps), grid optimization technologies, nuclear fusion

Focus on: Improving energy networks and storage and a focus on improving energy optimization of buildings

Materials and chemicals

Total investment in 2023:
US$5.78 billion (unchanged from 2022)

Key innovations to watch in 2024:
Cathode manufacturing innovations[45], green steel production technologies, electrofuels made from captured carbon, water and electricity

Focus on: Local production to address supply chain vulnerabilities, materials innovation and sustainable production of fuels and reducing industrial emissions

Resources and environment

Total investment in 2023:
US$5.85 billion (down 33% from 2022)

Key innovations to watch in 2024:
Direct lithium extraction, battery recycling, corporate sustainability developments (especially in risks and carbon offsets markets)

Focus on: Critical materials and minerals, mining and recycling

Agriculture and food

Total investment in 2023:
US$6.64 billion (down 55% from 2022)

Key innovations to watch in 2024:
Animal-focused cleantech, livestock management, animal feed innovators and alternative-protein innovations

Focus on: Sustainability and emissions-reduction potential

44 Microbility includes two wheelers, scooters, mopeds and cargo bikes.

45 Cathode active materials are the largest part of the EV battery cost (more than 30%). The production of cathode active material for lithium-ion batteries is a complex process that involves several steps from drying, milling and mixing of the raw material to refining of active material and coating.

References

1. *A snapshot of Canada's energy storage market in 2023*, Rangooni, J., Energy Storage News, 2023
2. *About renewable energy in Canada*, Natural Resources Canada
3. *AI's energy needs may boost a small modular reactor startup*, Ben Geman, Axios.com, 2024
4. *AI Index Report 2024,* Stanford Institute for Human-Centered AI, Stanford University, 2024
5. *Accelerating Climate Action with AI*, Dannouni et al., Boston Consulting Group, 2023
6. *Artificial Intelligence Is Fueling A 'Nuclear Renaissance.' Bill Gates And Jeff Bezos Are In On It,* Norton K., Investor's Business Daily, Investors.com, 2024
7. *Canada's clean energy gazelles are outperforming fossil fuels,* Sawyer D, Policy Options, November 2020
8. *Canada's Energy Future,* Canada Energy Regulator, 2023
9. *Canada's low-carbon exports are growing nearly twice as fast as other exports,* Zhang A., Sawyer D., Canadian Climate Institute, April 2024
10. *China's domestic and foreign influence in the global cobalt supply chain*, Gulley A.L., McCullough E.A. & Shedd K.B., Resources Policy, 62, 2019
11. *Clean Fuel Regulations,* Government of Canada, retrieved August 2024
12. *Clean hydrogen has a serious demand problem,* John. J, Canary media, 2024
13. *Cleantech: Can the U.S. raise its game?* Corb, L. et al, McKinsey and Company, 2022
14. *Data centres and data transmission networks,* International Energy Agency *United States Data Center Energy Usage Report*, Shehabi, A. et al., United States: Web. Doi: 10.2172/1372902, 2016
15. *Electricity 2024—analysis and forecast to 2026*, International Energy Agency, 2024
16. *Energy Technology Perspective 2023*, International Energy Agency, Paris, Licence: CC BY 4.0, 2023
17. *From Buzz to impact: AI's role in accelerating the clean economy,* Cleantech Group, 2024
18. *Global Cleantech 100: Leading cleantech solutions to solve the world's biggest challenges,* Cleantech Group, 2024
19. *Global Energy Outlook 2024: Peaks or Plateaus,* Raimi, D., Zhu, Y., Newell, R.G. and Prest, B.C., 2024.
20. *Global Energy Perspectives 2023: Sustainable fuels outlook,* Krutnik M., et al, McKinsey and company, 2024
21. *Measuring the environmental impacts of artificial intelligence compute and applications: The AI footprint*, OECD Digital Economy Papers, No. 341, OECD, 2022, OECD Publishing, Paris,
22. *Net zero by 2050,* International Energy Agency, Paris, Licence: CC BY 4.0, 2021
23. *PitchBook-NVCA Venture Monitor,* National Venture Capital Associations and PitchBook, 2023
24. *Reduce carbon and costs with the power of AI*, Degot C. et al, Boston Consultancy Group, 2021
25. *Resource realism: The geopolitics of critical mineral supply chains*, Goldman Sachs, 2023
26. Statistics Canada
27. *The Hydrogen Strategy,* Government of Canada, 2020
28. *United States Data Center Energy Usage Report,* Shehabi et. Al, 2016
29. *Why AI and energy are the new power couple,* Rozite et al., IEA, Paris IEA (2023), Licence: CC BY 4.0
30. *World Energy Investment 2024,* World Energy Investment 2024, IEA, Paris IEA (2024), Licence: CC BY 4.0

About this report

The cleantech report is part of a publication series of concise reports written by Export Development Canada's Economics team on the future potential for Canadian exports. The views expressed in this report are those of the author and shouldn't be attributed to Export Development Canada or our Board of Directors.

This report is written by EDC senior economist Prerna Sharma and reviewed by EDC's national cleantech ecosystem lead Jeff Keats, Shariq Akhlaq, EDC's cleantech lead for energy transition, Meena Aier, EDC's Economics' manager and Brian Goodman, EDC's government relations' senior advisor. The report was copy edited by Karen Turner and Janet Wilson. The French report was copy edited by Gilles Brault.

For questions or comments, please contact Prerna Sharma (psharma@edc.ca).

For media inquiries, please contact media@edc.ca.

About Export Development Canada

Who are we?

Export Development Canada (EDC) is a financial Crown corporation dedicated to helping Canadian businesses make an impact at home and abroad. EDC has the financial products and knowledge Canadian companies need to confidently enter new markets, reduce financial risk and grow their business as they go from local to global. Together, EDC and Canadian companies are building a more prosperous, stronger and sustainable economy for all Canadians.

For more information and to learn how we can help your company, call us at 1-800-229-0575 or visit www.edc.ca.

Disclaimer

Canada

Export Development Canada EDC