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ALBERTA IN CANADA'S NET ZERO FUTURE: SEIZING OPPORTUNITIES WHILE ADAPTING TO CHANGE*

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ALBERTA FUTURES PROJECT PRE-PUBLICATION SERIES

Alberta has a long history of facing serious challenges to its economy, including shocks in the form of resource price instability, market access constraints, and federal energy policies. However, the recent and current challenges seem more threatening. It seems that this time is truly different.

The collapse of oil and gas prices in 2014 combined with the rapid growth of U.S. oil production, difficulties in obtaining approval for infrastructure to reach new markets and uncertainty regarding the impacts of climate change policies world-wide have proven to be strong headwinds for the province's key energy sector. Together, the negative effects on employment, incomes and provincial government revenues have been substantial. To make matters worse, in early 2020 the Covid-19 pandemic struck a major blow to the lives and health of segments of the population and to livelihoods in many sectors. The result has been further employment and income losses, more reductions in government revenues and huge increases in government expenditures and debt. These events, combined with lagging productivity, rapid technological shifts, significant climate policy impacts and demographic trends, call for great wisdom, innovation, collective action and leadership to put the province on the path of sustainable prosperity.

It is in this context that we commissioned a series of papers from a wide range of authors to discuss Alberta's economic future, its fiscal future and the future of health care. The plan is that these papers will ultimately be chapters in three e-books published by the School of Public Policy. However, in the interest of timeliness and encouraging discussion, we are releasing selected chapters as pre-publications.

INTRODUCTION

The key outcome of the 2015 United Nations Climate Change Conference (COP 21) was a commitment to undertaking actions to hold "the increase in global temperatures to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (United Nations 2015, Article 2.1(a)). Known as the Paris Agreement, it was adopted at COP 21 by 196 countries and has since been ratified by 189. Following COP 21, the Intergovernmental Panel on Climate Change (IPCC) wrote a special report on the impacts of global warming of 1.5°C. An important finding in the report was modelling results showing that to meet the 1.5°C target, global anthropogenic carbon dioxide emissions must reach net zero around 2050 and go net negative thereafter (IPCC 2018).

Following the IPCC report's publication, a growing number of countries have made commitments to reach net zero emissions by 2050. As of December 2020, six countries have legislated the commitment, an additional five countries plus the European Union have proposed legislation, and 13 countries have made the commitment in policy documents (Bazilian and Gielen 2020). Canada is among the countries with proposed legislation.[1] In the U.S., President Biden has announced net-zero by 2050 as the long-term objective of his climate change plan (Reuters Staff 2021; Biden n.d.).

While Alberta does not have an explicit net-zero goal, it has indicated that it will work towards achieving emissions reductions — through technology and innovation — that are consistent with Canada's international climate commitments (Ryan 2020; Cryderman and Graney 2021). The transition towards net-zero will affect Alberta in two major ways. First, through internal adjustments to reduce emissions and contribute to Canada's goal of net-zero as a country, and second, by confronting changes in demand for its products and services as other jurisdictions shift to meet their own net-zero goals. We outline transition pathways for Alberta along Canada's net zero pathways and discuss the challenges and opportunities for Alberta on each of these fronts.

As the highest emitting province in Canada — Alberta's per capita emissions are 63.2 tonnes per capita, compared to the Canadian average of 19.4 (Statistics Canada 2021; Government of Canada n.d.) — it is easy to think Alberta will face the greatest challenges in supporting a national net zero target. Beyond achieving its own emissions reductions, the province must also confront potential changes in global (and local) oil and gas demand.

At the Earth Day 2021 Leaders' Summit on Climate, for example, both the United States and Canada committed to ambitious reduction targets for 2030. President Biden announced an emissions reduction goal of 50 to 52 per cent below 2005 levels by 2030 (Sullivan and Liptak 2021; The White House 2021). With the United States currently on track to achieve emissions reductions of only 13-14 per cent relative to 2030 (U.S. Department of State 2016; Environmental Defense Fund 2021), the new

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[1] The *Canadian Net-Zero Emissions Accountability Act*, tabled November 19, 2020, makes Canada's 2050 target legally binding and introduces rolling five-year emissions reduction plans and targets (Environment and Climate Change Canada 2020a; Wilkinson 2020).

goal will require a sharp pivot towards cleaner energy systems and increased energy efficiency. Two pillars of Biden's plan are personal vehicle electrification and a clean electricity grid (Biden n.d.); both will have a sharp impact on American demand for Alberta crude oil and natural gas.[2]

Canada's reduction target, which was previously a 30 per cent decrease in emissions in 2030 relative to 2005, was adjusted to 36 per cent below 2005 levels in Budget 2021 (Department of Finance 2021). The target increased sharply to 40 to 45 per cent on April 22, 2021 (Office of the Prime Minister 2021). Underpinning Canada's target is a rising carbon price, currently proposed to increase by $15 per year starting in 2023 and reach $170 in 2030 (Environment and Climate Change Canada 2020b). This will negatively impact domestic demand for crude oil and natural gas. Complementary policies outlined in Canada's most recent climate plan (released in December 2020) and the 2021 federal budget will further reduce demand. The policies include support for zero-emissions vehicles and public transit, improving energy efficiency in buildings, cleantech technology investment and tax incentives, and a clean fuel standard (Environment and Climate Change Canada 2020b; Department of Finance 2021).

What is less evident are the extensive opportunities for Alberta in the shift towards net-zero. We use provincial results based on modelling from the recent Canadian Institute for Climate Choices (CICC) report on potential Canadian pathways to net zero to outline these opportunities (Canadian Institute for Climate Choices 2021; Navius Research 2021). Of particular note are the continuing benefits that will be afforded by the Western Canadian Sedimentary Basin (WCSB), underlying much of northeast BC, Alberta and Saskatchewan. The WCSB can safely and permanently absorb as much carbon dioxide (CO_2) as we could ever anticipate storing. This makes Alberta a favourable location for direct air capture (DAC) — where CO_2 is pulled from the air and either injected into underground storage or used as an input in other processes — as well as advanced forms of carbon capture, utilization and storage (CCUS).[3] CCUS allows for the capture of industrial CO_2 emissions in Alberta, and potentially other areas of the country if new east-west CO_2 pipelines are built (or existing oil and gas pipelines are repurposed). Advanced forms of CCUS would also support blue hydrogen production, where hydrogen is produced by steam methane or autothermal reforming of natural gas. Hydrogen production in turn leads to additional opportunities in Alberta's chemical sector (a core sector in which it already has significant expertise and capacity), including the production of potentially net-zero synthetic fuels and feedstocks like hydrogen, ammonia, methanol, ethanol, ethylene, and BTX. Last, there are also potential opportunities in biofuels production; geothermal energy production;

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2 Some of the decline in U.S. demand for Alberta's crude oil and natural gas may be offset by rising international demand. British Columbia in particular may be a key export point to Asian markets. A portion of the Trans Mountain pipeline expansion, for example, may carry crude oil for export. It is scheduled to be completed in 2022 and will increase capacity on the pipeline by 590,000 barrels of oil per day. Construction is also underway on the LNG Canada export facility in Kitimat, which will likely export natural gas from both British Columbia and Alberta. The facility is projected to be completed in 2025 and will provide initial export capacity of 14 million tonnes per annum.

3 CCUS is a family of technologies where known and commercialized chemical absorption and separation processes capture CO_2 from chemical waste streams or combustion flue gas for reuse or disposal underground.

and lithium and iron ore mining, the latter reduced to elemental iron using hydrogen instead of coal.

In this paper, we explore what a net zero emissions policy means for Alberta. We start with a brief overview of the CICC report, its net zero scenarios and some of the key provincial level results for Alberta. We then move to a discussion of the pathways within specific subsectors of Alberta's economy. We conclude with a discussion of the numerous opportunities for Alberta along a net-zero path.

Canadian Institute for Climate Choices' Net Zero Scenarios

CICC released its report, "Canada's Net Zero Future: Finding Our Way in the Global Transition" in February 2021 (hereafter referred to as the CICC Net Zero report). The report outlines different pathways Canada can take as a country to achieve net zero emissions in 2050. These pathways are generated using the gTech computable general equilibrium model from Navius Research. Further background information on the gTech model is available in both the CICC Net Zero report and an accompanying study with technical details on the model from Navius Research (Navius Research 2021).

In total, the CICC Net Zero report examines national pathways to net zero across 62 scenarios characterized by nine separate assumptions. These nine assumptions are: electric vehicle costs; hydrogen costs and blending rate potential; the cost of new non-emitting "firm" electricity generation costs; climate policy action in other major countries; availability of DAC and advanced forms of CCUS (carbon capture utilization and storage);[4,5] global oil price; competitiveness protection measures; availability of second-generation biofuels; and oil sands production emissions intensity improvements.

We present Alberta-specific results across the 62 scenarios in our analysis below. Most often this takes the form of paths that track the upper and lower bounds on key indicators of interest such as total greenhouse gas emissions, GDP or oil production.

Broadly speaking, Alberta's economy is bookended by two sets of pathways to net zero. In the first set, engineered negative emissions solutions and advanced forms of CCUS are not available and the global price of oil is low. The low oil price causes a significant contraction in oil and gas production, while the absence of negative emissions solutions means that meeting net-zero also requires a significant curtailment in other industrial segments of the province's economy. We refer to these as the "Transformation Pathway" as they necessitate a relatively rapid reorientation by the province towards new areas of economic activity and significant changes in energy systems, necessitating broad structural change to Alberta's economy.

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4 Advanced forms of CCUS refer to CCUS technologies that can be used for unconcentrated post-combustion emissions. In scenarios in which advanced CCUS is not available, CCUS technology still exists but can be used for concentrated process emissions only, e.g. from raw formation gas processing and hydrogen production.

5 This assumption can be further divided into three subgroups. Scenarios in which neither DAC nor advanced CCUS is available, scenarios in which only advanced CCUS is available and scenarios in which both DAC and advanced CCUS are available.

In the second set of pathways, engineered negative emissions solutions and advanced forms of CCUS are available and the global oil price is high.[6] These pathways are consistent with continued steady growth in Alberta's oil sector, and there is a narrow set of conditions where production reaches upwards of 5 million barrels per day in 2050. We refer to these as the "Transition Pathway" as they characterize a less rapid change in energy systems and result in the least structural change in Alberta's economy over the next 30 years. Rather, these pathways allow Alberta to continue growth in many of its current sectors, while simultaneously transitioning at a slower rate into new economic opportunities and imply much less structural change in energy systems and the overall economy.

In the discussion that follows, we largely focus on these pathways as they represent "bookends" in a range of potential outcomes. Both pathways should be interpreted with substantial caution. In the Transformation Pathway, the gTech model is constrained by assumptions based on current information and data — only what is known to be commercial today, or soon, is well described in the model. As a result, the model does not capture the full potential upside of new industries such as blue hydrogen production and synthetic net-zero chemical and fuel manufacturing that will likely transform the Alberta energy sector (Bataille et al. 2018; Bataille 2020), for which it has substantial competitive advantages and capacity. In the Transition Pathway, while Alberta achieves net-zero emissions using engineered negative emissions to compensate for largely business-as-usual fossil fuel CO_2 emissions, only under a highly improbable combination of circumstances would this be consistent with global efforts to reach net-zero. More realistically, to achieve the Paris Agreement target any DAC capacity built in Alberta cannot be used to support ongoing domestic fossil fuel production and consumption in perpetuity. It would instead be used to avoid stranded capital, ease the transition, and offer a means of building up negative emissions capacity for the eventual push toward global net negative emissions post 2050 to 2070.

ALBERTA'S NET ZERO SCENARIOS

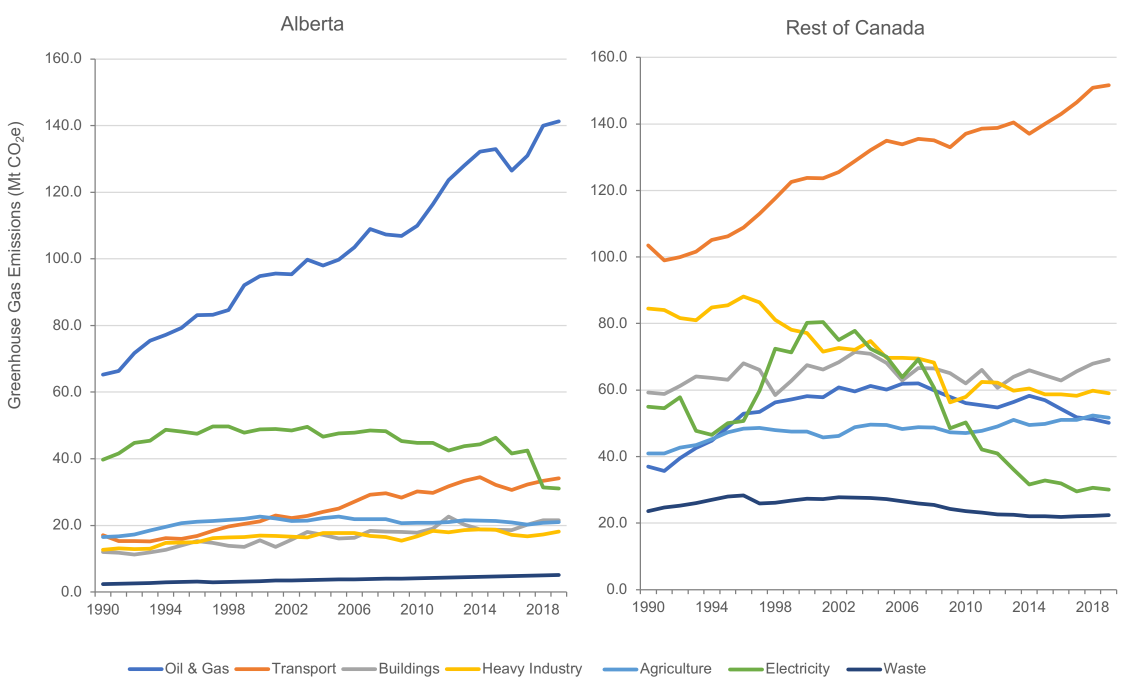
The most recent official estimate of Alberta's greenhouse gas emissions from Canada's National Inventory Report is 276 Mt CO_2e in 2019 (Environment and Climate Change Canada 2021). Over half of emissions (141 Mt CO_2e) are attributable to the oil and gas sector, with an additional 8 per cent (21 Mt CO_2e) attributable to other industrial and resource sectors. The remaining significant sources of emissions are transportation (12%/34 Mt CO_2e), electricity (11%/31 Mt CO_2e), buildings (8%/22 Mt CO_2e) and agriculture (8%/21 Mt CO_2e). The starting (2020) level of emissions for Alberta in the gTech model is approximately 310 Mt CO_2e. Most of this difference is attributable to an estimated increase in emissions from the oil sands, which are calibrated to align with the oil sands production forecast from the Canada Energy Regulator's 2019 Energy Futures report.

6 The two sets of pathways we describe here only isolate two of the nine assumptions that characterize each scenario in the gTech model. As a result, they each encompass a group of scenarios (12 individual scenarios for the Transformation Pathway and nine for the Transition Pathway). Also of note is that while these scenarios typically bookend economic indicators such as GDP and oil and gas production, they are not a bookend to all results in the model. For example, along the Transition Pathway, Alberta's greenhouse gas emissions in 2050 fall in the mid-range across all possible scenarios (see Figure 1 and accompanying discussion).

Relative to the rest of Canada, Alberta's greenhouse gas emissions have followed a unique path over the last thirty years (Figure 1), rising from 172 Mt in 1990 to 276 Mt in 2019. This increase is primarily from rising emissions in the oil and gas sector. Also contributing is strong economic growth in other industrial sectors, coupled with above average incomes and population growth. The combination of these factors has resulted in Alberta's greenhouse gas emissions outpacing the rest of Canada in virtually all sectors. The rest of Canada, in contrast, has only seen substantial emissions growth in a single sector — transportation. Further, these increases have been nearly offset by substantial declines in emissions in heavy industry and electricity. As a result, from 1990 to 2019, emissions in the rest of Canada increased by only six per cent, rising from 430 to 454 Mt.

The pathway for Alberta's greenhouse gas emissions over the last 30 years presents unique challenges along a pathway to net zero over the next 30 years. A continued high level of emissions from Alberta's industrial sector means the success of negative emissions technologies will be a key determinant of the degree to which Alberta's economy will need to restructure — and potentially find new sources of economic activity — along a net zero path. While Alberta is transitioning from coal to natural gas power by 2023, there are no plans at present to reduce the use of most of the natural gas.[7] In addition to being a large source of emissions that still needs to be eliminated, this also limits the province's near-term options for using electrification to reduce emissions in sectors such as transportation and buildings.

Figure 1: GHG Emissions by Economic Sector, 1990 - 2019



Source: Government of Canada (n.d.).

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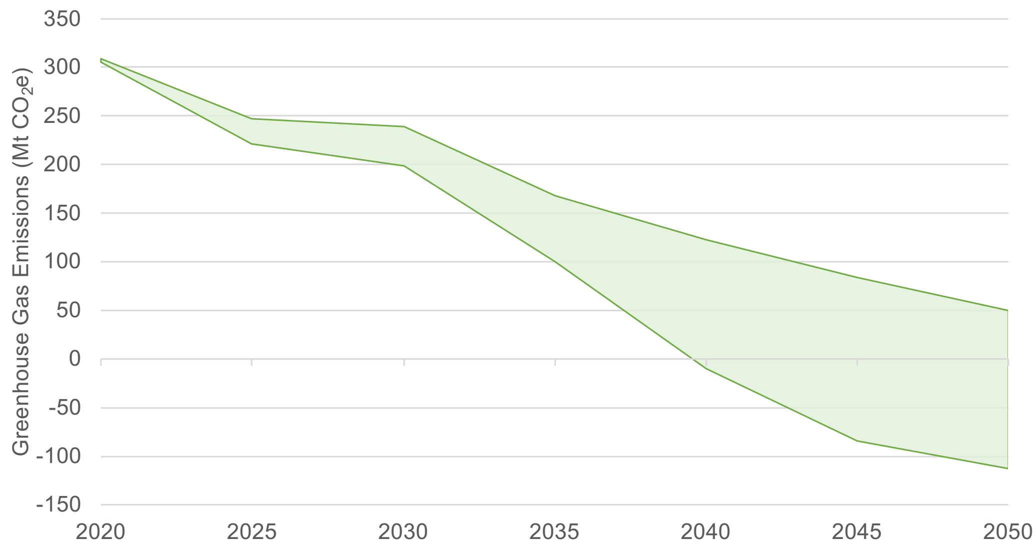
7 Alberta announced its goal to eliminate emissions from coal power electricity generation in November 2015. The phaseout is currently anticipated to be completed by 2023, well in advance of the province's original goal of 2030. The phaseout, however, still lags other provinces; Ontario, for example, eliminated coal power between 2007 and 2014.

All scenarios show that Alberta's pathway to net zero starts immediately, with emissions declining by 61 to 88 Mt over the next five years (Figure 2). Most of these early reductions would be driven by natural gas fuel switching (primarily in electricity and the oil sands), with smaller amounts potentially attributable to a shift towards non-emitting electricity, energy efficiency and CCUS. Emissions reductions slow down significantly between 2025 and 2030, before picking up and steadily declining across all scenarios through to 2050. Alberta's final 2050 emissions level is estimated to range between -113 Mt and +50 Mt. This range does not include any negative emissions attributable to nature-based solutions, as land use estimates included in the model are not disaggregated to the provincial level.

Figure 2: Alberta's GHGs Across Pathways to Net Zero



Note: Greenhouse gas emissions in 2050 do not include any reductions in emissions attributable to land use.

Negative emissions occur in scenarios where DAC is available, and DAC facilities operating in Alberta offset gross emissions in Alberta, along with positive emissions in other provinces. In contrast, the highest level of emissions occurs when DAC is unavailable, leaving primary reliance on advanced forms of CCUS. This is primarily from CCUS supporting ongoing production in the oil and gas sector, which results in emissions of between 14 and 23 Mt in 2050 (although reaching net zero emissions nationally means these amounts will be offset somewhere in Canada by negative emissions from nature-based solutions).[8]

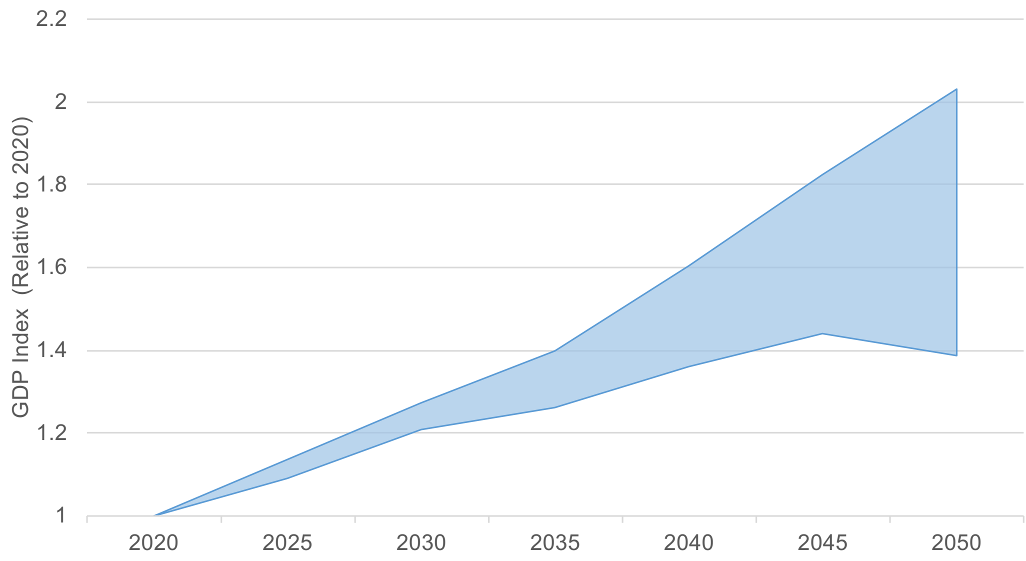
Last, the mid-range emissions correspond to scenarios where neither DAC nor advanced forms of CCUS are available. This is largely driven by a sharper contraction in oil and gas production, and correspondingly, lower emissions. It also highlights,

8 Negative emissions from nature-based solutions are only provided at a national level in the CICC analysis and cannot be attributed to a specific province. In practice, this exchange requires a functioning national offset market to facilitate negative emissions from nature-based solutions offsetting the remaining emissions from Alberta's oil and gas sector.

however, that the availability of negative emissions technology may defer the adoption of lower- or zero-emissions technologies in other areas. For example, when negative emissions technologies are not available, there is a sharper decline in emissions in the transportation and building sectors. This is likely indicative of earlier widespread adoption of technologies such as electric vehicles and zero-emissions options for space heating.

Regardless of the path Alberta takes to achieve net zero emissions, the model suggests its economy will continue to grow, albeit at a slower rate than in the province's recent history. Chained GDP in 2050 is forecast to increase by 1.4 to 2.0 times relative to 2020, corresponding to an annualized growth rate of between 1.1 and 2.3 per cent (Figure 3). The upper end of the growth path corresponds to the Transition Pathway, in which the oil and gas sector and DAC (as a new industry) drive growth in the provincial economy. The lower range corresponds to the Transformation Pathway.

Figure 3: Alberta's Chained GDP, Indexed to 2020



A sharp contraction in Alberta's oil and gas sector drives the lower forecast growth rate for GDP in the Transformation Pathway. The oil and gas sector (including support services) accounted for approximately 28 per cent of Alberta's economy in 2019 (Statistics Canada n.d.). A contraction in the sector will be challenging, but historical data suggest that other current economic drivers can sustain a reasonable growth rate in the province's economy moving forward.[9] The Transformation Pathway is also likely to accelerate economic growth and diversification opportunities in Alberta's non-oil-and-gas sectors. GDP growth along the pathway is driven by a mix of current sectors

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9 From 2000 to 2019, chained GDP in Alberta's non-oil-and-gas sectors grew at an annualized rate of 2.3 per cent. Sectors contributing the largest amounts to this growth included real estate and rental and leasing, health care and social assistance, construction, and finance and insurance. Continued annualized growth at this rate in the province's non-oil and gas sectors will be more than sufficient for Alberta's chained GDP index to grow to 1.4 (relative to 2020) in 2050.

such as agriculture, services and light manufacturing, as well as emerging sectors with future potential such as hydrogen and biofuels production.[10]

The contribution of these sectors means that Alberta's low path for GDP growth still exceeds the minimum forecast for Canada. It is also worth remembering the gTech forecast of GDP growth along all paths is likely an underestimate (Lee and Beugin 2021). The model does not account for possible emergence of new sectors (for which economic data does not currently exist). Also lacking in the model (and in GDP) are many of the benefits — such as cleaner air and positive health impacts — that come with a net zero transition.

In the discussion that follows, we provide a closer look at the paths to net zero in the following key sectors: oil and gas, industrial (excluding oil and gas), electricity, buildings, and medium- and heavy-duty transportation. We do not include a discussion of personal transportation, as Alberta's path to net zero in this sector is similar to the national pathway (already discussed in the CICC Net Zero report).

OIL AND GAS

The future of Alberta's oil and gas sector along a path to net zero is primarily dependent on whether Alberta follows a Transformation or Transitions Pathway. Also key, however, is the oil price.[11] When the price of oil is low, then regardless of other assumptions, oil production sharply declines from its 2020 level of 3.5 million barrels per day (bpd) to approximately 500,000 bpd in 2035 (Figure 4). This is followed by a gentler decline over the next 15 years, with minimal oil production of 100,000 to 260,000 bpd continuing to persist in 2050. Conventional oil (including enhanced oil recovery) surpasses oil sands as the primary source of oil production by (approximately) 2035. By 2050 oil sands production is forecast to be less than 25,000 bpd while conventional oil production varies between approximately 80,000 and 230,000 bpd.

In comparison, when the oil price is high, availability of engineered negative emissions solutions is the primary determinant of the path for oil production. When available, DAC and/or advanced CCUS support continued growth in oil sands and conventional oil production over much of the next 30 years, with total production increasing to between 4.0 and 4.9 million bpd in 2050.[12] Also of note in these scenarios, however, is that further expansion of Alberta's oil production will require continued investment in the sector, which is conditional on expectations of future market conditions. As a

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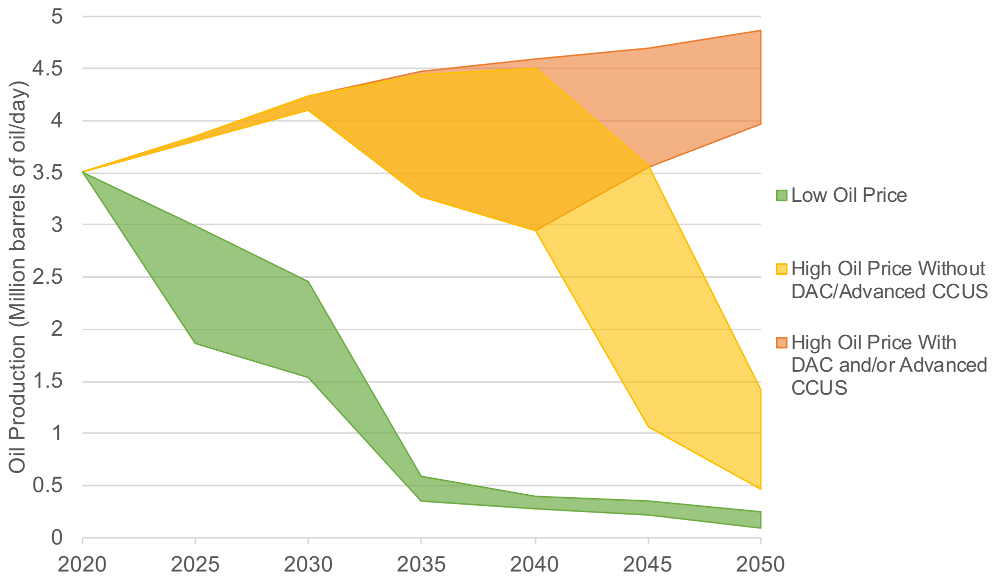
10 As identified in the CICC Net Zero report, additional sectors that may contribute to economic diversification and growth in Canada's oil-producing provinces are lithium and uranium mining, battery production, small modular reactors and geothermal energy.

11 All oil prices are in 2020 US dollars. In 2020 the price of oil (per barrel) is assumed to be $58 in the high oil price scenario and $54 in the low oil price scenario. From there the two oil price paths diverge significantly. Along the low oil price path, prices from 2025 to 2050 range from $39 to $37 while along the high oil price path they range from $63 to $88.

12 Along the path with high oil price and negative emissions solutions, oil production declines from 2030 to 2040 in scenarios where the rest of the world takes action on climate change and competitiveness measures are not in place.

result, forecast production along this pathway will only occur if oil companies and their lenders correctly anticipate this scenario unfolding, which implies and requires policy certainty and stability.

Figure 4: Alberta's Oil Production Under High and Low Global Oil Price Scenarios



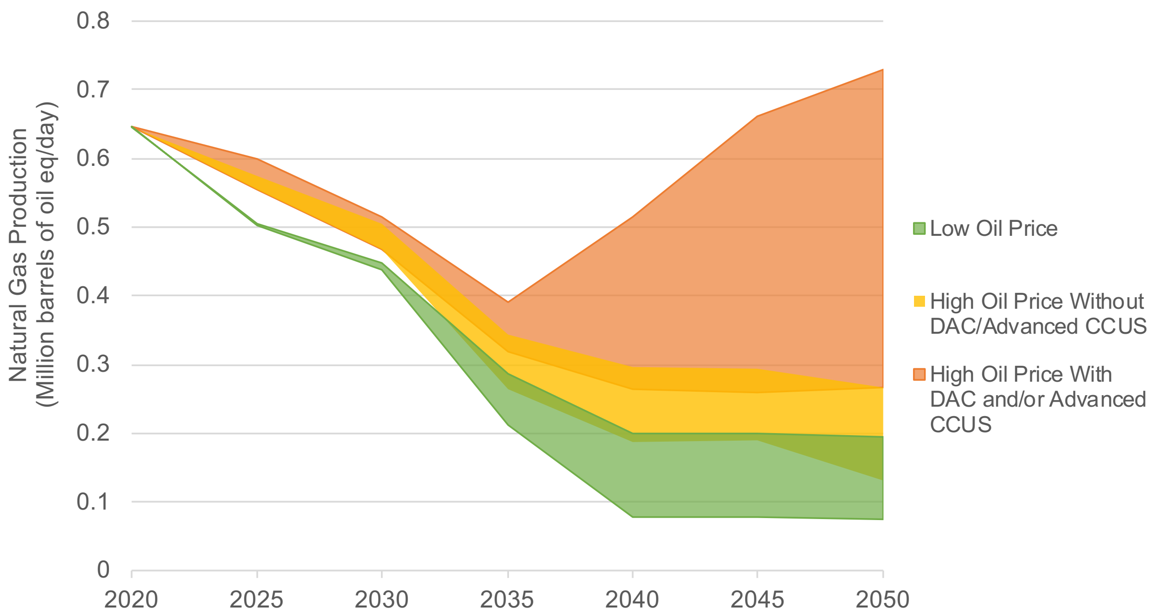
Note: The high oil price with DAC and/or Advanced CCUS pathway includes scenarios in which both DAC and advanced CCUS are available, and scenarios in which only advanced CCUS is available. There are no scenarios in which DAC is available and advanced CCUS is not.

When negative emissions solutions are not available, increases in oil production are only sustained to 2030 for the oil sands and 2040 for conventional oil. Between 2030 and 2040, continued oil sands production depends on the availability of second-generation biofuels.[13] Specifically, when second generation biofuels are available, they support ongoing demand for conventional fuels in North America (e.g. under LCFS regulations) due to blending. In the absence of biofuel availability, there is likely to be a faster transition to electrification and hydrogen fuel, and correspondingly, a faster decline in oil sands production. Post-2040 the absence of negative emissions technologies leads to an unambiguous and sharp decline in oil sands and conventional oil production, with cumulative 2050 production between approximately 465,000 and 1.4 million bpd. With many current and planned oil sands projects having forecast production lives that extend beyond 2040, these pathways could result in significant stranded production assets.

13 Second-generation biofuels in the gTech model are fuels derived from feedstocks comprised of agricultural and forestry harvest residues. Agricultural residues are what is remaining of plants after harvest while forestry harvest residues include treetops and branches that are left by the road after logging (Navius Research 2021).

Similarly, the oil price and availability of engineered negative emissions solutions strongly influence natural gas production.[14] The highest forecast production paths occur in the Transition Pathway and the lowest forecast production paths occur in the Transformation Pathway (Figure 5). Relative to oil production, however, there are some key differences. Across all scenarios, natural gas production is forecast to decline over the next 15 years, from 650,000 barrels of oil equivalent (boe) per day in 2020 to between 210,000 and 390,000 boe per day in 2035. This is consistent with other forecasts for Alberta's natural gas production (Canada Energy Regulator 2019, n.d.; Alberta Energy Regulator 2020), which anticipate continuing declines in export (U.S.) demand.[15] Most scenarios continue to see natural gas production decline, albeit at different rates, after 2035. The exception is in the Transition Pathway, with the highest production levels reached when the rest of the world is taking action on climate change and competitiveness measures are in place. This could be consistent with the U.S. (and other countries) adopting advanced CCUS and DAC technology, and Alberta's natural gas producers being competitive in an international market where demand for natural gas (as a relatively less carbon intensive fossil fuel) is correspondingly increasing.

Figure 5: Alberta's Natural Gas Production Under High and Low Global Oil Price Scenarios



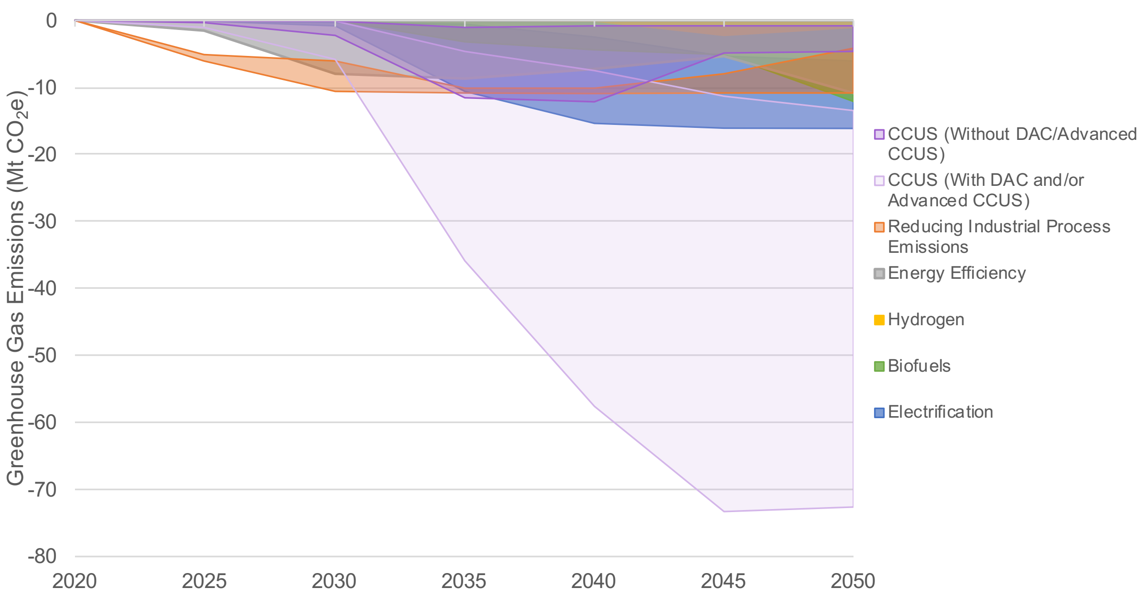
14 We refer to the oil price here as it is a key scenario assumption and an exogenous input to the gTech model. The natural gas price is determined endogenously, via a calibration of both oil and natural gas prices to the Canada Energy Regulator's 2019 Energy Futures report (Canada Energy Regulator 2019; Navius Research 2021). Notably, there is significant overlap between the natural gas price ranges that correspond to the low and high oil price paths, with a small divergence in prices only starting in 2035. Along the high oil price path (all prices in 2020 US dollars per mmBTU), natural gas prices increase from $3.50 in 2035 to $4.60 in 2050. Along the low oil price path, they increase over this same period from $3.50 to $4.00.

15 As previously referenced in footnote 2, it is possible that a decline in U.S. export demand for Alberta natural gas is offset by rising demand for LNG exports in other international markets, but this scenario is excluded from our analysis. The CICC Net Zero report only includes scenarios where the global market follows trends in U.S. markets. That is, it does not include scenarios where U.S. demand for natural gas is down but global demand persists.

Turning briefly to the greenhouse gas reduction pathway for Alberta's oil and gas sector, the primary contributor to emissions reductions in the sector is advanced CCUS, when it proves viable and cost-effective at scale (Figure 6). The full range of emissions reductions attributable to advanced CCUS is 12 to 72 Mt, with the highest reductions occurring in scenarios in which DAC is not available and the oil price is high. These scenarios are conducive to higher oil production, and in the absence of DAC, CCUS carries a larger amount of the emissions reduction load. Electrification also plays a larger role when DAC is not available, supporting emissions reductions of up to 16 Mt.

As discussed, when negative emissions solutions are not available then regardless of the oil price, the lack of options for emissions reductions consistent with net zero means that continued growth in oil and gas production cannot be sustained. The contraction in production accordingly limits the amount of emissions reductions that are required. Maximum emissions reductions in these scenarios are 44 Mt with electrification and reductions in industrial process emissions generally contributing the largest amounts.

Figure 6: Oil and Gas Sector GHG Reduction Pathways



Note: The oil and gas sector includes conventional oil production, oil sands production, natural gas production, natural gas transportation and petroleum refining. When advanced CCUS is not available, a limited amount of CCUS technology can be used to capture concentrated process (non-combustion) emissions only.

INDUSTRY EXCLUDING OIL AND GAS

Emission reduction options for Alberta's other industrial sectors are similarly dominated by advanced CCUS, which offers reductions of 5 to 30 Mt by 2050 when available (Figure 7).[16] As was the case with oil and gas, the availability of advanced

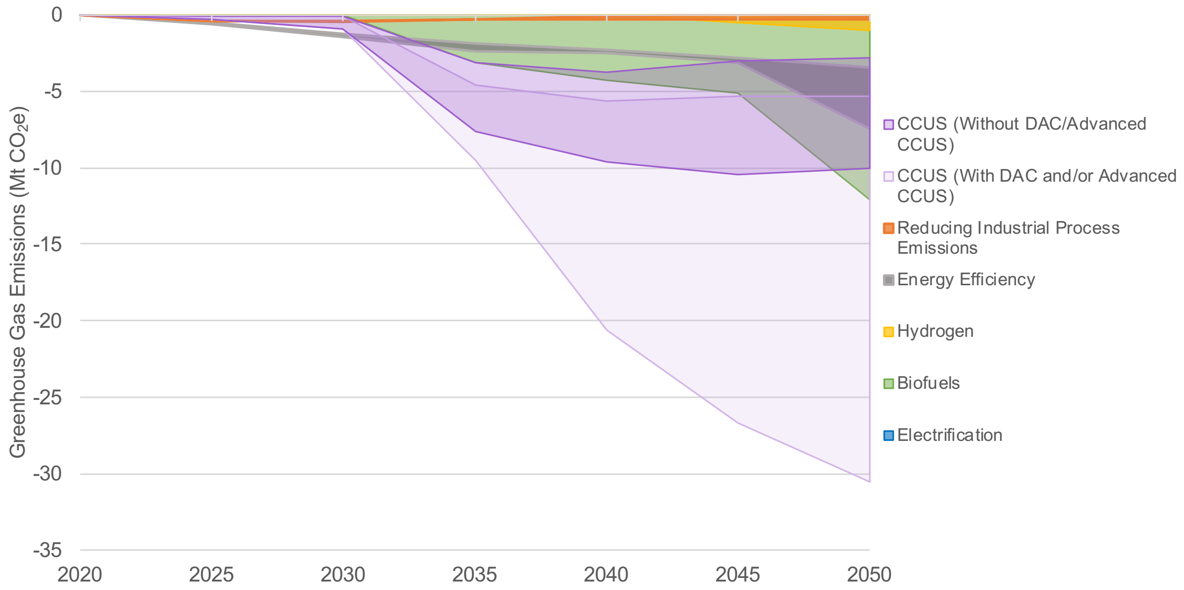
16 "Other industry" in the gTech model includes agriculture and forestry, biofuels manufacturing, cement and lime, DAC, hydrogen production, manufacturing, mining, and steel.

CCUS helps sustain ongoing production in other industrial sectors using existing production methods, which in turn results in a higher level of emissions requiring offset. Once again, the highest level of CCUS reductions occur when alternative options for reductions, most notably DAC, are not available.

While advanced CCUS provides the most potential for emissions reductions in Alberta's industrial sectors, it is less critical to their ongoing growth. This is largely due to the fact that the starting level of emissions in these sectors is much smaller (41 Mt for other industry in 2019 as opposed to 141 Mt for oil and gas). Further, Alberta's other industrial sectors — most notably fertilizer and chemicals production — have higher levels of process emissions, for which CCUS technology is available across all scenarios. Accordingly, when advanced forms of CCUS are not available, CCUS for process emissions still provides a consistent source of emissions reductions. These reductions start in 2030, and grow to reach annual reductions of between (approximately) 4 and 10 Mt by 2040. They largely stay within this range for the entirety of the 2040 to 2050 period.

Second generation biofuels, when available, are also an important source of emissions reductions in the absence of negative emissions solutions. Projected emissions reductions along the upper path for biofuels slowly grow from 2030 to 2045 (rising from 0 to 5 Mt), and then sharply kick up in the final five years, offering emissions reductions of up to 12 Mt in 2050. Last, offsets from nature-based solutions would be required for any remaining positive emissions in Alberta's industrial sector (excluding oil and gas) when DAC and advanced CCUS are unavailable.

Figure 7: Industrial Sector GHG Reduction Pathways (excluding oil and gas)



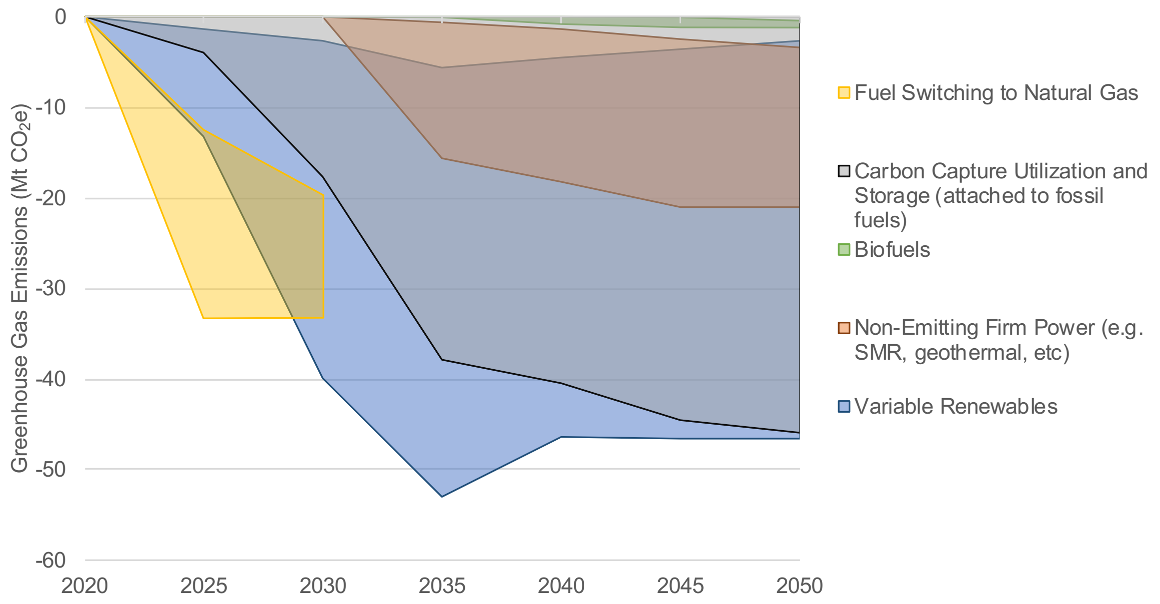
ELECTRICITY

While Alberta has been successful in achieving significant reductions in emissions from its electricity sector in recent years, most of this is the result of fuel switching from coal to natural gas. Alberta's remaining coal plants are scheduled to switch to natural gas by 2023, achieving its coal phase-out seven years ahead of its original target of 2030 (The Canadian Press 2020). Despite this shift, Alberta will likely continue to be the most heavily reliant on fossil fuel thermal electricity generation among the provinces. Sources of emissions reductions in the electricity sector will correspondingly be highly dependent on whether it is in a Transition or Transformation Pathway.

When DAC and/or advanced CCUS are available, thermal generation continues though emissions reductions attributable to CCUS start to increase steeply beginning in 2025. In 2035 the maximum level of potential reductions reaches 38 Mt annually (Figure 8). From 2035 to 2050, CCUS continues to play a steady and rising role, contributing a maximum of 46 Mt of emissions reductions in 2050. This maximum level occurs in scenarios where new non-emitting firm power is not available.

In the absence of DAC or advanced CCUS, the emissions reduction path for the electricity sector is primarily dependent on the availability and cost of non-emitting firm power. When available and cost-effective, these technologies (e.g. flow batteries, impoundment hydro, geothermal, small modular reactors, power to hydrogen and back) are introduced in Alberta starting in 2030. Along their upper path, they provide emissions reductions of just over 21 Mt in 2050. In addition to the lack of advanced CCUS, this upper path is characterized by lower electric vehicle battery costs and lower hydrogen costs, both of which are likely to increase demand on Alberta's electricity grid.

Figure 8: Electricity Generation GHG Reduction Pathways



Note: Attributed reductions to fuel switching fall to zero in 2030 as a result of the coal phase-out. That is, post-2030, fuel switching to natural gas (which itself has associated greenhouse gas emissions) is no longer credited as a source of greenhouse gas emissions reductions.

There is also a role for variable renewables in Alberta's future electricity grid, with their exact contribution largely determined by the availability and cost of DAC, advanced CCUS and non-emitting firm power. When these technologies are not available, the emissions reduction path for renewables increases steeply starting in 2020, reaching a maximum level of up to 53 Mt in 2035. Post-2035, the maximum emissions reductions attributable to renewables recedes slightly, reaching 47 Mt annually in 2040 (and remaining at this level through to 2050). In contrast, when DAC and advanced forms of CCUS are available and new non-emitting firm power is being built, emissions reductions attributable to renewables reach a maximum of less than 6 Mt annually over the entire 2020 to 2050 period.

Last, we note the gTech model does not allow for expansion of storage or electricity interties between regions, both of which may be key components of Alberta's electricity supply on a pathway to net zero. The Government of Canada announced support for intertie projects that connect regions dependent on fossil fuel electricity generation to those with abundant hydroelectricity supply (Environment and Climate Change Canada 2020b). Recent research also shows that if new Alberta-British Columbia interties are established and decarbonization levels for the electricity sector exceed 80 per cent then there is an economic case for British Columbia's Site C hydroelectric project (Dolter, Fellows, and Rivers 2020a, 2020b). New interties with British Columbia may also support greater investment in wind and solar power in Alberta as the dispatchability of firm hydroelectric power is a needed complement to the intermittency of renewables (Jaccard and Shaffer 2020).

BUILDINGS

Relative to the rest of the country, Alberta again faces a steeper path to net zero in the buildings sector due to a heavier reliance on fossil fuels — particularly natural gas — for energy use in buildings. In 2018, fossil fuel sources accounted for 75 per cent of energy use in Alberta's commercial, institutional and residential buildings, compared to the national average of 52 per cent (Natural Resources Canada n.d.). Provinces with lower fossil fuel energy use in buildings are those that currently have significant sources of hydroelectricity. Unsurprisingly then, the national shift towards net zero in the buildings sector is expected to be driven primarily by electrification.

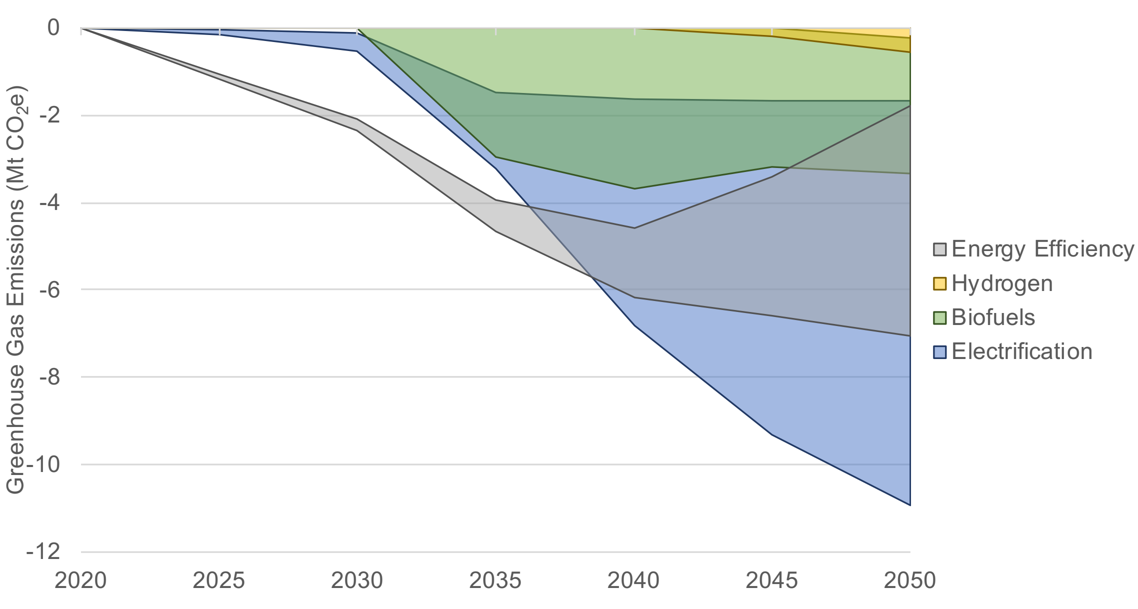
While electrification will also play a role on Alberta's path to net zero in the buildings sector, there are several challenges specific to the province. Most significant is the current low share of zero-emissions electricity sources in the province. As a result, substantive emissions reductions attributable to electrification are not forecast to be available until 2030.[17] From 2030 to 2035 emissions reductions from electrification are forecast to grow across all scenarios to between 1.5 and 3.2 Mt (Figure 9). Post-2035, the potential for emissions reduction from electrification diverges substantially. The lower emissions reduction path for electrification effectively stays flat, with 2050

17 While 2030 is also the year in which new non-emitting firm power potentially becomes available, the availability of this technology does not have a significant impact on the emissions reduction pathway for electrification. Small-scale nuclear reactors are not included in the modelling, though were they to prove viable they could present new generation and economic opportunities in the province.

reductions remaining below 2 Mt. Along the upper path, in comparison, reductions grow steadily and reach as high as 11 Mt in 2050.

The highest level of emissions reductions from electrification corresponds to scenarios in which DAC, advanced CCUS and second generation biofuels are all unavailable. In opposite scenarios — where all three are available — emissions reductions from electrification track along the lower path, with both energy efficiency and biofuels providing greater emissions reductions instead. This likely occurs for a number of reasons. First, the main source of greenhouse gas emissions from buildings is space heating, with virtually all of Alberta's commercial, institutional and residential space heating currently fueled by natural gas. A shift towards renewable natural gas (when available) or the use of negative emissions solutions therefore allows a larger share of current heating technology (some of which would not otherwise require replacement prior to 2050) to continue to operate without significant retrofits. Second, a shift to electrification will increase electricity demand, which in turn will require further build-up of zero-emissions electricity sources. Also of note is that emissions reductions from electrification in the buildings sector tend to be driven by the adoption of heat pumps. Heat pumps, however, require ambient humidity to optimally transfer heat and are therefore less effective in — and not as well suited to — Alberta's drier climate. More investment in building shell efficiency, ground source heat pumps, RNG, and passive thermal systems is optimal in Alberta and Saskatchewan compared to other regions.

Figure 9: Buildings Sector GHG-Reduction Pathways



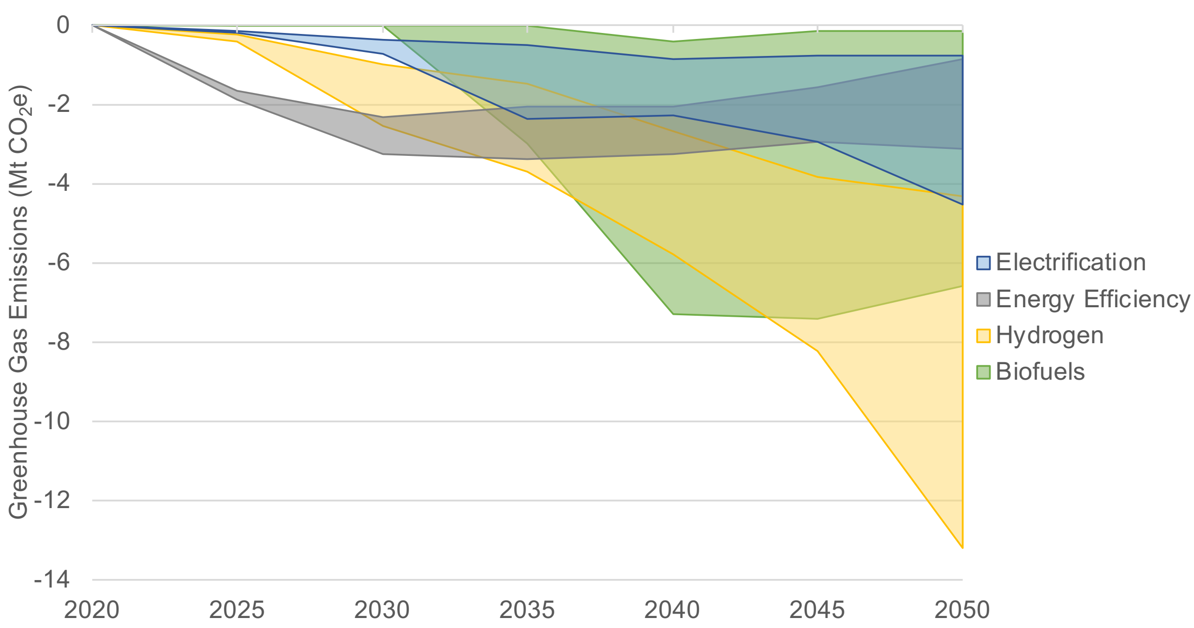
MEDIUM- AND HEAVY-DUTY TRANSPORTATION

Unlike the sectors discussed thus far, the emissions reduction pathway in Alberta's medium- and heavy-duty transportation sector largely follows the rest of Canada. We offer a brief discussion, however, as there are a range of possible outcomes for the sector and government action is needed in the short-term to respond to this uncertainty.

The simulation results suggest that over the next ten years conventional vehicles will continue to comprise the bulk of Alberta's freight transportation fleet. Accordingly, increased efficiency of internal combustion engines is the most likely source of emissions reductions over this period (Figure 10). Hydrogen will likely start contributing to emissions reductions as of 2025, with reductions of 1.0 to 2.5 Mt forecast by 2030.

Post 2030, there is a shift towards alternative fuels, with an unknown mix of hydrogen, biofuels and electrification likely delivering the largest emissions reductions. Given the current modelling assumptions, hydrogen has the most potential across all scenarios, with total forecast emissions reductions between 4 and 13 Mt in 2050. When second generation biofuels are available, their use increases steeply from 2030 to 2040, with maximum emissions reductions of over 7 Mt by 2040. Their contribution decreases slightly from 2040 to 2050, as a result of hydrogen and electrification being more cost-effective options. Last, electrification is forecast to deliver emissions reductions of between 1 and 4.5 Mt by 2050. Its exact pathway is, however, very sensitive to a number of highly uncertain scenario assumptions including the oil price, electric vehicle battery costs, the availability of second-generation biofuels and the availability of engineered forms of negative emissions solutions and advanced forms of CCUS.

Figure 10: GHG Reduction Pathways in Alberta's Medium- and Heavy-Duty Transportation Sector



The split of emissions reductions across technologies suggests there is likely to be at least two — and potentially three or four — fueling technologies with significant market share in 2050. This will in part be driven by diversity within the sector, with different forms of transport facing different needs and constraints. For example, while electrification may become a feasible option for delivery vans and transit vehicles that stay within urban areas, it will likely face greater challenges as a solution for long-haul freight. Also of note are the different fueling networks that will be required. While bioliquids can be administered through the province's current network for conventional gasoline and diesel fuel, the transition to hydrogen fuel cells and electrification will require establishing new hydrogen fueling and electric vehicle charging networks. It is therefore important for the government to take initial action now to support building both potential networks, with policy that is technology-agnostic.

OPPORTUNITIES FOR ALBERTA

There are four major opportunities for Alberta in its transition to net zero, drawing on the province's existing strengths. First is development and widespread use of negative emissions technologies: CCUS combined with DAC. Carbon dioxide reuse can occur in partially depleted oil and gas reservoirs for enhanced oil recovery, cement curing, hydrocarbon fuel- or feedstock-making, or other purposes. Dedicated underground disposal can take place in depleted oil and gas reservoirs, but deep saline aquifers, which typically underlay oil and gas bearing regions, are preferred for longevity and leakproofness. Carbon capture and storage costs are estimated at $50-$150 per tonne of CO_2e for combustion, and $20-$120 per tonne for non-combustion, not including CO_2 transport costs (Navius Research 2021).

DAC is a family of technologies that, like CCUS, takes known and commercialized chemical absorption and separation technologies and repurposes them to extract CO_2 from the air (which is mainly nitrogen) to compress and push underground for permanent geological storage using CCUS in disused oil and gas wells or deep saline aquifers. The key difference with DAC from waste- or post-combustion-CCUS is it starts with cleaner air at much lower concentrations. Depending on the process design, DAC requires significant quantities of energy and access to a geological reservoir. Once established, costs are currently estimated at $100-$300 per tonne CO_2e, with very high uncertainty. There are also institutional questions about how the large sums necessary to pay for DAC would be raised and dispersed.

The Western Canadian Sedimentary Basin is an ideal location for both CCUS and DAC. Developing these technologies in Alberta means the province could become a centre of low-emissions heavy industry using CCUS, and eventually a supplier of net-negative DAC and CCUS disposal credits to Canada and potentially the world — the ultimate additive, verifiable, permanent and traceable offset.[18] Both CCUS and DAC are to a certain extent extrapolations of current engineering, and so are largely implementable with appropriate incentives and long-term policy signals (such as Canada's planned carbon tax increases), though significant investment is required. Moreover, the build-out of these technologies in Alberta takes advantage of existing human capital. These technologies would also allow for a more gradual transition of Alberta's economy and energy system, potentially even sustaining oil and gas production. The uncertainty with this opportunity lies in international demand for crude oil, willingness of other jurisdictions to pay Alberta for these offsets, and the presence of a global offset market (which currently does not exist).

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18 Current offset markets are criticized as not being additive (true emissions reductions) and being unverifiable (Rivers, Harrison, and Jaccard 2021).

The second opportunity for Alberta is in hydrogen production, either blue hydrogen made from low-cost natural gas with CCUS, or green hydrogen manufactured through electrolysis. Hydrogen is a potential source fuel for heat, transportation and industrial use. While there is uncertainty about whether hydrogen will become a widespread heat and transportation energy source, its industrial use is nearly certain.

Alberta's third opportunity is in the refining and chemicals industry, again leveraging Alberta's pre-existing expertise and industrial infrastructure.[19] Alberta could be a significant producer of net-zero high value fuels (e.g. synthetic net zero jet fuel, diesel; ethanol) and chemical feedstocks (e.g. hydrogen, ammonia, methane, methanol, ethanol, ethylene, BTX). The chemical feedstocks can be made from blue or green hydrogen, captured CO_2, gasified biomass, or direct-air-captured CO_2. Relatedly, Alberta could also be an important biofuels supplier.

Finally, there is a fourth opportunity for Alberta, masked as a challenge. Alberta's electricity grid has historically used mainly coal, and yet it has an accelerated coal phase-out by 2023. This phase-out has initially focused on a mix of natural gas, legacy hydro, wind and solar, but eventually natural gas will have only a load-following and firm-power-backup role. Alberta already has one of the most efficient deregulated markets in Canada and the world. If the province can look ahead, and use its electricity market development savvy to build new, efficient, and low cost internal markets for firm clean power on multiple time scales (seconds, minutes, hours, overnight, and seasonal) to supplement its very large and inexpensive variable wind and solar resources (Bakx 2021), it will be in a position to export this institutional knowledge to similar jurisdictions globally.

We note that these opportunities are unlikely to be fully realized without government intervention. Many paths lead to net zero, and each involves opportunities, trade-offs and risks. There is an important role for policy — from both the Government of Alberta and the federal government — in providing incentives for emissions reductions and technology investments that enable further GHG reductions and new economic opportunities. Government policy is particularly important in addressing externalities from innovation (where social net benefits exceed private returns on investment) and innovations' benefit stems from environmental goals rather than improving firms' bottom line (Fellows, Goodday, and Winter 2021). Policy also has an important role in resolving uncertainty regarding future energy systems and energy use, and will be key in determining whether Alberta is on the Transformation or Transitions Pathway, or somewhere in between.

CONCLUSION

Canada's net zero commitments and the transition to net zero emissions by 2050 will create challenges and opportunities across the country. Alberta, with its current economic focus on oil and gas production and processing, may seem at risk of

[19] Alberta's Industrial Heartland is "Canada's largest hydrocarbon processing region" (Alberta's Industrial Heartland Association n.d.).

economic decline and becoming a "have not" province. However, the very features that make Alberta's economy the most emissions-intensive at present could create major opportunities for Alberta in its net zero transition. Importantly, preparing for net zero in 2050 and making the most of Alberta's opportunities will require policy change and policy action from all levels of government.

Notably, the scenario assumptions lead to significant differences in possible outcomes for Alberta. This highlights two key results. First is the role that provincial and federal policy decisions can play in influencing Alberta's economic and emissions reduction pathways over the next 30 years. Second is recognition that certain key scenario assumptions are outside of government's control. Most notable are the low oil price scenarios, which create an uncertain future for oil and gas both within the context of a net zero transition and outside of one. A conscious shift to net zero — accompanied by proactive planning and policy decisions — could help ensure the province increases its economic resiliency and diversity through pursuit of future opportunities.

The less disruptive Transition Pathway we describe above relies crucially on negative emissions technologies, described as "wild cards" rather than "safe bets" in the CICC Net Zero report. This high-risk, high-reward opportunity has a role for government in supporting commercialization of the technologies, as this is a clear case of social benefit exceeding private benefits concomitant with insufficient market signals for the private benefit. Continued oil and gas production in Alberta depends on global factors (the price of oil and international demand) and internal factors (emissions management), and the development and widespread deployment of these early stage technologies. Accordingly, reducing emissions from oil and gas will require substantial policy attention.

Responsible governments should also plan to ensure resilience across different possible futures.[20] The Transformation Pathway requires aggressive energy system change, and hence aggressive policy action. Current uncertainty about the form of future energy sources (electrification, hydrogen, biofuels) creates the potential for supply chain disruption and broader labour and economic dislocation if, for example, distribution networks are not built out quickly. More importantly, the Transformation Pathway articulates major changes in Alberta's economy. To avoid unnecessary economic disruption, re-skilling programs and other labour market supports will be important government interventions. There may be valuable lessons from Alberta's coal phase-out.

Alberta's and Canada's net zero transition will require substantial policy and economic changes, creating both disruption and opportunity. Failure to transition is a significant threat to Albertans' prosperity and well-being. Future-thinking governments are necessary to ensure policy is in place to maximize new opportunities and minimize unnecessary disruption.

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20 A worst-case scenario would likely be *not planning* for the Transformation Pathway and betting (and losing) on the Transition Pathway.

REFERENCES

Alberta Energy Regulator. 2020. 'ST98: Alberta Energy Outlook 2020'. ST98. Alberta Energy Regulator. https://www.aer.ca/providing-information/data-and-reports/statistical-reports/st98.

Alberta's Industrial Heartland Association. n.d. 'The Region'. Alberta's Industrial Heartland Association. Accessed 11 April 2021. https://industrialheartland.com/region/.

Bakx, Kyle. 2021. 'A Wave of Electricity Storage Projects Is Coming to Alberta and Could Be the Linchpin for More Renewables'. *CBC News*, 15 April 2021, sec. Business. https://www.cbc.ca/news/business/bakx-windcharger-1.5987252.

Bataille, Christopher. 2020. 'Physical and Policy Pathways to Net-Zero Emissions Industry'. *WIREs Climate Change* 11 (2): e633. https://doi.org/10.1002/wcc.633.

Bataille, Christopher, Max Åhman, Karsten Neuhoff, Lars J. Nilsson, Manfred Fischedick, Stefan Lechtenböhmer, Baltazar Solano-Rodriquez, et al. 2018. 'A Review of Technology and Policy Deep Decarbonization Pathway Options for Making Energy-Intensive Industry Production Consistent with the Paris Agreement'. *Journal of Cleaner Production* 187 (June): 960–73. https://doi.org/10.1016/j.jclepro.2018.03.107.

Bazilian, Morgan, and Dolf Gielen. 2020. '5 Years after Paris: How Countries' Climate Policies Match up to Their Promises, and Who's Aiming for Net Zero Emissions'. *The Conversation*, 10 December 2020, Canada edition. http://theconversation.com/5-years-after-paris-how-countries-climate-policies-match-up-to-their-promises-and-whos-aiming-for-net-zero-emissions-151722.

Biden, Joe. n.d. 'Plan for Climate Change and Environmental Justice'. Joe Biden for President: Official Campaign Website. Accessed 3 April 2021. https://joebiden.com/climate-plan/.

Canada Energy Regulator. 2019. 'Canada's Energy Future 2019: Energy Supply and Demand Projections to 2040'. Canada's Energy Future. Government of Canada. https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2019/index.html.

———. n.d. 'Canada's Energy Future Data Appendices'. Canada Energy Regulator. Accessed 9 April 2021. https://doi.org/10.35002/ZJR8-8X75.

Canadian Institute for Climate Choices. 2021. *Canada's Net Zero Future*. https://climatechoices.ca/wp-content/uploads/2021/02/Canadas-Net-Zero-Future_FINAL-2.pdf.

Cryderman, Kelly, and Emma Graney. 2021. 'Alberta Seeks Billions in Federal Funding for Carbon Capture Projects'. *The Globe and Mail*, 7 March 2021. https://www.theglobeandmail.com/business/article-alberta-seeks-billions-in-federal-funding-for-carbon-capture-projects/.

Department of Finance. 2021. 'Budget 2021: A Recovery Plan for Jobs, Growth, and Resilience'. Government of Canada. https://www.budget.gc.ca/2021/report-rapport/toc-tdm-en.html.

Dolter, Brett, G. Kent Fellows, and Nic Rivers. 2020a. ‘Energy and Environmental Policy Trends: Is the Site C Dam Worth Its Growing Price Tag?’ *The School of Public Policy Publications* 13 (December). https://doi.org/10.11575/sppp.v13i0.71461.

Dolter, Brett, G. Kent Fellows, and Nicholas Rivers. 2020b. ‘The Economics of the Site C Hydroelectric Project in British Columbia’. SSRN Scholarly Paper ID 3742136. Rochester, NY: Social Science Research Network. https://doi.org/10.2139/ssrn.3742136.

Environment and Climate Change Canada. 2020a. ‘Government of Canada Charts Course for Clean Growth by Introducing Bill to Legislate Net-Zero Emissions by 2050’. News releases. Gcnws. 19 November 2020. https://www.canada.ca/en/environment-climate-change/news/2020/11/government-of-canada-charts-course-for-clean-growth-by-introducing-bill-to-legislate-net-zero-emissions-by-2050.html.

———. 2020b. ‘A Healthy Environment and a Healthy Economy’. Government of Canada. https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy.html.

———. 2021. ‘National Inventory Report 1990-2019: Greenhouse Gas Sources and Sinks in Canada’. National Inventory Report (NIR). Government of Canada. https://unfccc.int/documents/271493.

Environmental Defense Fund. 2021. ‘Recapturing U.S. Leadership on Climate’. Environmental Defense Fund. https://www.edf.org/sites/default/files/documents/Recapturing%20U.S.%20Leadership%20on%20Climate.pdf.

Fellows, G. Kent, Victoria Goodday, and Jennifer Winter. 2021. ‘A Review of Barriers to Full-Scale Deployment of Emissions-Reduction Technologies’. *The School of Public Policy Publications* 14 (April). https://journalhosting.ucalgary.ca/index.php/sppp/article/view/70772.

Government of Canada. n.d. ‘Canada’s Official Greenhouse Gas Inventory - Open Government Portal’. Accessed 14 April 2021. https://open.canada.ca/data/en/dataset/779c7bcf-4982-47eb-af1b-a33618a05e5b.

IPCC. 2018. ‘Summary for Policymakers’. In *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Geneva, Switzerland: World Meteorological Organization. https://www.ipcc.ch/sr15/.

Jaccard, Mark, and Blake Shaffer. 2020. ‘OPINION | Bridging the Electricity Gap between Alberta and B.C. Makes Perfect Climate Sense’. *CBC News*, 22 December 2020. https://www.cbc.ca/news/canada/calgary/road-ahead-alberta-bc-electricity-bridge-interties-1.5848042.

Natural Resources Canada. n.d. ‘Comprehensive Energy Use Database’. Accessed 9 April 2021. https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm.

Navius Research. 2021. ‘Achieving Net Zero Emissions by 2050 in Canada’. https://www.naviusresearch.com/wp-content/uploads/2021/02/Deep-Decarbonization-Report-2021-01-21-FINAL-english.pdf.

Office of the Prime Minister. 2021. ‘Prime Minister Trudeau Announces Increased Climate Ambition’. Prime Minister of Canada. 22 April 2021. https://pm.gc.ca/en/news/news-releases/2021/04/22/prime-minister-trudeau-announces-increased-climate-ambition.

Reuters Staff. 2021. ‘Biden Says U.S., Canada to Work toward Achieving Net Zero Emissions by 2050’. *Reuters*, 24 February 2021. https://www.reuters.com/article/us-usa-canada-meeting-climate-idUSKBN2AN2K2.

Rivers, Nicholas, Kathryn Harrison, and Mark Jaccard. 2021. ‘OPINION | Federal Carbon-Offset Proposal Will Likely Give Illusion of Progress, Even as It Increases Emissions’. *CBC News*, 29 March 2021. https://www.cbc.ca/news/opinion/opinion-carbon-offsets-1.5951395.

Ryan, Sarah. 2020. ‘What Do Canada’s Net-Zero Targets Mean for Albertans?’ Global News. 19 November 2020. https://globalnews.ca/news/7473772/canada-net-zero-targets-alberta-environment/.

Statistics Canada. 2021. ‘Table 17-10-0005-01 Population Estimates on July 1st, by Age and Sex’. Government of Canada. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501.

———. n.d. ‘Table 36-10-0402-01 Gross Domestic Product (GDP) at Basic Prices, by Industry, Provinces and Territories (x 1,000,000)’. Government of Canada. https://doi.org/10.25318/3610040201-eng.

Sullivan, Kate, and Kevin Liptak. 2021. ‘Biden Announces US Will Aim to Cut Carbon Emissions by as Much as 52% by 2030 at Virtual Climate Summit’. *CNN*, 22 April 2021, sec. Politics. https://www.cnn.com/2021/04/22/politics/white-house-climate-summit/index.html.

The Canadian Press. 2020. ‘Alberta Set to Retire Coal Power by 2023, Ahead of 2030 Schedule, Says Pembina Institute | CBC News’. *CBC News*, 4 December 2020. https://www.cbc.ca/news/canada/calgary/alberta-coal-pembina-province-ucp-goal-energy-industry-1.5828769.

The White House. 2021. ‘FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies’. Briefing Room. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

United Nations. 2015. ‘Paris Agreement’. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

U.S. Department of State. 2016. '2016 Second Biennial Report of the United States of America'. UN Framework Convention on Climate Chnage. https://unfccc.int/sites/default/files/resource/2016_second_biennial_report_of_the_united_states_.pdf.

Wilkinson, Jonathan. 2020. *An Act Respecting Transparency and Accountability in Canada's Efforts to Achieve Net-Zero Greenhouse Gas Emissions by the Year 2050*. https://parl.ca/DocumentViewer/en/43-2/bill/C-12/first-reading.

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THE STATE OF THE ALBERTA ECONOMY AND THE PATH FORWARD
https://www.policyschool.ca/wp-content/uploads/2021/05/AF2_AB-Economy_Hirsch_final.pdf
Todd Hirsch | May 2021

THE VIEW FROM BUSINESS
https://www.policyschool.ca/wp-content/uploads/2021/05/AF12_View-From-Business_Kobly.pdf
Ken Kobly | May 2021

THE SURFACE OWNER'S BURDEN: LANDOWNER RIGHTS AND ALBERTA'S OIL AND GAS WELL LIABILITIES CRISIS
https://www.policyschool.ca/wp-content/uploads/2021/05/RF19_AB-Oil_Goodday-Larson.pdf
Victoria Goodday and Braeden Larson | May 2021

CANADA IN THE INDO-PACIFIC?
https://www.policyschool.ca/wp-content/uploads/2021/05/IE-45_Indo-Pacific_Nagy.pdf
Stephen Nagy | May 2021

SOCIAL POLICY TRENDS: POVERTY REDUCTION: POLICY INITIATIVES OR ECONOMIC GROWTH?
https://www.policyschool.ca/wp-content/uploads/2021/05/HSP84-Poverty-reduction.pdf
Ron Kneebone | May 2021