POLICY BRIEF / NOVEMBER 2025

The Immense Potential of Wind, Solar, and Storage in Manitoba

James Wilt, Policy Development Manager

COVER SUMMARY

This brief outlines the opportunities for wind, solar, and energy storage to support a clean energy transition in Manitoba in the next five years and the decades to come.

Manitoba must expand sources of electricity generation to meet growing peak demand. This brief finds that Manitoba could meet its short-term demand requirements by building 600 megawatts (MW) of wind power and at least 200 MW of batteries to increase reliable power supply. To support electrification in the longer-term, Manitoba should build an average of at least 200 MW of wind, 160 MW of solar, and 80 MW of energy storage every year over the next 25 years.

These investments can ensure electricity rates remain affordable while reducing emissions, fostering green industries and jobs, and supporting Indigenous-led development, among other benefits.

Climate Action Team Manitoba
info@climateactionmb.ca / 431-478-1708
climateactionmb.ca

Executive Summary

Meeting Near-Term Peak Electricity Requirements

- **Summary:** Manitoba is facing a wintertime peak capacity shortfall of about 270 megawatts (MW) of electricity by 2030, which Manitoba Hydro has proposed to address by building a new gas-fired power plant. This report argues that Manitoba should instead invest public resources in building grid-scale battery storage, which would maximize the benefits of existing and new wind power projects by matching supply with demand.
- **Recommendations:** Manitoba could meet its short-term peak demand requirements by building 600 MW of wind power and at least 200 MW of batteries. In addition to the 120 MW of winter firm capacity from new wind power, batteries would unlock an additional 170MW from existing and new wind power projects. If Manitoba Hydro procures less than 600 MW of wind power through the current process, it should build additional wind power to meet upcoming requirements.

Developing a Long-Term Vision for Manitoba's Electrification

- **Summary:** Provincial electricity demand is projected to more than double by 2050 due to electrification of transportation, buildings, and industry. Significant new generation capacity will be needed alongside demand reductions. Wind and solar power are highly complementary generation sources; Manitoba should plan to invest in both, and switch reliance between the two between summer and winter.
- **Recommendations:** By 2050, Manitoba should aim to reach at least 5,000 MW of wind power, 4,000 MW of solar power, and 2,000 MW of a diverse mix of energy storage. This would require annual additions of at least 200 MW of wind, 160 MW of solar, and 80 MW of energy storage every year between 2026 and 2050. Along with grid-scale battery storage, Manitoba should consider other forms of longer-duration energy storage such as compressed air and thermal storage.

Benefits to Manitoba

- These investments in clean electricity would reduce greenhouse emissions, promote provincial economic development, create good green jobs, eliminate wasteful spending on imported fossil fuels, improve affordability, and increase the reliability and stability of the grid. Crucially, Indigenous Nations and organizations can be a central part of the transition, advancing energy justice and Indigenous-led development.

Introduction: The Challenge of Meeting Manitoba's Growing Electricity Demand

Manitoba Hydro anticipates that the province may need up to 270 MW of additional electricity generation to meet peak demand within five years.[1] It expects that a share of this will be supplied by new wind power, while some additional capacity will likely also come from new power purchases from U.S. utilities.[2] However, Manitoba Hydro proposes to address most of the shortfall with a new 496 MW simple cycle gas turbine "peaker plant" that will provide dispatchable supply during periods of peak demand and severe drought conditions.[3] While it claims that "no decision on the fuel source has been made," the only realistic option for this proposal given the existing state of technologies is burning fossil gas.[4] The power plant would be built next to the existing Brandon Generating Station and would cost at least $738 million, with a total of $1.36 billion budgeted for contingency and financing costs.[5] It would also incur significant ongoing costs of purchasing fossil gas to burn as fuel, on top of the costs of routine operations and maintenance. Fossil fuel prices can be extremely volatile and contribute to higher energy prices, as well as broader inflationary pressures.[6]

The issue of peak demand is serious, and requires careful planning to address capacity gaps while improving affordability, job creation, and economic development.[7] Significant additional electricity supply will also be required in the coming years and decades given the need for the electrification of transportation, buildings, and industry, alongside measures to limit demand growth such as strong building codes, replacing electric baseboard heating with ground-source heat pumps, and limiting the overburdening of the grid by new heavy power users like data centres.[8]

This report argues that there are viable and reliable alternatives to addressing peak demand.[9] Specifically, it describes the benefits of building wind and solar combined with energy storage, especially grid-scale batteries. Importantly, Manitoba's hydroelectric system features extensive reservoir storage—with Lake Winnipeg engineered as a massive battery of sorts controlling flows into the Nelson River—that can release or hold back water based on demand, providing a major advantage for integrating wind and solar that many other jurisdictions do not have.[10] Rather than having to curtail renewable generation during periods of high production, like extremely sunny or windy stretches, this system allows Manitoba Hydro to store water that would otherwise be required to spin turbines for periods when renewable generation is lower.

The first part of this brief argues that Manitoba can best meet the more immediate needs of winter peak capacity requirements by investing in batteries to maximize the benefits from the

new Indigenous majority-owned wind power projects, along with excess supply from existing generation facilities.[11] If 600 MW of new wind power and at least 200 MW of batteries was online by 2030/31, this would provide sufficient electricity supply to meet projected peak demand requirements, alongside the additional capacity unlocked from existing wind resources. If Manitoba Hydro procures less than 600 MW of wind power through the current process, it will need to build additional wind power to meet these demand requirements. Additional battery investments beyond the immediately required 200 MW of installed capacity would provide even greater energy security.

The second part of this brief argues that to meet longer-term demand increases, the province should exclusively build a combination of wind and solar power, energy storage (including longer-duration systems like compressed-air and thermal batteries), and additional grid flexibility improvements like inter-provincial transmission and demand-side management.[12] If well-planned, such a combination would provide a highly reliable and cost-effective solution to energy needs, including during periods of peak demand, extreme weather events, and even compound energy droughts.

This approach would help further reduce Manitoba's already low emissions from electricity generation, reduce exposure to the supply and price volatility of fossil gas, create good green jobs, improve resilience for extreme weather, and achieve a zero-emissions electricity grid by 2035, as recommitted to in *Manitoba's Path to Net-Zero* plan published in October 2025. This wind, solar, energy storage, and grid flexibility buildout would also strengthen Manitoba's economic development in tandem with an east-west electricity grid, providing strong opportunities for energy exports to neighbouring provinces and territories.

Manitoba could likely develop these energy resources fairly quickly within a supportive policy context. Even with increasing delays in past years, the mean commissioning time—or the time between when the permitting and completion of a project—for solar and wind projects built in Canada from 2020–2022 were two and 3.1 years, respectively.[13] Ontario's recent battery storage procurement in mid-2024 will mean the systems will come online no later than 2028.[14] By contrast, the global demand surge for new gas-fired turbines has meant that estimated wait times for the equipment have increased to between three and seven years.[15] Wind, solar, and energy storage offer a lower-risk combination of energy resources than gas-fired power plants.

Costs of various electricity sources are currently difficult to project for the sake of comparisons due to the massive economic turmoil caused by U.S. tariffs. Manitoba Hydro is currently drafting a new Integrated Resource Plan (IRP), which will likely include up-to-date cost estimates for new electricity generation and storage; however, this information is not yet public. As a result, this report does not cite specific cost estimates but focuses instead on the technical viability of generation and storage options. With that said, the most recent estimates of the levelized cost of energy plus the levelized firming cost prepared by Lazard's of the U.S. shows that solar or wind combined with battery storage in California produces electricity at a cost well below that of a gas-fired peaker plant.[16] **This means that a pathway of variable renewables and energy storage will likely prove more cost-effective than further investments in fossil fuel infrastructure, especially over the lifetime of a project, contributing to increased affordability for Manitobans**.[17]

Meeting Near-Term Peak Capacity with Battery Energy Storage and Wind Power

Harnessing Manitoba's Wind Potential

Wind power is exceptionally well suited to meet Manitoba's wintertime requirements, as wind speeds tend to be strongest during cold months. Average monthly generation from wind power in Manitoba is highest between October and April, and drops to its lowest levels in July and August. In 2024, Manitoba's two wind farms—which have a combined installed capacity of 258 MW—generated more than 80,000 megawatt-hours (MWh) monthly in January, March, April, October, and December, and decreased to less than 45,000 MWh in July.[18] This relationship between cold weather and generation potential is ideal to help meet Manitoba's peak demand.

Manitoba's wind power potential is especially strong in the province's southwest; there is also significant wind potential in Northern Manitoba, including in Hudson Bay.[19] Wind turbines face issues with extreme cold and the icing of turbine blades; however, manufacturers are increasingly designing them to withstand such conditions, including through the combination of passive anti-icing and active de-icing technologies.[20] The issue of extreme cold also poses risks to fossil gas extraction facilities and power plants, with examples of cold-related shutdowns in recent years.[21] Spreading wind installations over a wide geographic area—which Manitoba is well suited for—allows for additional risk-reduction of adverse weather.[22]

Manitoba Hydro credits wind power with a firm capacity (the electricity available during peak demand hours) of 20 MW per 100 MW of installed capacity—half of its average capacity factor of 40%—due to it not being dispatchable during peak demand periods.[23] Put differently: on average, wind power can only be relied on to generate electricity when most needed 20% of the time, with the remaining generation occurring during non-peak hours. **The solution to this problem is utility-scale energy storage, especially lithium-ion batteries that have plummeted in cost in recent years**, dropping almost 20% between 2024 and 2025, although the impacts of tariffs may reverse this trend (along with cost trends for all energy resources).[24]

Firming Wind Power with Battery Storage

Batteries can store excess wind generation—which tends to be strongest at night, when demand is low—for peak demand loads in the mornings, along with recharging during the daytime ahead of the early evening peak. Demand peaks typically last several hours at a time, which is why battery systems are often designed with a four-hour duration, meaning that it can discharge electricity at its nameplate capacity for four consecutive hours. For example, a battery project with 100 MW of installed capacity and a four-hour duration will discharge 400 MWh of energy each cycle.

Batteries are also being built for longer-duration storage as well—such as eight hours of continued discharge—which can also provide cost efficiencies and extend the lifetime of the project.[25] Other energy storage options feature different profiles: the compressed air energy storage project that Hydrostor is currently building near Kingston, Ontario, will have an installed capacity of 500 MW and eight-hour duration, discharging 4,000 MWh of energy. Ontario's Independent Electricity System Operator is currently procuring long-duration energy storage projects that can discharge for at least eight hours at a time.[26] Most energy storage options can also be discharged at a lower rate if required. They can also store energy for longer periods than the standard diurnal cycle before discharging, although energy will gradually be lost over time, especially in the extreme cold.

In 2019, the U.S. National Renewable Energy Laboratory predicted that grid-scale battery storage could "satisfy a substantial portion of U.S. peak capacity needs." [27] This is increasingly borne out by the fact that electricity from batteries is eroding gas-fired generation during peak hours in California and Texas.[28] In California, the "firming cost" of using batteries to provide reliable electricity during peak demand remains below even the lowest cost for a gas peaker plant.[29] Many solar projects are now being built with battery storage to maximize benefits.[30]

Batteries are also well-suited for many other important functions.[31] One is to provide operating reserves; unlike thermal power plants, which take time to ramp-up, batteries can provide near-instantaneous energy to the grid, including for system restarts after a blackout.[32] They can also contribute to grid stability, with massive battery storage projects in China now being developed with large-scale grid-forming capacities.[33] Yet another service is as a non-wires alternative that can postpone costly transmission and distribution development and help ease grid congestion if well-coordinated.[34]

Finding the Right Mix of Wind and Storage

Despite dramatic cost reductions and the acceleration of energy storage globally, Manitoba Hydro states they have a "finite ability to reduce our peak demand."[35] Specifically, Manitoba Hydro has reported that 350 MW of batteries would be "the maximum amount of short term batteries that can effectively be connected to our system" due to the narrow difference between daytime and nighttime loads during extremely cold temperatures.

However, battery storage would effectively *double* wind power's firm capacity to 40%, by saving the electricity for when it is most needed in a day (see Figure 1). Installation of 200 MW of batteries could unlock an additional 50 MW of firm capacity from the 258 MW of existing wind power currently generated at non-peak times. It would also improve contributions of new generation by 20 MW for every 100 MW of installed wind power capacity. For example, if Manitoba builds 600 MW of installed wind capacity, it would unlock 240 MW of winter firm capacity, rather than only 120 MW. **In combination, battery storage paired with existing and new wind power would create about 290 MW of firm capacity to help address peak demand requirements.**

Due to this peak demand benefit, Manitoba should accelerate the installation of new wind power projects to reach 600 MW of additional installed capacity by 2030/31, alongside the coordinated installation of at least 200 MW of batteries. **While costs for all energy resources are in major flux at present, this approach will likely be cost-competitive, if not more cost-effective, than building a gas-fired power plant that is only used for a fraction of the year.** Brookfield Renewable's South March Battery Energy Storage System proposed to be built in Ottawa is estimated to cost $650 million for 250 MW of battery storage.[36] If this same cost-to-storage ratio was applied to Manitoba battery projects, this means it would cost about $520 million to build 200 MW of storage: about 70% of the base cost of a gas-fired peaker plant, not including any of its contingency or interest costs. Building 350 MW of battery storage, which Manitoba Hydro reports as the maximum amount in relation to addressing peak wintertime demand, would cost about $910 million assuming this cost-to-storage ratio.

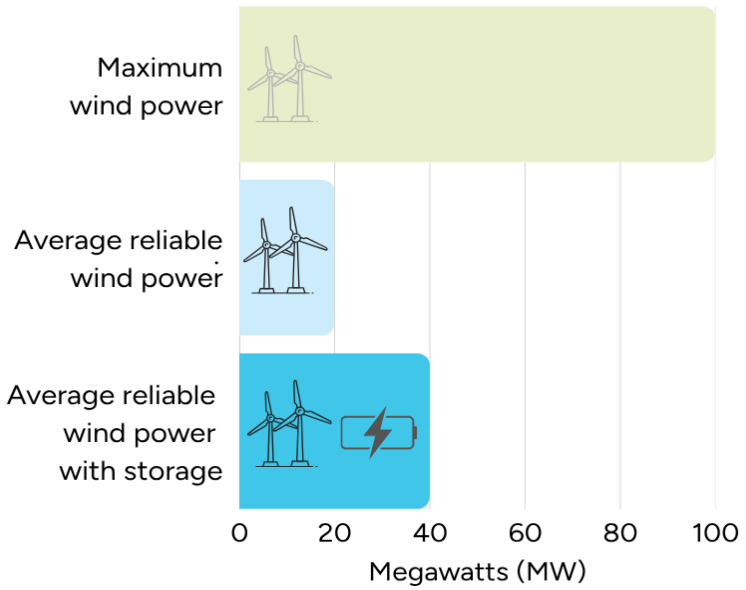

Figure 1. Firm wind power compared to maximum installed capacity, with and without battery storage.[37]

A Long-Term Vision for Manitoba's Electrification: Wind, Solar, Storage, and Grid Interties

Scaling Up Renewables and Storage over 25 Years

While vitally important, building new energy storage and wind power to address peak demand requirements in the next five years will only be the beginning of necessary investments to support electrification. In 2024-25, Manitoba Hydro generated 30,600 gigawatt-hours (GWh) of energy, with nearly 75% used domestically and the remainder exported; the utility also spent $105 million on imported electricity, down from $216 million in 2023-24.[38] Rapid and widespread electrification to displace current oil and gas consumption will require at least double this amount of energy; Manitoba Hydro's "high-load projection" by 2050 includes increases of 10,700 GWh for transportation, 8,200 GWh for space heating, and 4,400 GWh for industry, with an annual demand reaching more than 50,000 GWh by 2050.[39] However, a Climate Action Team (CAT) analysis has suggested that total energy requirements could exceed 70,000 GWh by 2050 to electrify *all* vehicles and space heating, not just most.[40]

According to CAT's previous analysis, Manitoba can meet about half of these energy requirements without requiring new generation by reducing demand through deep energy retrofits of buildings and re-allocating energy currently exported for provincial consumption to bolster supply.[41] This leaves about 20,000 GWh of new energy generation needed in Manitoba by 2050 (with accelerated deployment enabling faster electrification and emissions reductions, along with increased buffers for below-average hydroelectricity generation).

T**o achieve this goal, Manitoba should plan to reach at least 5,000 MW of installed wind power capacity (17,800–19,050 GWh per year), 4,000 MW of installed solar power capacity (5,760–7,520 GWh per year), and 2,000 MW of a diverse mix of energy storage (see Figure 2)**.[42] This would require annual additions of at least 200 MW of wind, 160 MW of solar, and 80 MW of energy storage every year between 2026 and 2050. For the sake of comparison, Alberta *already* has more than 5,700 MW of installed wind power capacity and more than 2,100 MW of installed solar power capacity.[43]

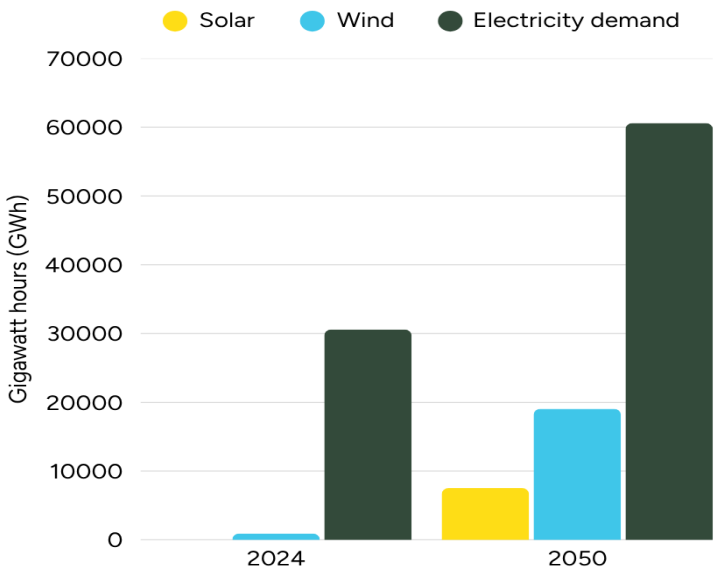

Figure 2. Estimated amounts of wind and solar generation required to decarbonize Manitoba by 2050, compared to 2024 levels.[44]

While land-use has been invoked as a case against wind and solar in favour of thermal power plants, these concerns are of little relevance to Manitoba; further, generation options like reservoir-based hydroelectric dams and fossil gas combustion tend to have high land-use impacts of their own, such as extensive networks of pipelines required for gas.[45] When it comes to wind power, a majority of land can and typically is used for other purposes, especially agricultural production. Direct land-use by turbines, roads and related infrastructure averages 0.75 acres/MW and wider land transformation averages 2.5 acres/MW.[46] Therefore, building 5,000 MW of wind power would require between 3,750 and 12,500 acres (less than 0.01% of Manitoba's land area), depending on location and calculation method.

Utility-scale solar uses more land than wind power—about five to 10 acres per MW—but the 20,000 to 40,000 acres required to build 4,000 MW of installed capacity is still a small fraction of the province's total area (less than 0.03%).[47] As another comparison, Manitoba's total farm area is 17.1 million acres, meaning developing 4,000 MW of utility-grid solar would only take up between 0.12% and 0.23% of agricultural land in the province.[48] Further, solar power can be combined with agriculture through agrivoltaics, allowing for the simultaneous generation of electricity, production of crops and cultivation of vital pollinator habitats.[49] There is also significant untapped potential for distributed solar development on the rooftops of residential, commercial, and institutional buildings.

Wind, solar, and energy storage are also more resilient to extreme weather events, including extended drought conditions. A study by the U.S. National Renewable Energy Laboratory found that "wind and solar generation tend to be available during the extreme weather events of today and do not introduce new resource adequacy concerns or system operation stress as their annual energy penetration increases."[50] This benefit is especially important in contrast to fossil fuel-powered generation, which already has immense cooling requirements and can experience outages and shutdowns due to higher temperatures.[51] A 2021 analysis of such risks concluded that hotter weather will lead to greater curtailment of electricity generation

by thermal power plants, rendering it a "systemically disadvantaged means of electricity production in a warming world."[52]

Further, while a gas-fired peaker plant will only generate electricity for a few days or weeks a year when most needed, a well-planned mix of wind, solar, and batteries will provide firm capacity for many various uses throughout the year—direct consumption, storage, export, or production of green hydrogen for industrial decarbonization—along with meeting peak demand in wintertime.

Complementing Wind with Solar Power

So far, this brief has discussed the many merits of wind power and battery energy storage. It is necessary to specifically examine the case for solar power, especially given the lack of investment in solar in Manitoba to date. **The cost of utility-scale solar installations dropped by more than 80% between 2010 and 2021.**[53] While it took several decades for the world to reach one million MW of installed solar capacity it only required *two more years* to double that, passing the two million MW mark in late 2024.[54] In 2024, solar met 40% of additional electricity demand in the world: triple the new demand met by coal and almost five times that of fossil gas.[55] SolarPower Europe recently projected that the world will reach seven million MW of solar capacity by 2030, requiring the addition of one million MW every year.[56] The International Energy Agency (IEA) has projected that solar will replace coal as the world's largest source of electricity generation in 2033.[57]

Winnipeg is one of the sunniest major cities in Canada.[58] A 2017 analysis identified Manitoba as one of four provinces—along with Alberta, Saskatchewan and Ontario—where there is considerable "solar farming" potential.[59] Studies have indicated that in combination with its extensive hydroelectric grid, wind and solar power could well exceed provincial demand and allow for Manitoba to export excess electricity to neighbouring jurisdictions.[60]

Of course, the impacts of the darkness of winter is an understandable concern when it comes to solar power in Manitoba and Canada more generally, particularly given such periods are precisely when electricity demand is highest.[61] A recent study conducted by Manitoba Hydro of 20 customers with solar generation—13 ground-mounted and seven rooftop—reported that average monthly solar generation hours in January was less than half than in July, and that total electricity generation was only *one-fifth* as much.[62] Crucially, solar generation in the winter takes place between about 9:00 AM and 4:30 PM, which does not help meet peak demand in early mornings and evenings.[63]

Some technologies can boost solar generation year-round, such as solar trackers that shift panels to always face the sun; studies have suggested that single-axis tracking can boost production by 20% and dual-axis tracking by 40%, compared to fixed-tilt systems.[64] However, trackers increase the upfront costs of installation and require regular maintenance and replacement of parts, especially in the extreme cold.[65] **Given these realities, Manitoba should design its rollout of wind, solar, and energy storage to largely switch reliance from solar to wind with the change in seasons.**

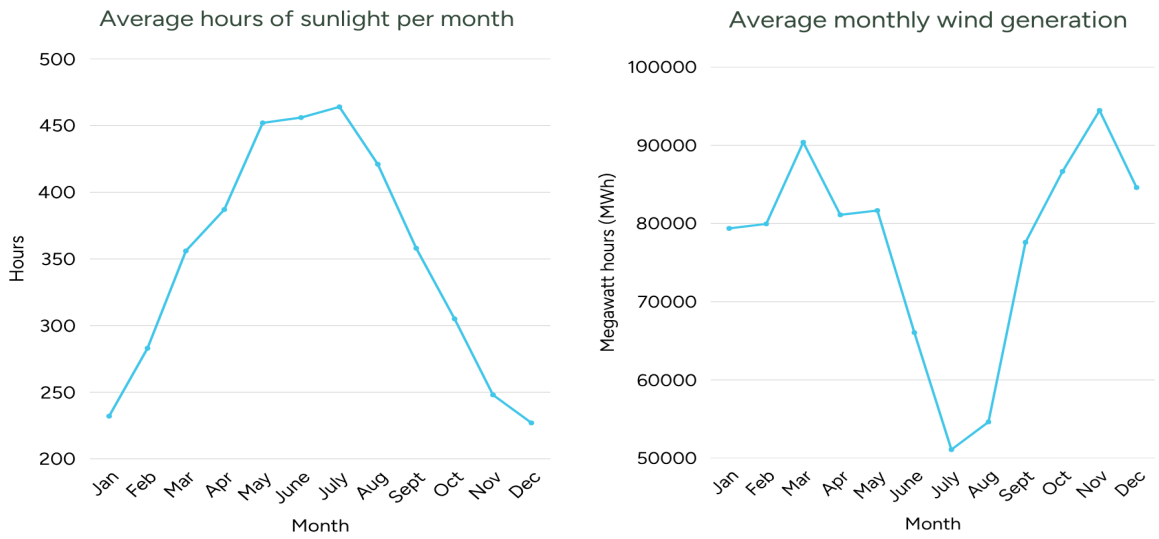

Figure 3. Average monthly solar potential (left; 2020) and wind generation (right; 2020-2024) in Manitoba.[66]

Options to Balance Out the Variability of Wind and Solar

Wind and solar power are highly complementary generation sources, with solar more productive during the daytime and summer months, while wind is strongest at night and during winter months or cloudy weather (see Figure 3).[67] This relationship allows for effective "co-location" of wind and solar power, which "significantly mitigate energy intermittency issues, enhance grid stability, and can be more cost-effective due to shared infrastructure."[68]

Transmission interties with neighbouring jurisdictions can further strengthen the resiliency of this combination, though these can come with their own socioecological impacts and risks. Manitoba could also use excess electricity to produce green hydrogen for industrial decarbonization.[69] There may also be a role for green hydrogen as a seasonal energy storage option but this requires caution and close comparison with other storage options.[70]

Further, developing a diverse mix of grid-scale energy storage can help smooth out the intermittency of wind and solar on multiple time scales by helping to save some energy generated during periods of excess supply to fill the gaps during low production.[71] Along with lithium-ion batteries, technologies like capacitors and flywheels can provide immediate bursts of energy (and kinetic inertia, in the case of the latter) to the grid.[72] Alternative battery chemistries, such as sodium-ion batteries, can provide specific benefits such as greater supply chain certainty and reduced need for expensive thermal management systems.[73]

Many longer-term energy storage options also exist including compressed air, thermal batteries, and flow batteries.[74] Compressed air storage may have significant potential in Manitoba due to the deep saline aquifers in the province's southwest, allowing for co-location with wind and solar.[75] In the thermal storage realm, the largest "sand battery" in the world recently started operations in Finland, storing excess renewable energy as high-temperature heat for later use in the small town's district heating system; the company reports that this heat can be stored

for close to a week in winter and a month in summer.[76] Electric thermal storage can also be implemented at the scale of individual residential buildings as well, such as Québec's financial incentives to combine heat pump and thermal storage installations and the long-running "Heat for Less" program in Summerside, Prince Edward Island.[77]

Energy storage would be a highly worthwhile area for the provincial government to direct funding for research and development, with a particular focus on maximizing storage capabilities and performance in extreme cold conditions. This work would be well-suited for the Province's new Ministry of Innovation and New Technology, along with collaborations with institutions such as Red River College Polytechnic. Further innovations in this space would provide ever-greater stability to this emissions-free grid and facilitate the continued expansion of wind and solar in the decades to come.

Conclusion

It will require care and coordination to develop a reliable and cost-effective system of wind, solar, and energy storage to electrify Manitoba. Yet this is true of *all* energy systems, particularly in the context of climate change and the cost-of-living crisis. Manitoba *cannot afford* to spend significant public resources on new fossil fuel infrastructure while reliable alternatives exist that can meet peak demand requirements and provide many other services. For starters, the Province should instruct Manitoba Hydro not to proceed with the proposed gas-fired power plant and to redirect its resources and efforts into a plan to develop and coordinate a large-scale wind and solar rollout over the coming decade, starting with a significant investment in batteries.

At a broader level, the provincial government must present a clear and ambitious vision for developing wind, solar, and energy storage in Manitoba as a core aspect of creating good green jobs, building provincial resilience and independence, and contributing to Canada's emissions reduction obligations. Manitoba cannot advance such a strategy in a piecemeal fashion, and should work to develop all aspects—generation, storage, grid flexibility, demand-side management—in tandem to produce necessary stability and benefits. This pivot will require courage and commitment by policymakers, but will position the province as a national leader in the fight against climate change, ensuring an affordable and clean future for Manitobans.

Endnotes

1 Manitoba Hydro, *Fiscal 2026 to 2028 General Rate Application: Appendix 4.3, 2024 Proxy Development Plan Tables*, March 28, 2025, https://www.hydro.mb.ca/docs/regulatory_affairs/pdf/electric/gra_2026_2028/04-3_appendix_4-3_2024_proxy_development_plan_tables.pdf; This estimate comes from subtracting "Total New Power Resources" from the "System Surplus/Deficit @ Point of Supply."

2 Manitoba Hydro, "RE: Manitoba Hydro Preliminary Estimate for Dispatchable Capacity Resource," February 25, 2025, https://www.pubmanitoba.ca/v1/proceedings-decisions/appl-current/pubs/mh-preliminary-estimates/mh-pub-re-preliminaryestimate-for-dispatchable-capacity-resource.pdf; Public Utilities Board (PUB), "Comments and Recommendations on Manitoba Hydro's Preliminary Estimate For a 500 MW Dispatchable Capacity Resource," March 28, 2025, https://www.pubmanitoba.ca/v1/proceedings-decisions/appl-current/pubs/mh-preliminary-estimates/pub-recommendation-on-preliminary-estimate-for-capacityresource-march2025.pdf.

3 PUB, "Comments and Recommendations."

4 PUB, "Comments and Recommendations"; International Energy Agency (IEA), *Outlook for Biogas and Biomethane: A Global Geospatial Assessment* (IEA, 2025); Feedback EU, *Biomethane: Setting a Target That is Fit for Food and Climate* (Foodrise EU, 2023), 4.

5 PUB, "Comments and Recommendations."

6 Jessica Kelly, *How Fossil Fuels Drive Inflation and Make Life Less Affordable for Canadians* (International Institute of Sustainable Development, July 2024).

7 *CBC News*, "Manitoba Hydro Sets New Daily Record for Electricity Demand," January 31, 2025, https://www.cbc.ca/news/canada/manitoba/manitoba-hydro-peak-usage-1.7446495.

8 Alyssa Nippard and James Gaede, "A Preliminary Look at Demand Flexibility and Peak Demand Reductions in Canada," Efficiency Canada, April 30, 2025, https://www.efficiencycanada.org/a-preliminary-look-at-demand-flexibility-and-peak-demand-reductions-in-canada/.

9 Ember, "Clean Flexibility," accessed November 3, 2025, https://ember-energy.org/focus-areas/clean-flexibility/.

10 Manitoba Hydro, "Energy Storage at Manitoba Hydro," October 1, 2019, https://www.hydro.mb.ca/articles/2019/10/energy_storage_at_manitoba_hydro/.

11 Manitoba Hydro, "Call for Power: Indigenous Majority-Owned Wind," accessed September 10, 2025, https://www.hydro.mb.ca/corporate/call-for-wind-power/.

12 Will Noel, Lia Codrington, and Scott MacDougall, *I'll Have What They're Having: Lessons Learned From Six Jurisdictions Leading in Wind and Solar Deployment* (Pembina Institute, 2024), 9

13 Anurag Gumber et al., "A Global Analysis of Renewable Energy Project Commissioning Timelines," *Applied Energy* 358 (March 2024): 122563, https://doi.org/10.1016/j.apenergy.2023.122563.

14 Government of Ontario, "Ontario Completes Largest Battery Storage Procurement in Canada to Meet Growing Electricity Demand," May 9, 2024, https://news.ontario.ca/en/release/1004567/ontario-completes-largest-battery-storage-procurement-in-canada-to-meet-growing-electricity-demand.

15 Jared Anderson, "US Gas-fired Turbine Wait Times as Much as Seven Years; Costs up Sharply," *S&P Global Commodity Insights*, May 20, 2025, https://www.spglobal.com/commodity-insights/en/news-research/latest-news/electric-power/052025-us-gas-fired-turbine-wait-times-as-much-as-seven-years-costs-up-sharply.

16 Lazard, *Levelized Cost of Energy+ June 2025* (Lazard, 2025), 21.

17 Will Noel et al., *Amped Up: Options for Growing British Columbia's Electricity Supply* (Pembina Institute, 2024), 4.

18 Statistics Canada, "Electric Power Generation, Monthly Generation By Type Of Electricity," Table 25-10-0015-01, September 2, 2025, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510001501.

19 Raidin Blue and Binnu Jeyakumar, *Offshore Wind in Canada* (Pembina Institute, 2022), 2–3.

20 Emmanuel Quayson-Sackey et al., "Technological Advancements for Anti-Icing and De-Icing Offshore Wind Turbine Blades," *Cold Regions Science and Technology* 231 (March 2025): 104400, https://doi.org/10.1016/j.coldregions.2024.104400; Natural Resources Canada, "Wind Energy in Cold Climates," January 7, 2025, https://natural-resources.canada.ca/energy-sources/renewable-energy/wind-energy-cold-climates; Northern Energy Capital, "Haeckel Hill-Thay T'äw Wind Energy Project," accessed November 3, 2025, https://www.northernenergycapital.com/haeckel-hill-wind-project..

21 Paul Arbaje and Mark Specht, *Gas Malfunction: Calling into Question the Reliability of Gas Power Plants* (Union of Concerned Scientists, 2024), 4; Mitchell Beer, "Alberta Premier Blames Renewables After Cold Snap, Idled Gas Plants Trigger Grid Emergency," *The Energy Mix*, January 19, 2024, https://www.theenergymix.com/alberta-premier-blames-renewables-after-cold-snap-idled-gas-plants-trigger-grid-emergency/; Scott Disavino, "US Winter Storms Could Cut Natural-gas Supplies," *Reuters*, January 5, 2025, https://www.reuters.com/business/energy/us-winter-storms-could-cause-power-outages-cut-natgas-supplies-2025-01-03/.

22 Anna Kanduth, "Solar and Wind: A Powerful Couple," Canadian Climate Institute, February 9, 2023, https://440megatonnes.ca/insight/solar-and-wind-a-powerful-couple/.

23 Manitoba Hydro, *2023 Integrated Resource Plan: Appendix 2 – New Resource Options* (Manitoba Hydro, 2023), 2–3.

24 Lazard, *Levelized Cost of Energy+*, 21.

25 Julian Spector, "Lithium-Ion Batteries Beat Novel Long-Duration Tech In California Contest," *Canary Media*, January 27, 2022, https://www.canarymedia.com/articles/long-duration-energy-storage/lithium-ion-batteries-beat-novel-long-duration-tech-in-california-contest; George Heynes, "Quinbrook, CATL Unveil 8-hour Duration BESS Technology Set for Australia," *Energy Storage News*, March 6, 2025, https://www.energy-storage.news/quinbrook-catl-unveil-8-hour-duration-bess-technology-set-for-australia/; Anne-Louise Stranne Petersen, "Getting to Grips With the Eight-hour Battery Opportunity," *Infrastructure Investor*, May 26, 2025, https://www.infrastructureinvestor.com/getting-to-grips-with-the-eight-hour-battery-opportunity/.

26 Independent Electricity System Operator (IESO), *Long Lead-Time Request for Proposals*, October 21, 2025, https://www.ieso.ca/-/media/Files/IESO/Document-Library/engage/llt/llt-rfp-20251021-presentation.pdf.

27 Paul Denholm et al., *The Potential for Battery Energy Storage to Provide Peaking Capacity in the United States* (National Renewable Energy Laboratory, 2019), 22.

28 Noel et al., *I'll Have What They're Having*, 9; Garrett Hering, "California Batteries Taking Bigger Bite Out of Gas-fueled Energy," *S&P Global*, December 26, 2024, https://www.spglobal.com/commodity-insights/en/news-research/latest-news/natural-gas/122624-california-batteries-taking-bigger-bite-out-of-gas-fueled-energy; Dennis Wamsted and Seth Feaster, "A Summer of Solar and Battery Storage Records in Texas," September 17, 2025, https://ieefa.org/resources/summer-solar-and-battery-storage-records-texas.

29 Lazard, *Levelized Cost of Energy+*, 30.

30 *Power Technology*, "UAE Launches World'S First 24/7 Solar PV Battery Storage Gigascale Project," January 15, 2025, https://www.power-technology.com/news/uae-24-7-solar-pv-battery-storage/.

31 Thomas Bowen et al., *Grid-Scale Battery Storage: Frequently Asked Questions* (USAID-NREL, September 2019), 2–3.

32 Owen Comstock, "About 25% Of U.S. Power Plants Can Start Up Within An Hour," *Today in Energy*, November 19, 2020, https://www.eia.gov/todayinenergy/detail.php?id=45956.

33 Marija Maisch, "China Switches on Its Largest Standalone Battery Storage Project," *PV Magazine*, July 21, 2025, https://www.ess-news.com/2025/07/21/china-switches-on-its-largest-standalone-battery-storage-project/; Cameron Murray, "Rongke Power Completes Grid-Forming 175mw/700mwh Vanadium Flow Battery In China, World's Largest," *Energy Storage News*, December 6, 2024, https://www.energy-storage.news/rongke-power-completes-grid-forming-175mw-700mwh-vanadium-flow-battery-in-china-worlds-largest/.

34 Alex Eller, "Energy Storage Will Disrupt Transmission and Distribution Investments," *Utility Dive*, October 17, 2017, https://www.utilitydive.com/news/energy-storage-will-disrupt-transmission-and-distribution-investments/506945/.

35 Manitoba Hydro, "2025 Integrated Resource Plan: July Information Session – Video Transcript," July 2025, https://www.hydro.mb.ca/docs/corporate/irp/2025-irp-interested-parties-july-information-session-audio-recording-transcript-en.pdf.

36 Joanne Laucius, "Massive Battery Energy Storage System Project Sparks Controversy at Ottawa Committee Meeting," *Ottawa Citizen*, June 9, 2025, https://ottawacitizen.com/news/rural-battery-energy-storage-system-project-ottawa.

37 Manitoba Hydro, *2023 Integrated Resource Plan: Appendix 2*, 2–3.

38 Manitoba Hydro, *2025 Integrated Resource Plan: PUB Information Session February 2025* (Manitoba Hydro, 2025), 32–39.

39 Climate Action Team Manitoba (CAT), *Manitoba's Road to Resilience, Volume 2: Energy Solutions* (CAT, 2024), 4.

40 Manitoba Hydro, *Manitoba Hydro-Electric Board 74th Annual Report for the Year Ended March 31, 2025* (Manitoba Hydro, 2025), 38, 83.

41 CAT, *Manitoba's Road to Resilience, Volume 2*, 5.

42 CAT, *Manitoba's Road to Resilience, Volume 2*.

43 Canadian Renewable Energy Association (CanREA), "By the Numbers," last updated December 31, 2024, https://renewablesassociation.ca/by-the-numbers/.

44 Manitoba Hydro, *Manitoba Hydro-Electric Board 74th Annual Report* 38, 83; Manitoba Hydro, *Integrated Resource Plan: Appendix 2*, 2–5; Canadian Renewable Energy Association (CanREA), "By the Numbers"; Manitoba Hydro, *2025 Integrated Resource Plan*, 45, https://mbeconetwork.org/wp-content/uploads/2025/04/25-02-24-2025-IRP-PUB-Information-Session-1-slide-deck.pdf; CAT, *Road to Resilience, Volume 2*, 5.

45 Rick Judson, "Energy Efficiency Is Only Part of the Puzzle," *Winnipeg Free Press*, August 28, 2025, https://www.winnipegfreepress.com/opinion/analysis/2025/08/28/energy-efficiency-is-only-part-of-the-puzzle; Sarah M. Jordaan et al., "Understanding the Life Cycle Surface Land Requirements of Natural Gas-fired Electricity," *Nature Energy* 2, no. 10 (September 28, 2017): 804–12, https://doi.org/10.1038/s41560-017-0004-0; Farha Akhtar, "Exploring the Impacts of Hydroelectric Megaprojects on Indigenous Lands," Society of Environmental Journalists, February 1, 2023, https://

www.sej.org/publications/features/exploring-impacts-hydroelectric-megaprojects-indigenous-lands.

46 Paul Denholm et al., *Land-Use Requirements of Modern Wind Power Plants in the United States* (National Renewable Energy Laboratory, 2009), 22–23; U.S. Department of Energy, *Wind Vision: A New Era for Wind Power in the United States* (US Department of Energy, 2015), 84, 214.

47 Solar Energy Industries Association, "Land Use & Solar Development," accessed September 15, 2025, https://seia.org/initiatives/land-use-solar-development/; Coldwell Solar, "How Much Investment Do You Need For A Solar Farm?" accessed September 15, 2025, https://coldwellsolar.com/how-much-investment-do-you-need-for-a-solar-farm/; Powertech Energy, "How Much Land Do I Need To Build A 5 MW Solar Farm?" February 2025, https://www.powertechenergy.com.au/a/how-much-land-do-i-need-to-build-a-5-mw-solar-farm.

48 Manitoba Agriculture, "Sector Profile At A Glance: Agriculture," June 2025, https://www.manitoba.ca/agriculture/markets-and-statistics/publications-and-proceedings/pubs/agriculture-sector-profile.pdf.

49 U.S. Department of Energy, "Agrivoltaics: Solar and Agriculture Co-Location," accessed September 15, 2025, https://www.energy.gov/eere/solar/agrivoltaics-solar-and-agriculture-co-location; *CBC News*, "Simulations in Agri-voltaics Suggest Canadian Farms Could One Day Double as Giant Solar Batteries," May 11, 2023, https://www.cbc.ca/news/canada/london/solar-panel-crops-agri-voltaics-canada-1.6832870; A. Ludzuweit et al., "Enhancing Ecosystem Services and Biodiversity in Agrivoltaics Through Habitat-enhancing Strategies," *Renewable and Sustainable Energy Reviews* 212 (January 31, 2025): 115380, https://doi.org/10.1016/j.rser.2025.115380.

50 Josh Novacheck et al., *The Evolving Role of Extreme Weather Events in the U.S. Power System with High Levels of Variable Renewable Energy* (National Renewable Energy Laboratory, 2021), viii.

51 Alberto Sergio and Francesco Pietro Colelli, "Weather-induced Power Plant Outages: Empirical Evidence From Hydro and Thermal Generators in Europe," *Energy Economics*, May 1, 2025, 108549, https://doi.org/10.1016/j.eneco.2025.108549.

52 Ethan Coffel and Justin Mankin, "How Global Warming is Making Power Plants Produce Less Electricity," *CarbonBrief*, February 15, 2021, https://www.carbonbrief.org/guest-post-how-global-warming-is-making-power-plants-produce-less-electricity/.

53 National Renewable Energy Laboratory, "Documenting a Decade of Cost Declines for PV Systems, February 10, 2021, https://www.nrel.gov/news/detail/program/2021/documenting-a-decade-of-cost-declines-for-pv-systems.

54 Susanna Twidale, "Exclusive: Global Solar Capacity Hits 2 TW on Path to Climate Goal, Data Shows," *Reuters*, November 7, 2024, https://www.reuters.com/sustainability/climate-energy/global-solar-capacity-hits-2-tw-path-climate-goal-data-shows-2024-11-07/.

55 Euan Graham and Nicolas Fulghum, *Global Electricity Review 2025* (Ember, 2025), 11–12, 22.

56 SolarPower Europe, "New Report: World Installed 600 GW of Solar in 2024, Could Be Installing 1 TW Per Year by 2030," May 6, 2025, https://www.solarpowereurope.org/press-releases/new-report-world-installed-600-gw-of-solar-in-2024-could-be-installing-1-tw-per-year-by-2030.

57 Josh Gabbatiss and Molly Lempriere, "Factcheck: 16 Misleading Myths About Solar Power," *CarbonBrief*, August 27, 2025, https://interactive.carbonbrief.org/factcheck/solar/index.html.

58 Solar by Kuby, "Wind and Solar Energy Potential in Canada and the World," accessed September 10, 2025, https://kuby.ca/solar/solar-information/articles/wind-and-solar-energy-potential-in-canada-and-the-world.

59 Christopher Barrington-Leigh and Mark Ouliaris, "The Renewable Energy Landscape in Canada: A Spatial Analysis," *Renewable and Sustainable Energy Reviews* 75 (August 2017): 812, https://doi.org/10.1016/j.rser.2016.11.061.

60 Barrington-Leigh and Ouliaris, "The Renewable Energy Landscape in Canada," 818; Mohammadali Saffari and Madeleine McPherson, "Assessment of Canada's Electricity System Potential for Variable Renewable Energy Integration," Energy 250 (July 2022): 123757, https://doi.org/10.1016/j.energy.2022.123757.

61 Canada Energy Regulator, "Market Snapshot: Solar Power Generation in Canada Is Highly Seasonal," June 30, 2022, https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2019/market-snapshot-solar-power-generation-in-canada-is-highly-seasonal.html.

62 Phil Merkel, *Solar PV Generation Performance Load Research Study* (Manitoba Hydro, January 2023), 22–23.

63 Merkel, *Solar PV Generation*, 25.

64 Felipe Rebolledo et al., "Performance Evaluation of Different Solar Modules and Mounting Structures on an On-Grid Photovoltaic System in South-Central Chile," *Energy Sustainable Development/Energy for Sustainable Development* 68 (March 25, 2022): 65–75, https://doi.org/10.1016/j.esd.2022.02.003; Sara Hoff and Jonathan DeVilbiss, "More Than Half of Utility-scale Solar Photovoltaic Systems Track the Sun Through the Day," US Energy Information Administration, April 24, 2017, https://www.eia.gov/todayinenergy/detail.php?id=30912; Krishna Kumba et al., "Solar Tracking Systems: Advancements, Challenges, and Future Directions: A Review," *Energy Reports* 12 (September 25, 2024): 3566–83, https://doi.org/10.1016/j.egyr.2024.09.038.

65 Jeremy Vickerman and Gorka Arrieta, "The Advantages and Disadvantages of Solar Tracking," *RatedPower*, March 14, 2024, https://ratedpower.com/glossary/solar-trackers/.

66 Merkel, *Solar PV Generation*, 23; Statistics Canada, "Electric Power Generation," Table 25-10-0015-01.

67 Kanduth, "Solar and Wind"; Noel, Codrington, and MacDougall, *I'll Have What They're Having*.

68 Qusay Hassan et al., "A Review of Hybrid Renewable Energy Systems: Solar and Wind-powered Solutions: Challenges, Opportunities, and Policy Implications," *Results in Engineering* 20 (November 23, 2023): 101621, https://doi.org/10.1016/j.rineng.2023.101621; RenewableUK, *Making the Most of Renewables: The Role of Onshore Co-location in Accelerating an Integrated Energy System* (RenewableUK, April 2024), 11; Ben Jervey, "Want to Improve Wind and Solar Power? Bring Them Together," *Ensia*, November 7, 2016, https://ensia.com/articles/renewable-energy-wind-solar/.

69 Clean Air Task Force, "Hydrogen for Decarbonization: A Realistic Assessment," July 8, 2024, https://www.catf.us/resource/hydrogen-decarbonization-realistic-assessment/.

70 Chingis Idrissov, "Evaluating Hydrogen's Role in Energy Storage Solutions," *EE Times Europe*, December 13, 2023, https://www.eetimes.eu/evaluating-hydrogens-role-in-energy-storage-solutions/; Kenji Shiraishi et al., "The Role of Hydrogen as Long-duration Energy Storage and as an International Energy Carrier for Electricity Sector Decarbonization," *Environmental Research Letters* 19, no. 8 (June 14, 2024): 084011, https://doi.org/10.1088/1748-9326/ad5856; U.S. Department of Energy, "Does the Use of Hydrogen Produce Air Pollutants Such as Nitrogen Oxides?" *Energy.gov*, accessed September 19, 2025, https://www.energy.gov/eere/fuelcells/does-use-hydrogen-produce-air-pollutants-such-nitrogen-oxides.

71 Evelina Stoikou, "Lithium-Ion's Grip on Storage Faces Wave of Novel Technologies," *BloombergNEF*, June 4, 2024, https://about.bnef.com/insights/clean-energy/lithium-ions-grip-on-storage-faces-wave-of-novel-technologies/.

72 Tim Newcomb, "A Staggering 19x Energy Jump in Capacitors May Be the Beginning of the End for Batteries," *Popular Mechanics*, May 9, 2024, https://www.popularmechanics.com/science/a60732620/capacitor-energy-storage-breakthrough/; Cameron Murray, "'World's Largest' 30MW Flywheel Energy Storage Project Connects To Grid In China," *Energy Storage News*, September 19, 2024, https://www.energy-storage.news/worlds-largest-30mw-flywheel-energy-storage-project-connects-to-grid-in-china/; Paul Denholm et al., *Inertia and the Power Grid: A Guide Without the Spin* (National Renewable Energy Laboratory, 2020).

73 Brian Martucci, "Are Sodium-ion Batteries Finally Ready to Compete With Lithium?," *Utility Dive*, October 28, 2025, https://www.utilitydive.com/news/are-sodium-ion-batteries-finally-ready-to-compete-with-lithium/803998/; Julian Spector, "Peak Energy's New Battery Is Cooler Than Lithium-ion Systems," *Canary Media*, August 21, 2025, https://www.canarymedia.com/articles/batteries/peak-energy-sodium-cool-first-installation.

74 Cameron Murray, "'World's Largest' Compressed Air Energy Storage Project Connects To The Grid In China," *Energy Storage News*, April 10, 2024, https://www.energy-storage.news/worlds-largest-compressed-air-energy-storage-project-connects-to-the-grid-in-china/; Jeffrey Rissman and Eric Gimon, *Industrial Thermal Batteries Decarbonizing U.S. Industry While Supporting a High-Renewables Grid* (Energy Innovation Policy & Technology, July 2023); Emily Chung, "These Giant Batteries Store Energy, but Not as Electricity," *CBC*, April 5, 2024, https://www.cbc.ca/news/science/thermal-storage-explainer-1.7163743; Alex Scott, "Flow Batteries, The Forgotten Energy Storage Device," *Chemical & Engineering News*, July 30, 2023, https://cen.acs.org/materials/energy-storage/Flow-batteries-forgotten-energy-storage/101/i25;

75 Melissa Felder et al., *Evaluation Of Carbon Capture And Storage Potential In Canada* (Clean Prosperity Canada, 2024); Brian Brunskill and Robert Stewart, "White Paper: Compressed Air Energy Storage (CAES) in Saskatchewan," Petroleum Technology Research Centre (PTRC) Sustainable Energy, November 1, 2023, https://ptrc.ca/pub/Blog/ptrc-caes-white-paper-2023-final.pdf.

76 Polar Night Energy, "World's Largest Sand Battery Now in Operation," June 11, 2025, https://polarnightenergy.com/news/worlds-largest-sand-battery-now-in-operation/; Sophie Berdugo, "A Scalding Hot 'Sand Battery' Is Now Heating A Small Finnish Town," *LiveScience*, September 6, 2025, https://www.livescience.com/technology/engineering/a-scalding-hot-sand-battery-is-now-heating-a-small-finnish-town.

77 Hydro-Québec, "Need to Replace Your Central Heating System?," accessed October 29, 2025, https://www.hydroquebec.com/residential/energy-wise/tips/windows-heating-air-conditioning/thermal-storage/; Jon Tattrie, "Summerside's Heat for Less Program May Expand Across P.E.I.," CBC, July 15, 2016, https://www.cbc.ca/news/canada/prince-edward-island/summerside-heat-for-less-program-may-expand-across-pei-1.3679966.