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UP TO THE CHALLENGE: ACHIEVING A NET ZERO GRID IN ALBERTA

By Tim Weis

SUMMARY

This scoping paper reviews recent studies of Alberta's electricity system in the context of an economy-wide transition to net zero emissions by 2050. Informed by new economic modelling, the review finds that Alberta's electricity system is likely to continue to decarbonize under current policies. The province has the ability and the natural resources to almost completely decarbonize electricity generation in the next decade, in line with the increased flexibility expected of the updated federal Clean Electricity Regulations.

Tim Weis *is a professional engineer and an Industrial Professor in Mechanical Engineering at the University of Alberta, where he teaches courses in energy systems and thermodynamics. He supervises graduate students modelling questions concerning renewable energy systems with a focus on the evolution of Alberta's electricity market as it phases out coal, as well as in remote communities transitioning off of diesel. Prior to joining the University of Alberta, he worked for the Pembina Institute, the Canadian Wind Energy Association, and the Government of Alberta, focusing on technical and policy issues surrounding low-carbon energy systems in Canada.*

August 2024

Calgary, Alberta, on January 15, 2024. In response to a cold snap, the Alberta government issued an emergency alert asking people to turn off electrical appliances and conserve energy to reduce strain on the electrical grid. THE CANADIAN PRESS/Todd Korol

1. INTRODUCTION

Alberta's electricity system has been a lightning rod for national news in the last year. In the fall of 2023, the provincial government launched a national advertising campaign claiming draft federal electricity regulations would result in high prices and blackouts sometime after 2035 (Black, 2023), both of which, unfortunately, Albertans had already experienced in the past year. Monthly average pool prices reached their highest point in Alberta's history in December 2022, peaking at rates over eight times above the record low prices in 2016-2017, and Edmonton and Calgary experienced brief brownouts in April 2024. The provincial government had imposed a controversial moratorium on new renewable projects in August 2023 (Fletcher, 2024), and issued an emergency grid alert to the general public during a cold snap in January 2024. Behind these headline-generating events, however, investment had been pouring into the electricity system, beginning a process that could fundamentally reshape the province's electricity supply.

The recent turmoil in Alberta has often pitted specific technologies and government policies against each other in the public discourse, while overlooking the expanded role the electricity system will need to play if Alberta aims to meet its publicly stated goals of achieving a carbon neutral economy by 2050.[1] Information gaps of available and relevant information on Alberta's options and pathways are contributing to an unproductive public discussion around these topics.

This paper seeks to fill that gap by presenting new modelling that addresses not only how Alberta can decarbonize its electricity system, but also the grid's expanded role in supporting broader decarbonization in Alberta. The paper discusses the current state and future trajectory of Alberta's electricity system, provides an overview of the recently proposed federal Clean Electricity Regulations, and outlines the results of various public models that have examined Alberta's electricity future. The paper also presents new modelling completed by Navius Research for the Canadian Climate Institute, focusing on pathways for the electricity sector to enable Alberta to achieve its goal of economy-wide carbon neutrality by 2050.

There is broad agreement across the models that low-cost wind and solar are likely to dominate much of the new electricity generation sources built in Alberta over the coming decades. These resources will likely be supported and balanced by existing and expanded gas facilities, many of which will require carbon capture and storage in order to achieve net zero, outcompeting other thermal options like nuclear power.

The forecasts for the pace and scale of different technologies' adoption vary depending on different modelling assumptions as well the role of policies such as the draft Clean Electricity Regulations. While

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1 There is broad scientific consensus that carbon dioxide (CO_2) is the primary greenhouse gases responsible for causing dangerous planetary warming. For ease of reading, this paper uses the term carbon when referring to emissions themselves, to the effort to lowering emissions (decarbonize), or to the process of capturing and sequestering carbon dioxide (carbon capture).

this has all garnered a lot of attention recently, the potential for huge growth in electricity demand driven largely by the speed of industrial electrification is poised to become a much more significant issue in determining the shape of Alberta's electricity future.

All the models find that a continued decarbonization of the electricity system is the most cost-optimal near-term path under current policies, and that Alberta has the ability and the natural resources to reach net zero electricity well before 2050. The speed and success of this transition will likely hinge on the province's ability to plan for major infrastructure scale-up, including low-carbon electricity generation and transmission.

Solar panels cover a rolling hill in Southern Alberta beside an agricultural field of stubble. Solar Krafte's Spring Coulee Solar Project is a 183-acre solar installation in Southern Alberta. iStock/meadowmouse

Wind turbines in Southern Alberta. iStock/Nalidsa Sukprasert

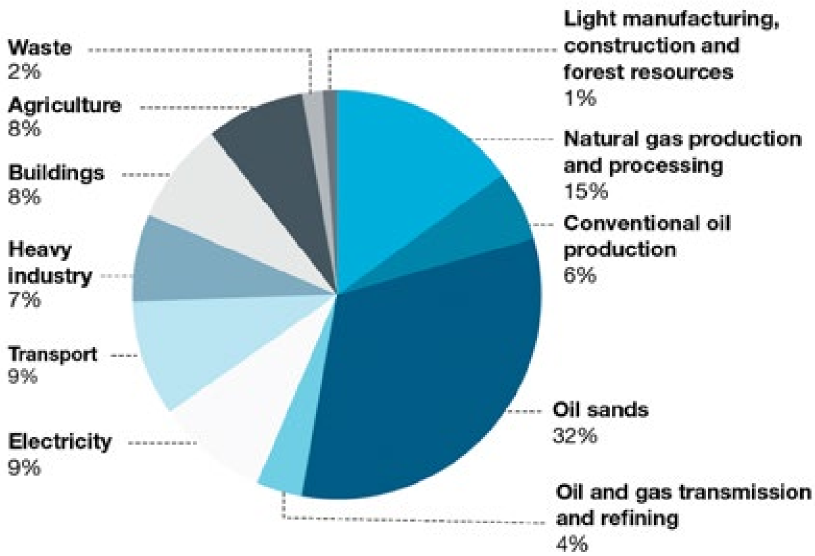
2 THE ROLE OF THE ELECTRICITY SYSTEM IN ACHIEVING NET ZERO IN ALBERTA

Climate change poses significant risks to Alberta's infrastructure (ICF Marbek and S.e.i. Inc., 2012) and the health of Albertans (Rutherford, 2022). Carbon dioxide emissions are widely recognized as the major driver of climate change, predominantly as a result of fossil fuel combustion (IPCC, 2021). Other emissions that can cause damage to human health and the environment can also be concurrently abated by reducing the combustion of fossil fuels, but the focus of this report is on the heat-trapping properties of emissions. The terms *emissions* and *net zero,* therefore, refer to greenhouse gas emissions only, as well as the policy and technology efforts being made to address them.

The Government of Alberta published a greenhouse gas emissions reduction plan where it states Alberta will "aspire to achieve a net zero carbon neutral economy by 2050" (Alberta Environment and Protected Areas, 2024). The plan discusses major options and ongoing opportunities across the major sources of emissions shown in Figure 1 below, but does not develop specific pathways or interim targets.

Figure 1:

Alberta's 2021 greenhouse gas emissions profile (Alberta Environment and Protected Areas, 2024)

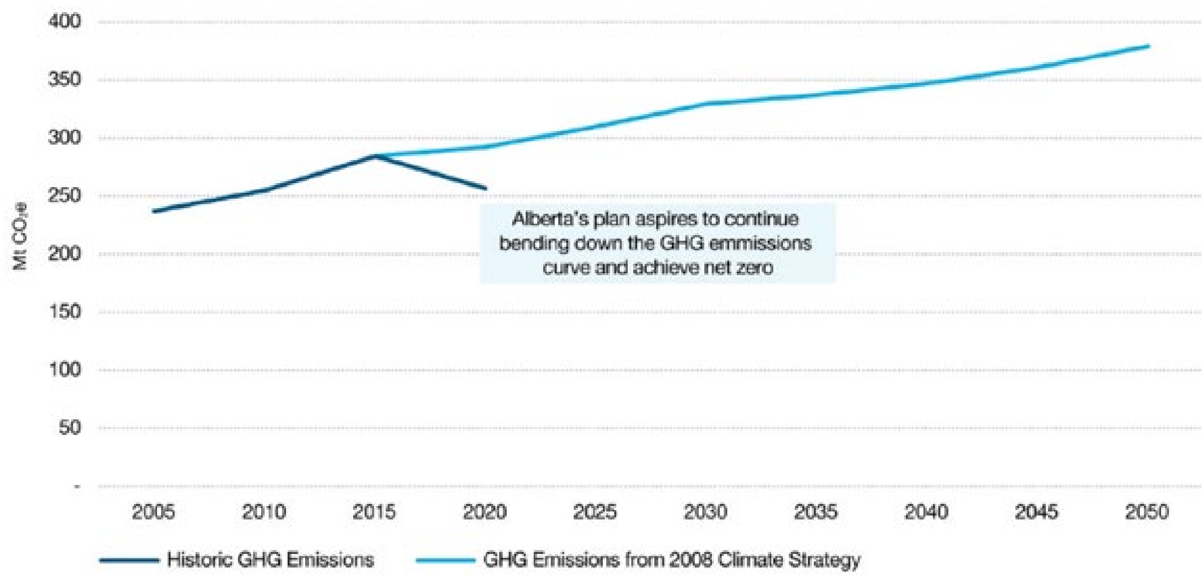


Data from ECCC (2023) National Inventory Report

After decades of increasing emissions, Alberta has made notable progress to reduce emissions in recent years, most notably as a direct result of the efforts made to phase out coal-fired electricity. Not only have electricity-sector emissions declined, but the reductions have been so large that overall provincial emissions have declined since 2015, even as emissions in other sectors have increased (Smith, 2024). In fact, Alberta's emissions have dropped close to 2010 levels, and are almost 15 per cent below government emissions forecasts in 2008, as illustrated in Figure 2.

Figure 2:

Alberta greenhouse gas emissions compared to 2008 forecast (Alberta Environment and Protected Areas, 2024)



Data from ECCC (2023) National Inventory Report

The ability of coal units to convert to relatively low-cost gas and the rapid build-out of wind and solar projects have enabled Alberta to reduce electricity emissions faster and more successfully than most imagined when its 2030 coal phase-out was first envisioned (see Text Box 1). Continuing this downward emissions trend, however, will require much more significant changes in the coming decades, including an expanded role for the electricity system—not only to continue to reduce emissions from electricity generation, but also to meet growing demand for low-carbon clean electricity as other energy uses such as transportation and housing convert to electric alternatives—a process known as electrification.

BOX 1

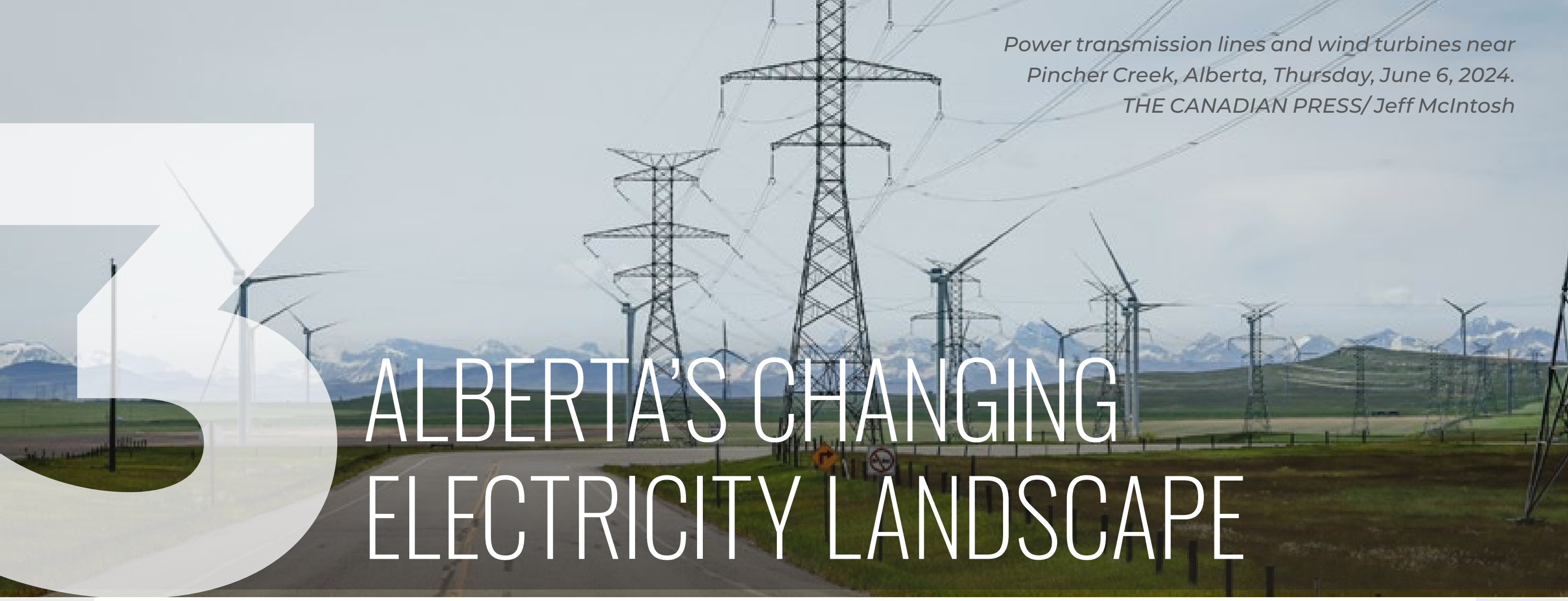
History of coal phase out in Alberta

Phasing out coal-fired electricity has been Canadian policy for over a decade. A maximum 50-year operating life was for coal units in Canada was initially prescribed by Prime Minister Stephen Harper in 2012 (Government of Canada, 2012), which would have phased out most coal in Alberta in the 2040s. These dates were accelerated to 2030 in Alberta under former premier Rachel Notley, but industry has acted faster than both deadlines largely due to changes in carbon pricing in Alberta.

Pre-2015 industrial carbon pricing in Alberta resulted in an average cost on the order of $2 per megawatt-hour for a typical coal plant, which is relatively small compared to historic power pool prices that have historically averaged close to $70 per megawatt-hour. Carbon pricing policy stringency has increased as a result of Alberta following the federal pricing schedule. By 2023, the average emissions from a typical unabated coal unit would be on the order of $40 per megawatt-hour by 2023, and would increase to over $105 by 2030. To get ahead of these costs, Alberta coal plant owners began rapidly transitioning their units to burn gas, well ahead of their scheduled end-of-life. The final coal unit transitioned in 2024 (Capital Power, 2024b), ahead of the accelerated 2030 target that was adopted by the provincial government (Government of Alberta, 2016).

Steam billows from the Sheerness coal fired generating station near Hanna, Alta., Tuesday, Dec. 13, 2016. THE CANADIAN PRESS/Jeff McIntosh

Perhaps the most well-known example of electrification is the switch from internal-combustion to electric vehicles. This switch can reduce emissions by displacing gasoline, but the extent of the emissions reductions depends on the emissions intensity of the electricity from which they charge. The same is true for other common residential applications such as heat pumps and electric hot water tanks, and new technologies are being developed for industrial applications such as microwave drying and arc furnaces, as well as indirect electrification via green hydrogen production from electrolysis. As the emissions intensity of Alberta's electricity grid falls, electrification's ability to drive economy-wide decarbonization increases.



Power transmission lines and wind turbines near Pincher Creek, Alberta, Thursday, June 6, 2024. THE CANADIAN PRESS/Jeff McIntosh

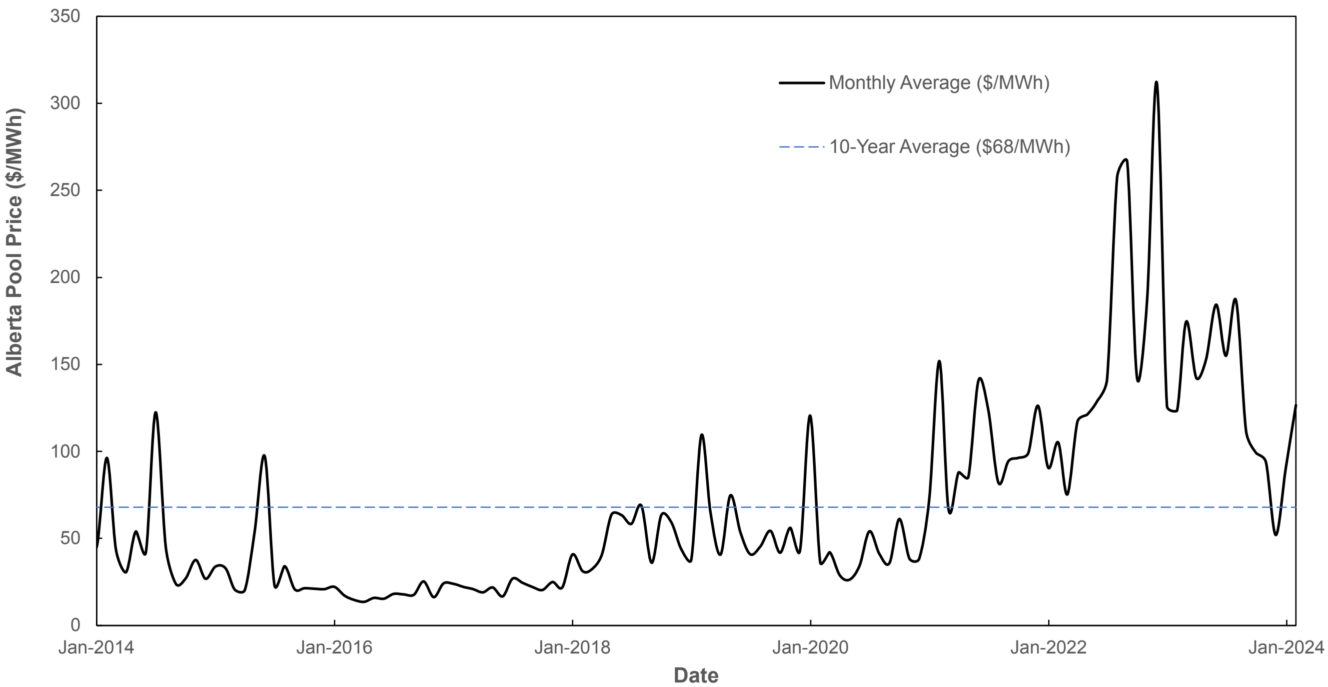
3 ALBERTA'S CHANGING ELECTRICITY LANDSCAPE

Alberta has the third-largest electricity system in Canada, generating over 86.5 terrawatt-hours annually, with an installed capacity of over 21,000 megawatts in 2024 (AESO, 2024a). Alberta's grid has many unique elements that make it an outlier in the broader Canadian context.

First, unlike most Canadian provinces powered by some combination of publicly owned utilities and government-regulated pricing, Alberta has a competitive wholesale energy market, where generators compete to set hourly prices. These market prices have experienced big swings of late, with periods of record highs in recent years, preceded by years of record lows (Figure 3).

Figure 3:

Alberta wholesale electricity prices (January 2014-January 2024)



The electricity market is operated by the Alberta Electric System Operator (AESO), which is a public agency, as is the Market Surveillance Administrator, which monitors competitive market behaviour (Market Surveillance Administrator, 2024a). Since its inception, the market has had a price floor of $0 and a ceiling of $999 per megawatt-hour, but hourly prices are not otherwise regulated. Periods of high supply availability can result in prices which may be below marginal fuel costs, while periods of scarcity can result in very high prices. But unlike regulated markets, which are the norm elsewhere in Canada, generators in Alberta are not guaranteed a return on their investments in the province.

The second element of Alberta's grid that makes it an outlier is that Alberta has a very significant industrial electricity load, representing close to two-thirds of electricity consumption in the province, which is roughly equally divided between on-site self-generation (commonly referred to as *behind-the-fence generation*), and purchases from the wholesale market, as seen in Figure 4. The vast majority of behind-the-fence generation is gas-fired cogeneration with steam. Despite using fossil fuel, cogeneration was considered a very high-efficiency use of gas that was widely promoted by Alberta's government in the 2000s. While greenhouse gas emissions from cogeneration facilities vary, electricity-related emissions are deemed in the regulatory framework to be on the order of 0.2 tonnes of carbon dioxide equivalent (t_{CO2e}) per megawatt-hour, which is notably lower than coal (~1.0 t_{CO2e}) and even combined cycle gas (~0.4 t_{CO2e}). This lower emissions profile has enabled some cogeneration facilities to earn credits under Alberta's carbon pricing framework, discussed below.

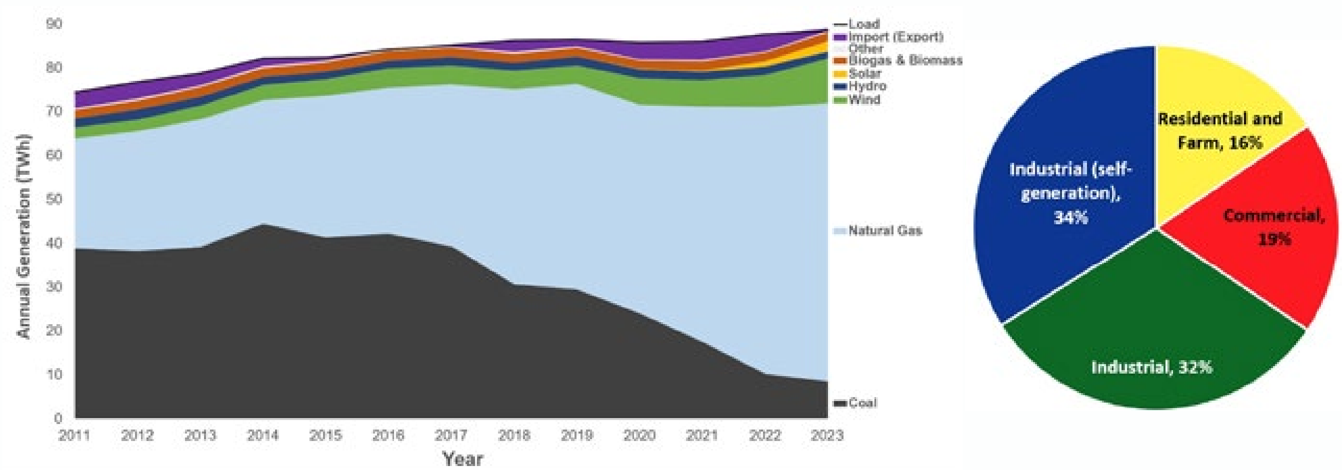
Finally, while the majority of Canadian provinces have large hydro assets and relatively low-carbon-intensity electricity, as recently as 2014, over 50 per cent of Alberta's electricity was generated from coal. In the last five years, Alberta's generators have undertaken a major transition away from coal, and all of the 18 coal units that were operating in 2016, have not converted to gas. Alberta's dependence on coal-fired generation has shrunk dramatically over the past decade, but over 80 per cent of all electrical energy in Alberta is still sourced from thermal generation, overwhelmingly gas.

Power lines and chimneys of the Sundance power plant, Alberta.

Alberta's success in phasing out coal was facilitated by the ability to rapidly substitute gas in many of the existing coal units that did retire. Gas is abundant, and has historically been available at relatively low cost in Alberta. Meanwhile, as wind and solar (supported increasingly by battery) technology become increasingly cost competitive, they are displacing thermal generation across much of North America, including in Alberta, where combined thermal generation (gas and coal) peaked in 2019, as Figure 4 illustrates. While this trend is likely to continue in the near term as renewable energy generation outpaces load growth, a widespread substitution of renewables for gas is not likely to happen as fast as with coal, given the anticipated lifespan of existing infrastructure.

Figure 4:

Electricity supply (left) and consumption (right) in Alberta (data source: Alberta Utilities Commission, 2023)



Electricity emissions will likely continue to decrease after the coal phase out is complete, with Alberta's open electricity market combined with its carbon pricing system and the federal government's proposed Investment Tax Credits enabling renewable energy development to persist.

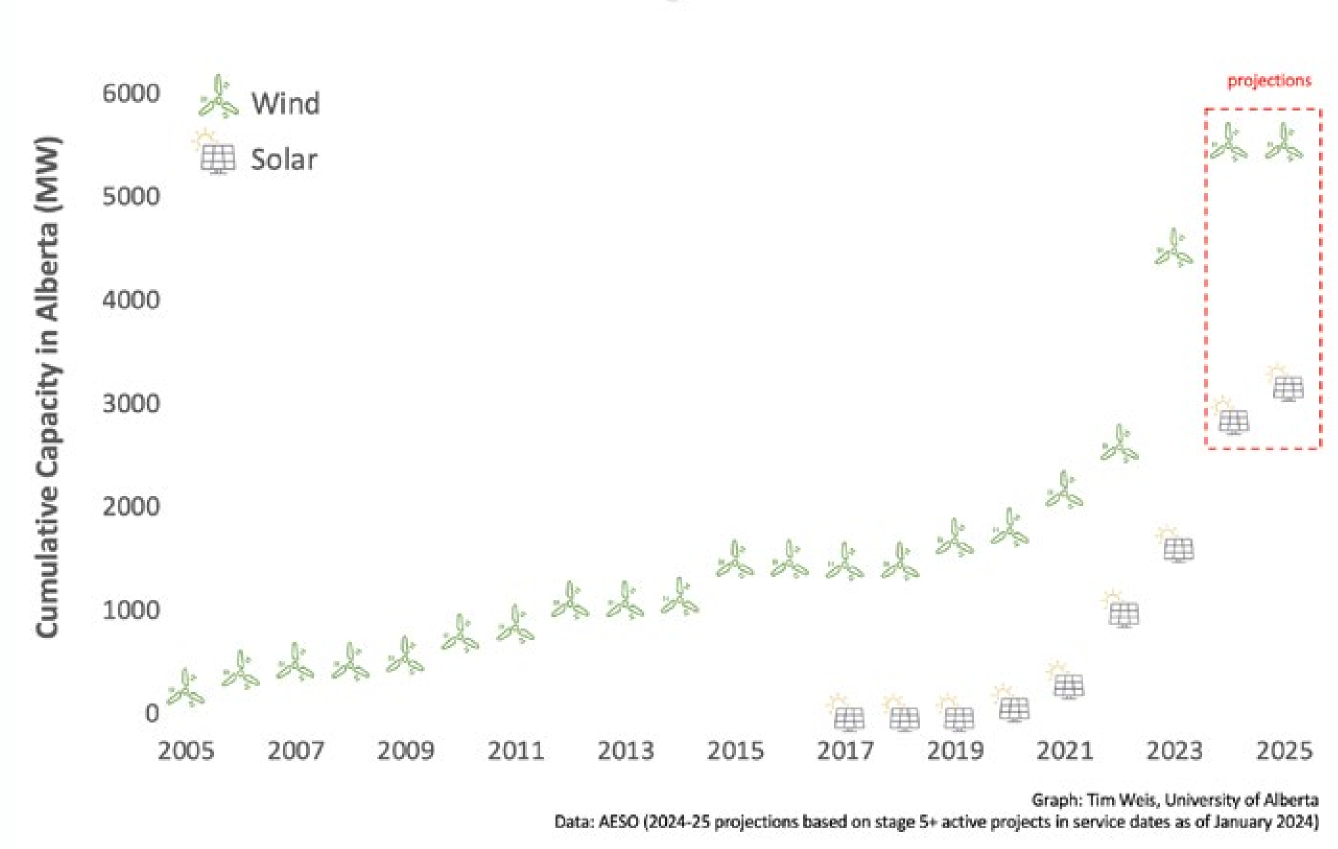
Alberta has had an industrial carbon price in place since 2008. While the carbon pricing regime was initially quite modest and treated different fuel sources differently (Alberta's largest coal unit was commissioned in 2011), the electricity sector price has increased repeatedly since 2016, resulting in an exodus of coal and a renewable energy boom. The carbon price has had a more muted effect on gas plants, but as it follows the scheduled increases officially adopted by the Alberta government in December 2022 (Savage, 2022), carbon pricing is widely expected to drive further emissions reductions from gas-fired plants.

The scale and pace of the renewables boom is worth reflecting on. In 2021, the AESO's Long-Term Outlook (AESO, 2021) scenarios suggested annual heat-trapping gas emissions would decline from over 30 megatonnes in 2019 to around 15 megatonnes by 2030, and roughly stabilize thereafter. The 2021 Reference Case anticipated carbon pricing and plant age to result in the retirement of over 3,300 megawatts of formerly coal units that had been converted to run on gas by 2035, with the remaining 1,700 megawatts retiring within the subsequent two years. The AESO's reference case only foresaw

1,880 megawatts of new renewables (1,580 megawatts of wind and 300 megawatts of solar) being developed by 2041, with an additional 2,560 megawatts of gas facilities added over the same timeframe. At the time, Alberta had approximately 1,800 megawatts of wind and 100 megawatts of installed commercial-scale solar, bringing the totals for each to 3,340 megawatts and 400 megawatts by 2041 respectively. In fact, midway through 2022, within one year of the report's publication, both wind and solar had already eclipsed the 2041 forecast, and solar capacity will likely reach nine times what was anticipated in 2021, as illustrated in below.

Figure 5:

Wind and solar cumulative installed capacity in Alberta



Wind and solar development in the past five years has grown significantly faster than anticipated by almost all forecasts in Alberta as a result of favourable market prices, the falling energy costs of wind and solar, and the fact that renewable energy plants can often monetize their carbon offsets.

This rapid growth is a major reversal of previous trends. Long-term price uncertainty had all but stalled new wind energy development by 2015, and no commercial solar farms existed in the province at that time. In 2016, the government of Alberta had launched a Renewable Energy Program, which entered into contracts-for-differences to build over 1,000 megawatts of new wind energy projects. This resulted in the government receiving over $100 million in revenues by 2022 due to the fact the contract prices (on the order of $40 per megawatt-hour) were significantly lower than the Alberta market (Hastings-Simon, Leach, Shaffer, & Weis, 2022). The low prices that these projects drove, along with the scheduled increases in the industrial carbon price, spurred significant new development, including long-term power purchase agreements from the industrial and commercial sectors for both wind and solar development.

> Alberta added more wind energy in the two years between 2022 and 2024 than it had in the previous two decades

BOX 2

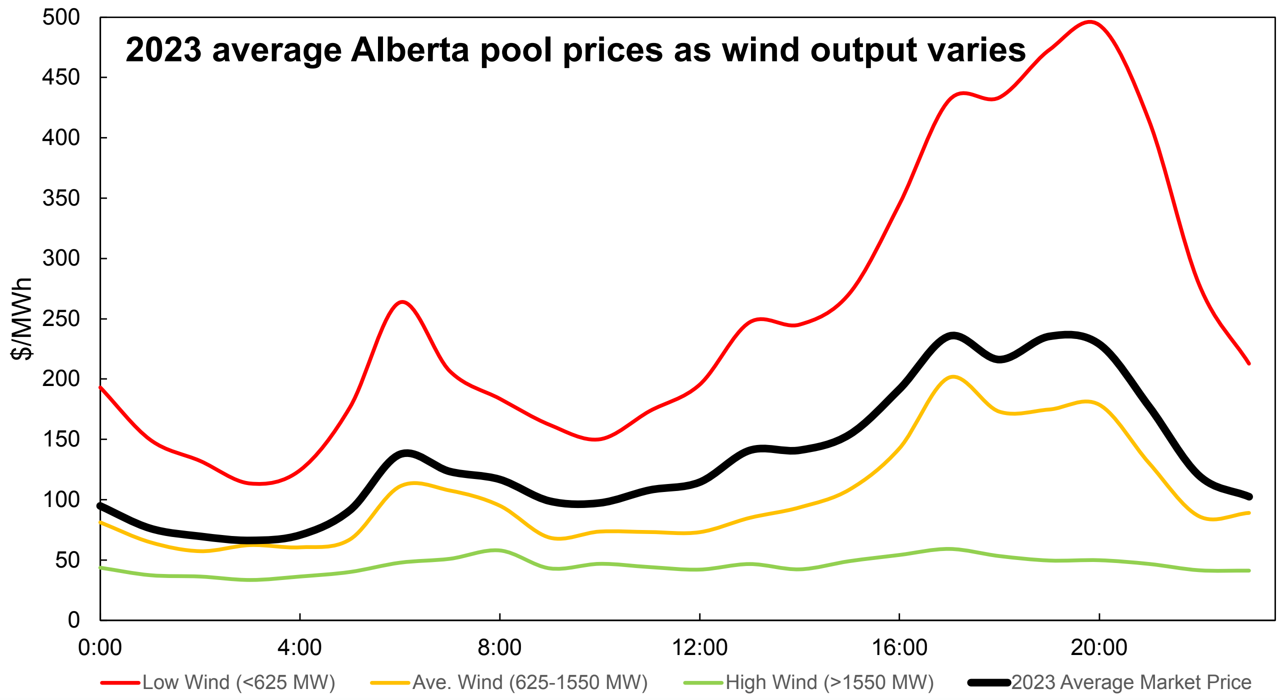
AESO 2023 Year In Review

"the annual average pool price for wholesale electricity...fell approximately 18 per cent from 2022 to $133.63/megawatthour (MWh). One of the drivers for the lower price was increased competition in the energy market from new wind and solar generation" (AESO, 2023a).

Alberta added more wind energy in the two years between 2022 and 2024 than it had in the previous two decades, while solar, non-existent prior to 2017, was generating more energy than hydro in Alberta by the end of 2023. Despite this rapid growth, a slowdown in the growth of renewables in Alberta's market in the medium term seemed likely, as their output consistently lowers the market prices when they are generating, as shown in Figure 6 below. By the end 2023, however, over 4,000 megawatts of new wind projects were in early stages of development, as were over 9,000 megawatts of solar and over 3,000 of storage, compared to around 2,000 megawatts of new gas generation (AESO, 2023b), so an immediate slowdown did not appear imminent despite the effects of lower market prices as pointed out by AESO in Text Box 2. However, many of these projects had been in development prior to a seven-month pause on renewable energy implemented by the provincial government in August 2023 (Government of Alberta, 2023), and the aftermath of the resulting changes seem to have cooled near-term interest in investing in renewable energy in the Alberta (The Canadian Press, 2024).

Figure 6:

Market prices are lowered during periods of high wind energy generation in Alberta



Solar panels pictured at the Michichi Solar project near Drumheller, Alta., Tuesday, July 11, 2023.THE CANADIAN PRESS/Jeff McIntosh

4 THE CLEAN ELECTRICITY REGULATIONS AND ALBERTA

In August 2023, the federal government introduced draft Clean Electricity Regulations for all electricity in Canada as it pertains to greenhouse gas emissions. These types of regulations are not new; in fact, under Prime Minister Stephen Harper in 2010, emissions standards were put in place for coal-fired electricity that required coal units to reach a performance standard of 0.37 tonnes of carbon dioxide equivalent per megawatt-hour by the time they reached their 50th year of operation (with a few exceptions).

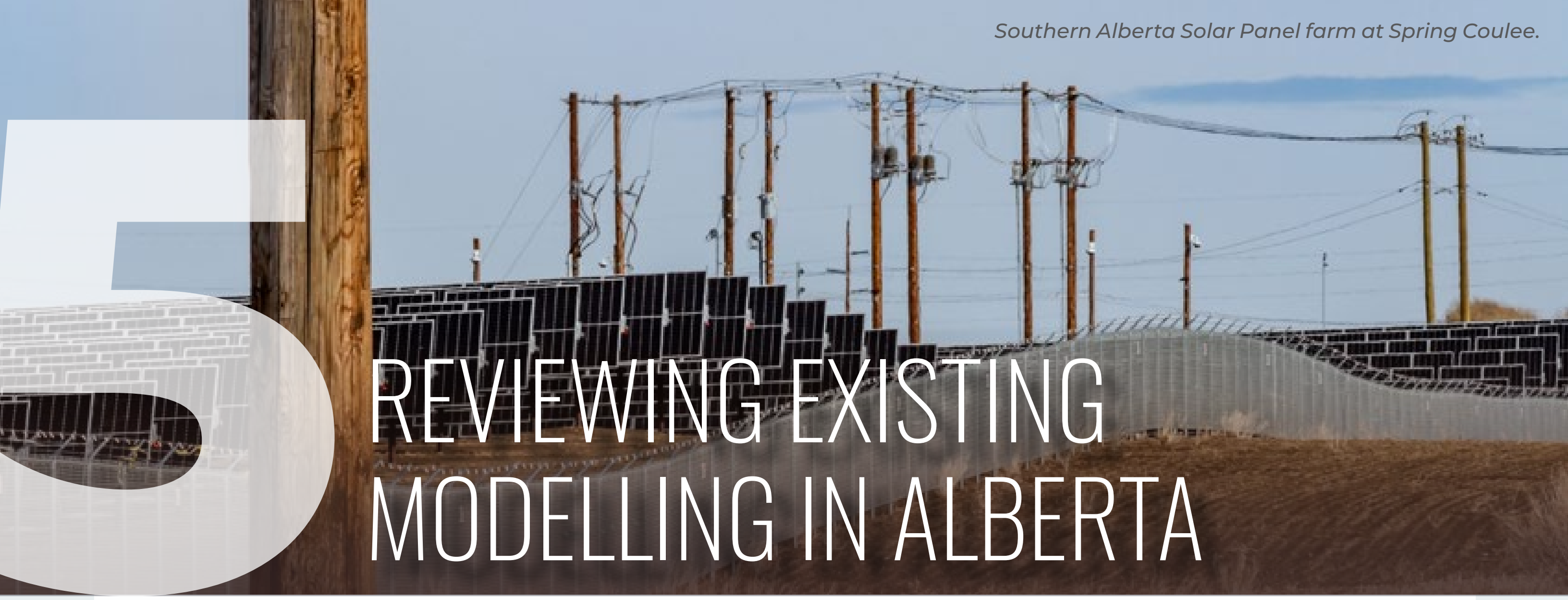
The first draft of the Clean Electricity Regulations required all fossil fuel-based power plants over 25 megawatts which were net-exporters of electricity to emit no more than 0.03 tonnes of carbon dioxide equivalent per megawatt-hour. The regulations were to come into effect in 2035, and the aforementioned emissions would be approximately equivalent to a carbon capture rate of 95 per cent of emissions for most combined-cycle gas plants. Exceptions were provided for power plants that were only expected to operate for short-term peaking requirements, allowing them to operate for up to 450 hours (approximately 19 days) while not emitting more than 150 kilotonnes of carbon dioxide equivalent in a given year. Existing fossil units were also allocated a “prescribed life” of 20 years wherein they could operate unabated, before the Clean Electricity Regulations would apply.

Avik Dey, the CEO of one of Alberta’s largest electricity generators, Capital Power, was critical of details of the regulations, but welcomed the idea of federal policy clarity to enable long-term decision making: “the general framework set out in the draft Clean Electricity Regulations is a positive step for Canada,” he wrote. “It is easily understood, can supply much needed market stability to attract capital and investment for new projects, and stands to offer increased clarity for all players” (Dey, 2023).

Nonetheless, thermal power plant owners and operators in Alberta as well as the Alberta government voiced major concerns with the draft Clean Electricity Regulations, with the government going as far as spending $8 million on a national advertising campaign in an attempt to shape public opinion regarding the regulations (Black, 2023). Substantive critiques by experts focused on the stringency of the emissions limit and the ability of gas units with carbon capture to meet it without some flexibility, as well as the limits on gas peaking units. In addition, cogeneration plants might be incentivized to stop exports to the grid under the draft regulations, reducing their ability to provide peaking support (Shaffer & Leach, 2023).

In February 2024, Environment and Climate Change Canada released a public update of “what we heard” that recognized these and similar concerns raised by the government of Alberta and other stakeholders (Environment and Climate Change Canada, 2024). The federal government appears to be taking the feedback seriously, proposing key changes that add flexibility to the draft regulations, including an increased emissions limit for unabated thermal units used to meet peaking demands, a relaxation in the required carbon capture rate for non-peaking units, allowing pooling of emissions for fleets, and allowing for a limited use of offsets for power plants that are unable to comply in particular years.

Capstone Infrastructure Corporation CEO David Eva at the opening of the Michichi Solar project near Drumheller, Alberta, Tuesday, July 11, 2023.THE CANADIAN PRESS/Jeff McIntosh



Southern Alberta Solar Panel farm at Spring Coulee.

5 REVIEWING EXISTING MODELLING IN ALBERTA

Multiple studies have been completed examining pathways for the decarbonization of Alberta's electricity system, including by the AESO (AESO, 2022) and the Pembina Institute[2] (Noel, 2023). The AESO released a further study following the release of the draft federal regulations (AESO, 2023c). In broad terms, the studies draw many similar conclusions:

- Wind energy and combined cycle gas with carbon capture are likely to constitute the largest share of new electricity capacity and generation between now and 2035.
- Energy storage is likely to increase, but relatively small amounts are essential to support significant new renewable energy development while maintaining supply adequacy, in part due to gas peaking units as well as using existing interconnections both for import and export.
- Gas-fired simple cycle peaking capacity increases to meet periods of low renewable energy output, but their overall energy and emissions totals remain small.
- Producing electricity from nuclear, geothermal, and hydrogen remains uncompetitive for the foreseeable future.
- Greenhouse gas emissions are likely to decline by almost 90 per cent from 2015 levels by 2035, although challenges remain to reduce these emissions to zero, notably around peaking capacity and remaining emissions from cogeneration.

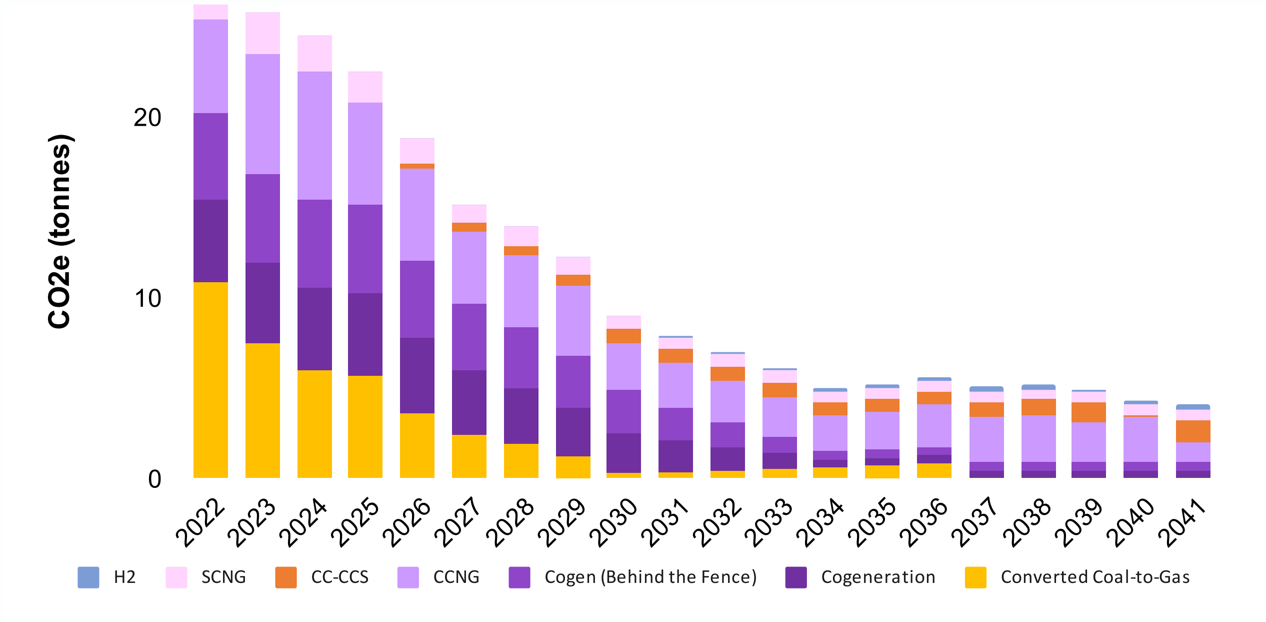
AESO examined several scenarios in its 2022 report *Net-Zero Emissions Pathways*, ranging from emphasis on carbon capture to emphasis on wind and solar to achieve significant greenhouse gas emissions reductions by 2035 (AESO, 2022). The scenarios that were developed found similar outcomes to the studies surveyed above, with annual emissions declining from approximately 27 megatonnes of carbon dioxide equivalent in 2022, to less than 6 megatonnes by 2035, and remaining roughly stable beyond. Figure 7 below illustrates these reductions using the data published in the *Net-Zero Emissions Pathways* report for the "Dispatchable Dominant" scenario (larger emphasis on carbon capture), and assumes that behind-the-fence emissions, which were not modelled in the report, follow the same trajectory as other cogeneration emissions.

The major near-term reductions are a result of the phase out of the relatively low-efficiency converted coal-to-gas steam units, followed by carbon capture and storage systems that would be required to dramatically reduce emissions from all forms of cogeneration as well as combined-cycle natural gas. Some simple cycle gas is replaced with hydrogen, and the gas plants that remain beyond 2040 are expected to operate relatively infrequently, resulting in less than one megatonne of carbon dioxide equivalent annually.

2 The Pembina Institute pathways were based on modelling done by Jessica Van Os, who was a mechanical engineering graduate student under my co-supervision at the University of Alberta.

Figure 7:

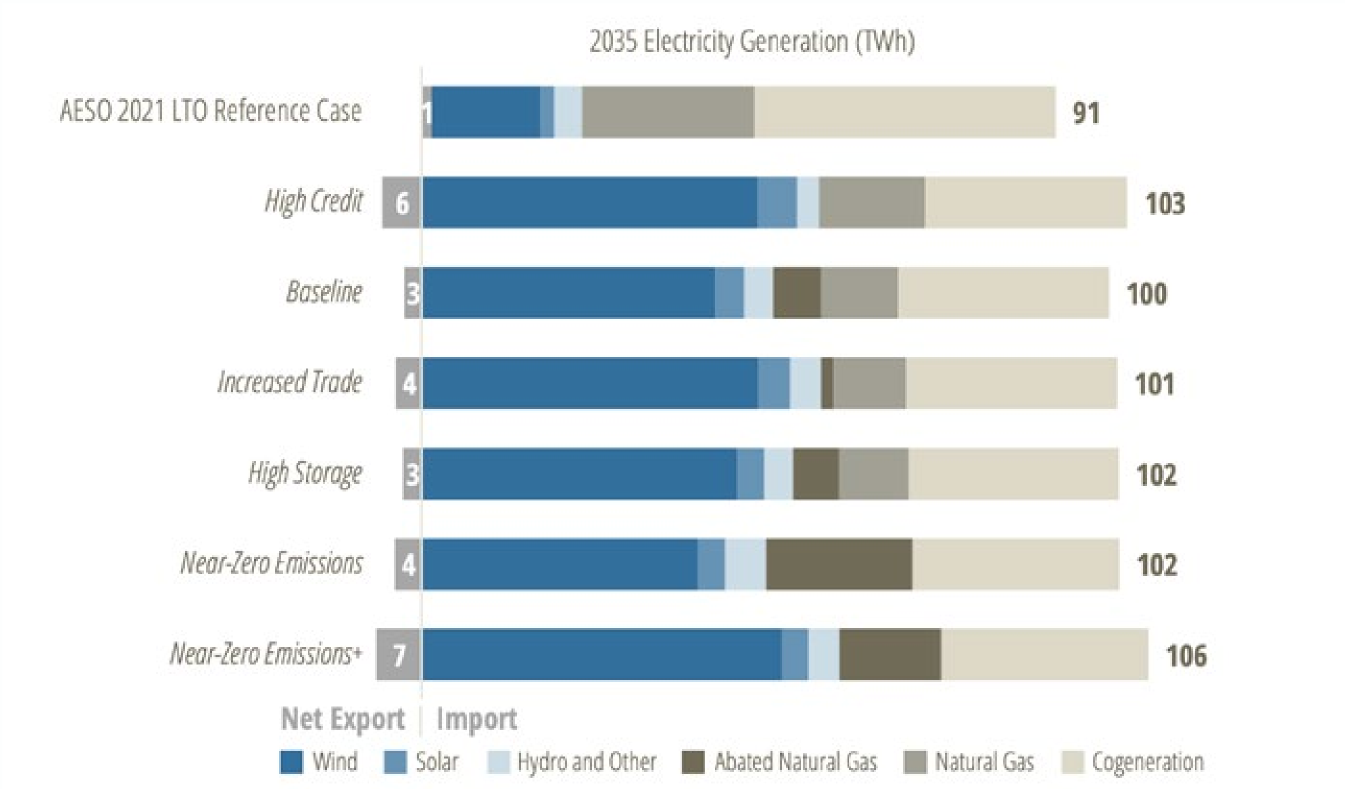
AESO modelled electricity related carbon emissions (behind the fence emissions are estimated)



AESO's report suggests cumulative new investment would range from $44 to $52 billion before 2041 compared to its 2021 Long-Term Outlook base case (which, as mentioned above, significantly missed the wind and solar growth). Long-term capacity expansion scenarios completed for the Pembina Institute (Noel, 2023) released using the AESO load projections from 2021 anticipated significantly lower costs, but came to similar broad conclusions around Alberta's future supply mix. The modelling found that renewable energy and carbon capture being added to new and existing gas plants are likely to become the dominant supply choices, as shown in Figure 8. This transition is largely due to the low cost of renewable energy, as well as industrial carbon pricing resulting in continued emissions reductions over the coming decade beyond the coal phase-out.

Figure 8:

Net-zero scenario modelling published by the Pembina Institute prior to the Clean Electricity Regulations



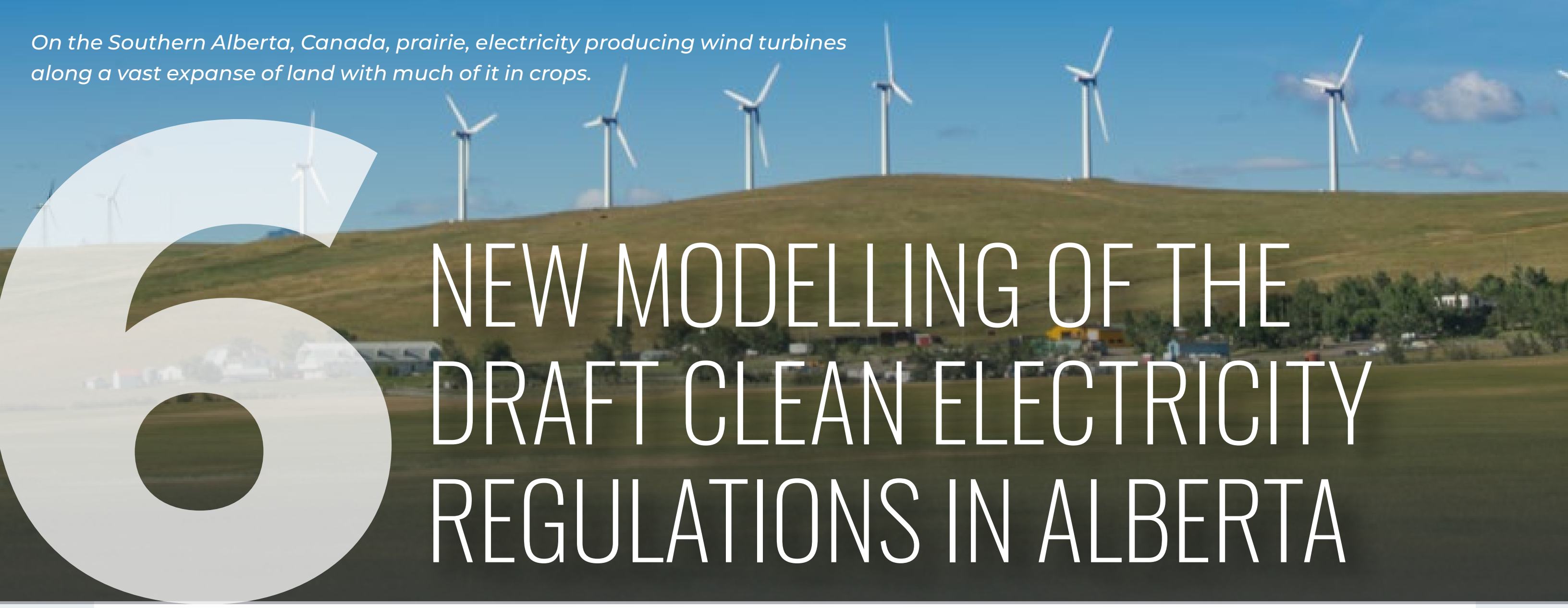
On May 15, 2024, the AESO released its most recent Long-Term Outlook, which includes a high electrification scenario as well as decarbonization by 2035 scenarios, in addition to the reference case (AESO, 2024b). All the scenarios are modelled using the draft Clean Electricity Regulations as they were originally announced in 2023, without any of the anticipated additional flexibility discussed by Environment and Climate Change Canada in February 2024.

The AESO Outlook states, "From a levelized cost perspective, the availability of significant investment tax credits for combined-cycle with [carbon capture] and emissions performance credits for solar and wind technologies positions these generation methods as the most cost-effective" (AESO, 2024b). However, the document assumes a significant slowdown in wind and solar development in all scenarios, while it anticipates carbon capture and storage to be broadly applied to the majority of existing gas-fired generation starting in 2028 and being completed by 2031.

A consortium of oilsands companies have recently filed a regulatory application to the Alberta Energy Regulator for a $16.5 billion carbon capture pipeline, suggesting these is continued interest in carbon capture and storage, although the member companies are only aiming for a 30 per cent emissions reduction by 2030 (Stephenson, 2024), which appears to be a slower pace than envisioned in any of the Long-Term Outlook's scenarios. Meanwhile, Avik Dey, Capital Power's CEO, told investors during its most recent investors' call, "fundamentally, the economics just don't work. Hopefully, the technology will improve, and we can revisit this when the economics improve," to explain the company's announcement that it is no longer pursuing carbon capture and storage on its gas facilities (Snowden, 2024).

In spite of these uncertainties, if carbon capture technology turns out to be viable in Alberta's electricity sector, AESO's 2024 Long-Term Outlook suggests the electricity system will reach around a 95 per cent emissions reduction compared to 2005 levels by the year 2035, while assuming the existing carbon pricing schedule and the Clean Electricity Regulations as originally proposed are in place. The first small nuclear reactors are not anticipated until around 2040, although the report states that "social acceptance remains a considerable hurdle and the technology is still in the nascent stages of commercial application" (AESO, 2024b). The forecast suggests that the major emissions reductions will have occurred by 2035, and as such the uncertainties around nuclear plants' timing would not affect reaching near-zero emissions in Alberta's electricity sector.

Enhance Energy CEO Kevin Jabusch's company has signed a deal to work on the Alberta Carbon Trunk Line project designed to capture CO2 and he is seen with a diagram of the project at his office in Calgary, Alta., Thursday, Aug. 23, 2018.THE CANADIAN PRESS/Jeff McIntosh



On the Southern Alberta, Canada, prairie, electricity producing wind turbines along a vast expanse of land with much of it in crops.

6 NEW MODELLING OF THE DRAFT CLEAN ELECTRICITY REGULATIONS IN ALBERTA

When the draft federal regulations were initially published, there were no Alberta-specific public models of their impact. Within a month of the Clean Electricity Regulations Gazette I (AESO, 2023c), the AESO completed an initial technical briefing that highlighted some concerns with respect to reliability and affordability associated with the initial Clean Electricity Regulations draft. It has recently come to light, however, that the AESO has been placed under significant public pressure with respect to renewable energy in Alberta (Anderson, 2024), which may cast some doubt in public opinion over the objectivity of these findings.

To address that information gap, this paper presents new modelling, conducted by Navius Research for the Canadian Climate Institute, that runs an economy-wide analysis simulating announced policies from Canada's 2030 Emissions Reduction Plan, with and without the draft Clean Electricity Regulations, to explore the impact of the regulations on different electricity systems in Canada. This analysis targets a 40 per cent reduction in greenhouse gas emissions relative to 2005 by the year 2030, such that national emissions would be 439 megatonnes of carbon dioxide equivalent in that year, and decline to 105 megatonnes by 2050 with an equal amount of negative emissions via land use, land use change, and forestry offsets to deliver net-zero.[3] The analysis allows existing free allowances of carbon currently, and phases them to zero by 2050, as well as considering results with and without the draft Clean Electricity Regulations as announced in August 2023.

Given that the federal government has signaled it plans to add additional flexibility in the final regulations as discussed above, the modelling likely underestimates the degree to which gas-fired capacity will be allowed to operate unabated and/or provide backup in Alberta.

3 Navius assumes net zero is met on the national level (not provincial level) and that the use of offsets from Direct Air Capture and land use, land-use change, and forestry—amounting to 105 megatonnes of carbon emissions by 2050— within Canada count towards net zero, based on a study by Drever et al (2021). A net-zero study where Alberta reaches net zero, not Canada as a whole, or different assumptions around direct air capture and land use are made could change results.

The key findings of this work are discussed below and compared to other recent modelling in Alberta.

FINDING 1:

Wind, solar, and carbon capture dominate development in all scenarios

Due to uncertainties in technological and economic development over longer time periods, this discussion will focus on the medium term, by looking at results out to 2040. The main findings in the Navius model with respect to Alberta's electricity generation are shown out to 2040 in Figure 9 below and are compared with 2023 actual generation.

The most notable finding is that the Clean Electricity Regulations appear to have little difference on the future development of Alberta's electricity grid. With and without the Clean Electricity Regulations, electricity demand more than doubles, and that increased demand is met primarily with the addition of wind, solar, and gas with carbon capture. Carbon capture is also deployed heavily on existing gas facilities including combined cycle and cogeneration units, although a recent announcement from Capital Power terminating its development of a carbon capture retrofit on combined cycle gas does suggest previous public cost estimates may have been low, as the company stated "the project is not economically feasible" (Capital Power, 2024a).

> With and without the Clean Electricity Regulations, electricity demand more than doubles, and that increased demand is met primarily with the addition of wind, solar, and gas with carbon capture.

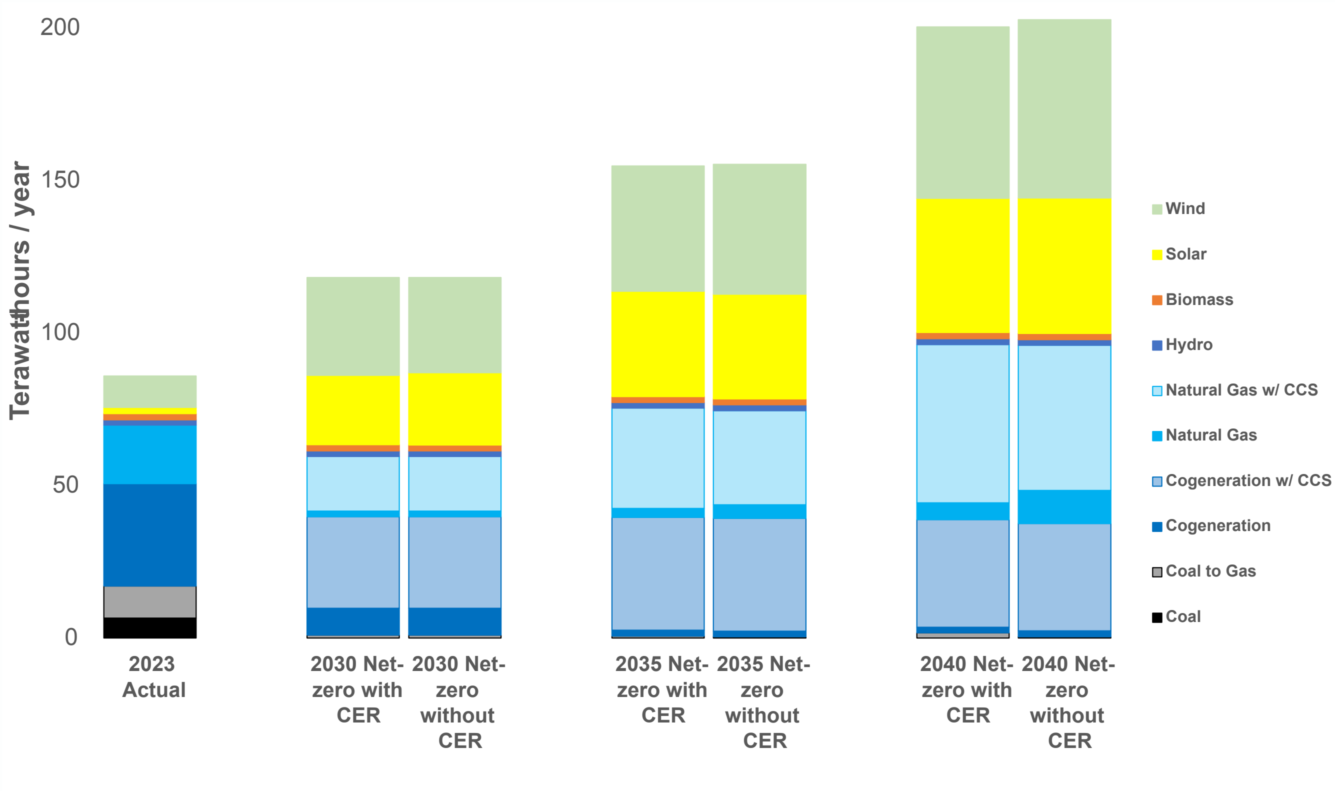
With or without the Clean Electricity Regulations in place, if Alberta is to achieve net zero economy-wide, Navius' model suggests a massive scale-up of wind and solar is required. In 2023, wind and solar combined with biomass and hydro generated about 16 terawatt-hours of renewable electricity in 2023, or 16 per cent of Alberta's overall supply. By 2040, wind and solar would need to grow by 650 per cent of today's combined renewable energy generation in order to supply over 100 terawatt-hours annually by 2040, while new hydro or biomass facilities are likely to be less cost-effective.

Furthermore, the combined gas technologies would also be expected to generate close to 100 terawatt-hours in 2040, resulting in a 50 per cent increase in gas-fired generation in the electricity sector, or 33 terawatt-hours more than 2023 levels, although the vast majority of this would be abated with carbon capture[4] both in behind the fence cogeneration facilities as well as other dedicated supply to the grid.

4 The Clean Electricity Regulations' emission standard for carbon capture is right on the cusp between allowing carbon capture to comply with the Clean Electricity Regulations or not. In the Navius analysis, a 90 per cent capture rate is just not enough to allow natural gas with carbon capture to be compliant with the Clean Electricity Regulations. To make carbon capture available as a compliance option, the analysis assumes a 95 per cent carbon capture rate.

Figure 9:

Alberta electricity generation towards economy-wide net zero emissions by 2050



FINDING 2:

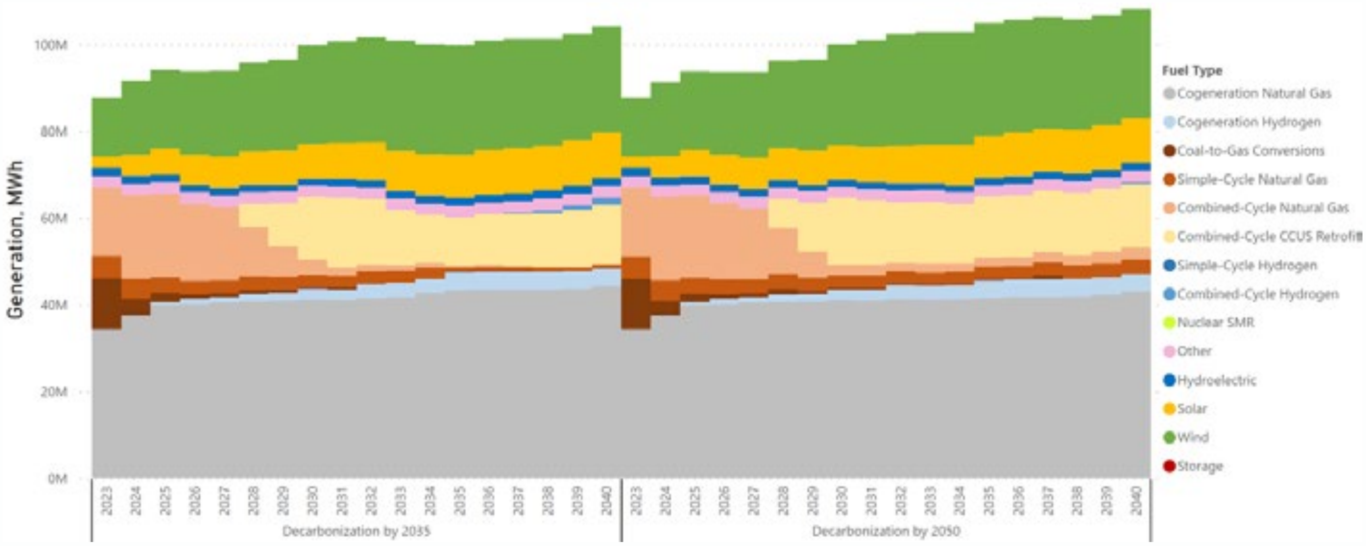
Transmission needs and load growth are predicted to be significant

The results of the model are dependent on transmission capacity keeping pace with the demand for new electricity generation capacity. Transmission constraints have already begun to be a problem for existing wind and solar in Alberta, with constrained volumes of wind and solar jumping from 14 gigawatt hours in the fourth quarter of 2022 to 188 gigawatt hours in 2023 (Market Surveillance Administrator, 2024b). The Competitive Renewable Energy Zone (CREZ) initiative in Texas, began in 2005, foresaw this issue, and has widely been considered a success in enabling rapid wind and solar development in the state (Lee, Flores-Espino, & Hurlbut, 2017). Alberta does not have similar plans for transmission build-out, and is in the process of a review that aims to shift more transmission costs to generators (Kennedy, Lees, Green, & Quinton, 2023). The pace of transmission development could severely limit renewable energy development and carbon emissions reductions in the United States (Jenkins, et al., 2023), and the same would be true in Alberta, particularly with the scale of development suggested in the current modelling.

In November 2023, the AESO published a preliminary update to its 2024 Long-Term Outlook, which included two decarbonization scenarios, one by 2035 and the other by 2050. The former comes seemingly in response to the draft Clean Electricity Regulations (which would not require net zero by 2035), and the latter, a target set out by the provincial government. While there are notable differences in anticipated load growth resulting from electrification, and the level of wind and solar penetration, both models illustrate the relatively small impact the federal Clean Electricity Regulations would have on medium to long-term supply mixes. The striking similarities in expected supply mix for the different scenarios are presented in the Long-Term Outlook dashboard Figure 10 below. It should be noted that these scenarios assume both the continuation of a robust industrial carbon pricing system, as well as the expansion of the existing transmission system in order to be able to support this new capacity.

Figure 10:

AESO generation forecast comparing initially proposed Clean Electricity Regulations (left) and a net-zero pathway by 2050 (right)



Where the Navius models differ significantly from AESO, even in its most recent high electrification scenario, is in the expected electrical load growth in Alberta, notably the electrification of industrial processes. Navius' electricity demand forecast is approximately double what AESO has recently modelled even in its most aggressive electrification scenario as part of their 2024 Long-Term Outlook's Decarbonization Scenario Modelling Dashboard (AESO, 2024c) as shown in Figure 11 below. The most significant differences appear to be the rate of industrial electrification as well the rate at which heat pumps and electric vehicles are adopted.[5] The very significant difference in growth forecasts has a much larger bearing on generation than the modelled impact of federal regulations.

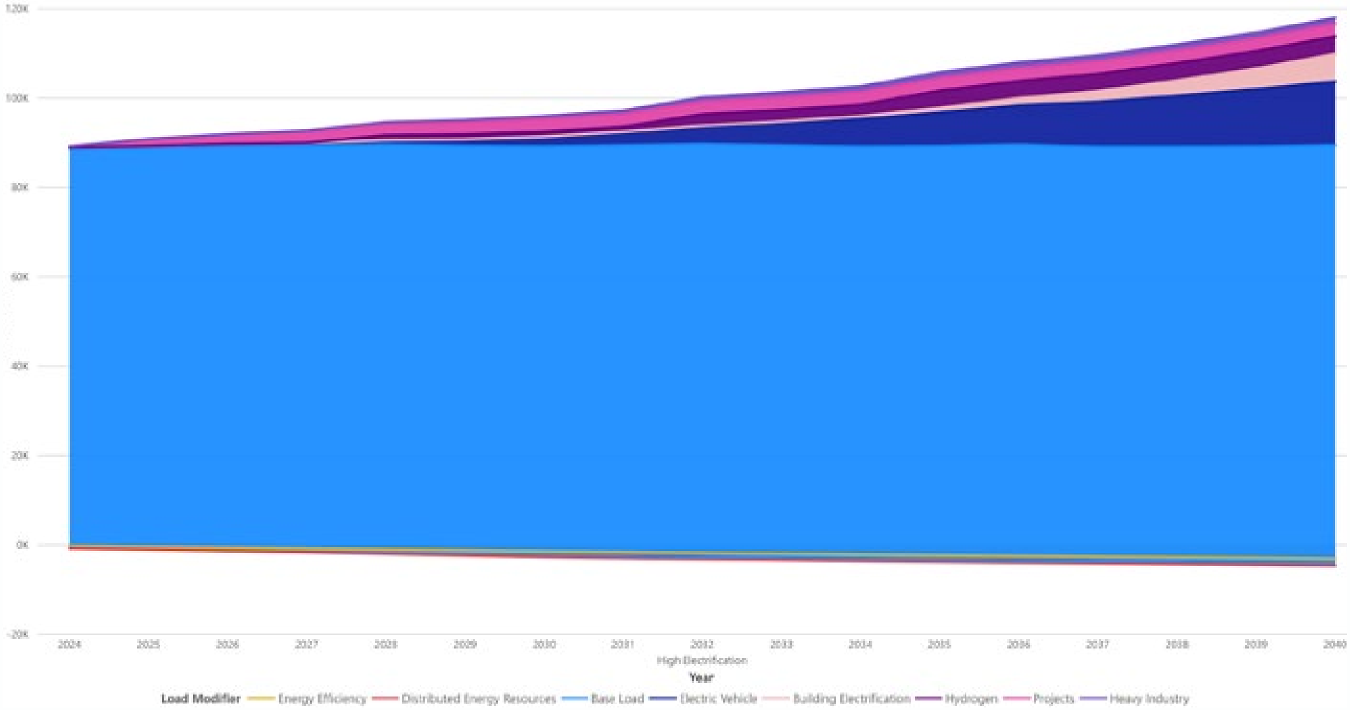
5 There are a few key policy assumptions that are responsible for the differences between the results from the AESO and Navius' announced-plus-net-zero scenario. Navius includes:

- the federal light-duty ZEV mandate (100 per cent ZEV sales by 2035),
- an illustrative representation of the announced ZEV mandate for medium- and heavy-duty vehicles (75 per cent sales for medium- and 40 per cent sales for heavy-duty vehicles by 2035),
- an illustrative representation of the announced National Net Zero Emissions Building Strategy, banning the installation of new natural gas and oil heating systems by 2026,
- and the announced oil and gas sector emissions cap.

The representation of these announced policies is illustrative, showing what the impact on electrification and emissions would be if these policies were implemented as designed for their analysis. The inclusion of these policies is likely the reason for the higher electrification results in their analysis (particularly the ban of new natural gas heating systems). A net-zero scenario without these policies would likely result in lower levels of electrification.

Figure 11:

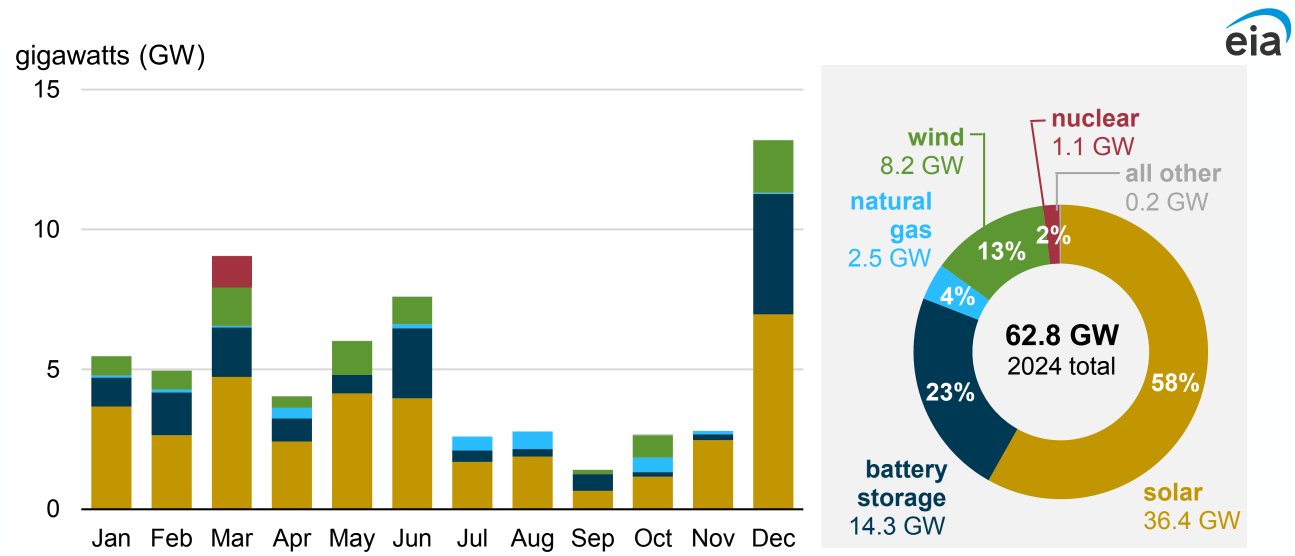
AESO high electrification scenario modelled in 2024



While the scale of load growth is notably different, the technology mix of generation anticipated to meet the demand is similar, with new wind, solar, and gas equipped with carbon capture making up almost all of the capacity additions by 2040. The pace of wind and solar growth is not a surprise given recent developments in new electricity generation, which have been dominated by these technologies, both globally as well as in the United States, as can be seen in Figure 12 below.

Figure 12:

Recent annual electric generating capacity in the USA (left) and globally (right)

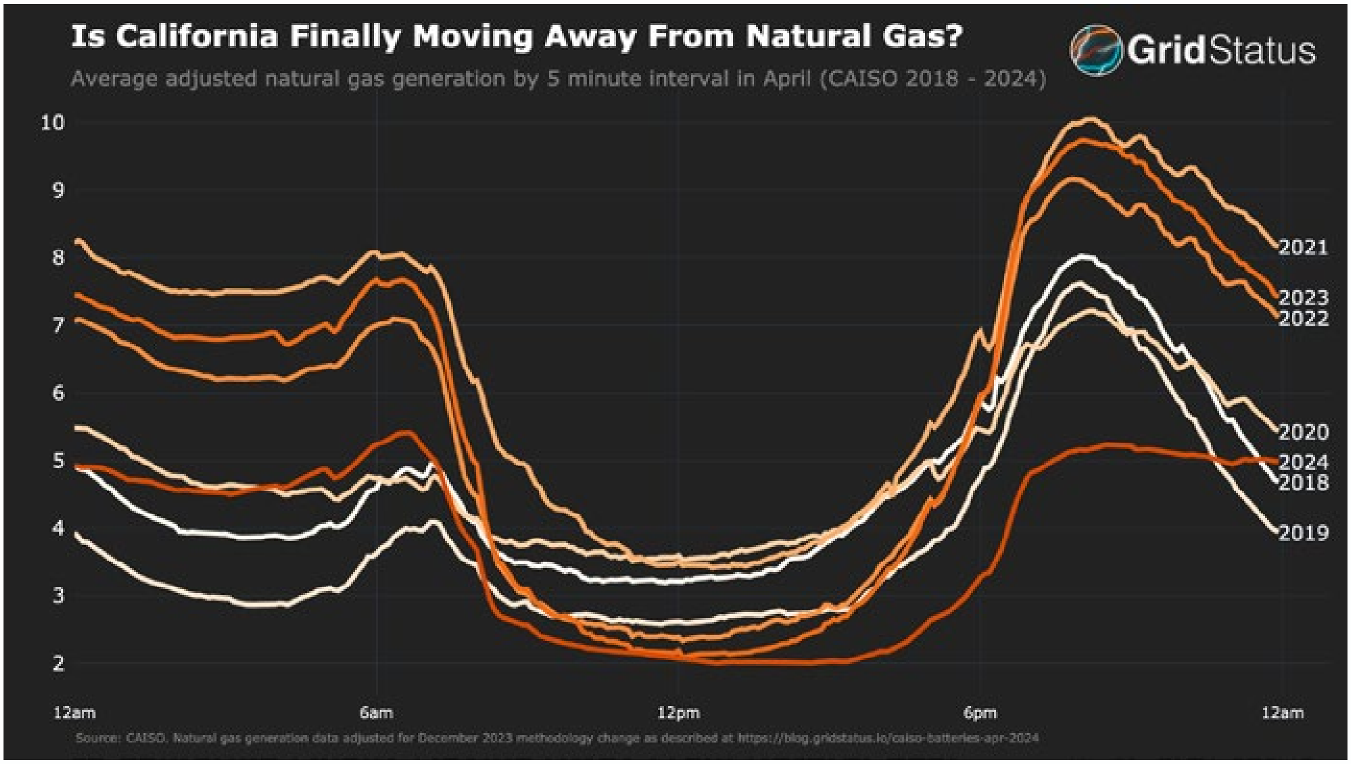


While gas facilities with carbon capture appear in all of the models, it has not been deployed at scale by the private sector in electricity generation, either in Alberta or around the world. Furthermore, as discussed earlier, progress on the most advanced project in the province was recently terminated (Snowden, 2024).

Nonetheless, Alberta is poised to be at the forefront of carbon capture on gas fired electricity facilities, if costs can be reduced while carbon prices and government subsidies remain at a level where industry is willing to adopt the technology (Tuttle, 2024). On the other hand, if technical challenges with respect to carbon capture persist (Schlissel, 2024), the technology might see increasing competition from energy storage paired with renewable energy, which was not widely deployed in any of the aforementioned models,[6] and which is continuing to experience cost declines (Colthorpe, 2023). While California has many differences from Alberta, recent gas generation data suggest that energy storage growth has begun to directly compete with gas' market share for short-term peaking (Grid Status IO, 2024).

Figure 13:

California gas-fired electricity generation in April 2024



6 In Navius' model, storage does not contribute large amounts on an annual energy basis as it serves primarily support peak load demand and in hours of the year when wind and solar are not operating, but can make the difference between additional wind and solar being economical or not.

FINDING 3:

Alberta is capable of meeting growing demand for clean electricity

There is broad consensus that electricity generation capacity will need to grow significantly in Alberta in the coming years, whether or not there will be high levels of electrification. Fortunately, Alberta is accustomed to managing a growing system, particularly in its industrial sector. Over the past two decades, while most provinces and states experienced relatively flat (and in some cases declining) demand, Alberta's generating capacity nearly doubled, reaching approximately 21 gigawatts by the beginning of 2024, up from 11.6 gigawatts at the end of 2004.

The growth in supply was largely driven by growing demand from industrial oil and gas facilities, (much of which has been met by behind-the-fence cogeneration), and to a lesser extent by a growing population. From 2004 to 2024, Alberta's annual electricity demand grew from 65 terawatt-hours to close to 86 terawatt-hours. The recent expansion of wind and solar facilities has meant larger growth in total installed peak capacity compared with average load, as these technologies have lower capacity factors than coal units, and both peak installed capacity and capacity factor should be considered when comparing to the historic fleet.

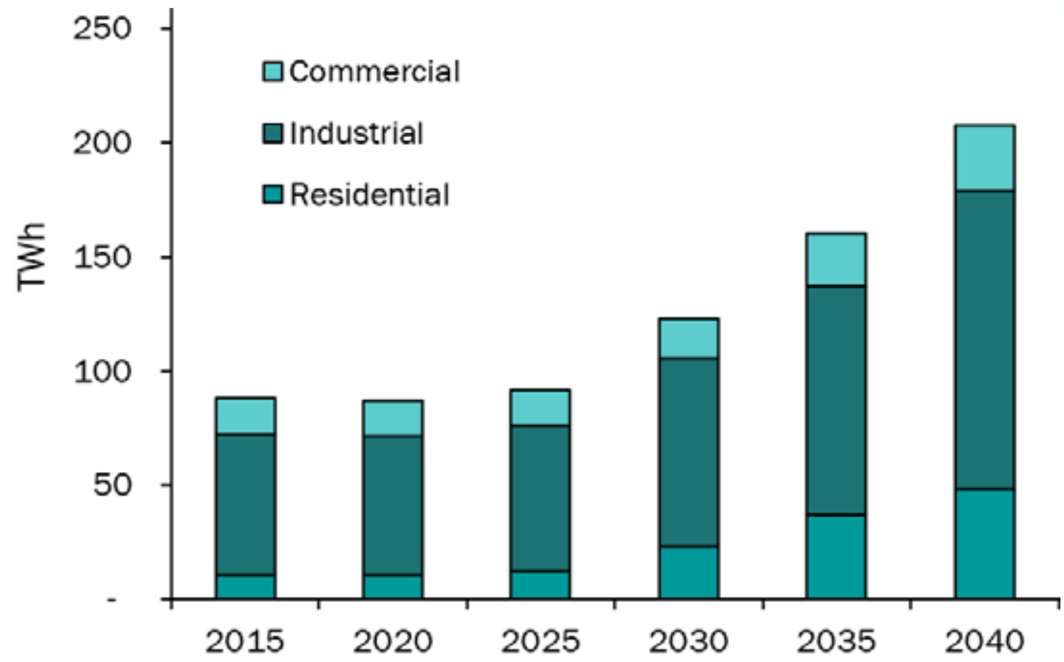
If Alberta achieves net zero economy-wide by 2050, growth in electricity demand would accelerate, potentially more than doubling by 2040, as shown in Figure 14. The Navius modelling suggests that significant electrification is a major enabler of achieving economy-wide net zero if policies go beyond those currently announced in order to line up with net zero.[7] While AESO's 2024 Long-Term Outlook anticipates steady but lower electricity growth, suggesting a doubling may occur sometime after 2040 in a high electrification scenario (AESO, 2024b), the results of a 2019 study for the Canadian Gas Association found that electrification could drive electricity growth to levels more in line with Navius' results (ICF, 2019).

The lion's share of electrification demand growth would be in the industrial sector, which on its own could reach 130 terawatt-hours of demand by 2040, compared to Alberta's entire system, which generated less than 90 terawatt-hours in 2023. These levels of electrification will certainly require significant increases in on-site generation such as solar farms, but may also require new transmission infrastructure in the province and new interties to its neighbors.

7 See footnote 5 for details on the multiple policies that drive electrification under the Navius results.

Figure 14:

Electricity demand growth in high-electrification scenarios modelled by Navius



In order to meet this demand, the Navius announced-policies-plus-net-zero scenario finds that wind energy capacity reaches 17.4 gigawatts of installed capacity by 2040, and 25 gigawatts for solar, a scale-up of over three times existing capacity for wind and 14-fold for solar. Wind turbines have grown in size such that the largest turbines operating in Alberta today are over four megawatts each, compared to turbines that have historically been less than two megawatts in the province. As such, a tripling of installed wind capacity is likely only to require a doubling of the number of turbines that are already operating.

The land footprint of this additional capacity is likely to be modest. Wind farms in Canada have historically required around one square kilometre for every two megawatts of installed capacity, even as turbine sizes have grown (Noel, Weis, Yu, Leach, & Fleck, 2022) (the wind turbine infrastructure directly only takes up less than 3 per cent of the land). Alberta's largest solar farm has 465 megawatts of installed capacity over 13.4 square kilometres. Even in the largest growth scenarios, around 800 square kilometres of land would be directly required for wind and solar infrastructure, compared to over 95,500 square kilometres of prairie land in the province or over 650,000 square kilometres. In other words, physical land constraints are not an issue even at these levels of development. By way of example, it is worth noting that Texas, a jurisdiction with roughly the same landmass as Alberta, already has over 40,000 megawatts of installed wind energy capacity and 15,000 megawatts of solar. While there are very significant geographic and renewable resource differences between the two jurisdictions, it is illustrative to note that Alberta's projected solar and wind footprint already exists in Texas today.

While the rates of electricity growth may seem high, they are not out of line with domestic precedents during times of significant national growth, for example, Canadian electricity consumption nearly tripled from around 140 terrawatt-hours in 1965 to close to 410 terawatt hours by 1985 (The World Bank, 2015).

Farmland and highway scenes along the highways of Eastern Alberta Canada.

7 POLICY UNCERTAINTY AND THE ROAD AHEAD IN ALBERTA

Despite some recent public sparring between the provincial and federal governments over the draft Clean Electricity Regulations, it is noteworthy that the models of Alberta's electricity system have many important similarities—notably, that a net zero system is within reach with current technology, and it is likely to be achieved through a large scale-up of wind, solar and gas with carbon capture, so long as policies like the industrial carbon price incentivize ongoing decarbonization and the cost of renewables and carbon capture continue to decline in Alberta's market.

While the details remain to be published, it appears as though the federal government has acknowledged and intends to address the major criticisms of its draft Clean Electricity Regulations relaxing the operating hours on peaking units, the capture stringency required of carbon capture plants, and the length of time existing plants can continue to operate. It is unlikely that the Clean Electricity Regulations—once finalized and implemented—will prove to be the largest challenge to Alberta's electricity system, compared to other uncertainty facing the provincial electricity market. Assuming the above modifications are implemented, federal Clean Electricity Regulations might, at the very least, help to provide some of the policy certainty needed for carbon capture and storage to materialize, as well as planning for transmission requirements.

What is much more uncertain is the pace of electrification in Alberta, particularly in industry, as well as the provincial long-term policy framework. Nonetheless, we can draw some important conclusions:

- Alberta's electricity fleet will need to grow anywhere from 50-200 per cent in the next 15 years compared to its current capacity.
- Existing technology is capable of delivering a net zero electricity system in Alberta in the mid-2030s.
- Carbon pricing is key to driving decarbonization in Alberta electricity models, but in practice, recent announcements suggest carbon capture may require additional regulatory clarity to ensure it is deployed.
- Private investment has been eager to respond to rapid expansion in Alberta's electricity system, so long as the policy environment has remained conducive.

A significant increase in electricity infrastructure build-out is widely expected in Alberta. However, significant uncertainty has recently been introduced into Alberta's market including new restrictions placed on wind and solar development, which may have the effect of chilling investment in renewable energy (Balaban, 2024), as well as a process of a market reform (Law, 2024). Clear goals and policy stability will be important if Alberta is to deliver on its potential to decarbonize.

Expanding Alberta's electricity system in line with updated Clean Electricity Regulations and the province's goal of a net zero economy by 2050 is certainly a massive undertaking, but this analysis finds that it is achievable in Alberta, for which precedents already exist. How fast this transition proceeds depends significantly on the province's ability to plan for major infrastructure scale-up, including low-carbon electricity generation and transmission.


Solar panels in a solar farm to generate clean electricity.

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