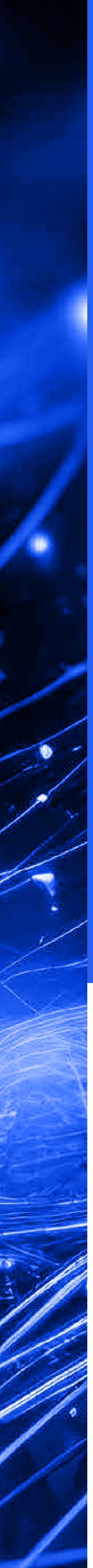
Canada's

VENTURES TO VALUE CHAINS

ELECTRICITY TECHNOLOGY

MARCH 2024

FORESIGHT CANADA



Foresight is Canada's cleantech accelerator.

We bring together innovators, industry, investors, government, and academia to address today's most urgent climate issues and support a global transition to a green economy.

ABOUT

ACKNOWLEDGEMENTS

Foresight acknowledges that the lands on which we conducted this work are the traditional, ancestral, and unceded territories of the xwməθkwəy̓əm (Musqueam), Sk̲wx̲wú7mesh (Squamish), and səlilwətaɬ (Tsleil-Waututh) Nations.

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NRC-IRAP

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INTRODUCTION

Canada has a well-established ecosystem of electricity technology. For example, based on data from the International Renewable Energy Agency, Canada ranks fourth in renewable energy capacity and generation and seventh in the number of patents filed between 2000 and 2021 for renewable energy and enabling technologies.[1,2]

Historically, Canada has a strong track record of innovation in hydroelectric power, [3] long distance transmission, [4] nuclear generation, hydrogen fuel cells, and geothermal energy.[5] The sector is also supported by a wide network of organizations, research institutions, and government initiatives.

Canada's abundance of natural resources places the country in a favorable position. Significantly, over 80 per cent of our electricity comes from renewable and non-emitting sources.6 Hydro sources [1] are most prominent, but nuclear, wind, solar, and biomass are also present.[6] On a global scale, Canada has a competitive advantage, as clean electricity grids are now a key decision factor for many investors, companies, and project developers.[7]

Despite Canada's leadership and advantages, the electricity sector will need to make significant adaptations to achieve the federal government's emissions reduction plan for a net zero electricity grid by 2035 while also keeping up with rising electricity demands. Electricity technology plays an essential role in decarbonizing our electrical grid and supporting widespread electrification across other sectors.

While the move to a net zero economy is critical in terms of reducing climate impact, it is also an enormous economic opportunity. Understanding the current landscape of electricity technology across the value chain is therefore an important step in identifying where supports are needed and enabling the sector's growing impact.

Government bodies, research institutions, and other organizations have already developed an extensive body of knowledge on the sector that covers key challenges, policy approaches, and technical pathways. This report aims to add to this body of knowledge by exploring the strengths, gaps, and areas of opportunity specific to the national electricity technology innovation ecosystem. It also aims to recognize that technology innovation is only part of a bigger picture where project developers, service providers, utilities, independent power producers, all levels of government, industry associations, communities, businesses, educational institutions, and individuals all have roles to play in shifting paradigms, adopting new technologies and methods, and supporting transformative change.

[1] Note that the Canada Energy Regulator definition of hydro sources includes hydroelectric and hydrokinetic (e.g., tidal, wave, riverine) electricity sources while they are considered separately in this report.

“...the path to a net zero grid will be an 'all of the above' approach. It won’t be one technology or the other, it will be all of them.”

- Electricity Canada, The state of the Canadian electricity industry 2023 [8]

Technology Innovation in the Electricity Sector: Enablers and Challenges

Overall, Canada has a strong framework to support innovation in the electricity sector. However, the sector is also facing increasing challenges.

Federal initiatives and support:

The federal government has multiple programs and initiatives to support progress, decision-making, and technology innovation to enable our net zero goals. Key examples include:

- The Canada Electricity Advisory Council, which was launched in 2023 and aims to advise the federal government on actions needed to achieve net zero goals, identifies "enabling electricity market innovations that can reduce the cost and risk of the energy transition" as one of their key focuses. [9]
- The Smart Renewables and Electrification Pathways Program is investing in the development and deployment of established and emerging renewable electricity and grid modernization technologies. [10]
- The Net Zero Accelerator initiative aims to support the adoption of clean technology among industrial emitters. [11]
- Canada's carbon pollution pricing system creates a financial incentive for reducing greenhouse gas emissions, incentivizing the adoption of innovative technologies. [12]
- The National Energy Code for Buildings identifies requirements for energy efficient building design and construction, and consequently promotes the adoption of technologies. [13]

Provincial and regional initiatives and support:

Provinces, utilities, and municipalities offer a range of financial incentives such as tax breaks and rebates to individuals, businesses, and communities to adopt cleaner electricity and become more energy efficient. While the landscape of regional initiatives is dynamic and can be difficult to quantify, Energy Hub identifies at least 80 incentive programs across the country in renewable energy, energy efficiency, and clean transportation. [14]

A strong network of knowledge generators and enablers:

For example:

- Industry associations that aim to support the energy transition such as the Canadian Renewable Energy Association (CanREA), the Canadian Geothermal Energy Association (CanGEA), the Canadian Nuclear Association (CNA), and Efficiency Canada.
- Research institutions such as Electricity Canada, the Clean Energy Research Centre (CERC), Clean Energy Canada, Pembina Institute, and several research labs and specialized research programs at Canadian colleges and universities.

A broad representation of service providers to support the sector:

Natural Resources Canada's 2022 survey of Canada's cleantech industry found that over three quarters of the service providers were in subsectors related to electricity: 53 per cent in renewable and non-emitting energy supply, 14 per cent in energy efficiency, and nine per cent in smart grid and energy storage. [15] While project developers, system integrators, and other service providers are not included in the electricity technology database, their expertise plays an essential role in bridging the gap between technology innovation and adoption, both at a large and small scale.

Innovation and adoption challenges:

Despite this strong support framework, there are also many challenges that affect innovation and adoption. For example, In their 2023 Powering Canada Forward vision, Natural Resources Canada identifies technology availability as one of the key challenges affecting the energy transition.16 They also identify that since electricity is primarily regulated at the provincial level, the fragmented regulatory structure can also make it difficult for provinces to collaborate or to adopt new technologies. [16]

The breadth and depth of the electricity technology sector shown in the database is promising. However, many of the companies are still in early stages of technical maturity, with products that are either not yet commercially available or still only available at a small scale.

Challenges driving technological innovation:

The challenges driving technological innovation are multidirectional. We need to reduce the emissions intensity of electricity generation. At the same time, demand is increasing as electricity becomes a desired source of energy for a range of applications such as heating, transportation, and industrial operations. Further, the impacts of climate change such as extreme weather and forest fires put further stress on critical electricity infrastructure.

Continued support for technology development and adoption in a coordinated and integrated way will be essential to producing electricity in a cleaner and more efficient way, optimizing how it is distributed and managed, and mitigating the impacts of climate change.

RATIONALE

VENTURES TO VALUE CHAINS

is a Foresight initiative that leverages data from technology companies and other key stakeholders to map and categorize strategically important industry value chains for Canada in the clean economy.

This initiative will result in a searchable database, which can be used as a tool to inform stakeholders on Canada's competitive strengths, ecosystem gaps, and areas of opportunity and growth. These insights can identify where targeted programming, research and development, or funding will bolster Canada's leadership and economic development as we transition to a net zero economy.

ELECTRICITY TECH: THE VALUE CHAIN

The electricity technology value chain (Figure 1) describes the journey of electricity from source to customer by outlining a series of processing steps [2] and inputs and outputs along the value chain. It covers how electricity is generated, transmitted, distributed, stored, and managed.

This value chain is intended to be forward looking and reflect a cleaner and more distributed future for electricity that focuses on renewable and non-emitting electricity sources. Technologies specific to electricity generation from fossil fuels are therefore excluded.

The value chain also represents the more distributed nature of today's electricity grid by expanding on the traditional linear model that represents generation, transmission, distribution, and the end user. For example, large-scale and small-scale generation are considered separately. [3] Further, to reflect growing technology spaces and trends driven by changing demand patterns, energy storage, demand side management, and electric vehicle charging are considered separately.

Because the electricity sector intersects with other sectors, this value chain also identifies areas where there are overlaps with other sectoral value chains that Foresight is mapping. These are not intended to be an exhaustive list of sectors that overlap with electricity.

[2] While these are labelled as processing steps, they include all types of actions within the value chain. For definitions of each of the processing steps, see Appendix A.

[3] For the purposes of this database, large-scale generation is defined as 100 kW and over and small-scale is defined as under 100 kW.

Electricity Technology Value Chain

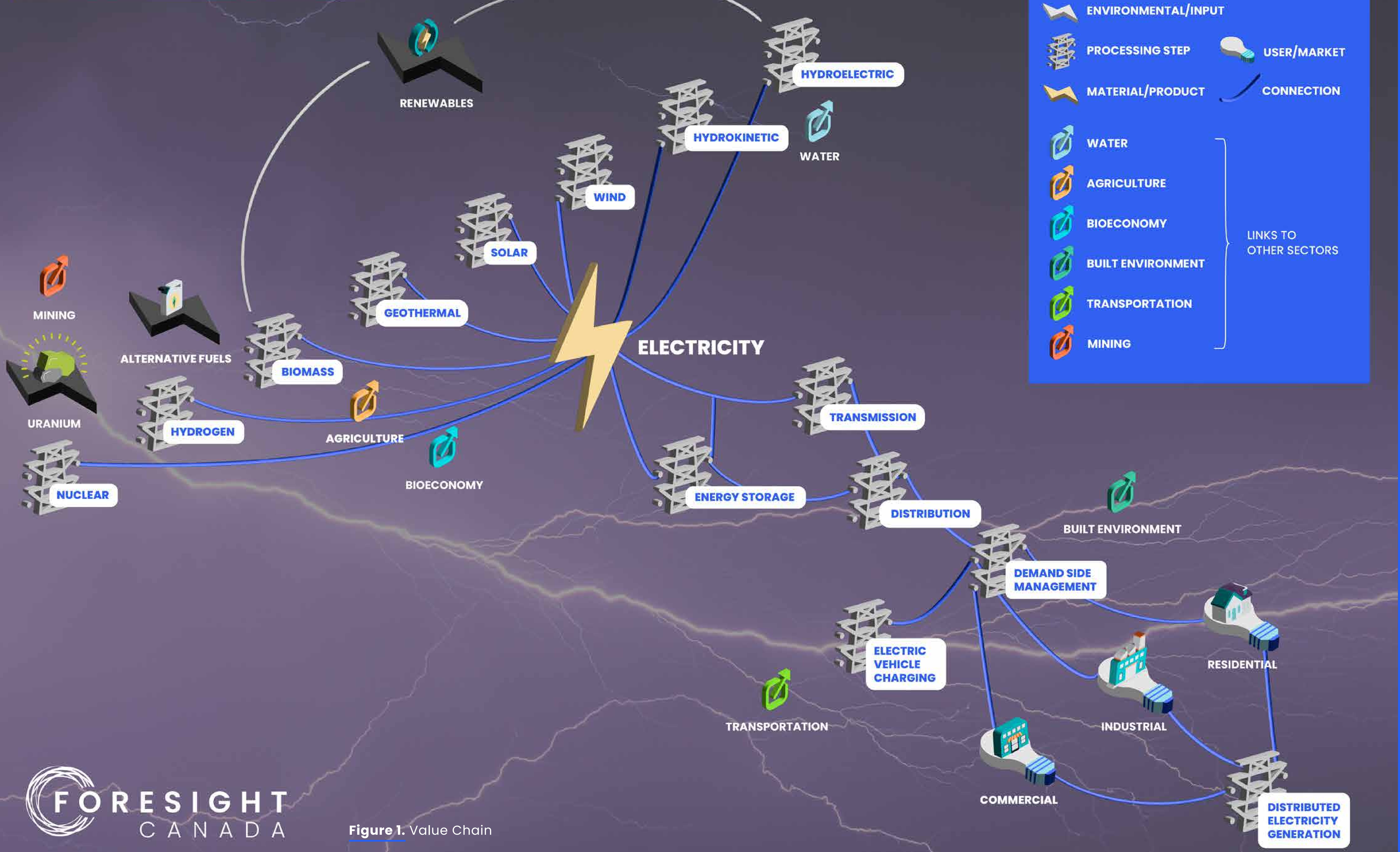


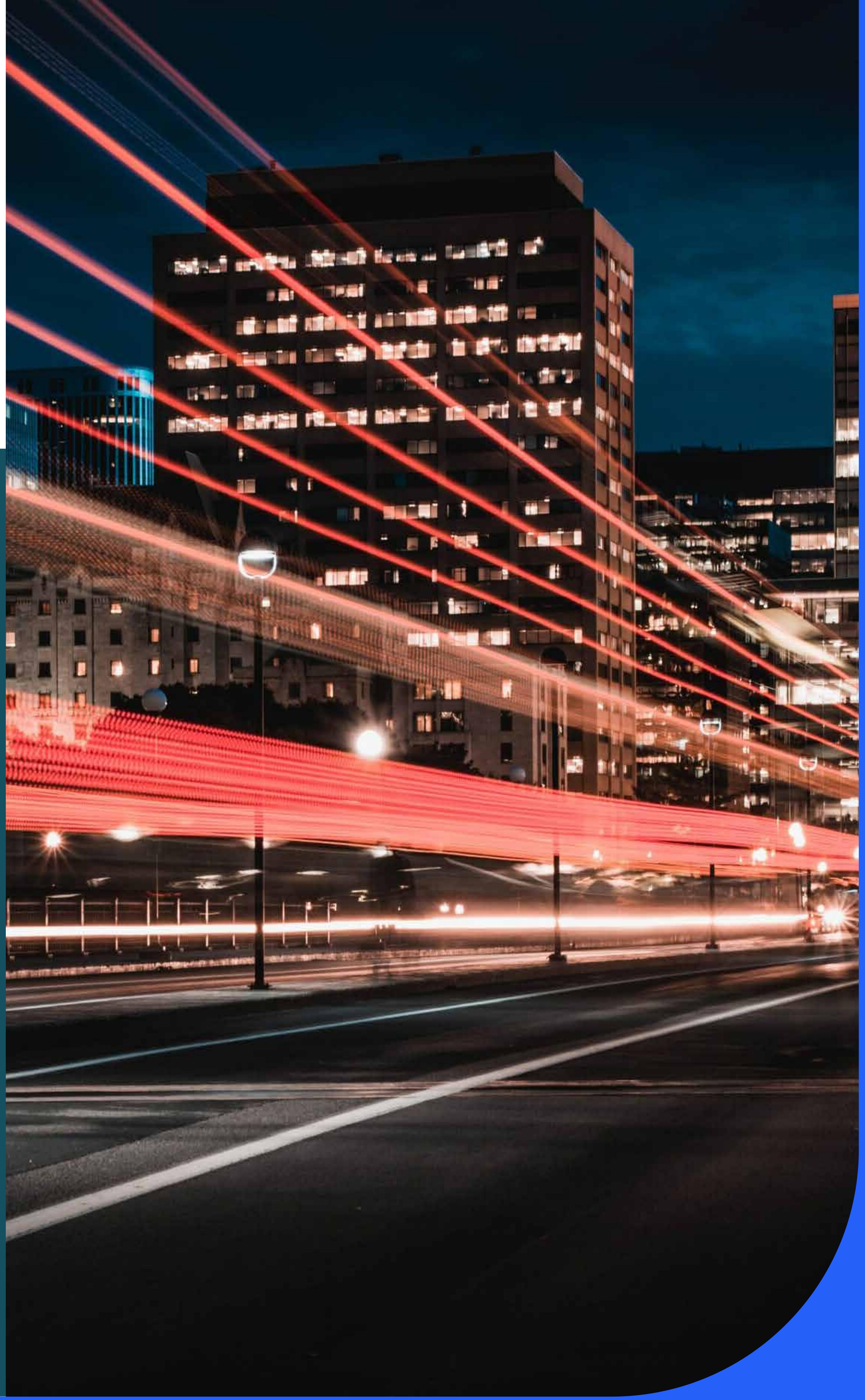
Figure 1. Value Chain

METHODOLOGY

This research was conducted by mapping the electricity technology ecosystem, categorizing companies based on value chain steps (VC steps), and analyzing how the companies were distributed across the value chain.

The electricity ecosystem database comprises technology companies, enablers, and knowledge generators. The value chain mapping and analysis focused on the companies, which were included based on the following criteria:

- Are involved in electricity technology innovation, research, and development. Excluded based on these criteria are project developers, utility companies, independent power producers, suppliers, distributors, service providers, and consulting/law firms, unless they also have their own technology.
- Are headquartered in Canada or have a strong Canadian presence in electricity technology innovation, research, and development. Examples of a strong presence would include companies with a dedicated research and development branch located in Canada or a Canadian subsidiary with its own technology that has retained its brand identity. In the electricity sector, utilities, independent power producers, and research institutions often work with international companies for feasibility testing and commercial demonstration (e.g., the Canadian Hydrokinetic Turbine Test Centre's testing of OPRC’s commercial RivGen system in Manitoba and Ontario Power Generation’s commercial demonstration of UNSC’s Micro Modular Reactor). While supporting research facilities may be included in the knowledge generators tab, the international technology companies involved are not included in the database.
- Have a valid website or online presence.



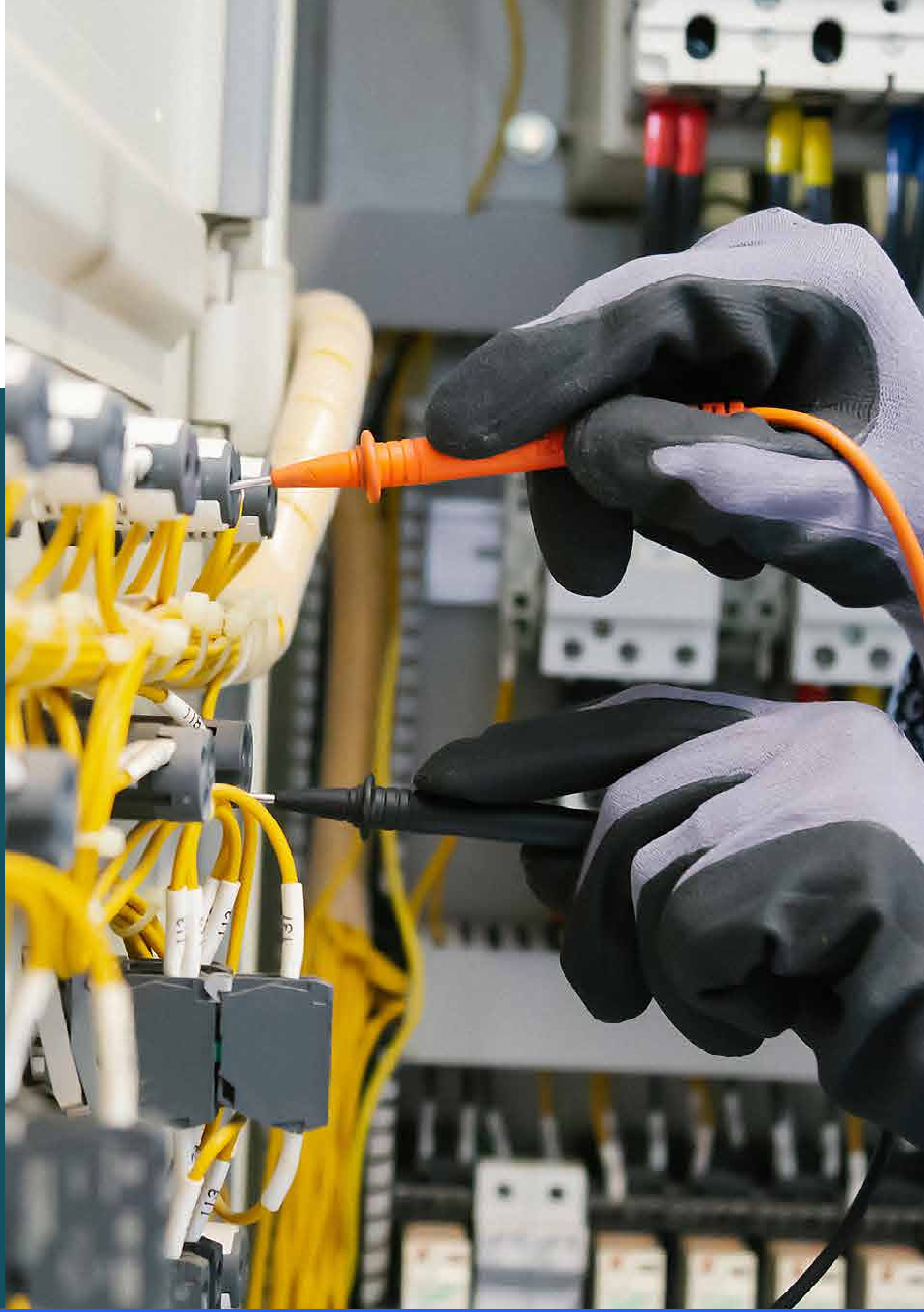
METHODOLOGY

Companies were categorized to up to two VC steps based on their innovation focus, then analyzed to identify both regional and national trends. Functional classifications, comments, and secondary research were also used to provide additional context to the trends. [4] Because the data can only indicate clustering and concentrations, and not why trends exist, observations are communicated as:

- **Areas of strength:** Areas where the data and supporting research suggests that the electricity technology sector is doing well and should continue to support.
- **Opportunities:** Areas where the data and supporting research suggests that there is an opportunity to grow, either because of minimal or uneven concentrations or because it is an area that can help meet the growing need for sustainable solutions.

See Appendix B for a more detailed methodology.

[4] The key functional classification used to better distinguish within categories was based on the climate adaptation technology (CAT) framing and taxonomy, which is the intellectual property of Mazarine Ventures LLC, available to all under the Creative Commons (CC) license. It distinguishes between technologies that address (effect change), analyze (interpret, understand trends), and observe (measure and monitor).



CANADA'S ELECTRICITY TECHNOLOGY COMPANIES

CANADA'S POWER TECHNOLOGY COMPANIES

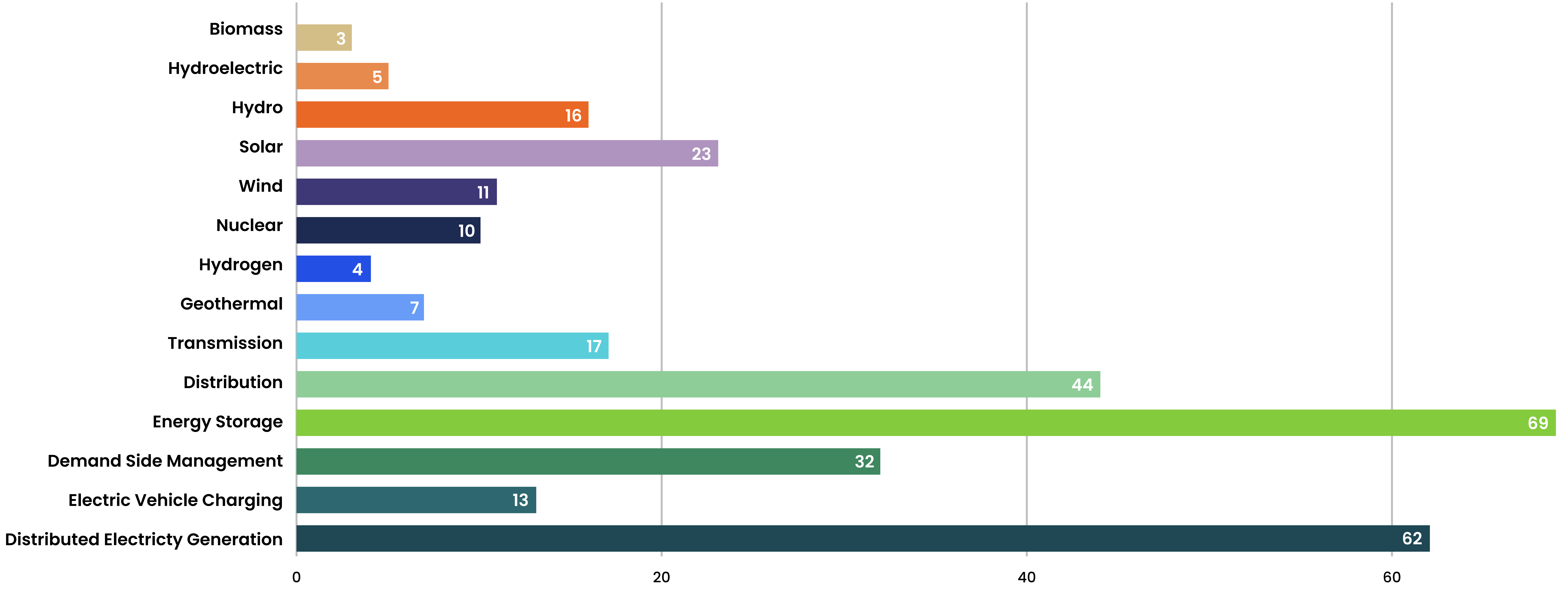


Figure 2. Distribution of Canadian Electricity Technology Across the Value Chain

245 companies are assigned to the electricity value chain.

- The top three VC steps with the highest number of companies assigned are energy storage **(69)**, distributed electricity generation **(62)**, and distribution **(44)**.
- While each large-scale generation VC step (biomass, geothermal, hydroelectric, nuclear, solar, hydrokinetic, and wind) is smaller individually, there are **76** combined.[5]
- Solar is the most prominent generation step.
- Companies that analyze and/or observe [6] are clustered in the demand side management, distribution, and transmission steps.

[5] The combined total includes some that do more than one so does not add up to the combined totals of each.

[6] See description of the functional classification based on Mazerine Ventures' framework in the Methodology section

Overall, most of the technology innovation represented in the database tends to be clustered in one of the following two themes:

- Modular and scalable technologies to enable a transition to a more renewable and distributed electricity grid. These types of technologies are prominent in distributed electricity generation, energy storage, and solar, hydrokinetic, and wind electricity generation.
- Technologies that optimize, integrate, and monitor infrastructure and processes, such as those represented in transmission, distribution, and demand side management VC steps and some of those in energy storage.

PROVINCIAL & REGIONAL TRENDS

This section explores how the companies are distributed geographically.

Understanding where companies are clustered provincially and where the regional centers of innovation are located can provide some valuable insight on how innovation happens across Canada's diverse landscape.

Overall, several combined factors contribute to the innovation landscape.

One key factor is variation in **resource availability** and, as a result, the **composition of provincial electricity grids**:

- Electricity grids in Quebec, British Columbia, Manitoba, Newfoundland and Labrador, and the Yukon are predominantly hydroelectric and Prince Edward Island's is predominantly wind.
- Alberta, Saskatchewan, Nova Scotia, and Nunavut rely heavily on fossil fuels such as petroleum and natural gas.
- Ontario, New Brunswick, and the Northwest Territories have more mixed grids. [7]

While there is not always a direct correlation between electricity grids and the types of electricity generation technology represented in the database, these variations do play into how the technologies are distributed provincially. For example:

- A concentration of nuclear technologies in Ontario does correlate with the province's current grid.
- Concentrations of hydrokinetic technologies in British Columbia and geothermal technologies in Alberta can be connected to geography and resource availability.

How the **provincial market is regulated** could also affect innovation. For example, Alberta's deregulated market likely plays a role in attracting innovators to Calgary. In contrast, Quebec's vertically integrated market could be a factor in the province's comparatively lower representation in the database.

Population density also plays into how technology companies are clustered regionally. While it is to be expected, technology innovation also clusters in larger centres where there are existing technology ecosystems. However, as electricity technologies affect all communities, there may be some opportunities to foster innovation clusters beyond the major centres.

[7] Reference data for these points, Canada Energy Regulator Provincial and Territorial Profiles

PROVINCIAL TRENDS

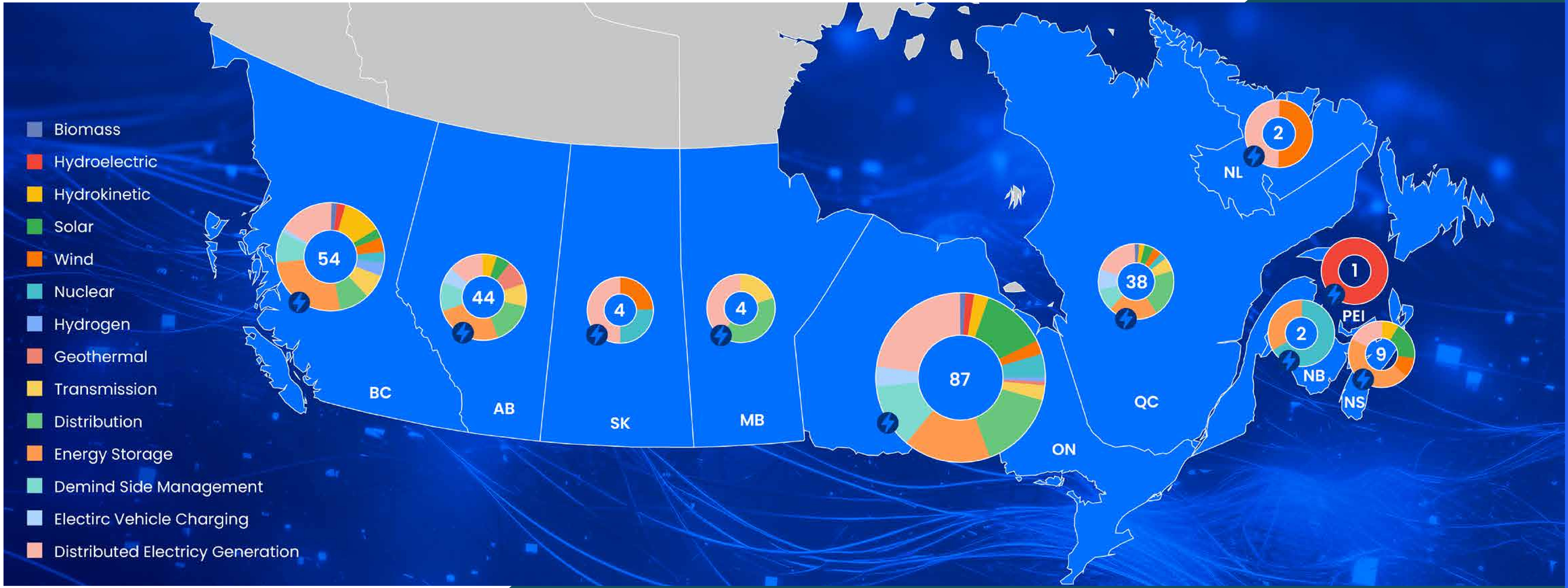


Figure 3. Provincial Value Chains

» All provinces are represented in the database. No companies are headquartered in the territories. Many of the companies, even if headquartered in one of the more densely populated regions, serve other provinces and territories as well.

» Not all steps are represented in every province, but the provincial value chains are consistent with trends observed in the overall value chain, with some variations and exceptions.

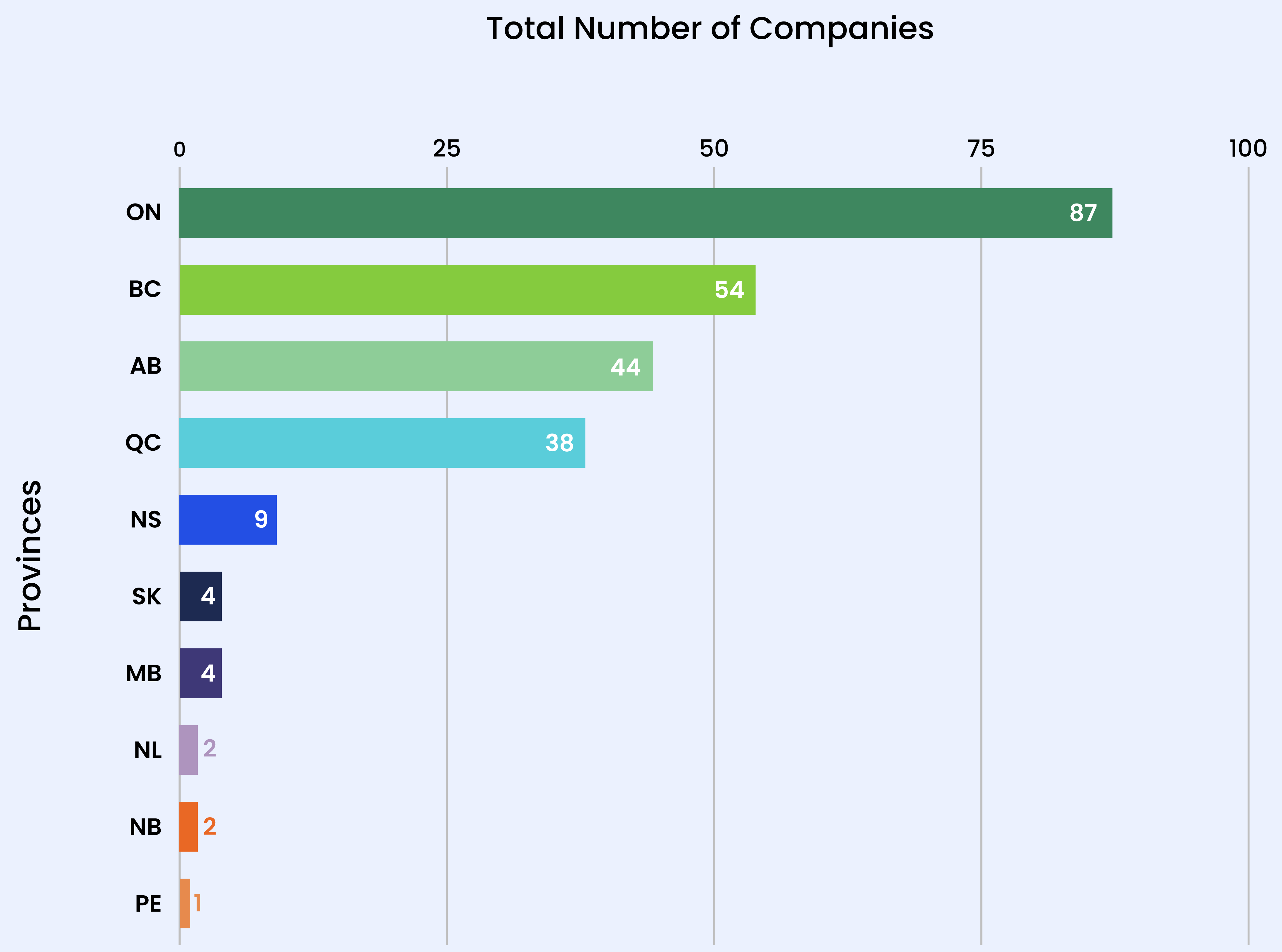


Figure 4. Total Companies by Province

» Companies are, unsurprisingly, clustered in the four most populated provinces, Ontario, British Columbia, Alberta, and Quebec (Figure 4).

» When looking at the distribution proportionally by population, British Columbia, Alberta, and Nova Scotia stand out (Figure 5).

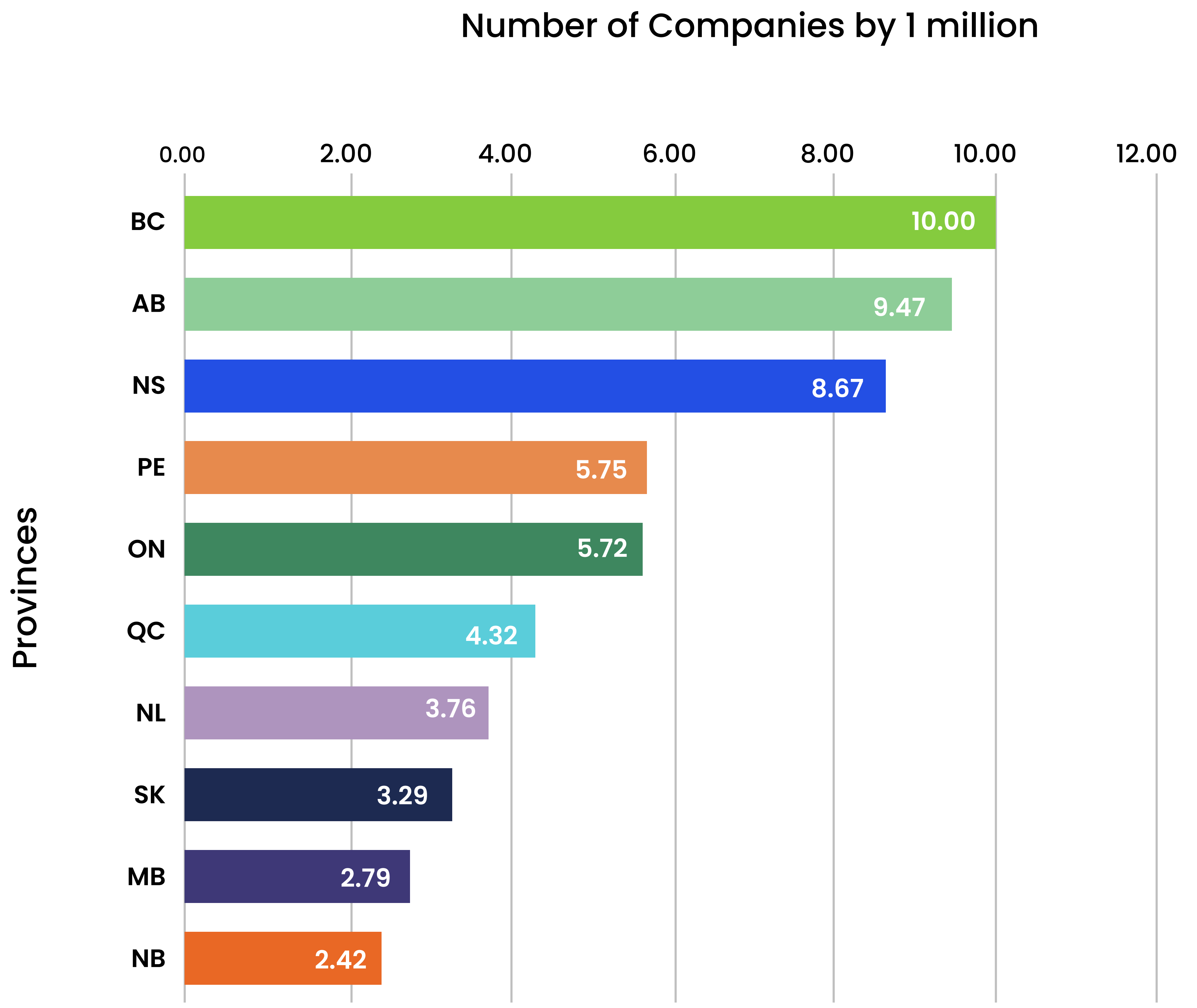


Figure 5. Number of Companies by Population

SUMMARY OF KEY PROVINCIAL TRENDS

The following summarizes key highlights in terms of strengths, clusters, and overall trends for each province represented in the database. Most of these strengths and clusters are discussed in more depth in the later sections of this report.

PROVINCE	HIGHLIGHTS
Ontario	» Area of strength in solar generation » Cluster of nuclear generation » Generally well-distributed value chain » Highest nominally in almost all VC steps but only the highest by population in solar. Both the province's population density and its regulatory structure with a lower level of vertical integration likely contribute to it being strong across many VC steps.
Bristish Columbia	» Area of strength in hydrokinetic generation » Area of strength in electricity generation with remote applications » British Columbia has a strong climate policy framework, which may contribute generally to strong representation across the value chain. For example, in 2008, the province was the first region in North America to implement a broad-base carbon tax.[17]
Alberta	» Area of strength in geothermal generation technologies » Generally strong representation across the value chain likely relates to the prominence of the energy industry overall in Alberta (including fossil fuels) and the province's deregulated market.
Québec	» Lower representation in total and by population compared to the other populated provinces » As they already have a primarily renewable grid, Quebec may be focusing innovation efforts in ways that might not be as well captured in the database, either because it is in an adjacent subsector such as transportation or because the innovation might focus on process improvement. Quebec's vertically integrated electricity market may also play a role.
Nova Scotia	» Most represented among the less populated provinces, and all companies are in the Halifax area.
Manitoba	» While there are only four companies, two are located in rural communities.
New Brunswick	» While there are only two companies, they are both in nuclear generation.

Saskatchewan, Prince Edward Island, and Newfoundland and Labrador have limited representation with no clear trends.

CENTRES OF INNOVATION

Nearly one quarter (178 of 245) of the companies in the database are located in large metropolitan areas with populations of over one million. This is to be expected, as larger centres attract technology development. Overall, the types of technologies represented in these large metropolitan areas are consistent with their corresponding provincial trends.

The prominence of these key clusters highlights that innovation does not happen in a vacuum and is driven by key factors such as:

- Presence of academic institutions and research facilities
- Industry-led associations and initiatives
- Government support through incentives and funding

Figure 6 and 7 identifies innovation clusters in Canada's six largest census metropolitan areas (CMAs) by total and by population.[8] Toronto, Vancouver, and Calgary come out on top. This is consistent with Startup Genome's global cleantech startup rankings that place the Toronto-Waterloo Corridor, Vancouver, and Calgary 12th, 16th, and 26th respectively. [18]

[8] Source for population data and census metropolitan area definitions is Statistics Canada. Table 98-10-0003-01 Population and dwelling counts: Census metropolitan areas, census agglomerations and census subdivisions (municipalities), https://doi.org/10.25318/9810000301-eng

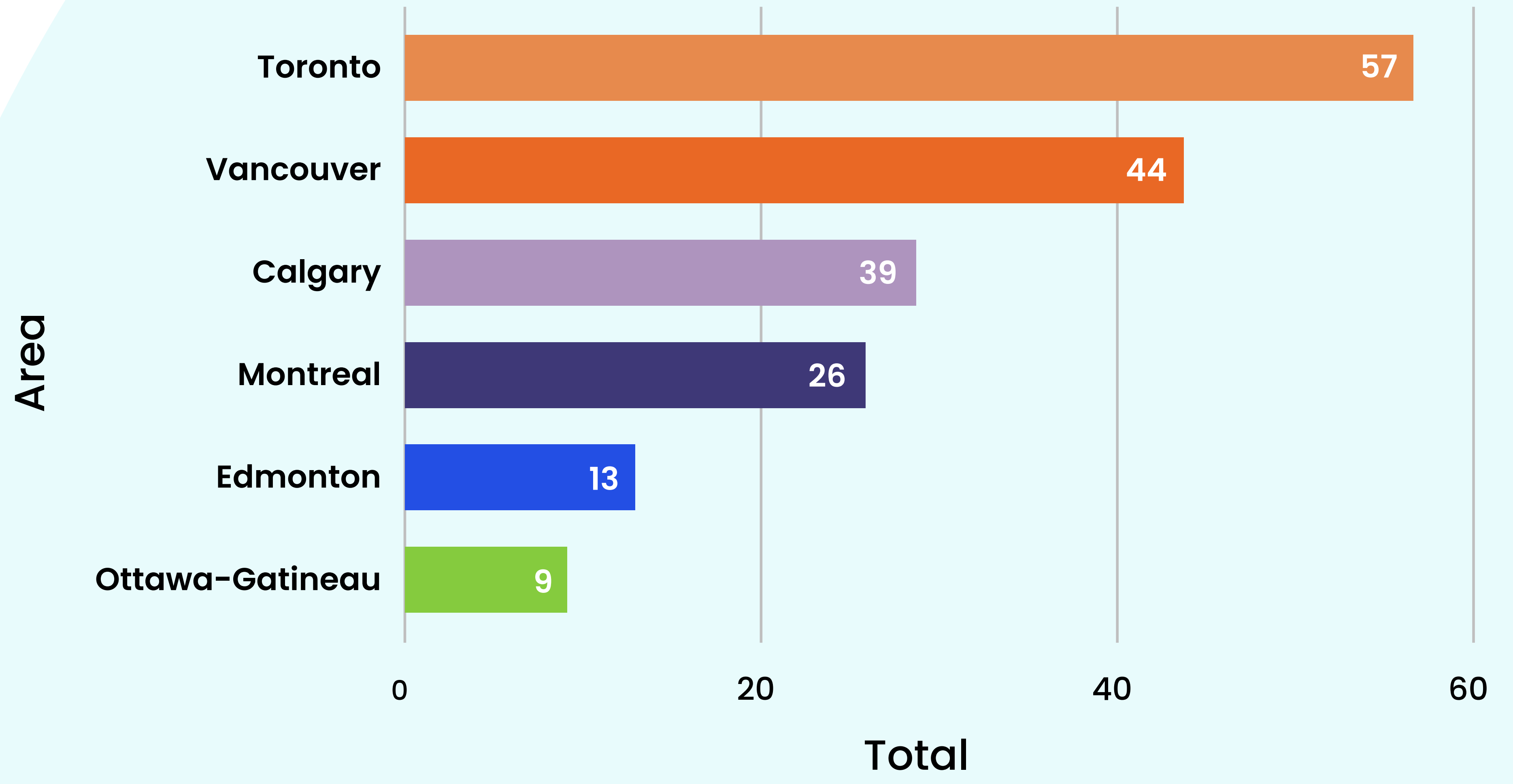


Figure 6. Total Companies by Metropolitan Area

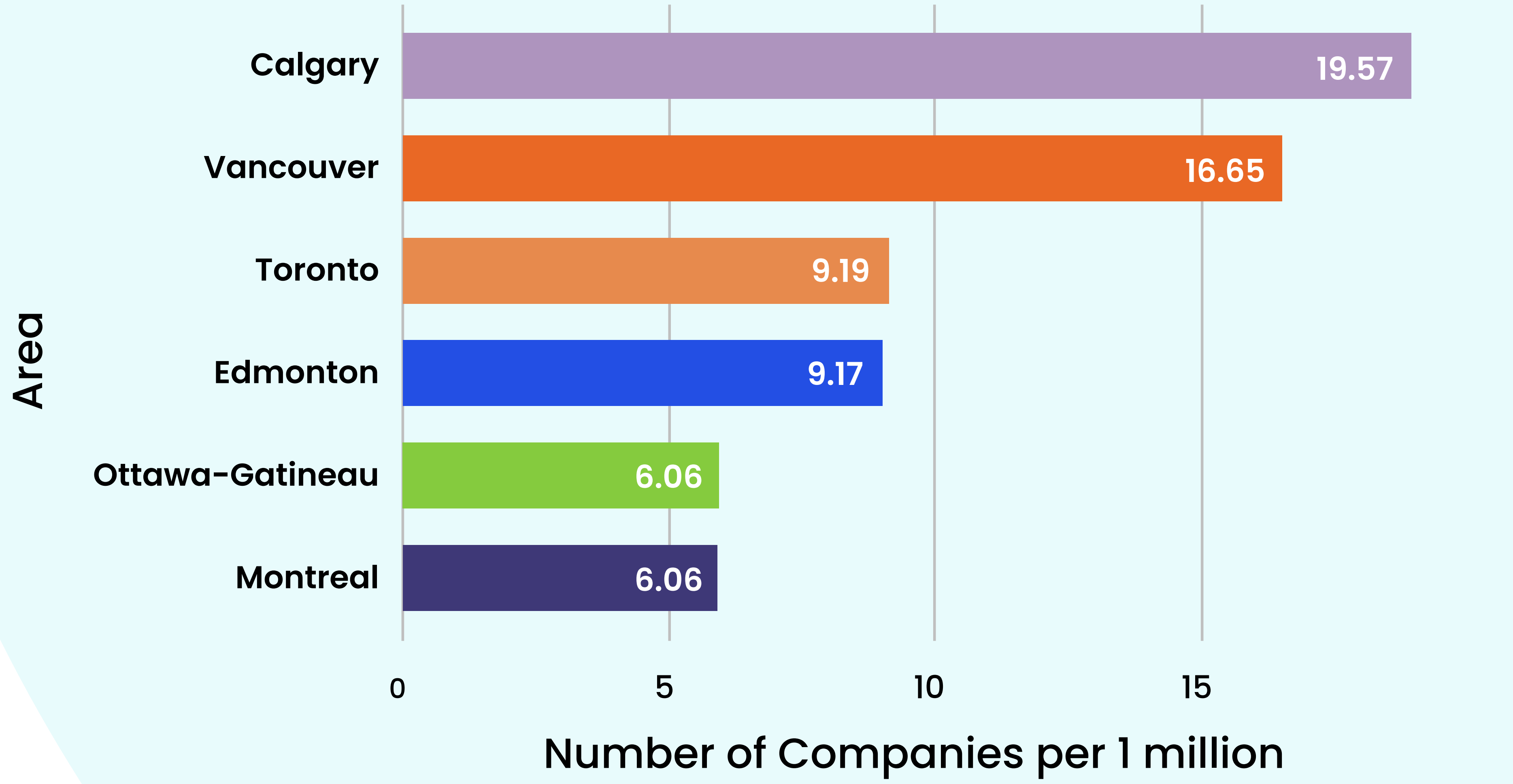


Figure 7. Total Companies in Metropolitan Areas by Population

OBSERVATIONS

By population, **Calgary** is the most prominent metropolitan area.

DATA

By population:

19.57

Total:

29

Energy Storage:

12

DISCUSSION

Calgary is a growing centre of technology innovation with a particular focus on cleantech and the energy transition. [19] A combination of municipal support, a lively ecosystem of enabling organizations (e.g, Calgary Economic Development, Platform Calgary), and academic institutions is supporting this development. Alberta's deregulated electricity market also likely plays a role in encouraging innovators to come to Calgary.

In particular, Calgary is home to several knowledge generators and enablers that relate to Alberta's stronger VC steps such as energy storage and geothermal. For example:

- Calgary Advanced Energy Storage and Conversion Research Technologies (CAESR-Tech) Group
- Centre for Energy Research and Clean Unconventional Technology Solutions
- Battery Metals Association of Canada
- Canadian Geothermal Energy Association (CanGEA)

The energy storage companies include a range of battery chemistries, containerized systems, and second life technology. This clustering is also consistent with findings from the Ventures to Value Chains: Mining Technology sectoral report and the presence of many companies and support organizations enabling innovation across the battery value chain.

OBSERVATIONS

Vancouver is the second most prominent metropolitan area both by total and population

DATA

By population:

16.64

per 1 M

Total:

44

Energy Storage:

17

DISCUSSION

Vancouver has a strong cleantech cluster that is supported by a long history of climate action and support. For example:

- The city has a strong framework of climate strategies such as the Climate Emergency Action Plan and the Greenest City Action Plan. [20]
- Vancouver is home to several knowledge generators and enablers such as Clean Energy Canada, the Canadian Hydrogen and Fuel Cell Association, and Microgrid Testing Facility.

Vancouver's strengths generally align with the province's, but there is a slightly larger proportion of energy storage technology. Hydrogen fuel cells are an area of particular innovation expertise. [21] Half of the hydrogen energy storage companies in the database are in Vancouver (four of eight).

OBSERVATIONS

Toronto has the highest total number of companies, but is much lower than Calgary and Vancouver by population

DATA

By population:

9.19

per 1 M

Total:

57

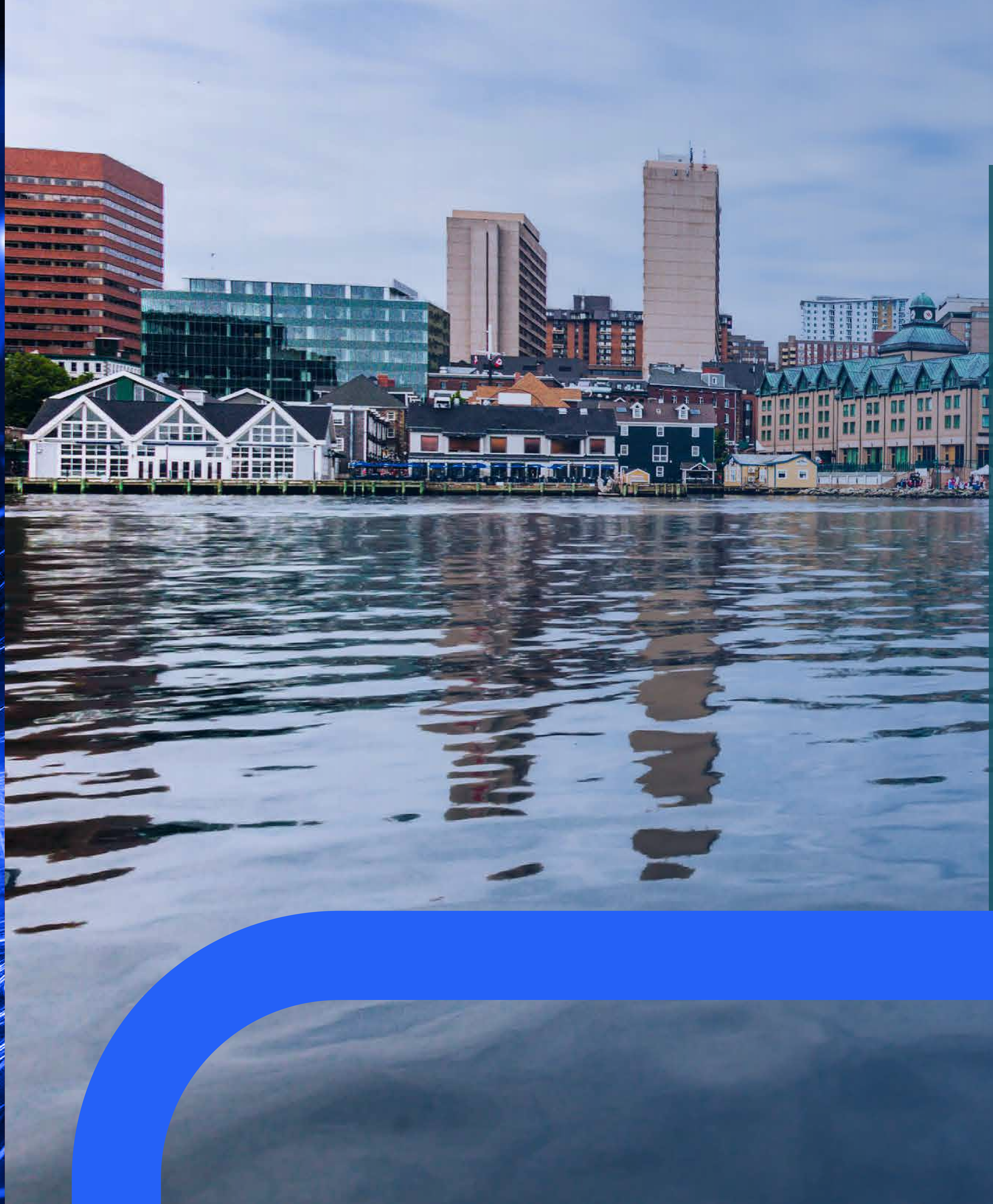
DISCUSSION

As it is Canada's most populated area, the Greater Toronto Area (GTA) having a large concentration of technology companies is not unusual. The prominent knowledge generators and enablers in the GTA align with Ontario's provincial strengths including solar, nuclear, and demand side management. Examples include the CANDU Owners Group, TREC SolarShare Co-operative, the Centre for Urban Energy, and the Centre for Power and Information.

While not part of the Toronto CMA, the Kitchener-Waterloo-Cambridge CMA (eight companies) and other cities in Southern Ontario are also well represented in the database.

OPPORTUNITIES FOR INNOVATION OUTSIDE OF LARGER CENTRES

The database shows that some innovation is happening in smaller cities and even in rural communities. All communities are affected differently by the energy transition. While larger centres can provide good innovation climates, smaller hubs may offer valuable thought diversity to the innovation landscape.



Innovation in Smaller Regional Centres: Halifax as an Atlantic Canadian Hub

Smaller regionally important centres might provide good opportunities for innovation. For example, Halifax has nine companies, the most of CMAs with populations under a million. Halifax is home to over 290 startups and scaleups, globally recognized educational institutions, and several innovation and startup accelerators and incubators, most with a general focus or focused on other subsectors such as the maritime industry. [22]

An electricity innovation cluster in Halifax could provide opportunities to support the province's efforts to reduce reliance on fossil fuels and provide Atlantic Canada with a centre for innovation more focused on the region's needs.

Indigenous, Rural, and Remote Communities

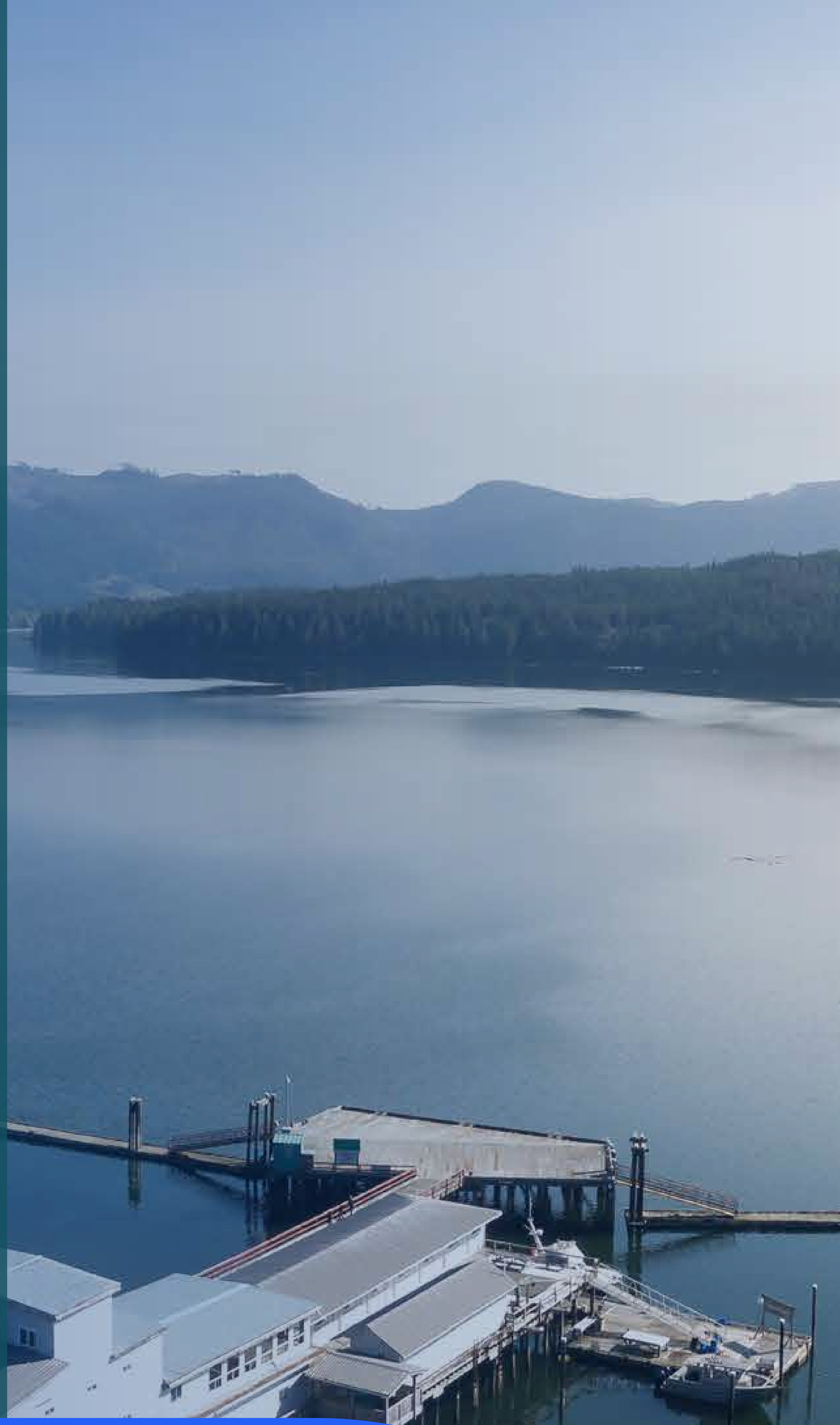
There could also be opportunities to support innovation in small population centers and rural areas.[9] While they are not prominent, small population centres and rural areas are represented in the database (12 small population centres and four rural areas). These range from more remote areas to small centres near larger ones. Key trends within them include:

- The most represented VC step is distributed electricity generation with seven companies
- Two of the four companies in rural areas are located in Manitoba

The Organisation for Economic Co-operation and Development (OECD) identifies that innovation in rural areas often focuses on a specific problem, process improvements, and adaptations. [23] Therefore, this database does not necessarily capture a full picture of innovation in rural Canada. For example, many of the projects funded through the Wah-ila-toos: Clean Energy in Indigenous, rural, and remote communities program are capacity building or deployment projects rather than technology development ones. [24]

In particular, Indigenous-led development has been a focus of federal strategy and programming. [16] In their scoping paper on Indigenous leadership in the clean energy sector, Indigenous Clean Energy states: “First Nations, Métis, and Inuit entities are partners or beneficiaries of almost 20 per cent of Canada’s electricity-generating infrastructure.” [25] While most of the programming focuses on project development, technology innovation specific to the communities they serve may also be required to support those developments.

[9] Defined based on Canadian Census definitions 2021: https://www12.statcan.gc.ca/census-recensement/2021/ref/dict/az/Definition-eng.cfm?ID=geo049a



Indigenous-led clean energy development projects have grown by 26.6% since 2017.

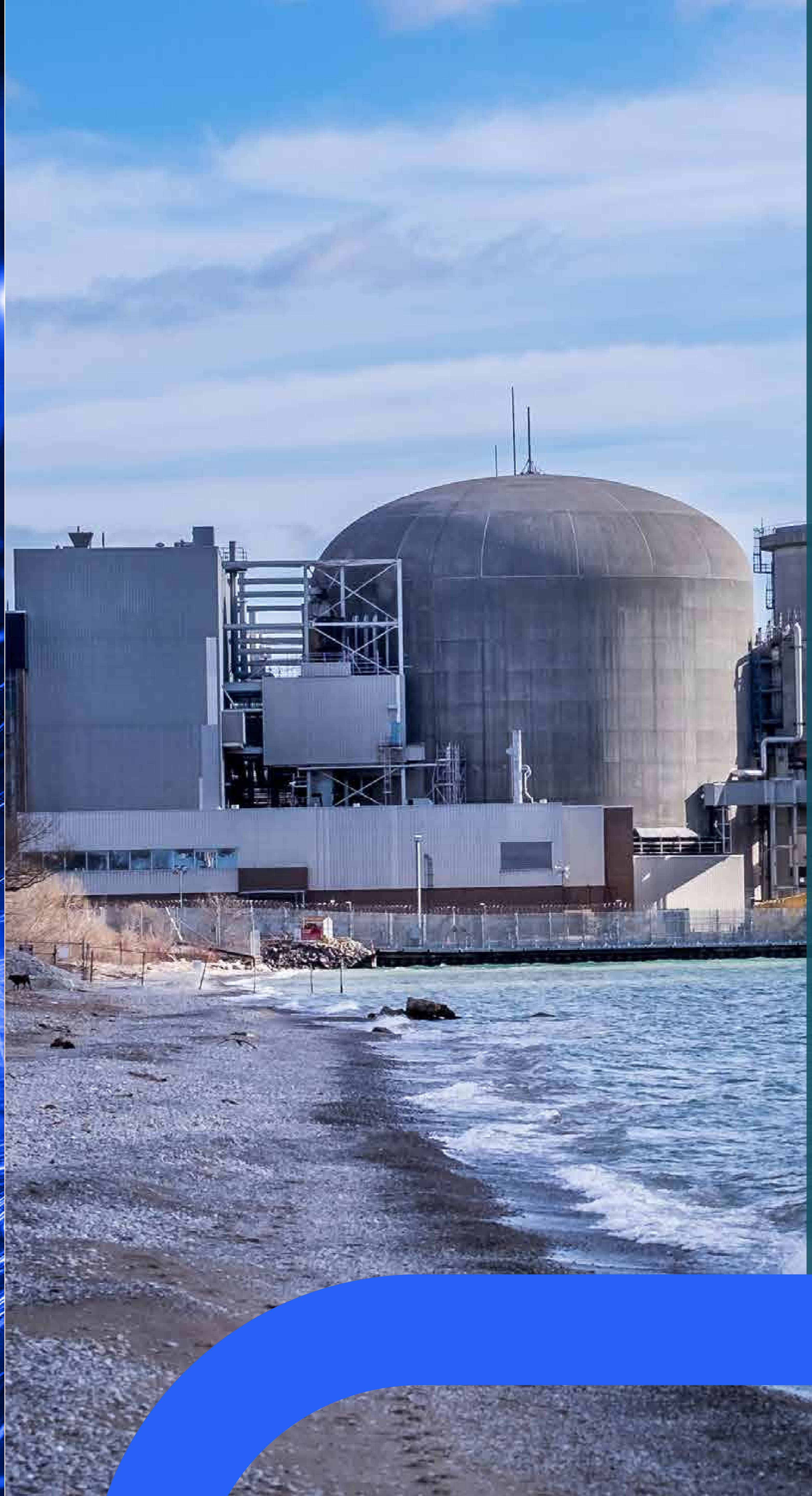
- Indigenous Clean Energy [25]

Considerations

While these numbers are not significant enough to indicate any strong trends, they could be a starting point for thinking about how innovation can develop differently in smaller centres. For example:

- What role does innovation in distributed electricity generation technology outside of larger centres have in enabling adoption?
- How does innovation happen differently in provinces with lower population densities, and what is the value of innovating in a more distributed versus centralized way?

DIVERSE AND DISTRIBUTED RENEWABLE AND NON-EMITTING ELECTRICITY SOURCES



This section explores the electricity generation steps and what they suggest about technology innovation trends in enabling a more diverse and distributed electricity grid.

It also explores the role of energy storage as an enabler. Overall, innovation in the electricity sector has a strong focus on supporting diverse and distributed electricity grids as electricity generation, large- and small-scale, makes up almost half of the companies in the database (114 of 245), and energy storage is the most represented VC step on its own (69).[10]

[10] For the purposes of this database, large-scale generation is defined as over 100 kW and small-scale under 100kW. Not all companies identified the scale of their technologies and some modular technologies could be applied to both. Companies without a clear scale were assigned based on qualitative factors such as marketing, case studies, news articles, and customer lists.

Figures 8 and 9 break down the types of electricity generation represented in the database.

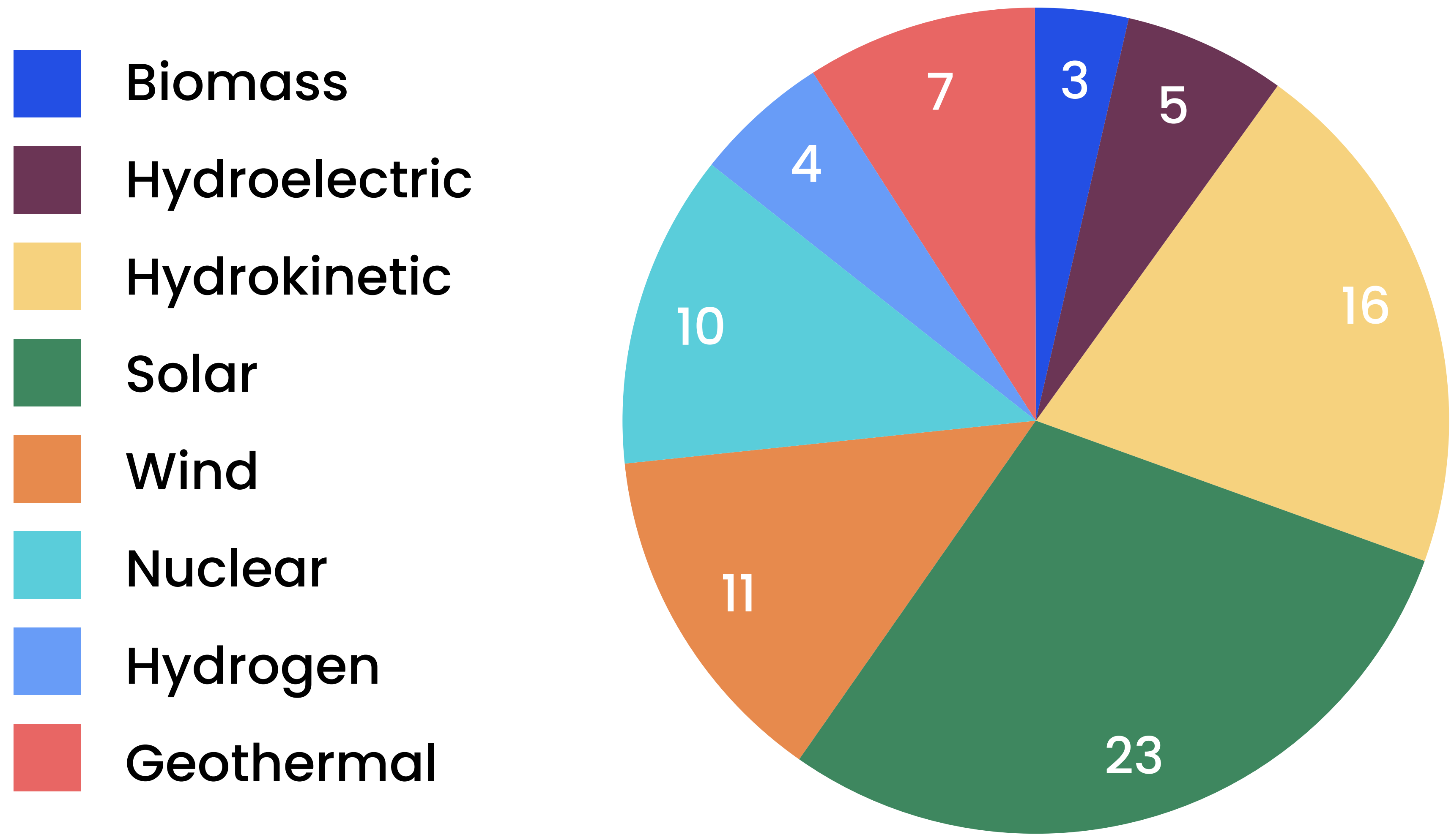


Figure 8. Large-Scale Generation Steps

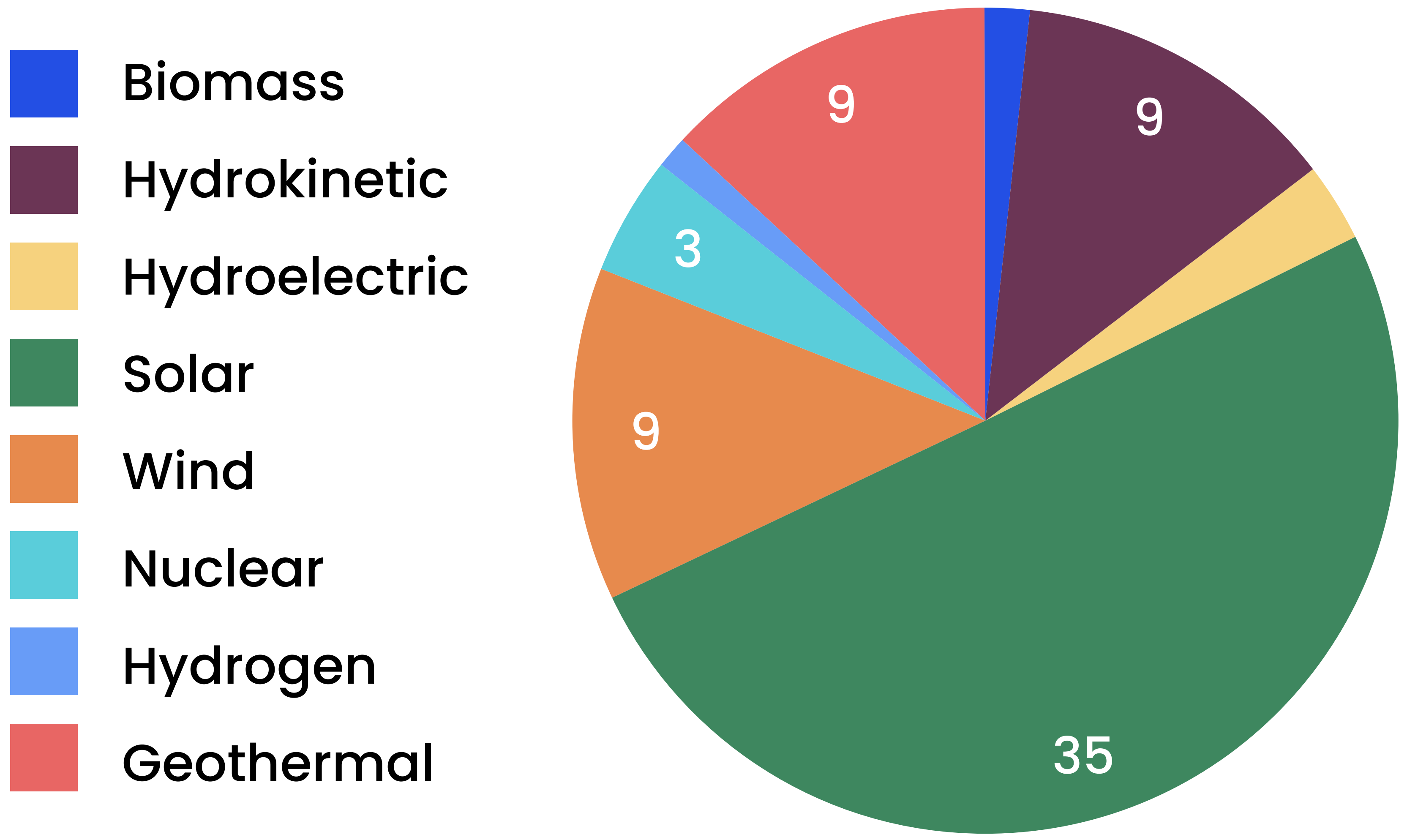


Figure 9. Small-Scale Generation (Keywords within distributed electricity generation)

Accessibility, speed of technology development, and provincial contexts all likely play a role in how technologies are clustered. Solar, hydrokinetic, and wind technologies are typically more modular and can be an easier entry point where innovators can start small and scale up when compared to infrastructure-heavy, tightly regulated, or geographically constrained methods like geothermal and nuclear. Mature technologies such as hydroelectric generation are also less represented, as efforts may be focused more on optimization, infrastructure upgrades, or other incremental and procedural changes that are often managed through utility companies and not captured in the database.

Growth in adoption and interest in non-hydro renewable and non-emitting electricity sources also likely plays a role in technology innovation. In the past decade, non-hydro renewables such as solar and wind have grown considerably and are expected to continue to grow. [26] While hydroelectric generation dominates Canada's electricity grid, hydroelectric capacity varies significantly across the country and some provinces have to focus on other sources for the energy transition. Alberta, for example, has implemented specific microgeneration regulations as one of their strategies to support the province's transition to renewable electricity. [27] Even provinces with a high hydroelectric capacity are feeling the pressures of increasing demands and are looking to new electricity sources to help meet them. For example, British Columbia recently issued a call for new sources of renewable, emission-free electricity.[28, 29]

Note that since project developers and system integrators and other service providers are out of scope of this database, the insights only cover a snapshot of technology development in the subsectors, while recognizing that process innovation also plays an important role in the journey to a renewable and non-emitting electricity grid.

SOLAR

Solar is the most reflected electricity generation technology in the database. Key factors likely include:

» Solar is the fastest growing renewable generation technology globally and is projected to grow steadily in Canada.[30, 31]

» It is becoming less expensive to adopt: for example, costs have decreased by 80 per cent since 2010.[32]

» Solar generation provides opportunities for individuals and businesses to play a role in the energy transition.

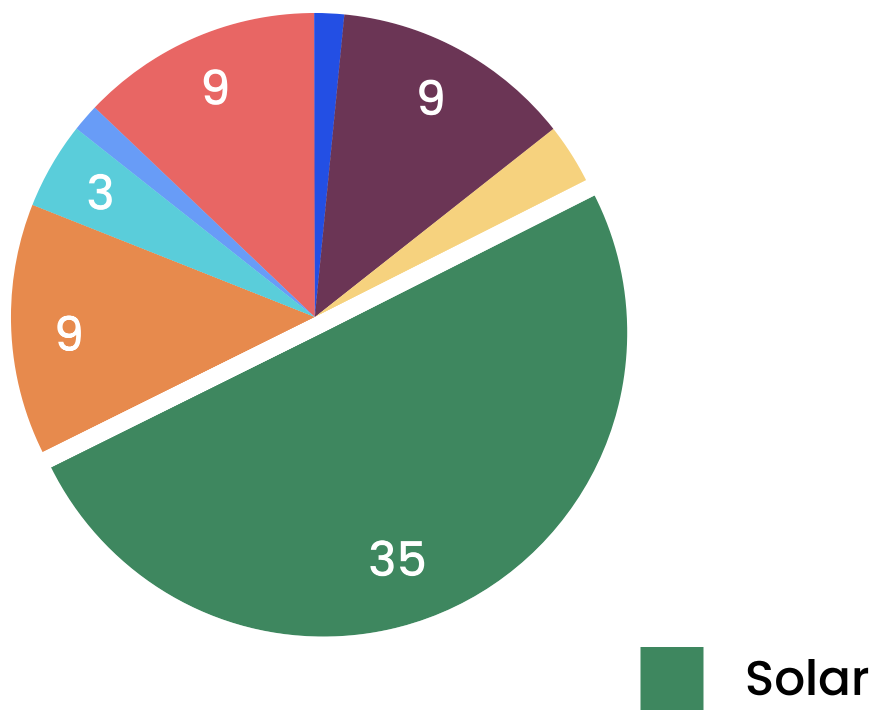
OBSERVATIONS

Solar generation is an area of strength overall and is the most represented, especially in distributed electricity generation.

DATA

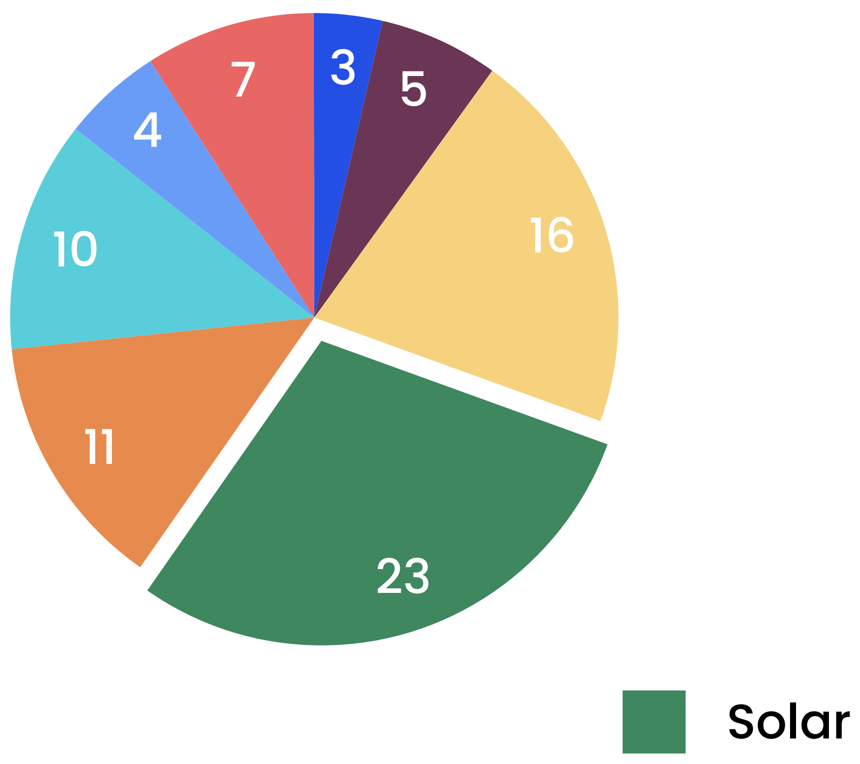
Distributed electricity generation keyword (small-scale):

- **Seven** are stand-alone systems



Solar generation (large-scale):

- **Six** observe and/or analyze
- **Four** are materials
- **Two** are infrastructure/support
- **10** companies overlap between the two VC steps.



DISCUSSION

The companies in distributed electricity generation are predominantly those that actually do the generation. These mostly comprise rooftop systems or small microgrid systems, but there are also some integrated solutions such as solar sidewalks, windows, and other building materials. There is also a cluster of technologies that stand alone, and most of these are PV lighting systems.

The companies assigned to large-scale solar generation include technology innovations such as developments in solar panels, associated infrastructure, materials (e.g., coatings), and monitoring and analytics for solar facilities and solar project planning.

The data suggests that solar generation is:

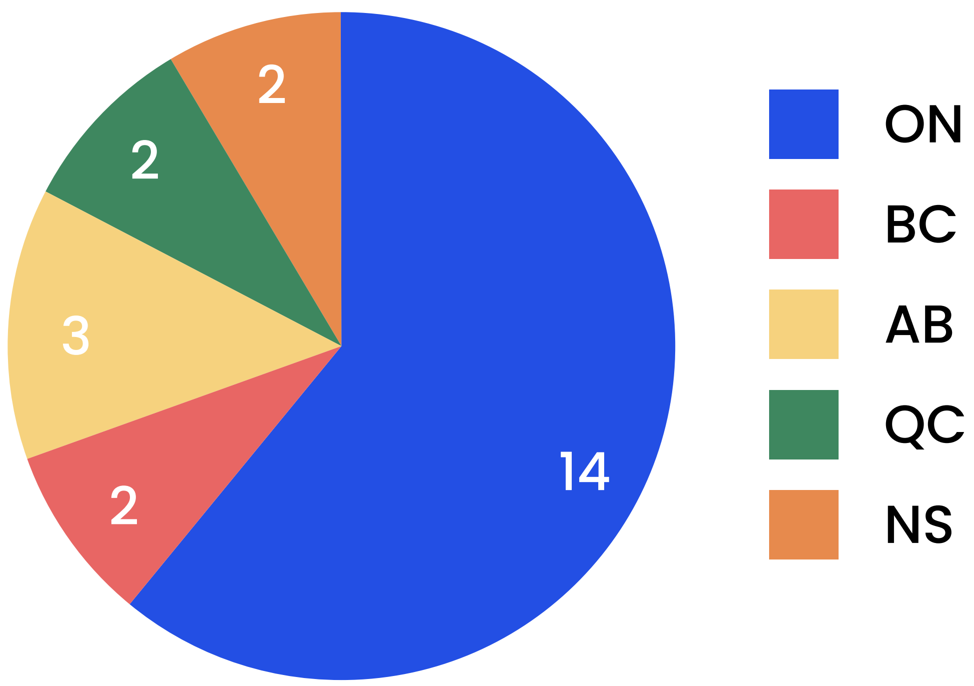
- **An attractive option for individuals and businesses:** Residential, commercial, and institutional users are the most represented, especially in distributed electricity generation. Adoption is supported by a range of incentives such as tax credits and rebates. For example, Energy Hub identifies 32 residential solar incentive programs across Canada. [33]
- **Scaling up**: CanREA states that utility-scale solar generation is "poised for significant growth," and the technologies in the database support this. [34] Utilities are the second most represented user. The overlap between large-scale and small-scale solar technologies, mostly modular panels and associated infrastructure, also suggests that technology is being developed with both markets in mind.

OBSERVATIONS

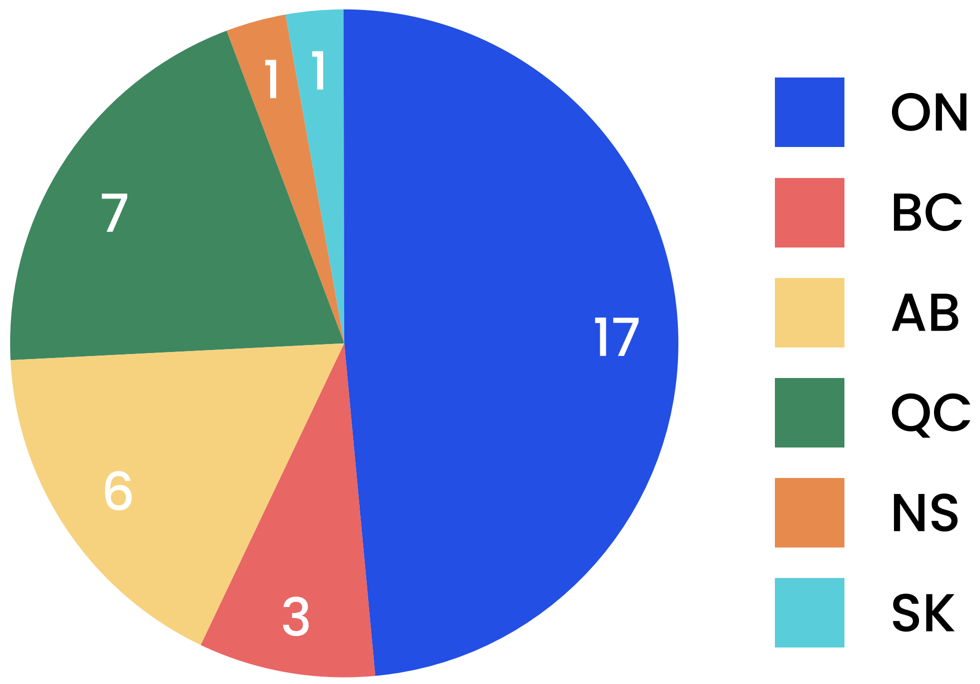
Solar generation, both large- and small-scale, is an area of strength in Ontario.

DATA

Solar generation (large-scale) by province:



Distributed electricity generation keywords (small-scale) by province:



DISCUSSION

Ontario has the largest installed solar capacity in Canada. [35] It is therefore understandable that technology development is clustered in Ontario.

There is also a slight cluster of companies that observe and analyze within large-scale solar generation. This could suggest a certain level of maturity to the sector in Ontario that enables technology developers to focus more on optimization going forward.

Ontario's large population and deregulated market are likely key factors in driving down the installation costs and making these technologies more accessible.

The Government of Ontario offers some incentive programming and several municipalities also offer incentives and rebates, but it is not centralized. [36] There may therefore be additional untapped opportunities for the province to build on this strength and enable adoption.

HYDROKINETIC

Growing Innovation

Hydrokinetic generation, including tidal, wave, and riverine systems, has many benefits:

- It is not intermittent while other methods like solar and wind are.
- The infrastructure is comparatively minimal and has less impact on the surrounding ecosystem compared to hydroelectric dams.
- Canada has abundant freshwater and marine resources and thus a lot of potential to embrace hydrokinetic generation, but it has been largely untapped. [37]

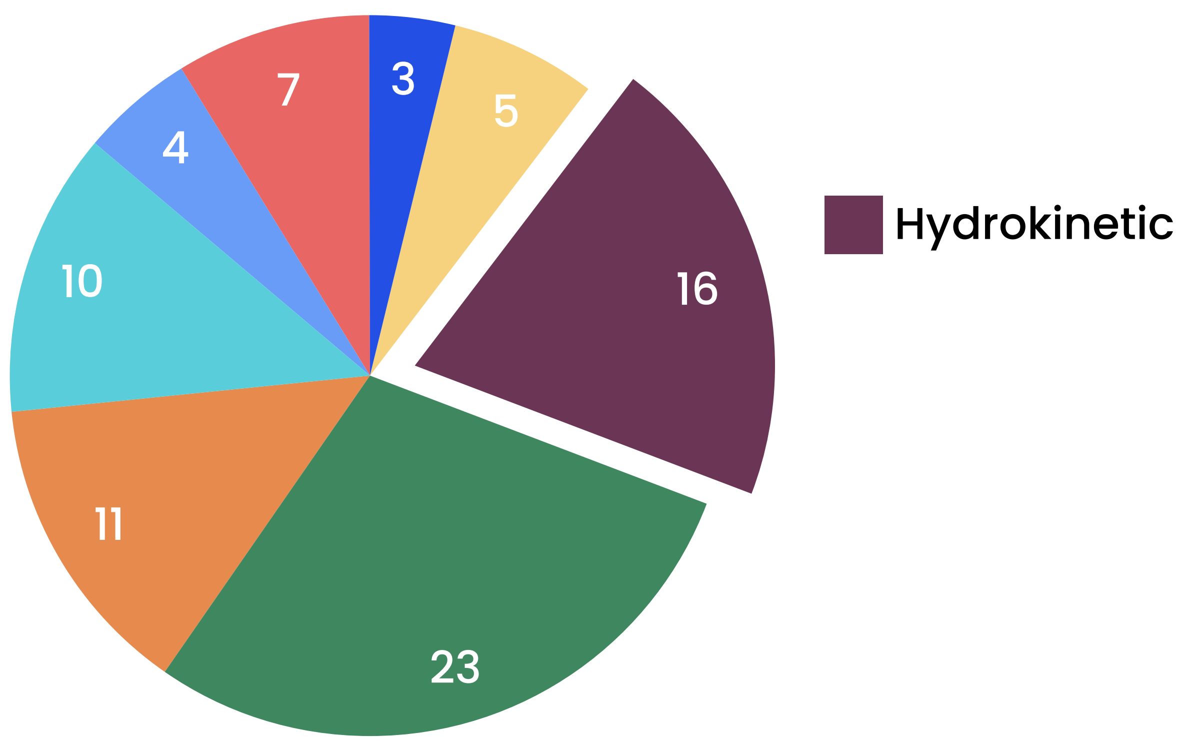
Global innovation in this space has been growing over the past 10 years; however, the technology is not mature and will require further research efforts to become sufficiently effective to gain traction.[38] The companies in the database reflect an ongoing commitment to growth and development in this space.

OBSERVATIONS

As the second most represented, hydrokinetic generation technology is a growing area of strength, but it is still in its earlier stages.

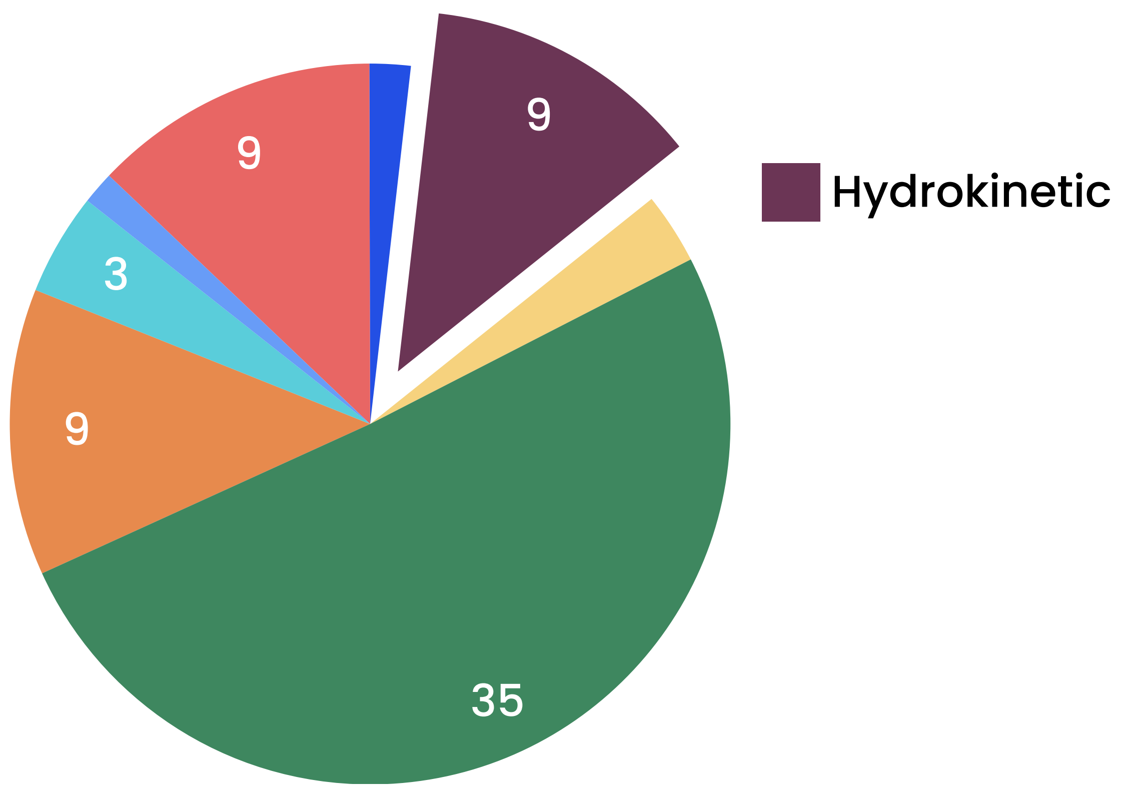
DATA

Hydrokinetic generation (large-scale):



Distributed electricity generation keyword (small-scale)

» **Six** companies overlap between the two VC steps



DISCUSSION

The technologies include both riverine and marine (tidal and wave) hydrokinetic generation. Most apply to both. Many are modular systems with both small-scale and larger-scale capabilities. A range of types of turbines are also represented.

Unsurprisingly, most of these companies are in provinces with hydroelectric dominated grids, as they depend on similar resources.

Many of these technologies are developed for remote applications. Provincial governments and hydroelectric utility companies are recognizing this opportunity. For example, a recent project in Manitoba focuses on establishing riverine hydrokinetic generation to reach regions off the hydroelectric grids.[39] Over the past decade and with remote communities in mind, Hydro-Québec has tested hydrokinetic turbines in the St. Lawrence River, and the Fundy Ocean Research Centre for Energy (FORCE) has tested tidal generation technologies in the Bay of Fundy.[40, 41]

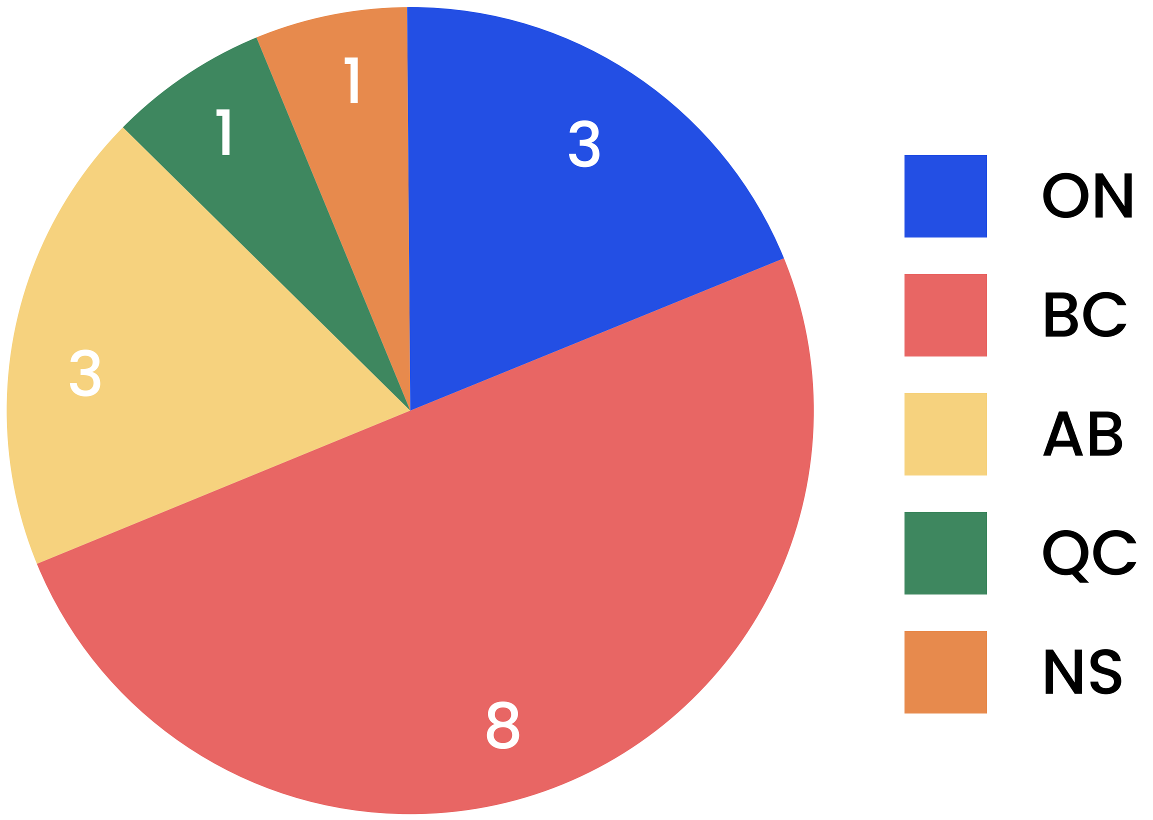
Most technologies are still pre-commercial, which is reflected in the database.

OBSERVATIONS

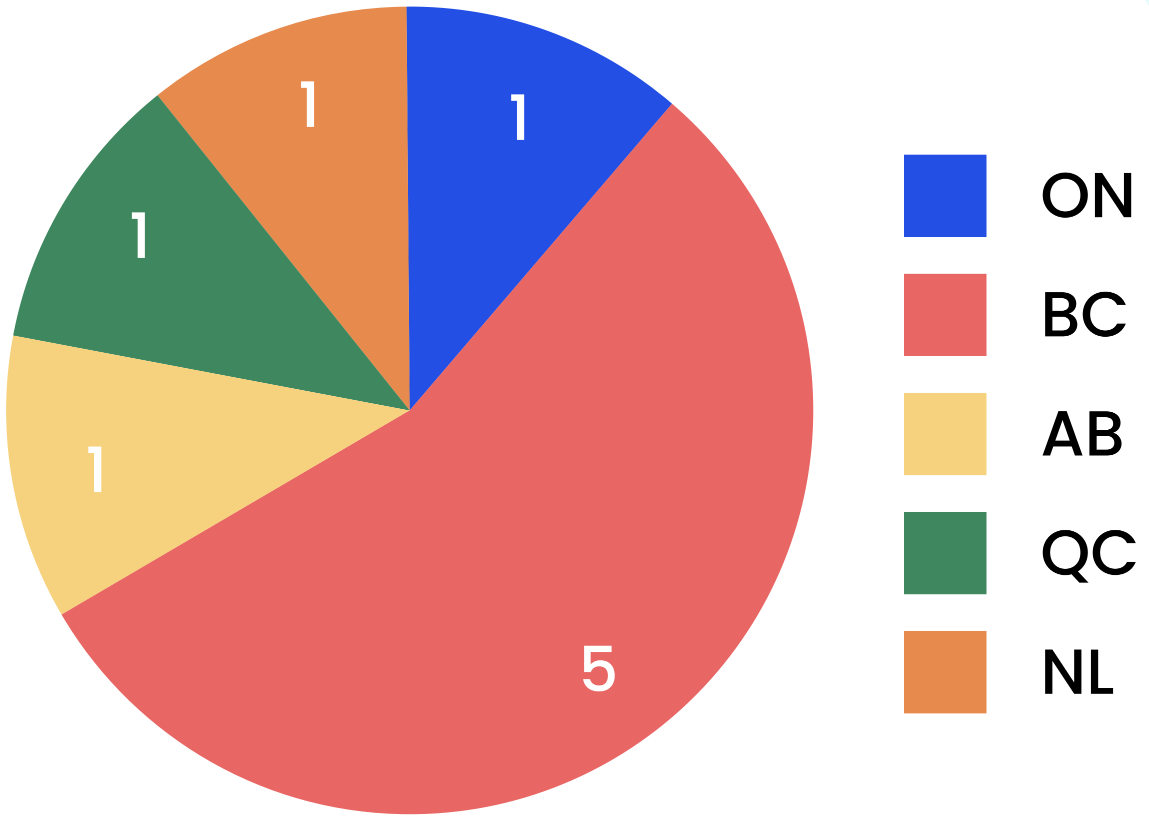
Hydrokinetic generation technologies are an area of strength in British Columbia.

DATA

Hydrokinetic generation (large-scale) by province:



Distributed electricity generation keyword (small-scale):



DISCUSSION

Overall, the trends among these companies are consistent with the overall VC step, though there is a slightly larger clustering of tidal technologies. Key factors likely include:

Natural resources: British Columbia is one of the provinces with the greatest hydrokinetic potential. [42]

Coastal cities: Major coastal cities like Vancouver and Victoria may provide opportunities for the technologies to be developed and tested close to educational institutions and other enablers.

Remote coastal population: Hydrokinetic projects in British Columbia have been recognized as an opportunity for serving the province's remote coastal communities. [43] Many of the companies in the database reflect this focus.

WIND

Stable and Well Distributed

Wind is both the largest and fastest growing non-hydro renewable generation source in Canada.[6, 44] In the database, wind technologies are the most well dispersed across the provinces (FIgures 10 and 11), but they are much less represented overall than solar and hydrokinetic. This is likely due to how the technology is applied, as most wind projects are utility-scale and use standardized technologies.[45]

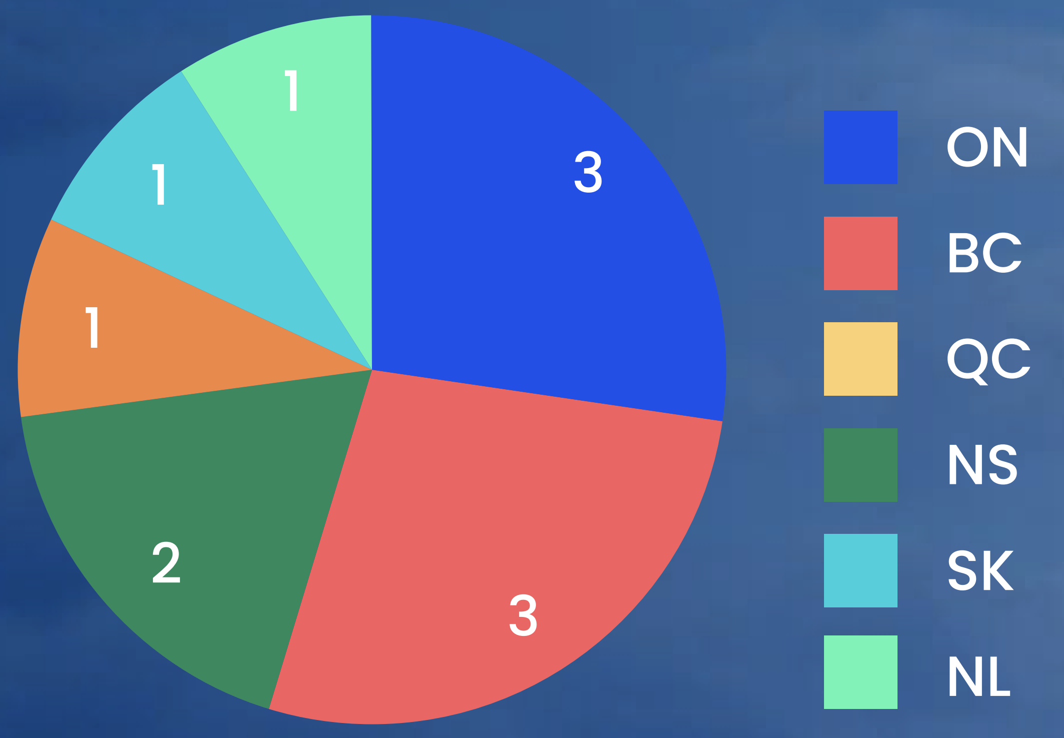


Figure 10. Provincial Distribution of Wind Generation

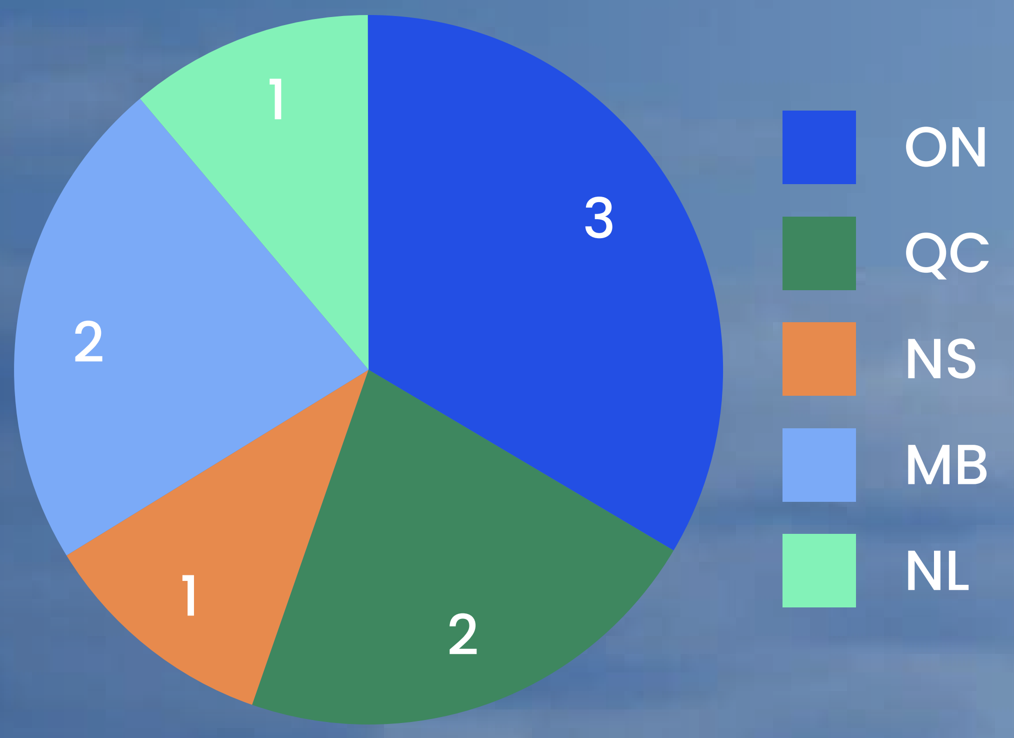


Figure 11. Provincial Distribution of Wind in Distributed Electricity Generation Chain

OBSERVATIONS

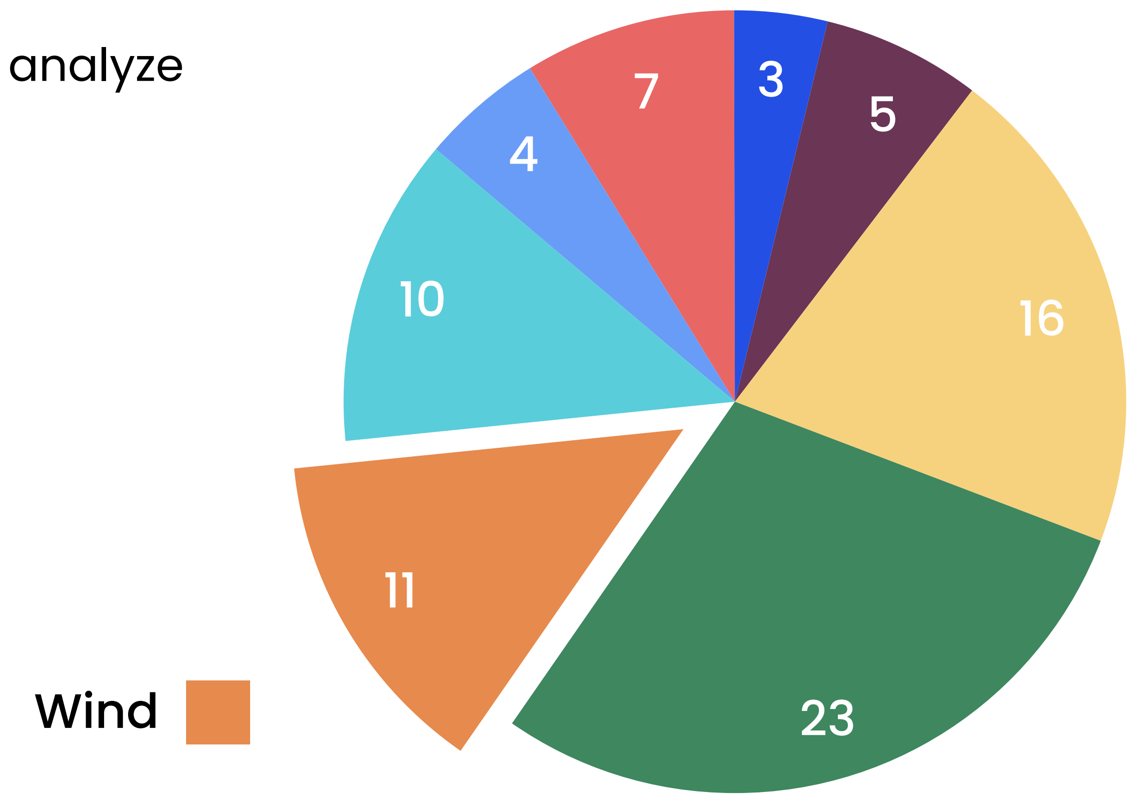
Wind is the third most represented large-scale generation VC step, and there is a cluster of companies that focus on optimization and analytics.

Wind is the second most represented keyword (tied with hydrokinetic) in the distributed electricity generation VC step.

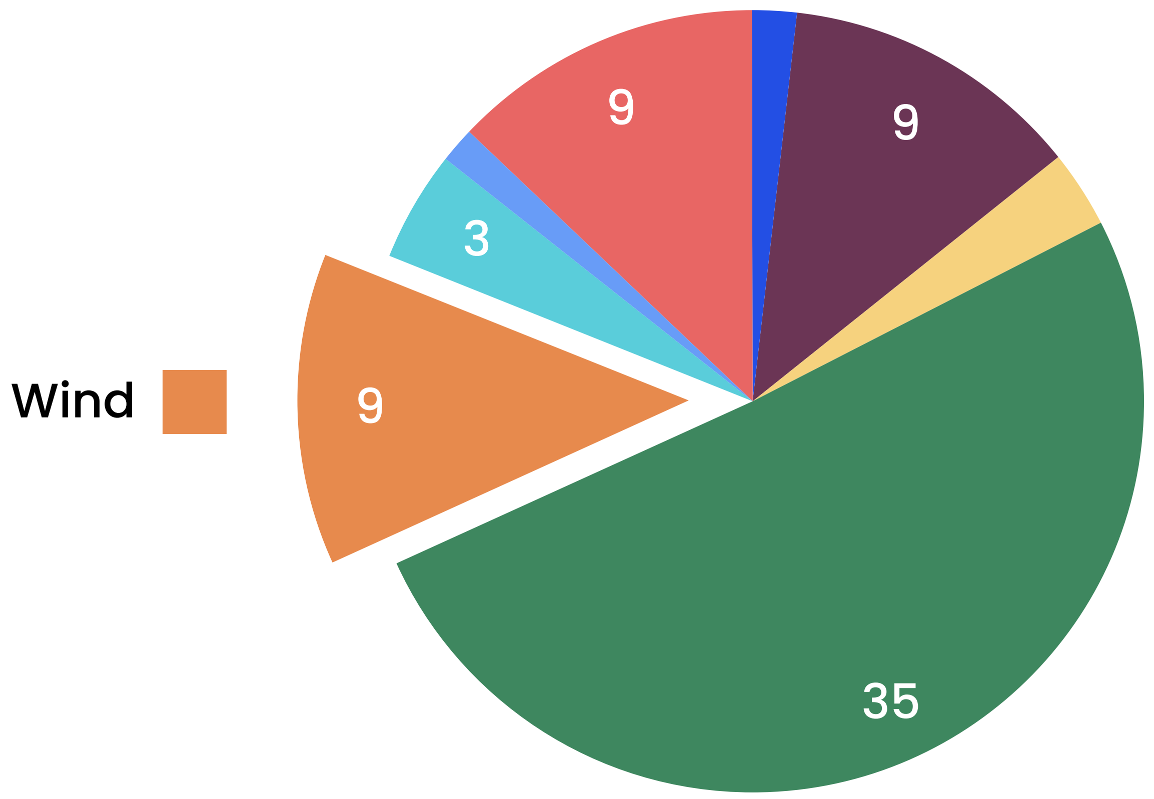
DATA

Wind generation (large-scale):

» **Six** observe and/or analyze



Distributed electricity generation keyword (small-scale)



DISCUSSION

Environmental monitoring and asset maintenance and analytics feature prominently alongside wind turbine and component innovations. This is likely due to wind facilities requiring very specific conditions to perform optimally.

Technologies represented include small-scale turbines in a range of configurations for smaller applications including microgrids, off-grid electricity, and stand-alone solutions.

NUCLEAR

A New Approach

Canada has historically been a leader in nuclear technology innovation, and nuclear generation makes up 15 per cent of our electricity grid. [46] However, many nuclear plants are nearing the end of their lives, and innovation is moving towards small modular nuclear reactors (SMRs). Compared to some of the other electricity sources in the database, innovation in nuclear generation will naturally be on a longer timeline in order to meet safety, regulatory, and community engagement requirements.

OBSERVATIONS

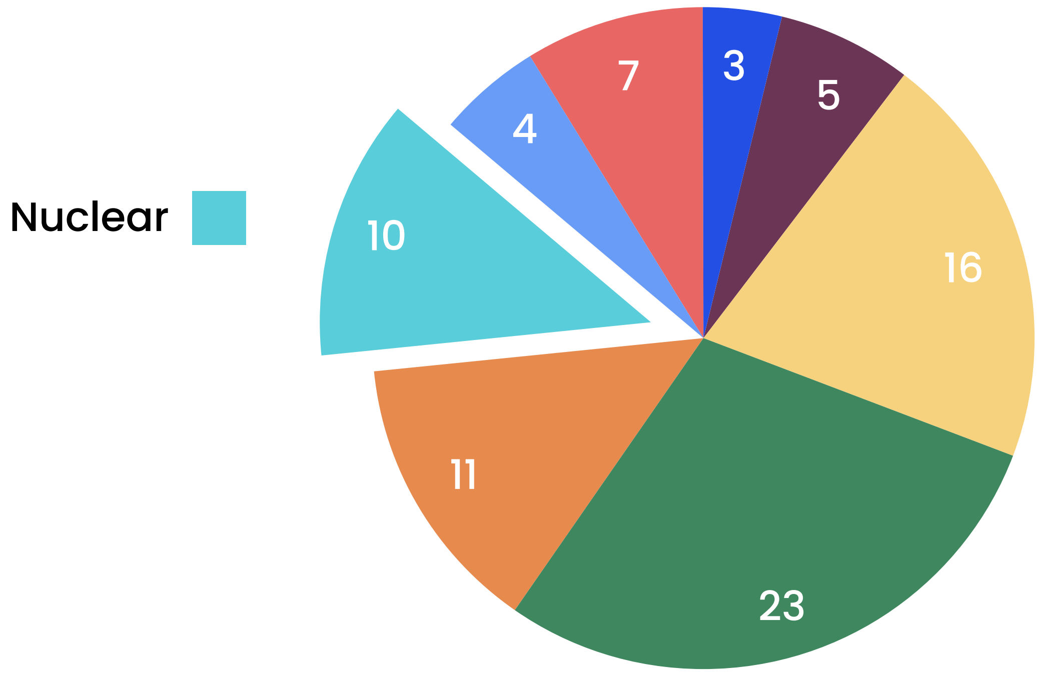
Nuclear is the fourth most represented large-scale generation VC step.

Regional clusters:

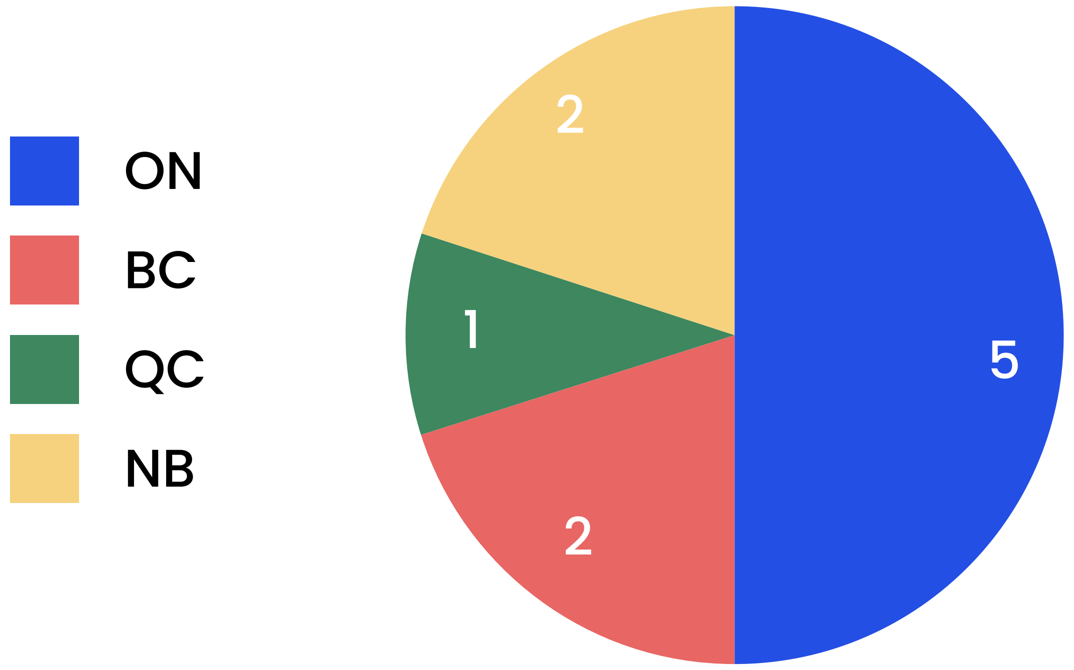
- Half are in Ontario
- All New Brunswick companies are assigned to nuclear

DATA

Nuclear generation (large-scale):



Nuclear generation (large-scale) by province:



DISCUSSION

Technologies represented are predominantly nuclear reactors, especially SMRs.

SMRs can be used for both utility-scale and microgrid applications. This direction aligns with ongoing strategic initiatives from the Federal government such as the SMR Roadmap and SMR Action Plan. [46]

Many of the companies in the database are in their earlier stages. The SMR roadmap recognizes that some innovative technologies are not yet mature and has thus made demonstration and proving new technologies one of the key priorities of the roadmap. [47]

Ontario and New Brunswick rely on nuclear generation for a significant portion of their electricity grids. As existing nuclear infrastructure ages, these provinces are looking to options like SMRs. Ontario is already working on deploying SMRs, and New Brunswick is in the planning stages of deployment. [16]

GEOTHERMAL

Opportunity for Some Regions

In Canada, geothermal energy is currently used for heating applications rather than electricity ones, and there is only one commercial geothermal power plant in operation. [48] Geothermal resources are dependent on geography, and British Columbia, Alberta, and the Yukon have the most potential in Canada.[48] Some other challenges that can affect the speed of innovation and adoption include the environmental and financial risks of resource exploration, long timelines and high costs for development, and social acceptance. [49] While geothermal generation may not have been an economically viable path in the past due to these challenges, recent developments in highly efficient geothermal technologies could open up opportunities for the future. [50]

There is a natural synergy between oil and gas and geothermal generation, which could make it a viable opportunity for the clean electricity transition in provinces like Alberta that currently depend on fossil fuels. Technologies, skill sets, and geographies often overlap between geothermal and oil and gas, so oil and gas companies are seen as a key contributor to enabling the transition.[51]

There are several efforts to tap into geothermal potential. For example:

- The federal government has expanded the Clean Technology Investment Tax Credit to include geothermal energy. [52]
- Alberta, British Columbia, and Nova Scotia governments have developed regulatory frameworks for geothermal energy.[48]

Other Electricity Generation Methods

Biomass and Hydrogen: The number of technology companies included in the database for electricity generation from biomass and hydrogen are quite low. However, for both of these, much of the innovation is in the production of alternative fuels, which was not included in the scope of the database and analysis. Canada does have a strong innovation landscape in the fuel production space.[53] Many of these insights are captured in the Canada's Ventures to Value Chains: Forest Bioeconomy sector report, or will be captured in future sectoral reports.

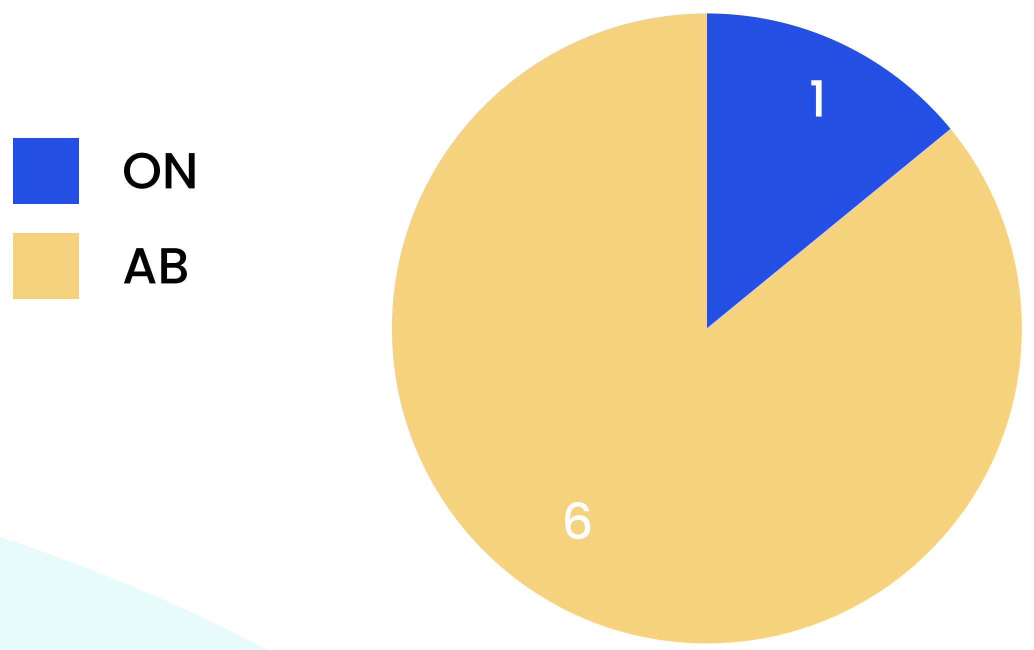
Hydroelectric: The lower representation despite this being the largest contributor to the Canadian electricity grid is likely due to the maturity of the sector and associated technologies, and the nature of innovation in this space often focusing on procedural or incremental changes and upgrades driven by utilities.

OBSERVATIONS

Geothermal generation is clustered in Alberta

DATA

Geothermal generation (by province):



DISCUSSION

Alberta is geologically well suited to geothermal generation and home to Canada's only commercial geothermal power plant at Swan Hills.[48]

The technologies represented are applicable to both geothermal heat and electricity applications. They include well-bore monitoring and imaging and innovations for facilities and infrastructure.

Many of the technologies also overlap with oil and gas applications. Geothermal could be an opportunity for redeploying well boring companies and employees.

ENERGY STORAGE AS AN ENABLER

With 69 companies total, energy storage is the most represented in the value chain and is also quite varied and well distributed across the country (Figure 11). Energy storage plays an essential role in enabling more diverse, distributed, and renewable grids, especially since sources such as solar and wind are intermittent. Energy storage can also help manage and optimize electricity distribution (this application is discussed later in this report).

CanREA describes energy storage as, "at a relatively early stage of development in Canada,"[54] which is also reflected in the database as there is a wide range of mature technologies and newer alternative technologies represented.

Ongoing federal initiatives such as the Clean Technology Investment Tax Credit and Smart Renewables and Electrification Pathways Program are currently key support structures to drive advancement in energy storage manufacturing and adoption.[55]

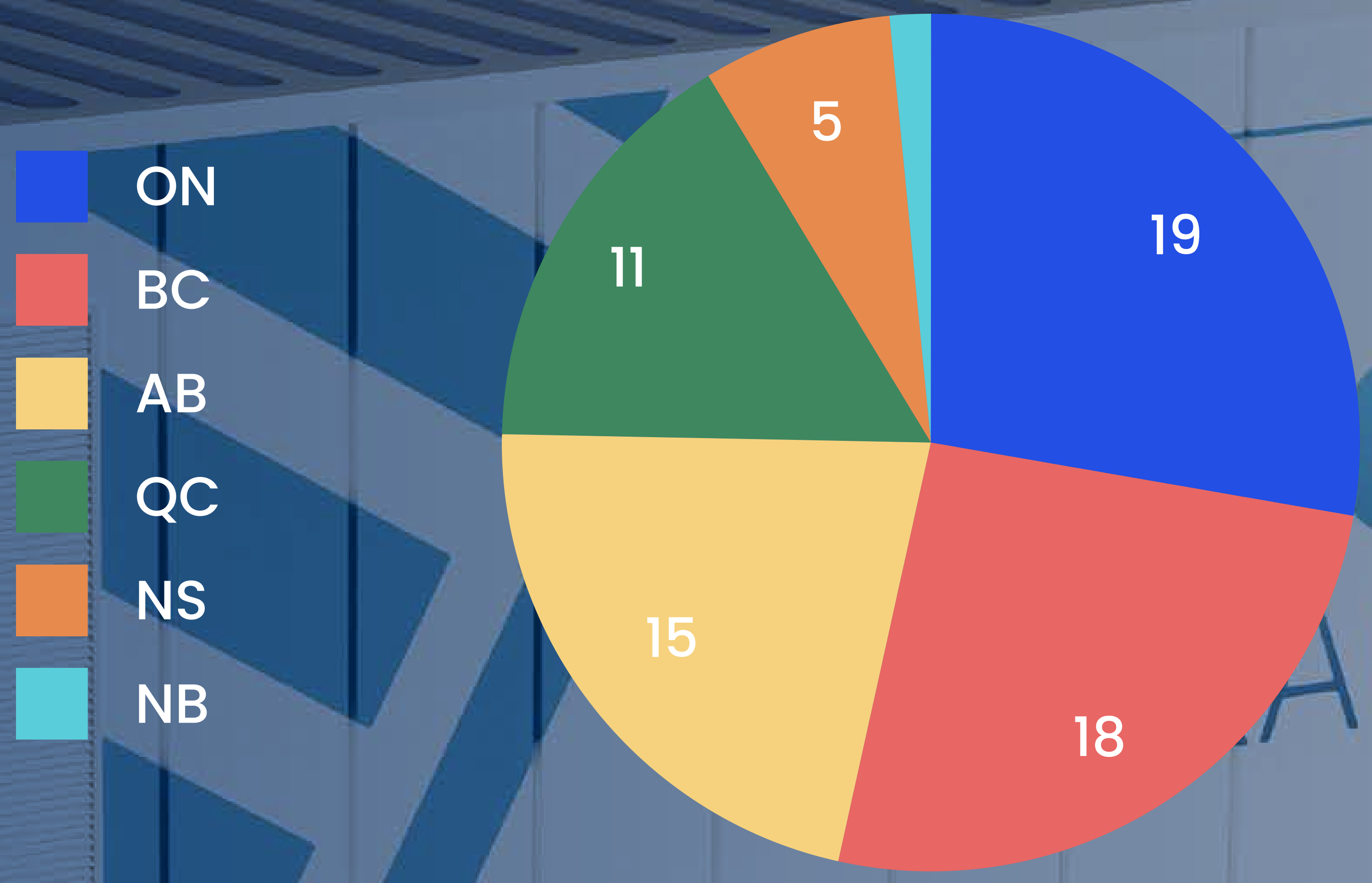


Figure 11. Energy Storage Companies by Province

OBSERVATIONS

Electrochemical energy storage is an area of strength.

Long-term energy storage technologies are an opportunity.

Microgrid, portable, and backup energy storage applications are present.

DATA[11]

27 of **69** companies assigned to energy storage are electrochemical energy storage systems, including materials.

13 of **69** are technologies that could have longer-term applications

See the discussion in the next section on reaching remote communities and sites.

DISCUSSION

The strong representation of electrochemical energy storage technologies in the database is consistent with the fact that they make up the largest portion of the energy storage market. [56] Among the electrochemical storage technologies in the database, lithium-ion energy storage systems are most prominent, but there are several other battery chemistries represented (e.g., sodium-ion, silicone gel). There are also some companies represented that focus on second life applications for electric vehicle batteries.

While lithium production is not considered in this database, Canada ranks sixth in the world in lithium reserves and eighth in terms of production, and is thus well positioned to support innovation in battery energy storage. [57]

In terms of enabling electricity generation from diverse and distributed sources, many of these technologies are modular and easily adapted to many applications. Battery energy storage is also the preferred solution for wind and solar applications, and it is seen as a viable solution in the energy transition. [58]

In the Canadian Climate Institute's *Bigger, Cleaner, Smarter. Pathways* report, they identify short-term grid storage such as lithium-ion battery storage as a "safe bet" for maximizing grid flexibility, while they identify long-term grid scale storage as a "wild card" due in part to a general lower level of technical maturity. [59] Technologies applied to long-term storage, such as hydrogen fuel cells, compressed air systems, pumped hydro storage, and flow batteries are present but not prominent in the database. There could be opportunities to grow.

[11] Note that the data within energy storage is based on comments that did not have any specific coding structure, so the numbers are only estimates.

REACHING OFF-GRID COMMUNITIES

There are over 200 off-grid communities in Canada, most of which rely on diesel.[60] As discussed previously, many initiatives are ongoing to enable Indigenous, rural, and remote communities' transition to renewables. The trends in this database suggest that a promising number of technologies are being developed with remote applications in mind, especially within the generation steps.

OBSERVATIONS

Remote applications for distributed electricity generation technologies are an area of strength.

British Columbia has the largest number of electricity generation companies with remote applications.

Microgrid, portable, and backup energy storage applications are a growing area of opportunity.

DATA

23 of **62** distributed electricity generation companies have the remote user keyword. [12]

10 companies with the remote keyword are in BC.

17 of **69** companies assigned to energy storage have backup, microgrid, or portable applications. [13]

DISCUSSION

These technologies include a range of small-scale, portable, and modular systems. Some technologies are aimed at remote work sites while others are aimed at remote communities.

Hydrokinetic, solar, and wind generation are the most represented, likely due to similar factors that contribute to them being well represented in the database overall.

There are several initiatives in the province to support rural, remote, and Indigenous communities such as the CleanBC Remote Community Energy Strategy (RCES), BC Hydro's Remote Community Electrification Program, and the province's recent $140 million investment in the BC Indigenous Clean Energy Initiative. [61, 62, 29]

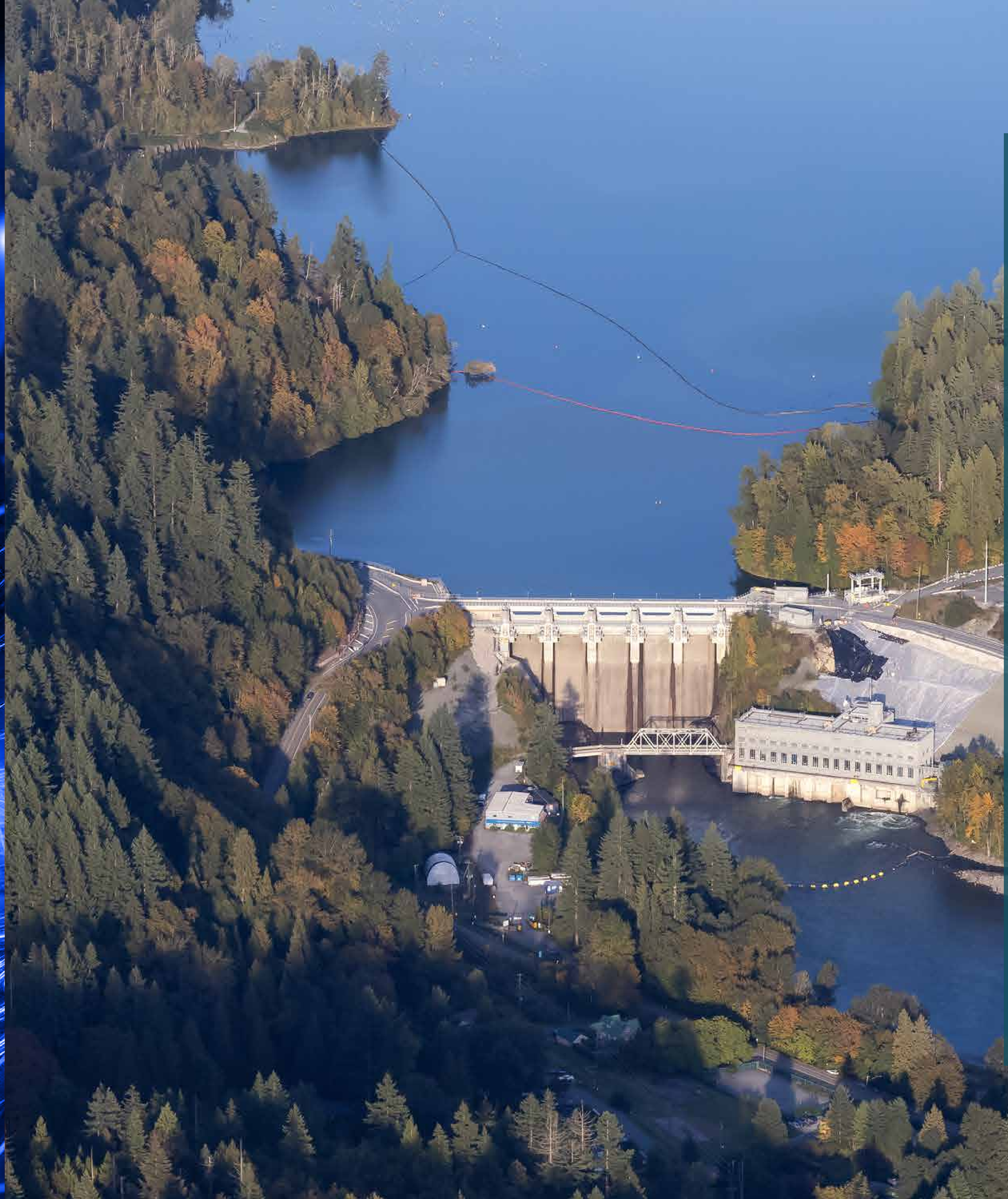
These technologies include modular and/or portable electricity for remote communities, disaster relief, and remote worksites. Most focus on enabling renewable electricity sources like solar and wind.

These types of energy storage technologies for microgrids and portable backup are key technologies in enabling these off-grid communities to transition away from diesel, as they can improve reliability, one of the key challenges with adopting renewables. [63] That said, the challenges with adopting renewables in off-grid communities are often non-technical ones, such as cost concerns and legal frameworks, that require intentional government support and funding. require intentional government support and funding. [64]

[12] Users were assigned based on the company's marketing, so this data is an estimate. There are likely additional technologies that can be applied but might have been marketed more towards other audiences. Also, many of these technologies apply to multiple users.

[13] Estimate based on applications noted in comments.

GRID RESILIENCE, OPTIMIZATION, AND DEMAND MANAGEMENT



With the country moving towards more distributed and diverse grids with more intermittent sources like wind and solar, transmission and distribution networks and patterns are changing. At the same time, demand is projected to increase steadily as we pursue efforts to decarbonize our transportation and industrial sectors through electrification. These efforts put a strain on supply, not only for regions already facing challenges transitioning away from fossil fuels, but also for regions that currently have a surplus of renewable electricity. For example:

- The IESO forecasts that Ontario's electricity demand will grow by 1.9 per cent annually. [65] While the electricity grid is currently quite clean and has a good track record of reducing emissions, without careful planning to keep it that way, energy shortfalls are likely to happen very soon. [66]
- Forecasts from BC Hydro and the BC Utilities Commission found that new electricity supply will be required sooner than expected, prompting the first competitive call for power in 15 years.[29]

Natural Resources Canada identifies infrastructure upgrades, efficiency and productivity improvements, smart grid technologies, storage capacity, and demand side energy resources as key ways to address challenges associated with increasing demand. [16]

In the database, most technologies that focus on efficiency and optimization are represented as those that observe and/or analyze (FIgure 12). These are clustered in the distribution, transmission, energy storage, and demand side management steps. While there are also some in the electricity generation steps such as wind, technologies that actually do the generation are much more prominent.

Climate Institute Canada identifies that technologies that make the grid more flexible are commercially available and growing more affordable.[67] However, many barriers facing adoption are non-technical ones. For example, the Canadian Institute for Climate Choices identifies non-technical challenges such as misalignment of goals, vested interests, siloed planning, information gaps, and lack of enabling infrastructure.[68]

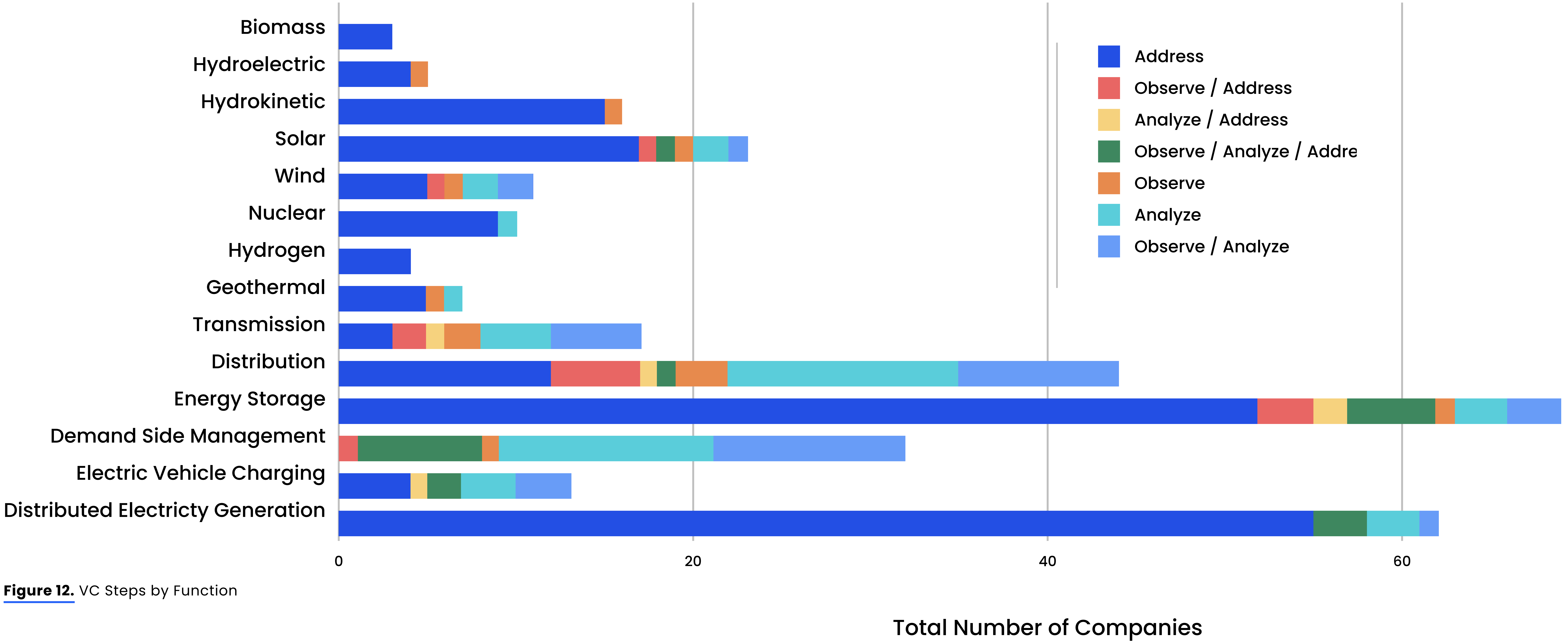


Figure 12. VC Steps by Function

OPTIMIZING SMART GRID FEATURES

A key technological pathway for managing increasing demands is through optimization technologies that monitor and adapt to conditions, provide decision-support, or improve existing processes. These types of technologies can also help electricity systems become more resilient and adaptable in the face of climate-driven pressures that pose a risk to infrastructure, such as extreme weather or natural disasters.

OBSERVATIONS

Optimization in distribution and transmission is an area of strength.

Demand side management is an area of strength.

Optimization technologies specific to energy storage are represented, but it is a growing opportunity.

DATA

32 of the **44** companies in distribution and transmission observe and/or analyze.

All **32** companies assigned to demand side management analyze and/or observe.

Of the **69** in energy storage:

- 17 companies are classified as those that observe and/or analyze
- 10 are containerized, microgrid, or portable systems

DISCUSSION

The technologies that analyze or observe transmission and distribution are mostly modeling, analytics, and monitoring solutions to optimize distribution and transmission in some way. Key applications include:

- Microgrid optimization and distributed resource integration platforms
- Facility and infrastructure management and optimization
- Power quality and correction

The technologies that address the VC step include advanced switching devices, microgrid infrastructure, and portable power stations. Advancements in these technologies are also important in providing the required infrastructure upgrades to enable smart grid features.

Technologies in this VC step include:

- Building energy management, monitoring, forecasting, and analytics
- Electric vehicle charging management platforms
- Smart IoT devices for energy management

Many of these technologies are aimed at residential or commercial users, and some are focused on industry.

Several supports are offered through all levels of government and utility companies to enable end users to adopt these kinds of technologies. These are often in the form of financial support such as rebates or grants.

Energy storage enables more resilient and distributed grids by providing opportunities to optimize and manage how electricity is distributed to them. The technologies that observe or analyze are mostly battery management systems or monitoring tools. The containerized, microgrid, and portable solutions reflected in the database are typically built with integrated energy management and monitoring capabilities.

While energy storage technologies are generally well represented, expanding optimization and management capabilities will likely be a growing area of opportunity as the grid grows more complex.

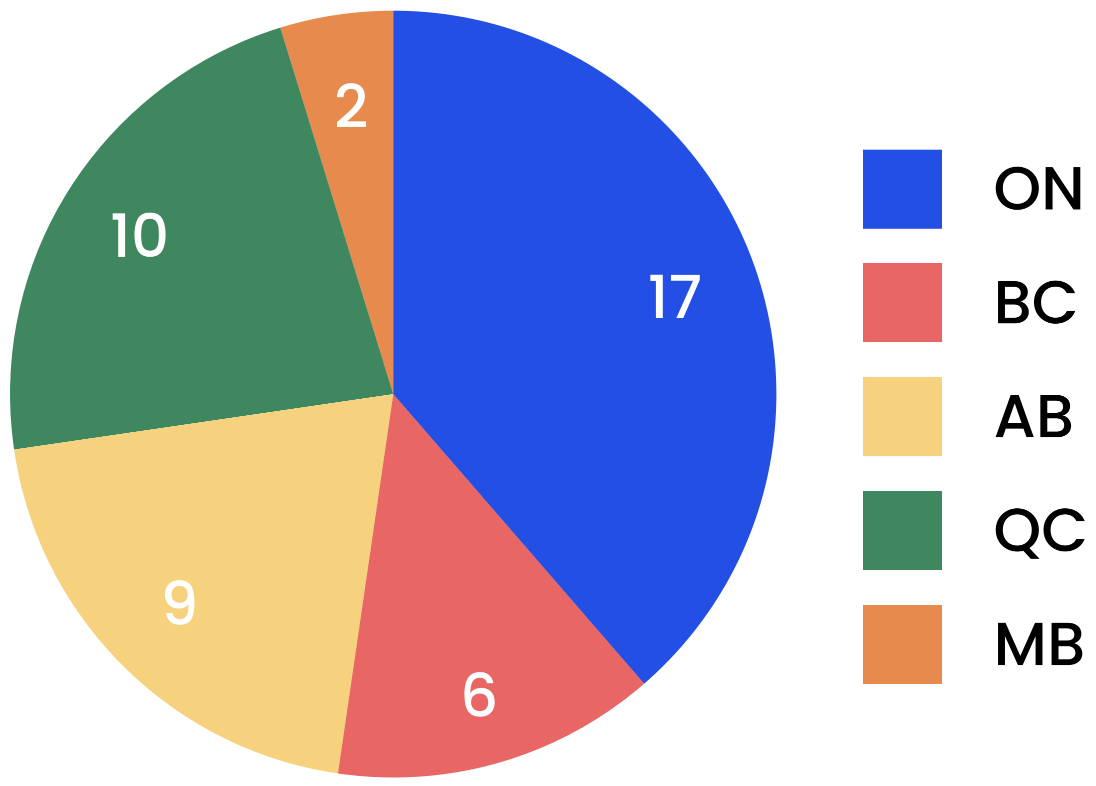
REGIONAL TRENDS

OBSERVATIONS

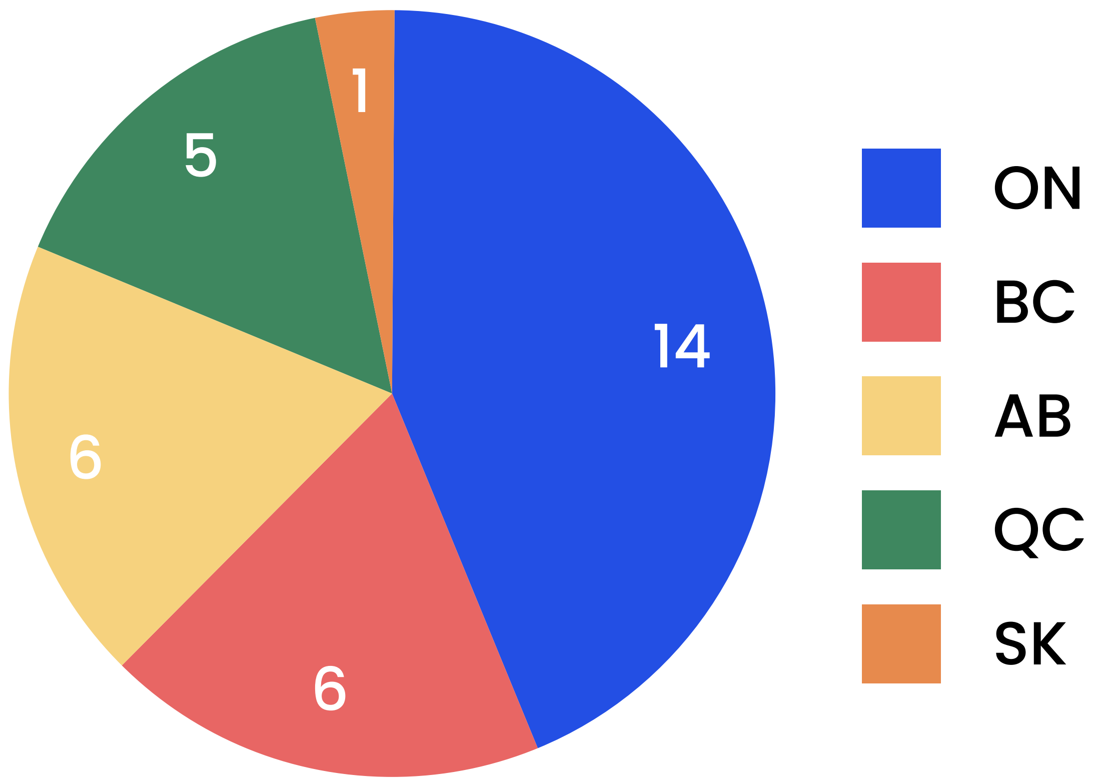
Distribution, transmission, and demand side management are almost exclusively in the four most populated provinces.

DATA

Distribution and transmission:



Demand side management:



DISCUSSION

While all VC steps are unsurprisingly clustered this way, these ones are even more so. Key factors that likely contribute to this trend include:

- Larger populations generally mean greater demand and more complex distribution. These provinces have both large urban populations and remote communities to consider on their grids.
- Many of these technologies are software systems and AI, and development of these types of technologies tends to be clustered in larger centres.

While these technologies are likely adopted beyond the location where they are developed, there could be opportunities to encourage more decentralized technology development to better meet the needs of all regions.

RECOMMENDATIONS

VENTURES, INVESTORS, GOVERNMENT, AND INDUSTRY CAN ALL BENEFIT FROM THIS DATA AND THE INSIGHTS IT PROVIDES ABOUT THE SECTOR AS WE TRANSITION TO A NET ZERO ECONOMY.

VENTURES ARE RECOMMENDED TO USE THIS DATABASE TO GLEAN VALUABLE INSIGHTS ON GAPS AND OPPORTUNITIES WITHIN THE ECOSYSTEM TO:

- Identify innovation opportunities, potential partnerships, and competitors segmented both by geography and position in the value chain.
- Apply a broader understanding of where technologies fit on the value chain, and take stock of what other companies fit around them to better promote their existing strengths and make informed business decisions.

INVESTORS AND INDUSTRY WILL ALSO FIND THIS DATA TO BE AN INVALUABLE TOOL TO USE WHEN EVALUATING INVESTMENT AND/OR ACQUISITION OPPORTUNITIES IN ORDER TO:

- Understand the value-add prospective ventures provide by identifying their role in the value chain.
- Determine what competitors might exist for any given company.
- Identify strengths, opportunities, and trends in the Canadian market to inform business decisions.

KEY INDUSTRY STAKEHOLDERS CAN ALSO USE THIS DATA TO ADVANCE ADOPTION:

- Utilities and independent power producers can apply a broader understanding of the technology landscape to make informed technology adoption decisions.
- Engineering consultants and other service providers can identify potential partnerships and collaboration opportunities that will support their clients' goals.

ADDITIONALLY, GOVERNMENTS CAN CONSIDER THE KEY INSIGHTS DERIVED FROM THIS DATA TO IDENTIFY TARGETED AREAS FOR SUPPORT IN A MORE COORDINATED AND INTENTIONAL WAY. KEY RECOMMENDATIONS FOR GOVERNMENT INCLUDE:

- Leverage and build on provincial strengths (e.g., solar generation in Ontario, hydrokinetic generation in British Columbia) and regional clusters (e.g., Calgary, Vancouver, and Toronto) to support a thriving innovation landscape.
- Consider opportunities to foster strategic technology innovation clusters beyond major centres or large cities.
- Continue to support adoption and continuous improvement of renewable and non-emitting electricity sources, energy storage, and technologies with smart grid features.
- Continue funding research and development in renewable and non-emitting electricity sources such as hydrokinetic generation and SMRs.

CONCLUSION

THE BREADTH AND DEPTH OF THE CANADIAN ELECTRICITY TECHNOLOGY ECOSYSTEM ACROSS THE VALUE CHAIN DEMONSTRATES THE SECTOR'S FAVORABLE POSITION IN OUR PATH TO NET ZERO. HOWEVER, CONTINUING TO SEIZE STRATEGIC OPPORTUNITIES TO ADVANCE THE SECTOR WILL BE INSTRUMENTAL IN ACHIEVING DECARBONIZATION GOALS AND KEEPING UP WITH GROWING DEMAND.

Interested in learning more about Canada's electricity technology value chain?

FORESIGHT CANADA

Please contact Alyssa Kelly, Director of Research at Foresight Canada: akelly@foresightcac.com

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