Manitoba's Environment for Rolling-out a Clean Energy Transition: embedded in a Global and Canadian Context

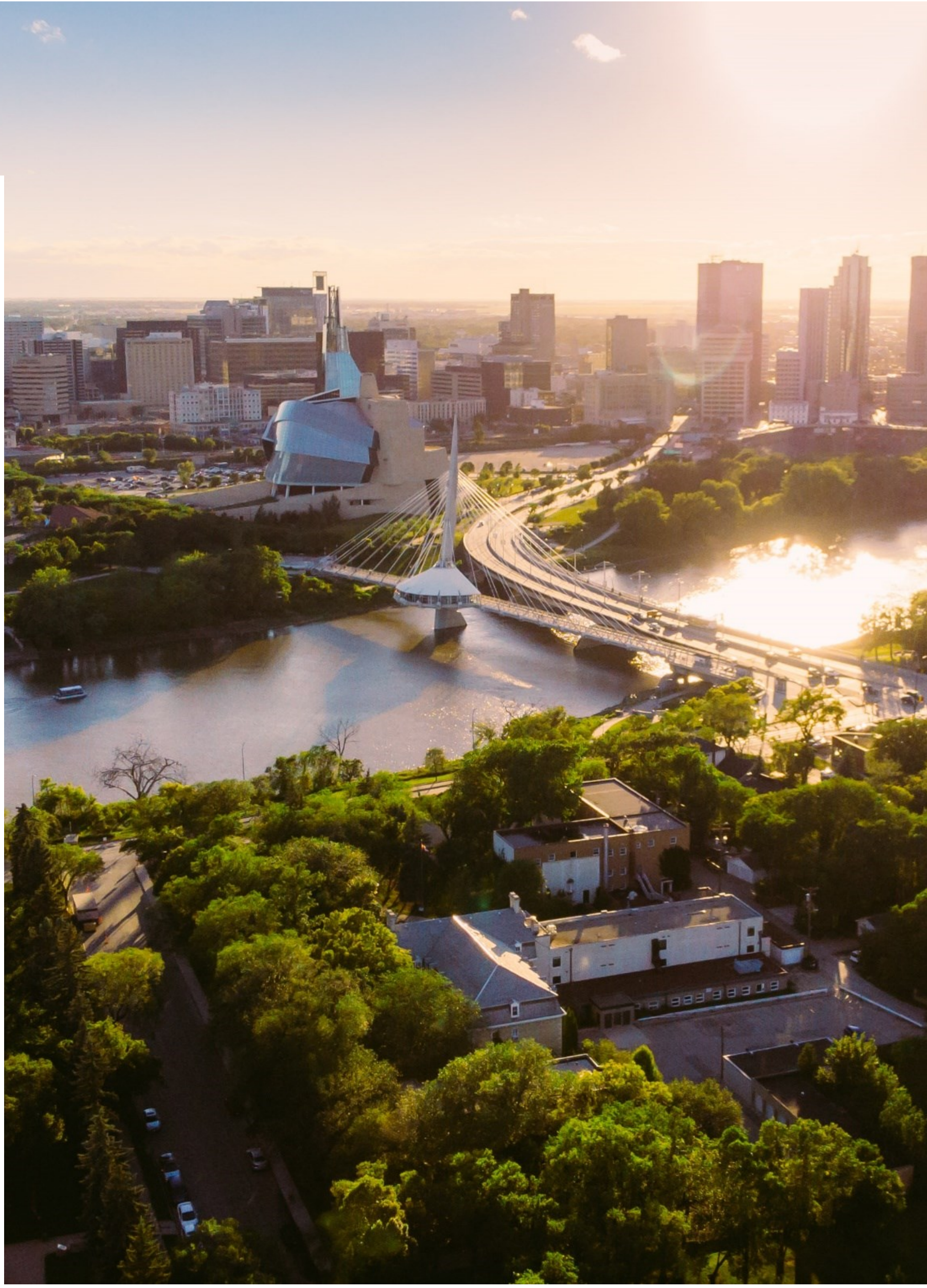

Image Credit: Mike Peters

Market Intelligence

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Acronyms

Acronym	Stands for / definition
BESS	Battery Energy Storage System
CER	Canadian Energy Regulator
CES	Clean Energy Standard
EIA	US Energy Information Administration
EPC	Engineering, procurement & construction
ESC	Energy Storage Canada
ESG	Environmental, Social and Governance
ESS	Energy Storage System
EV	Electric Vehicle
EVCI	Electric Vehicle Charging Infrastructure
GHG	Green House Gases
IEO	International Energy Outlook
IPCC	Intergovernmental Panel on Climate Change
NZ	Net Zero
NZE	Net Zero Emissions
PV	Photo voltaic
UPS	Uninterrupted power supply
Measures of Power Capacity	
kW	Kilowatt (10^3 watts)
MW	Megawatt (10^6 watts)
GW	Gigawatt (10^9 watts)
TW	Terawatt (10^12 watts)
Measures of Energy Capacity	
kWh	Kilowatt-hours
MWh	Megawatt-hours
GWh	Gigawatt-hours
TWh	Terawatt-hours

Definitions

Power capacity: “the maximum instantaneous amount of electric power that can be generated on a continuous basis and is measured in units of watts.” [i]

Energy capacity: “the total amount of energy that can be stored in or discharged from the storage system and is measured in watt-hours.” [ii]

Executive Summary

Energy storage systems (ESS) are expected to play an increasingly significant role in power systems. This is due to short-term backups for critical infrastructure, the normal swings in hourly demand, and the increasing role of intermittent power sources (e.g., photovoltaic and wind power generation).

According to Energy Storage Canada (October 2022). “Energy Storage: A Key Net Zero Pathway in Canada,” projections for Canada’s Energy Storage demand will be between 8 and 12 GW installed capacity by 2035. This is due to:

- Replacing power plants with high greenhouse gas emissions (with solar, wind, hydro and/or nuclear, depending on the province), and
- Electrification of more economic sectors: transportation (e.g., EV), space heating (e.g., heat pumps), and various industrial and commercial applications.

The fact that supply from solar and wind is intermittent, and demand varies, there are cases for both short- (less than a day) and long-term (more than a day) ESS being added in the grid and elsewhere.

While the most common ESS system is currently pumped hydro (it is about 10X battery ESS in the USA), BESS is rapidly expanding, and is expected to keep on rapidly expanding for the foreseeable future.

The US Energy Information Agency has a two segment take on BESS, but McKinsey and Co. suggest three BESS segments:

1. Utility: (X > 10 MWh),
2. Commercial and Industrial: (30 kWh <= x <= 10 MWh), and
3. Residential: (x < 30 kWh)

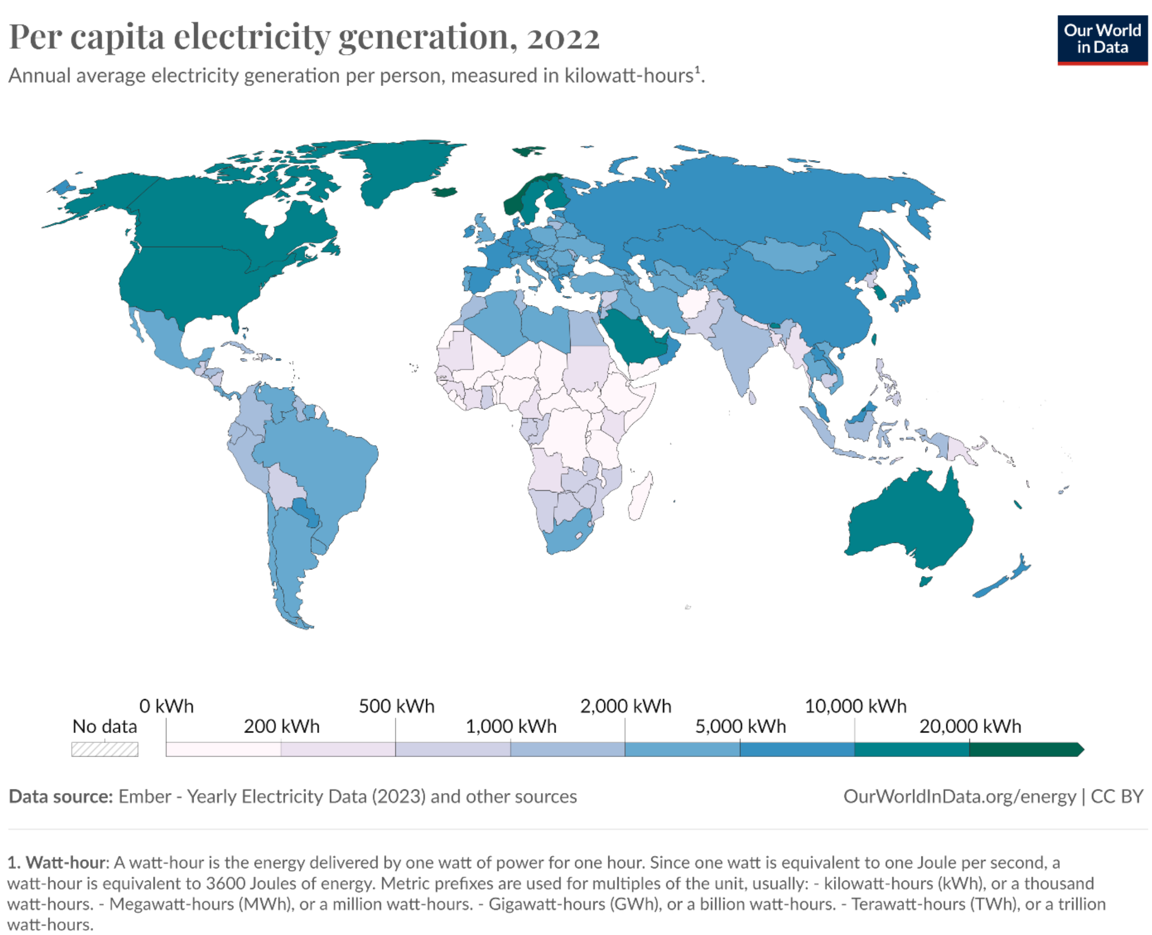
McKinsey and Co. also note the breakdowns of the value chain for BESS, helping put the various stages in context.

Introduction

The Global Context

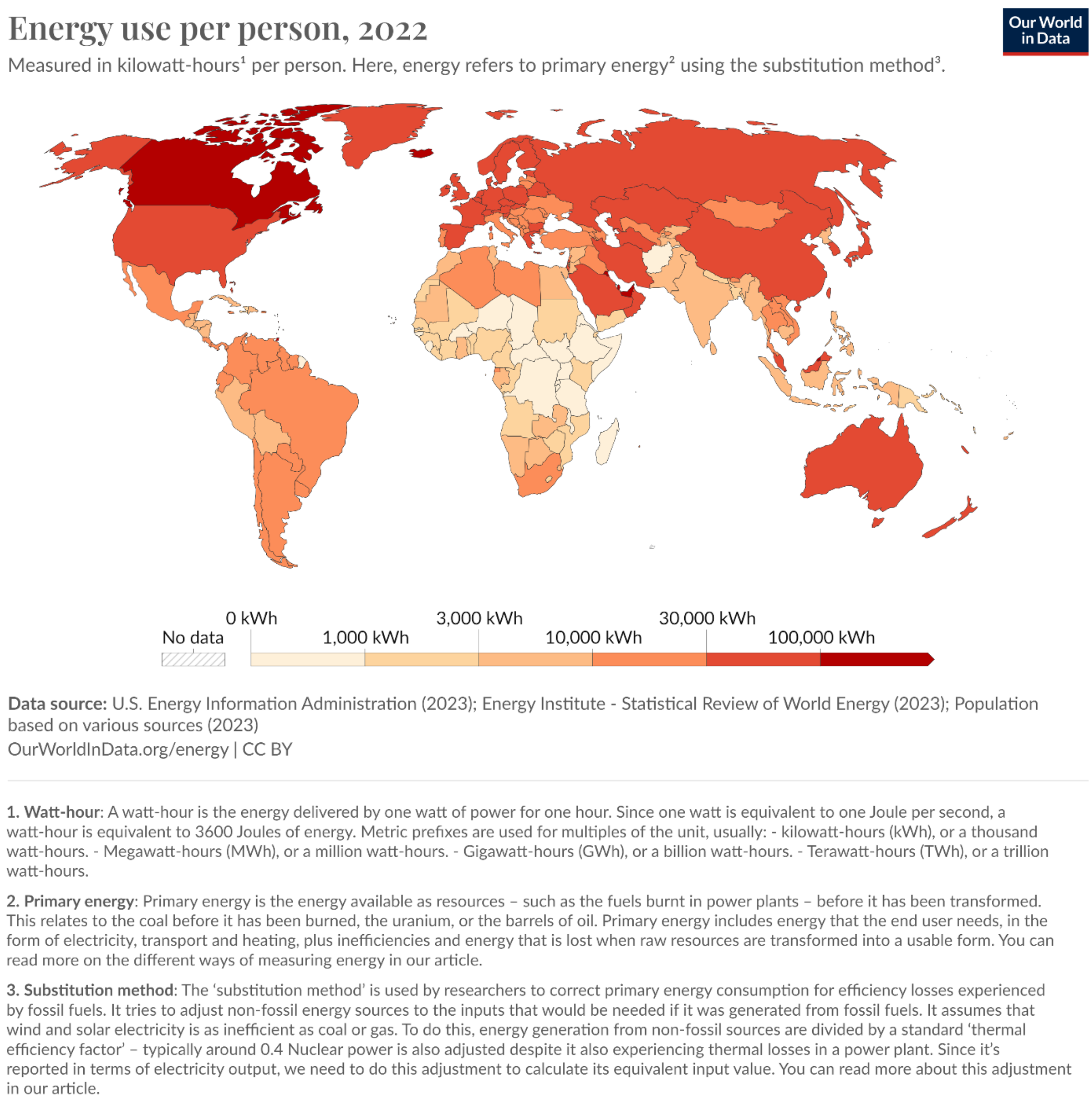
The people of Earth have several interrelated challenges facing us about energy use and rising levels of anthropomorphically generated greenhouse gases (GHG). The Intergovernmental Panel on Climate Change (IPCC) has produced significant research showing the existence of climate change and put forward related ideas. A research note[iii] by Our World in Data in 2023 noted "The world emitted 41 billion tonnes of $CO2$ in 2022.[iv] To have a 50% chance of staying below 1.5°C, we can only emit 250 billion tonnes. That's just six years of our current emissions."[v]

Figure 1: World per capita electricity generation (kWh), 2022



It is unlikely we will achieve this in the time indicated, given current projections and the slow legislative and investment activity to date. Vaclav Smil (2022) notes that the transition will likely take decades, particularly for four key pillars of the modern world: Ammonia, Plastics, Steel, and Concrete.[vi] Still, we are at last seeing serious efforts to shift our energy mix, particularly as technology matures and costs fall.

Figure 2: Energy use per person, 2022

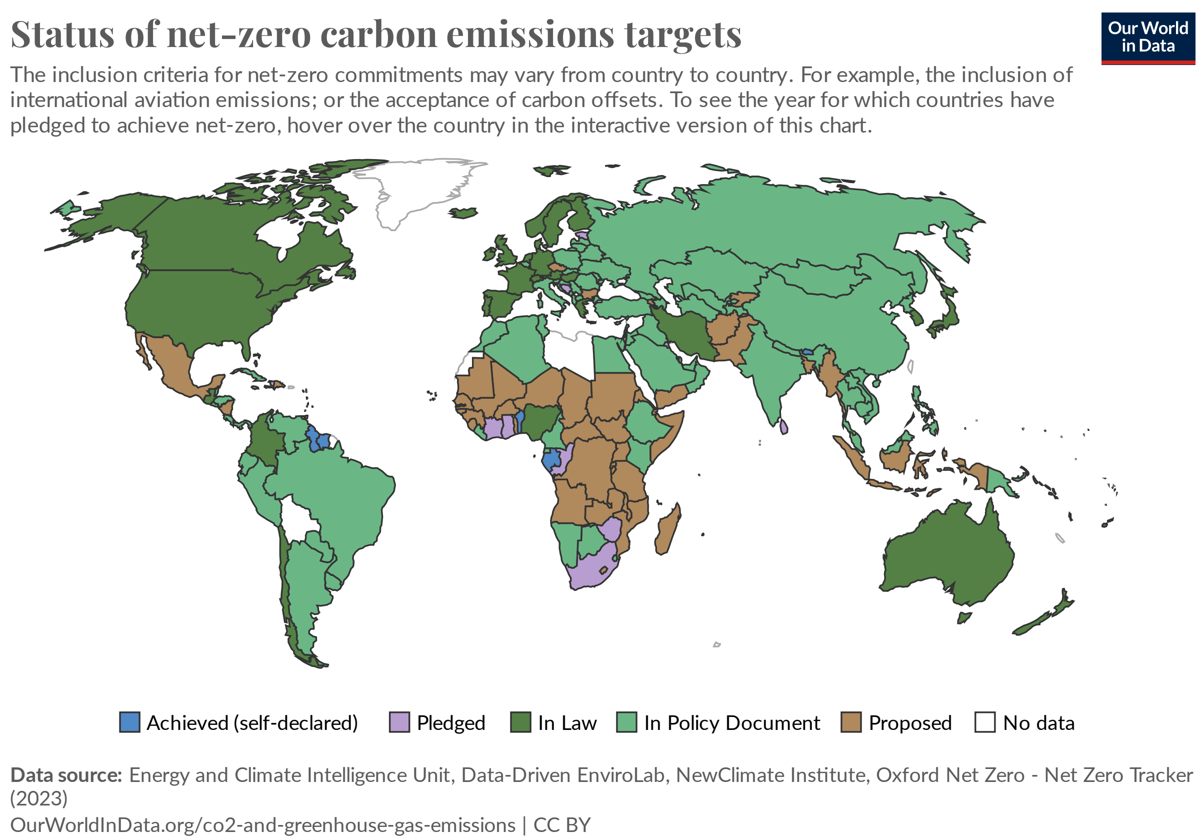


At the same time, people who currently do not have access to energy want access to it, along with improved transportation, and other infrastructure. Also, those people who already have access to energy and other infrastructure need to transform their energy mix to reduce their GHG emissions. Understandably people who already have access to energy and infrastructure do not want to be made worse off by changing their energy use for electricity and various prime movers.

For **world per capita electricity generation** (kWh) see **Figure 1**, and for **primary energy use per person** see **Figure 2**, both from Our World In Data.[vii]

On a global basis, most countries have net zero declarations of some sort. This is illustrated by **Figure 3**'s map from Our World in Data.[viii]

Figure 3: Status of net-zero carbon emissions targets



For some information about energy storage, a good Canadian source is Energy Storage Canada, particularly their webpage ES 101.

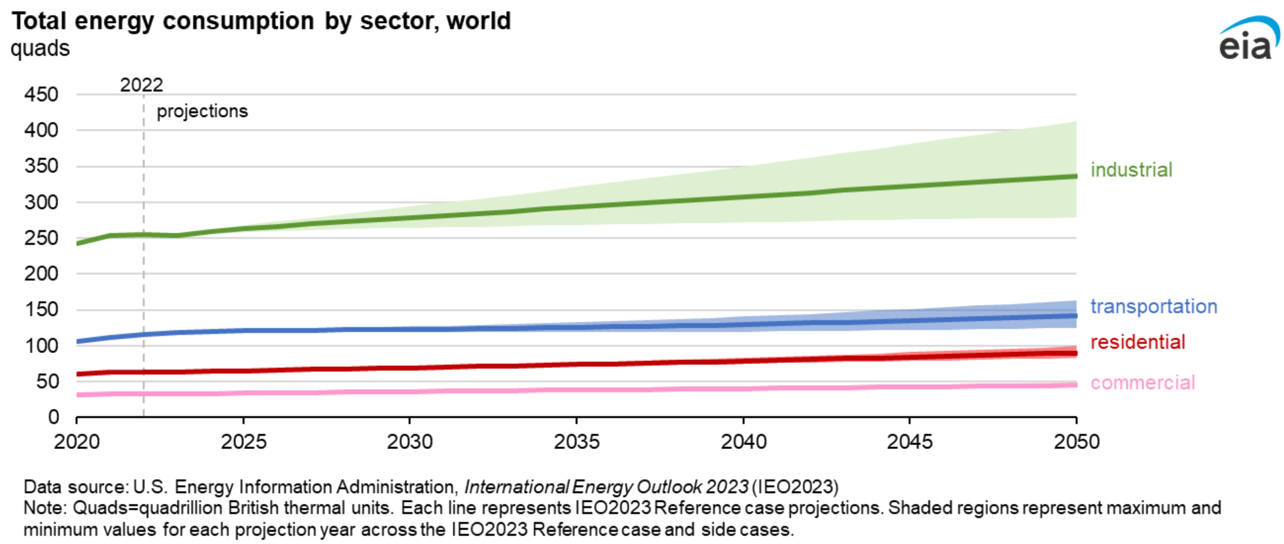
Projections

The US Energy Information Administration (EIA) produces analysis & projections of crude oil and petroleum liquids, gasoline, diesel, natural gas, electricity, coal prices, supply, and demand projections and more.[ix]

International energy outlook 2023 - EIA

According to the US EIA, total world energy consumption will be driven by industrial use, followed by transportation, residential and then commercial use, see **Figure 4**.[x] They note that “across all IEO2023 cases, energy consumption increases, and global demand grows fastest in the industrial and residential sectors.” [xi]

Figure 4: Total energy consumption by sector, world



USA Annual Energy Outlook 2023

The US EIA produces an annual projection for the USA as well.[xii] Their projections to 2050 sees total installed generating capacity more than doubling across most scenarios (**Figure 5**), with a significant increase installed solar capacity and the use of stand-alone storage to manage the intermittent power supply that results, see **Figure 6**.

Figure 5: USA Total Installed capacity in all sectors, 2022 and 2050 (in GW)

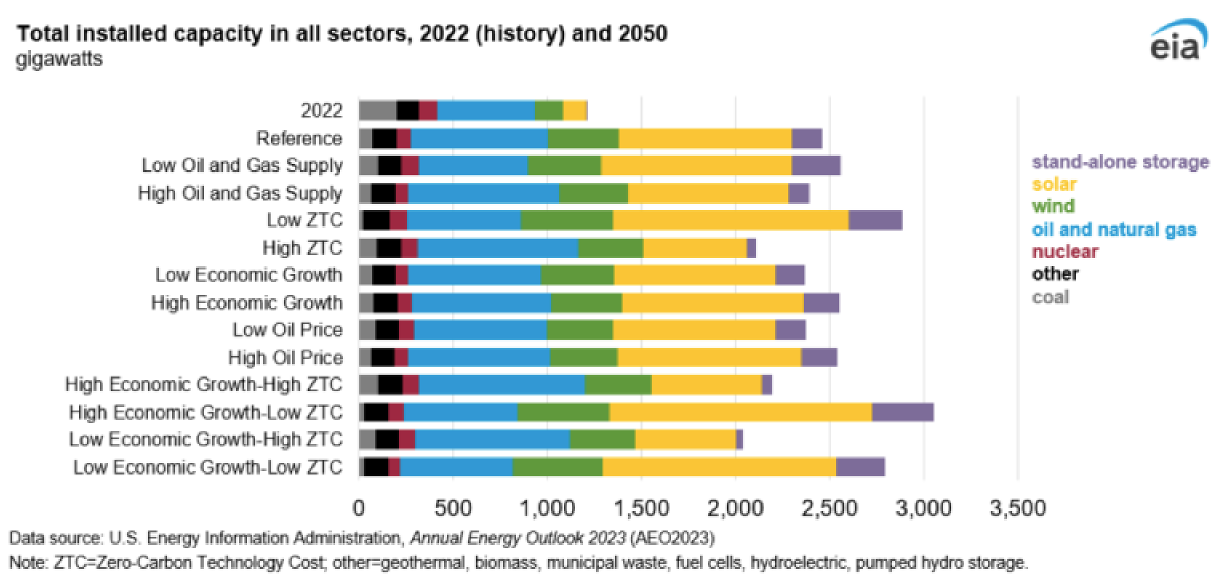
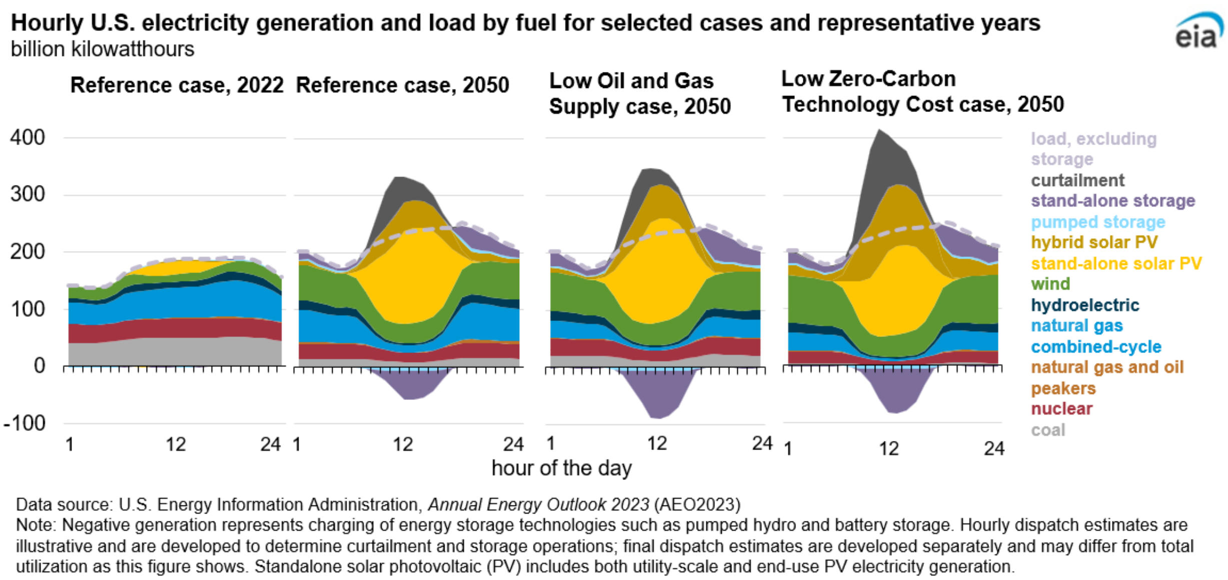


Figure 6: Hourly US electricity generation and load by fuel for selected cases and representative years (billion kilowatt-hours)



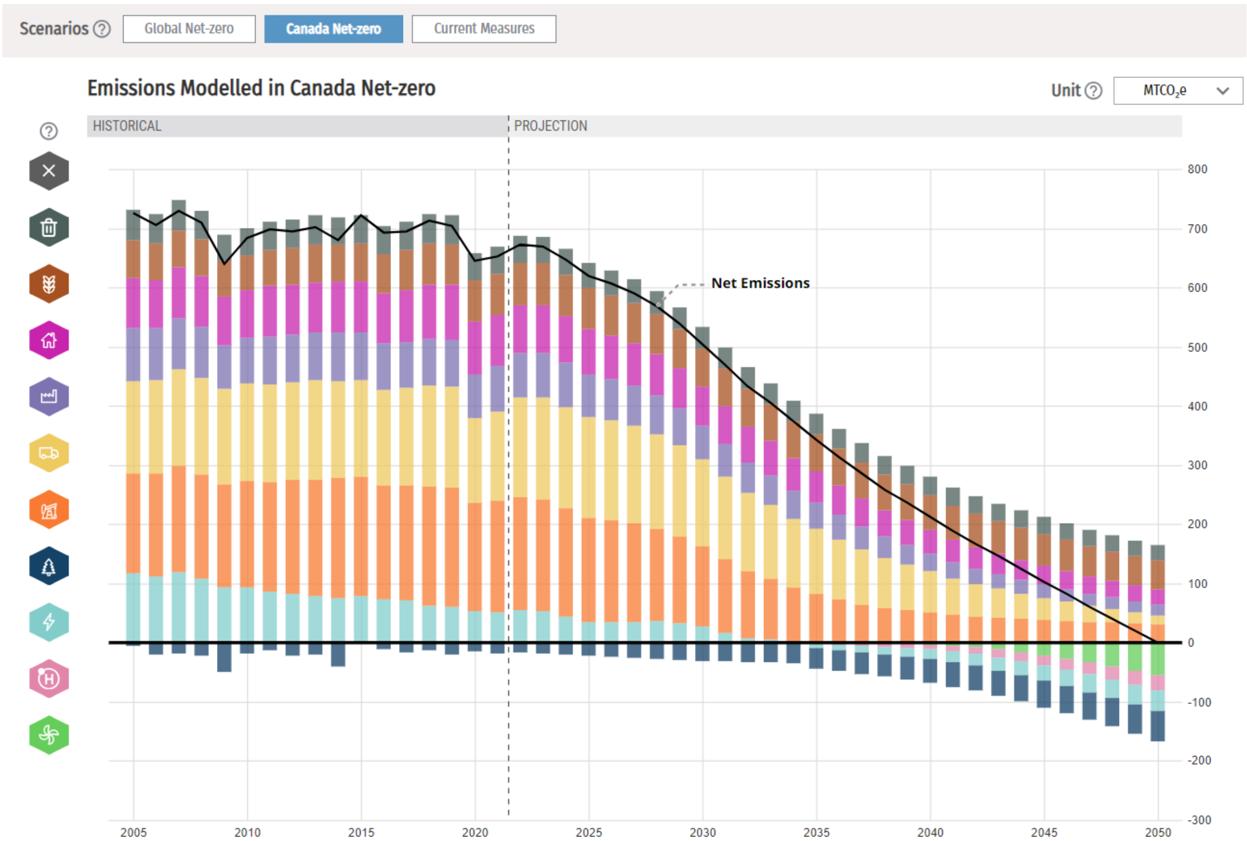
Canada Projections

For a Canadian projection to 2050, we turn to Canada Energy Regulator (CER)'s Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050.[xiii]

A Projected Path to Net Zero

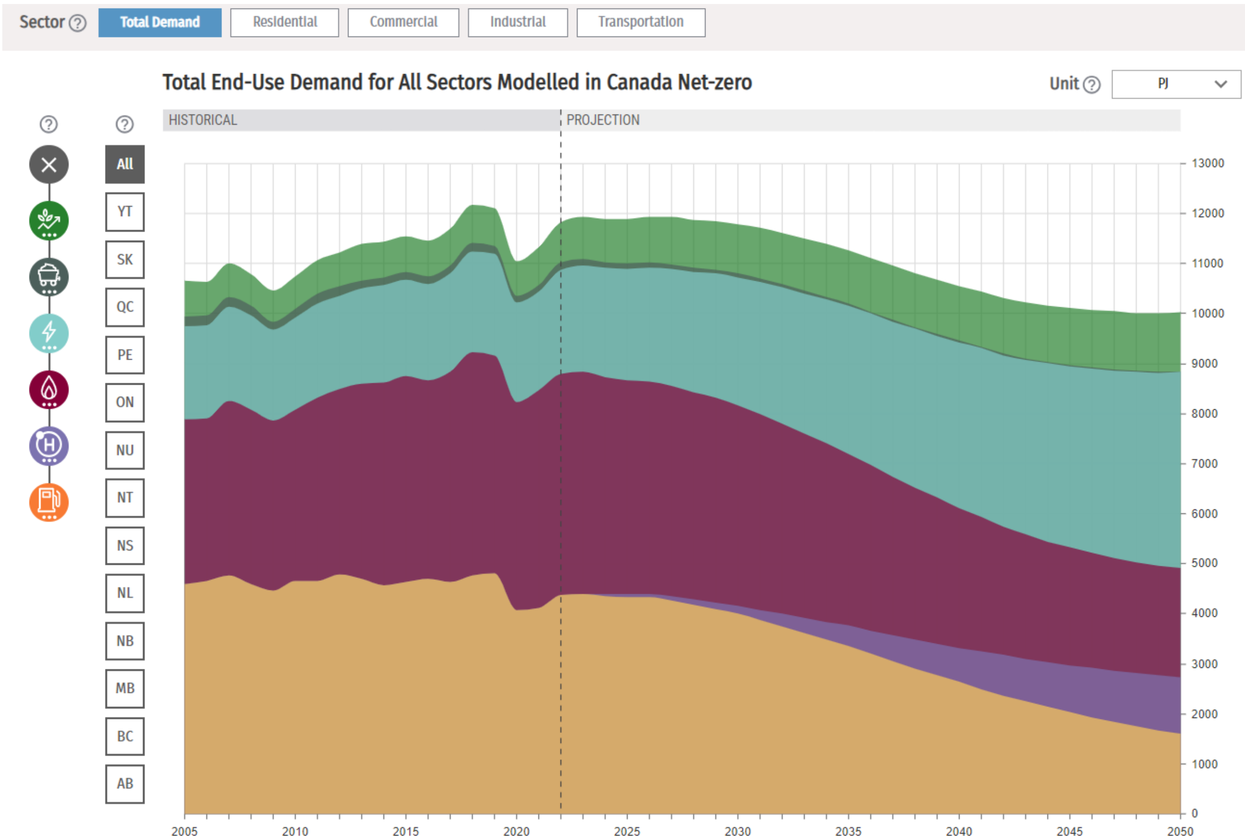
We saw the Net Zero pledges by country as of 2022 in **Figure 3**. How does Canada get to net zero GHG (leaving aside other's actions)? We can see from **Figure 7** by Canada Energy Regulator (CER) a projected path by 2050.[xiv]

Figure 7: Canada GHG Emissions Modelled to get to Net-zero by 2050



The CER's projections for energy demand by 2050 are heavily dependent on hydrogen, moving from zero percent of the demand mix to 11.3 per cent in 2050, **Figure 8**. According to the US EIA, hydrogen, produced by electrolysis may be considered a form of energy storage.[xv] This may be a realistic ESS demand once the technology is mature enough to be commercialized at scale.

Figure 8: Canada Total End-Use Demand for all Sectors Modelled in Canada Net-Zero



Risk to Canada's Net Zero Scenario

Hydrogen for industrial use seems realistic (since this is currently the main area that hydrogen is used), so long as it is used close to where it is produced. Hydrogen for transportation close to where it is produced may also be realistic. But hydrogen as such, used for transportation far from where it is produced, or transported over long distances as supercooled hydrogen is thought to be unrealistic at this time, and may remain so.[xvi]

Thus, the hydrogen part of the projection is at risk. Various technologies are being researched, as noted by papers such as Hassanpouryouzband, A., Joonaki, E., Edlmann, K. et al. (2020).[xvii] Still, the lack of any commercial-scale installations to date makes assuming we can rely on the technology a risky bet. At this time, it is more likely that we will see some mix of **nuclear**,[xviii] **solar** and **wind** [collocated with expanded energy storage systems (ESS) – most likely some form of BESS] taking up the slack.

See Energy Storage Canada (2024) report: Long Duration Energy Storage (LDES) Opportunity Assessment.[xix] The report covers hydrogen risks, and costs, benefits and other factors related to many different LDES systems from a view on Ontario's market.

Canada Electricity Generation Mix 2050

Figure 9: Electricity Generation by Region Modelled in Canada Net Zero (2022 vs 2050)

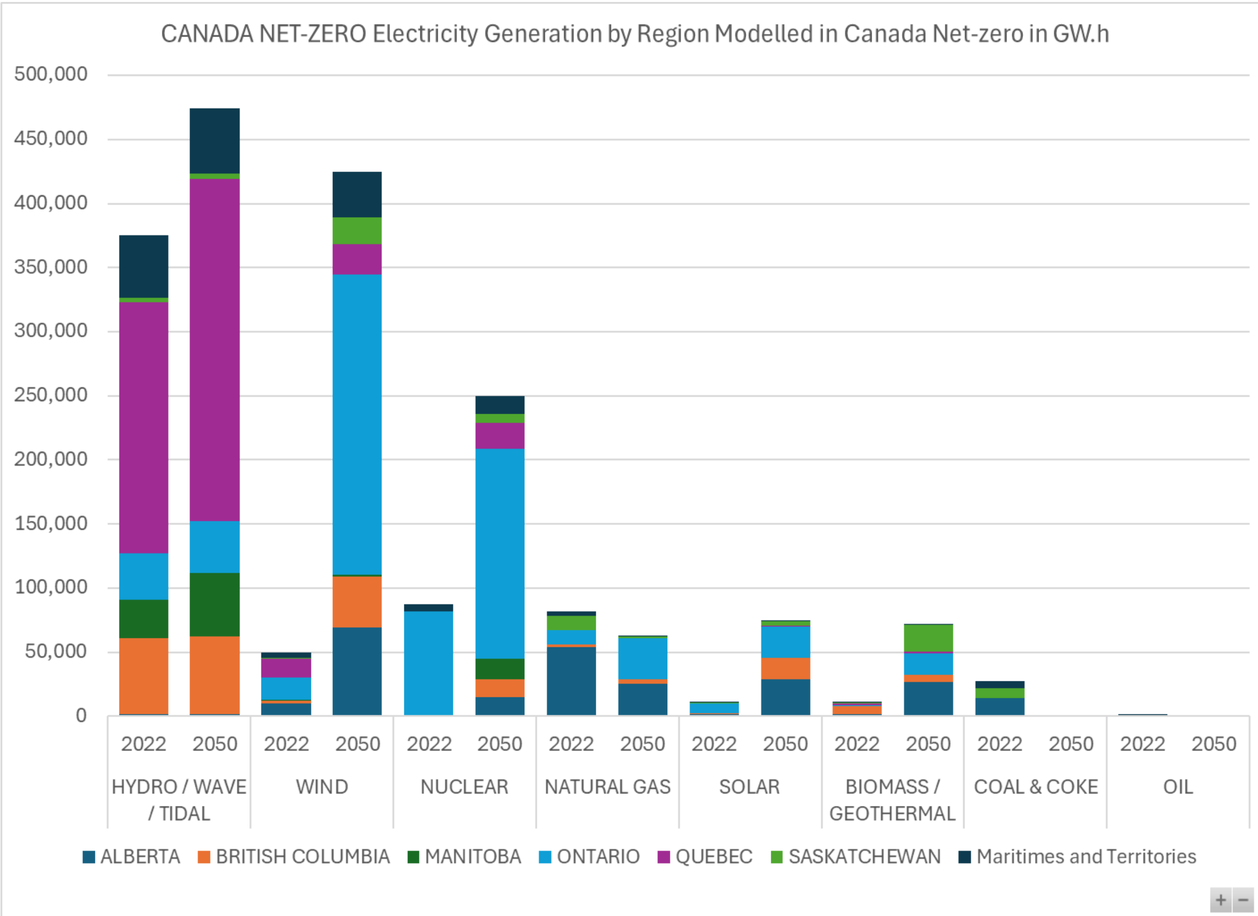


Figure 9 shows hydro (+ wave and tidal) power increasing in Canada, with a significant increase in generation of electricity using wind, nuclear, solar, and biomass / geothermal.[xx] Canada may see more of an increase of solar versus wind, but both will need to rely on ESS or BESS installations to smooth out the delivery of their intermittent electricity generation throughout the day, as noted in **Figure 6**. Coal & Coke, and Oil are projected to be essentially irrelevant to electricity generation by 2050.

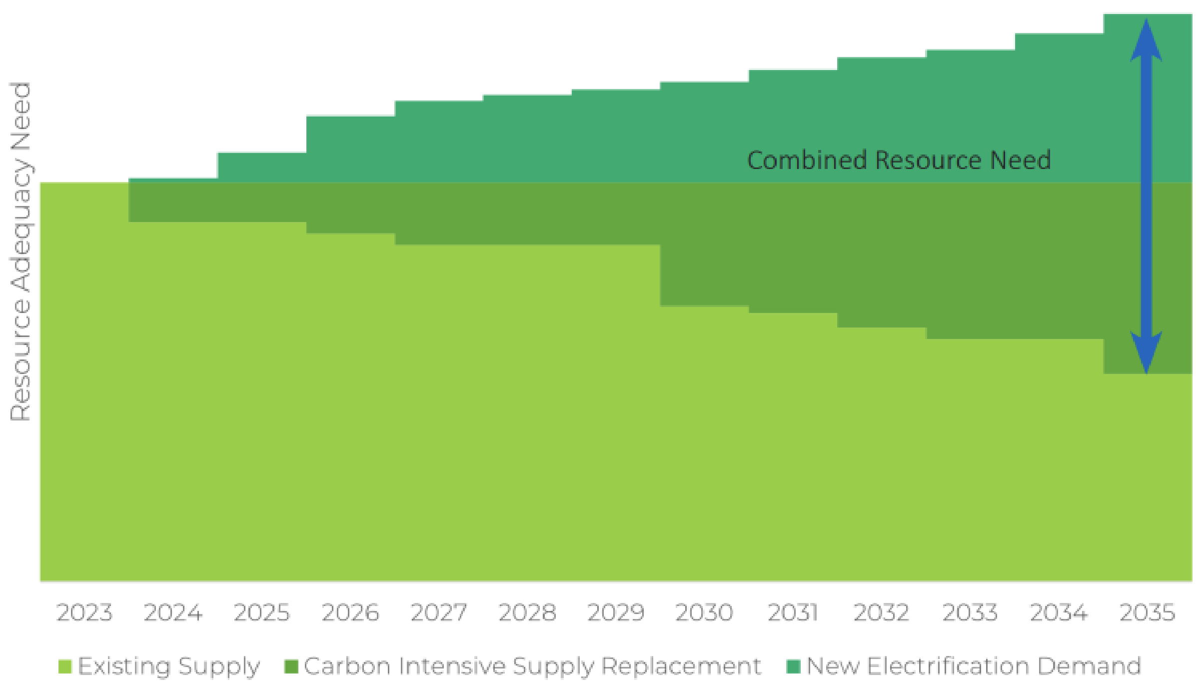
Energy Storage Canada's ESS projection to 2035 [xxi]

While the CER projections are a potential future, they have some potentially problematic assumptions and do not address how constraints can be unlocked and product built and installed. This is better addressed by an Energy Storage Canada report.

Energy Storage Canada (2022)[xxii] contracted Power Advisory LLC to author a report considering the role that energy storage can play in helping Canada reduce greenhouse gases (GHG) and achieve net zero emissions (NZE) by 2035. They estimated the potential installed capacity necessary to achieve NZE and highlighted the importance of removing barriers to implementing ESS within each Canadian jurisdiction. They note that two primary components determine how much ESS is needed to achieve NZE by 2035. See **Figure 10**, for an illustration of one and two below. These are:

1. Growing electricity consumption is due to the electrification of other economic sectors: **transportation** (EV), **spacing heating** (source heat pumps), and other industrial and commercial applications.
2. Replace/Convert existing carbon-intensive generating units (coal, or natural gas). The reduction of carbon-intensive generation is driven by: Government policy, corporate environmental, social and governance (ESG) objective, and general support by Canadians.

Figure 10: Illustrative Example of Resources Needed for Net Zero



Non-emitting generation resources include nuclear, hydroelectric, wind, and solar. Each has their strengths and weaknesses, and each province has their own unique potential with some provinces having significant remaining hydroelectric potential, while others have already exploited much of their potential.

The report estimated electrification demand growth from electrification in three broad steps:

1. Established a baseline demand growth by province using published power system planning documents. [xxiii, xxiv]

2. Added energy growth from various electrification sources (transportation, space heating, industrial, commercial, and residential appliances), and
3. Convert annual energy demand growth (TWh/year) into a winter peak demand resource requirement (GW/year).

Figure 11: 2035 Energy Consumption Forecast Growth by Province (Stats Canada Table 25-10-0016-01 and projection) [xxv]

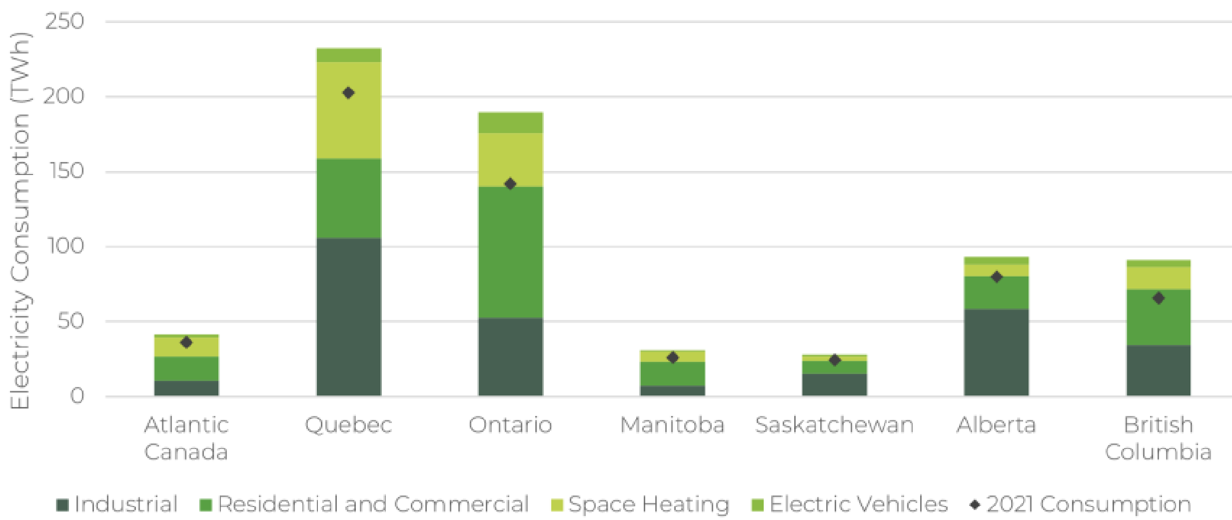


Figure 12: Total Energy Production from Combustible Fuels, 2021 (Statistics Canada Table 25-10-0015-01)

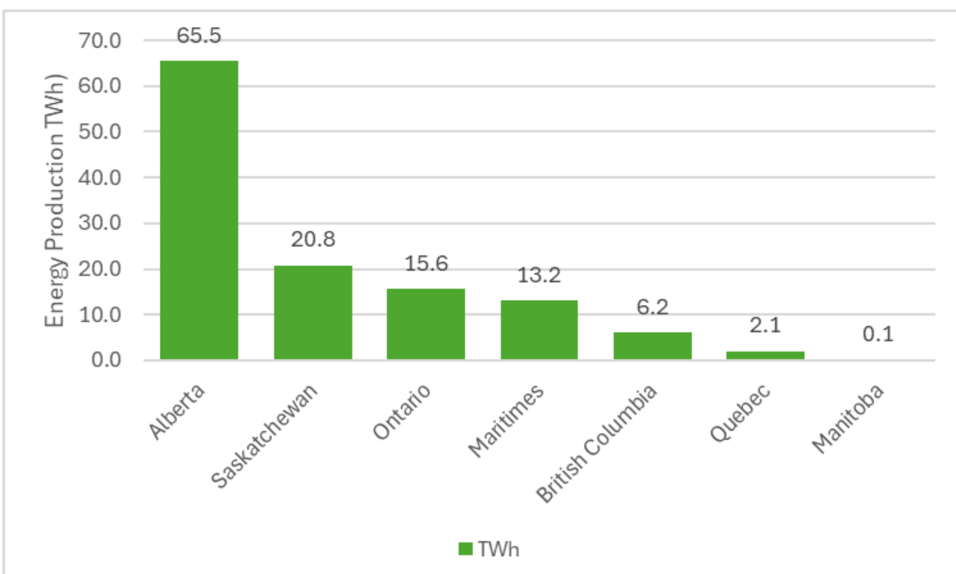
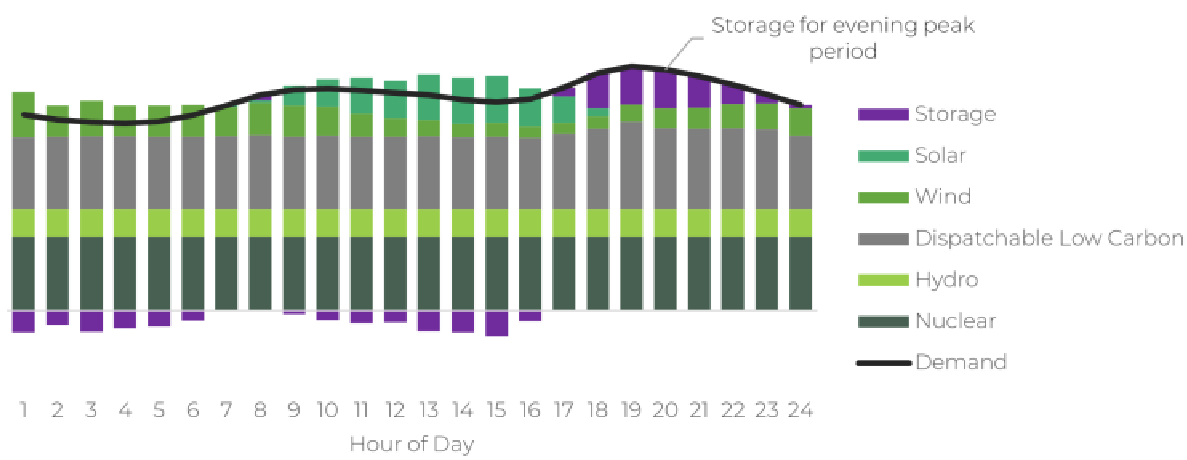


Figure 11 compares electricity consumption in 2021 (580 TWh for Canada, of which QC is 36%, ON is 24%, AB is 14% and BC is 11%) to ESC's 2035 projection. **Figure 12** shows how much of the provinces and regions' electricity is generated by combustible fuels. The Canadian total for 2021 was 124 TWh, of which AB is 53%, SK 17%, ON 13%, and Atlantic Canada 11%.

The 2035 energy mix was projected using planning documents or rate-regulated supply outlooks as a base.[xxvi]

The ESC projection also modeled electricity demand by hour, summing up separate load shapes for EV, space heating, industrial, and residential/commercial demand growth, including local weather sensitivities. **Figure 13** gives an example of Storage for Capacity on a Winter Peak Day.

Figure 13: Example of Storage for Capacity on a Winter Peak Day



Excess net supply from inflexible generation can be stored and dispatched when supply would be in deficit. This projection process results in energy storage potential of 8 to 12 GW by 2035 in support of a net zero electricity grid.

Essentially, for periods of time where electricity supply exceeds electricity demand, the excess would be stored in ESS, and drawn on in periods where electricity supply is less than electricity demand (within day storage). Longer duration storage helps when there is a need to shift energy over several days.

Changes to Land Use Can Cut GHG Emissions

According to research published on RMI's website, Korn, et al (2024), urban sprawl is directly or indirectly responsible for one-third of all GHG pollution.[xxvii] This is based on PhD research by Michael Mehaffy (2015)[xxviii] Urban sprawl responsible for 30% of all greenhouse gases (tudelft.nl).

Numerous papers address this, including The Impact of Urban Sprawl on Environmental Pollution: Empirical Analysis from Large and Medium-Sized Cities of China - PMC (nih.gov), and Luqman, M., Rayner, P.J. & Gurney, K.R. "On the impact of urbanization on

CO_2 emissions.” *npj Urban Sustain* **3**, 6 (2023). https://doi.org/10.1038/s42949-023-00084-2.

How ESS markets are segmented

US examples

McKinsey & Company (2023) segment the demand side of the BESS market into three segments.[xxix] These installation segments include: electricity generation and distribution, commercial and industrial, and residential (**Table 1**).

Table 1: Customer Segments for Battery energy storage systems

	Front-of the Meter	Behind-the-Meter	
	Utility/ Electricity generation and distribution installations	Commercial and Industrial installations	Residential installations
Electricity generation ranges	X > 10 MWh	30 kWh <= X <= 10 MWh	X < 30 kWh
Use Cases			
Use Cases	Public arbitrage	Renewable integration (rooftop photovoltaic)	Home integration of:
	Long-term capacity payments	Uninterruptable power supply (UPS)	Renewable integration (rooftop photovoltaic)
	Ancillary service markets	Power cost optimization	EV charging infrastructure
	Derisking renewable generation	Electric-vehicle (EV) charging infrastructure	
	Investment deferral		

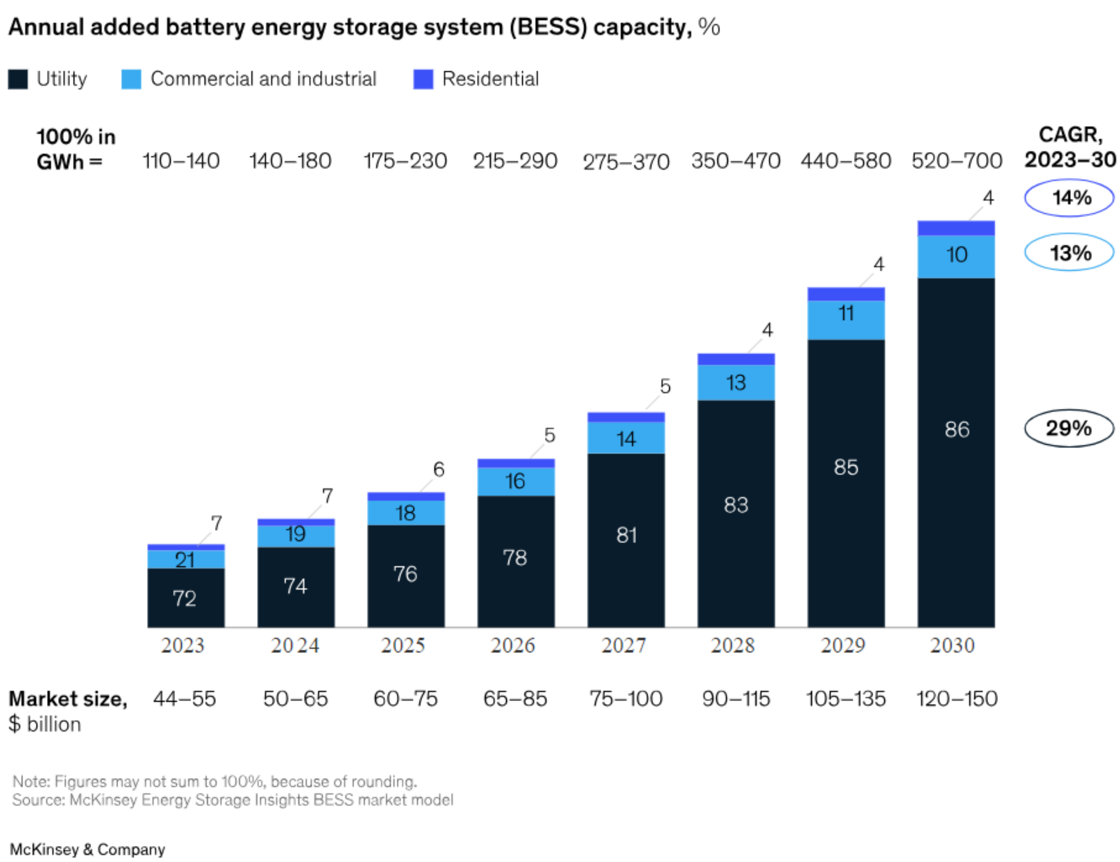
McKinsey & Company estimates that most of the growth through 2030 in the USA would be for the utility market (**Figure 14)**.

Table 2: US utility-scale energy storage systems for electricity generation, 2022[xxx]

Storage Systems	Number of plants and of generators	Power capacity (MW)	Energy capacity (MWh)	Gross generation (MWh)	Net Generation (MWh)
Pumped-storage hydro	40 - 152	22,008	NA	22,459,700	-6,033,905
batteries	403 - 429	8,842	11,105	2,913,805	-539,294
Solar-thermal	2 - 3	405	NA	NA	NA
Compressed air	1 - 2	110	110 h	NA	57
flywheels	4 - 5	47	17	NA	0
NA is not available.					

The US EIA segmented the ESS market (**Table 2**) into:

Figure 14: Annual added BESS capacity (%)



- **utility or large scale**: (X>= 1 MW) net generation capacity, owned by electric utilities or independent power producers to provide grid support services,

- **Small scale**: (X < 1 MW) net generation capacity, often use photovoltaic systems to charge a battery.

For the US in 2022, an increasing number of BESS are paired or co-located with a renewable energy facility (e.g., 3,612 MW BESS near PV or wind energy projects).

Benefits and Uses of ESS for electricity generation[xxxi]

1. Balancing grid supply and demand, and improving quality and reliability,
2. Peak energy demand shaving and price arbitrage opportunities,
3. Storing and smoothing renewable electricity generation,
4. Deferring electricity infrastructure investments,
5. Back-up power,
6. Reducing end-user demand and demand charges, and
7. Integration with microgrids.

ESS can be designed for **short duration** (scale of minutes and power oriented), and **diurnal** or **daily duration** (scale of hours and energy oriented).

Which US states have utility-scale BESS installed[xxxii]

Table 3: Power and Energy capacity and gross electricity generation of US BESS in selected states, 2022

State	Power Capacity (MW)	Energy Capacity (MWh)	Gross Generation (MWh)
California	4,738	4,726	2,086,196
Texas	2,087	2,078	268,209
Florida	538	528	203,606
All other states	1,488	3,773	355,794
US Total	8,842	11,105	2,913,805

Uses of utility-scale BESS in the US

Table 4: Applications served by US utility-scale BESS, 2021

Reported application	Number of Generators	Percentage of total power capacity (%): [xxxiii]
Frequency regulation	128	63%
Arbitrage	103	58%
Ramping/spinning reserve	64	42%
Excess solar and wind energy storage	148	30%
Voltage or reactive power support	34	23%
Load management	62	18%
Load following	32	10%
Peak Shaving	147	10%
Co-locating renewable firming	38	5%
T&D deferral	14	2%
Backup power	33	2%

In the US, here is where BESS was installed (**Table 3**), and the applications of BESS (**Table 4**). US BESS capacity surged from 2020 onwards.

Commercial and Industrial

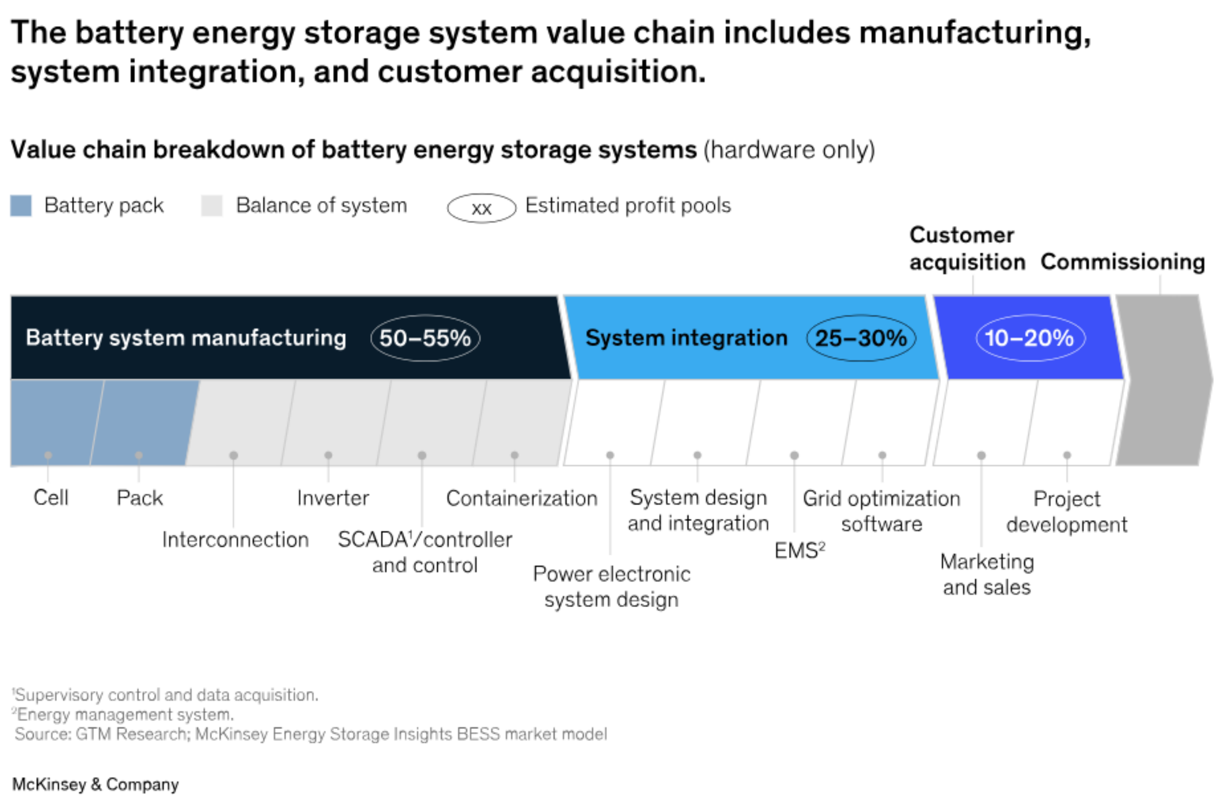
The McKinsey & Company (2023) article lays out four subsegments for the commercial and industrial segment (**Table 1**). They are:

- Electric vehicle charging infrastructure (EVCI),
- Critical infrastructure: telecom towers, data centres, and hospitals,
- Public infrastructure, commercial buildings, and factories, and
- Harsh environments: mining, construction, oil and gas exploration, and events such as outdoor festivals.

Other BESS Market Analysis

BESS Value Chain

Figure 15 The BESS value chain includes manufacturing, system integration, and customer acquisition



The McKinsey & Company (2023) article lays out the BESS value chain in **Figure 15**. They estimate 50 to 55% of the profit pool will be in the battery system manufacturing part of the value chain.

They estimate that system integration will compose between 25 and 30 % of the profit pool, with the remaining 10 to 20% of the profit pool falling into the customer acquisition portion of the value chain.

Recipes for Success in the BESS Market

The McKinsey & Company (2023) article lays out some factors they view as being needed for success in the BESS market.

1. **Identify an underserved need in the value chain.**
    a. E.g., software to improve the management of energy flows.
2. **Build resilience in supply chains**

    a. Strategic partnerships,
    b. Multiple sourcing,
    c. Local sourcing,
    d. Plan for technology shifts, and
    e. Another bottleneck: engineering, procurement & construction (EPC) capability and capacity.
3. **Focus on the product features that matter most**
    a. Have a customer segmentation strategy. The right product roadmap improves the odds of having a unique value proposition for any segment that a firm is trying to address.
4. **Think Big and Move Fast**
    a. Those with IP need to take some risks to build market share and avoid being muscled out by those backed with more money.

Canada – relevant legislation, frameworks, and plans

Canada's legislative framework

Canada's federal government passed the Canadian Net-Zero Emissions Accountability Act (justice.gc.ca),

Prairie's Region framework

Canada's federal government passed the Building a Green Prairie Economy Act (justice.gc.ca), and Prairie's Can prepared The Framework to Build a Green Prairie Economy - Canada.ca.

Manitoba Government Plans

Province's plan: subject to change, since it was made before the October 2023 election: Province of Manitoba | Climate and Green Plan (gov.mb.ca).

CER information for Manitoba: CER – Provincial and Territorial Energy Profiles – Manitoba (cer-rec.gc.ca).

City of Winnipeg

The City of Winnipeg put together their Community Energy Investment Roadmap (CEIR) that shows their plan to reach net zero. This may have some relevance to understand the City of Winnipeg opportunity Community Energy Investment Roadmap (CEIR) - Sustainability - City of Winnipeg.

Other Resources

A few other useful reports/papers worth reviewing for more technical information about ESS that include:

- Energy Storage Canada (2024),[xxxiv]
- Haas, et al (2022),[xxxv]
- Reilly, et al (2022),[xxxvi] and
- Hossain, et al (2020).[xxxvii]

A new report from the International Energy Agency (April 2024) Batteries and Secure Energy Transitions – Analysis - IEA may also be worth looking into.

Conclusion

Regardless of the global politics of the energy transition, the changing nature of power generation to increasingly intermittent sources means that there is a case for adding some form of ESS. BESS is increasingly being turned to around the world.

Given Canada's legislation, and Net Zero goals by 2050 (including achieved goals by 2035), offering ESS solutions, particularly BESS solutions will be needed.

Energy Storage Canada estimates that the ESS capacity in Canada by 2035 will range from eight to 12 GW installed capacity. The largest opportunity is expected to be in Ontario.

End Notes

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[i] Source: Energy storage for electricity generation - U.S. Energy Information Administration (EIA).
[ii] ibid.
[iii] Source: Our World in Data. How much CO2 can the world emit while keeping warming below 1.5°C and 2°C? - Our World in Data.
[iv] This figure includes fossil fuels, industry, and land use change.
[v] [250 / 41 = 6 years].
[vi] Vaclav Smil (2022). "How the World Really Works," Viking.
[vii] Energy and Climate Intelligence Unit, Data-Driven EnviroLab, NewClimate Institute, Oxford Net Zero - Net Zero Tracker. (2023). with minor processing by Our World in Data. "Data page: Status of net-zero carbon emissions targets." [data set]. Retrieved April 25, 2024, from Our World in Data: https://ourworldindata.org/grapher/net-zero-targets.
[viii] Energy and Climate Intelligence Unit, Data-Driven EnviroLab, NewClimate Institute, Oxford Net Zero - Net Zero Tracker. (2023). with minor processing by Our World in Data. "Data page: Status of net-zero carbon emissions targets." [data set]. Retrieved April 25, 2024, from Our World in Data: https://ourworldindata.org/grapher/net-zero-targets
[ix] Source: Analysis & Projections Projection Data - U.S. Energy Information Administration (EIA).
[x] Source: International Energy Outlook 2023 - U.S. Energy Information Administration (EIA).
[xi] Ibid.
[xii] Source: Annual Energy Outlook 2023 - U.S. Energy Information Administration (EIA).
[xiii] Source: Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050.
[xiv] Source: Exploring Canada's Energy Future - Canada Energy Regulator (cer-rec.gc.ca)
[xv] Source: Energy storage for electricity generation - U.S. Energy Information Administration (EIA).
[xvi] Source: SPECIAL REPORT | Why shipping pure hydrogen around the world might already be dead in the water | Recharge (rechargenews.com).
[xvii] Hassanpouryouzband, A., Joonaki, E., Edlmann, K. et al. Thermodynamic and transport properties of hydrogen containing streams. Sci Data 7, 222 (2020). https://doi.org/10.1038/s41597-020-0568-6
[xviii] Source: The Future of Nuclear Power | MIT Energy Initiative.
[xix] Energy Storage Canada (January 2024). "Long Duration Energy Storage (LDES) Opportunity Assessment: A Critical Component in Growing Ontario's Clean Energy Economy," Download PDF, and link.
[xx] Source: Exploring Canada's Energy Future - Canada Energy Regulator (cer-rec.gc.ca). The author combined the Maritimes and Territories.
[xxi] This section is based on Energy Storage Canada (October 2022). "Energy Storage: A Key Pathway to Net Zero in Canada," download PDF, from link.
[xxii] Ibid.
[xxiii] Manitoba Hydro (July 2023). "Integrated Resource Plan," Download PDF, link. See also Integrated Resource Plan (hydro.mb.ca). The Energy Storage Canada (2023) document's analysis may not have considered Manitoba Hydro's Integrated Resource Plan from July 2023. This plan noted increased demand for electricity from earlier analysis, so would boost the amount of both generating capacity and for ESS.
[xxiv] Manitoba Government (2023). "Manitoba's Energy Roadmap: Pathway to Prosperity," Download PDF
[xxv] Energy Storage Canada (October 2022). "Energy Storage: A Key Pathway to Net Zero in Canada," download PDF. Data is from Statistics Canada Table 25-10-0016-01.
[xxvi] This did not consider Manitoba Hydro's Integrated Resource plan from 2023, since it was released after the ESC report.
[xxvii] Korn, J., Lombardi, J., Muralidharan, R., Subin, Z., Zetkulic, A., House, H., and Nanavatty, R. (Feb 2024) "Why State Land Use Reform Should Be a Priority Climate Lever for America, RMI, link.

[xxviii] PhD Thesis 'Urban Form and Greenhouse Gas Emissions: Findings, Strategies, and Design Decision Support Technologies." Urban sprawl responsible for 30% of all greenhouse gases (tudelft.nl).

[xxix] McKinsey & Company (August 2, 2023). "Enabling renewable energy with Battery energy storage systems," link: Enabling renewable energy with battery energy storage systems | McKinsey.

[xxx] Source: Energy storage for electricity generation - U.S. Energy Information Administration (EIA).

[xxxi] Ibid.

[xxxii] Ibid.

[xxxiii] some have multiple uses so total exceeds 100%.

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