Bitumen Beyond Combustion in a Net Zero Alberta

Prepared for: Alberta Innovates
Updated: November 7, 2023

In March 2023, Navius Research completed a study titled "Impacts and Opportunities in Alberta's Net Zero Energy System". This study evaluated future possible energy systems that achieve net zero emissions by 2050 in Alberta and provided insight into key uncertainties and opportunities for Alberta's energy system in a net zero future.

A custom version of Navius' energy-economy model, gTech, and electricity model, IESD, were created for this analysis. One of the capabilities added to gTech for this study was the ability to simulate different grades of crude oil being used to produce different refined products (i.e., bitumen beyond combustion).

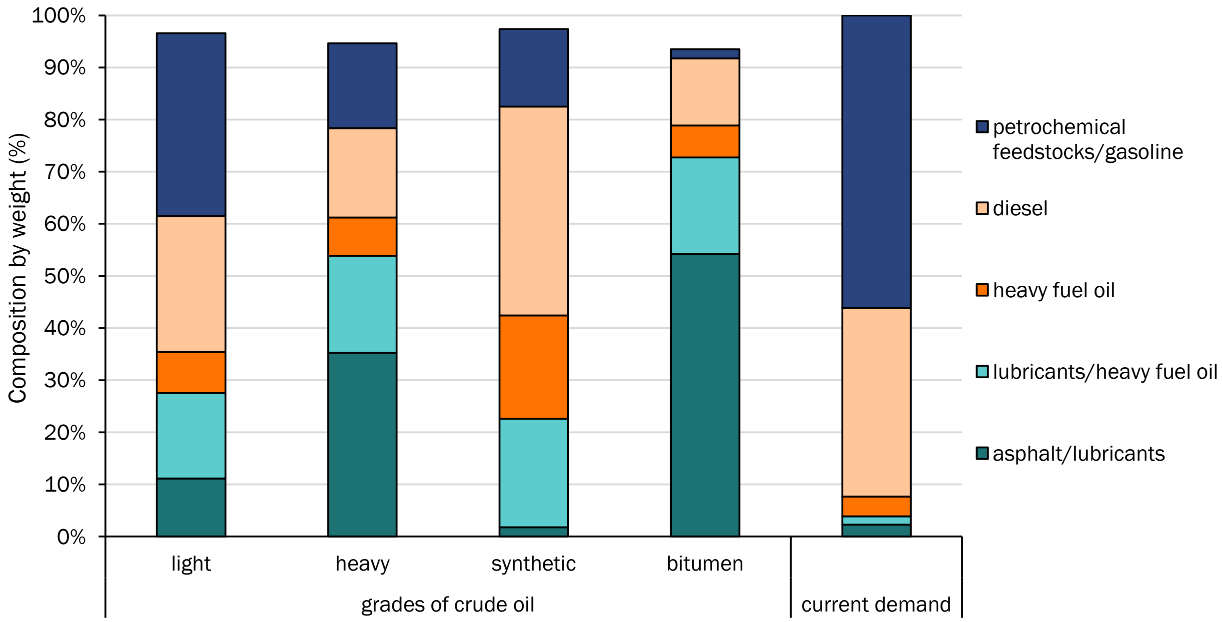
Alberta Innovates commissioned Navius to prepare a memo that summarizes the key assumptions and findings of this modeling addition, covering what bitumen beyond combustion means for Alberta's oil sands sector under net zero policy and how this compares to previous net zero analyses that Navius has completed. What follows is that summary memo, with greater context and detail about the analysis available in the full report.

Bitumen beyond combustion assumptions

Alberta's oil sands are unique among other global oil resources in that they are uniquely "heavy" and the resulting distillation fractions are misaligned with current demand for refined petroleum products (Figure 1). While light crude oil produces products directly in line with current demand, only 15% of a barrel of bitumen can produce products in the range of diesel and gasoline (unless cracked), which account for over 90% of current product demand in Canada and the U.S. More than half of a barrel of bitumen can directly produce refined products in the range of asphalt and lubricants, while current demand for these products within Canada and the U.S. accounts for just 4% of refined petroleum products.

As a result of this misalignment between the product demand and what comes out of a barrel of bitumen, the oil industry currently deploys several costly processes to "crack" the heavier ends of the barrel into lighter ends. Refining light oil also requires these processes, but to a lesser extent. These processes are the largest reason why bitumen trades at a discount relative to lighter oil. We currently estimate this discount to be about $20 per barrel.

Figure 1: Composition of a barrel of crude oil by weight



Future demand for refined petroleum products under climate policy

Policies designed to reduce emissions are expected to significantly change the product slate for refined petroleum. Based on our analyses, the demand for gasoline is expected to decline significantly (if not be eliminated entirely) under net zero policy as consumers switch to battery electric vehicles. The demand for diesel is also expected to decline as the freight industry adopts battery electric or fuel cell electric vehicles, or as they substitute traditional fuels with biofuels. Finally, demand for heavy fuel oil is expected to decline as industry increases utilization of lower carbon fuels (e.g., renewable natural gas or natural gas coupled with CCS).

However, some uses for refined petroleum do not emit GHGs once produced, and climate policy does not necessarily discourage their use. These products include asphalt (used in road construction and other building materials like shingles), lubricants (used in industrial machinery as well as engines), and petrochemical feedstocks. Asphalt is disproportionately on the heavier end of the barrel, in which bitumen has a comparative advantage to other crudes as illustrated in Figure 1.

To simulate the future of the upstream and downstream oil industry in Canada and the U.S., we made three changes to gTech, as summarized below.

1. Greater disaggregation of crude oil by grade

Other versions of gTech included two grades of crude oil: bitumen and light oil. Bitumen was upgraded into light oil before it could be refined.

The version of gTech developed for this analysis includes four grades of crude oil: light oil, heavy oil, bitumen, and synthetic crude oil (upgraded bitumen). While upgrading remains an option within the model, synthetic crude oil is no longer analog to light oil. As will be discussed below, refineries can now directly refine bitumen.

Figure 1 above shows each grade of crude oil represented in the version of gTech used for this analysis.

2. Greater disaggregation of refined petroleum products

Other versions of gTech disaggregated most liquid fuels, but did not explicitly disaggregate petrochemical feedstocks, lubricants and asphalt. The model used for this analysis has been updated to explicitly disaggregate these products.

3. New refinery module

To account for how refineries can alter their product slate under climate policy or other economic conditions, a simplified refinery module (Figure 2 provides a schematic) was built into gTech for this analysis to explicitly model how crude oil is:

- **Distilled into various "fractions":** When crude oil arrives in a refinery in gTech, it is distilled into six fractions representing different distillation temperatures.
- **Cracked into more valuable fractions:** gTech has a simplified representation of processes available to "crack" heavier fractions into lighter fractions. These include a delayed coker (for cracking the vacuum residue) and a fluid catalytic cracker and a hydrocracker (for cracking heavy ends that are lighter than vacuum residue).
- **Blended into final products:** Final products include gasoline, petrochemical feedstocks, diesel, heavy fuel oil, lubricants, etc.

The model also accounts for how each unit in the refinery has specific energy requirements. Units require process heat, electricity, and hydrogen. The new model retains the ability for refineries to alter the technologies used to meet the demand for energy end-uses (e.g., deploy carbon capture and storage).

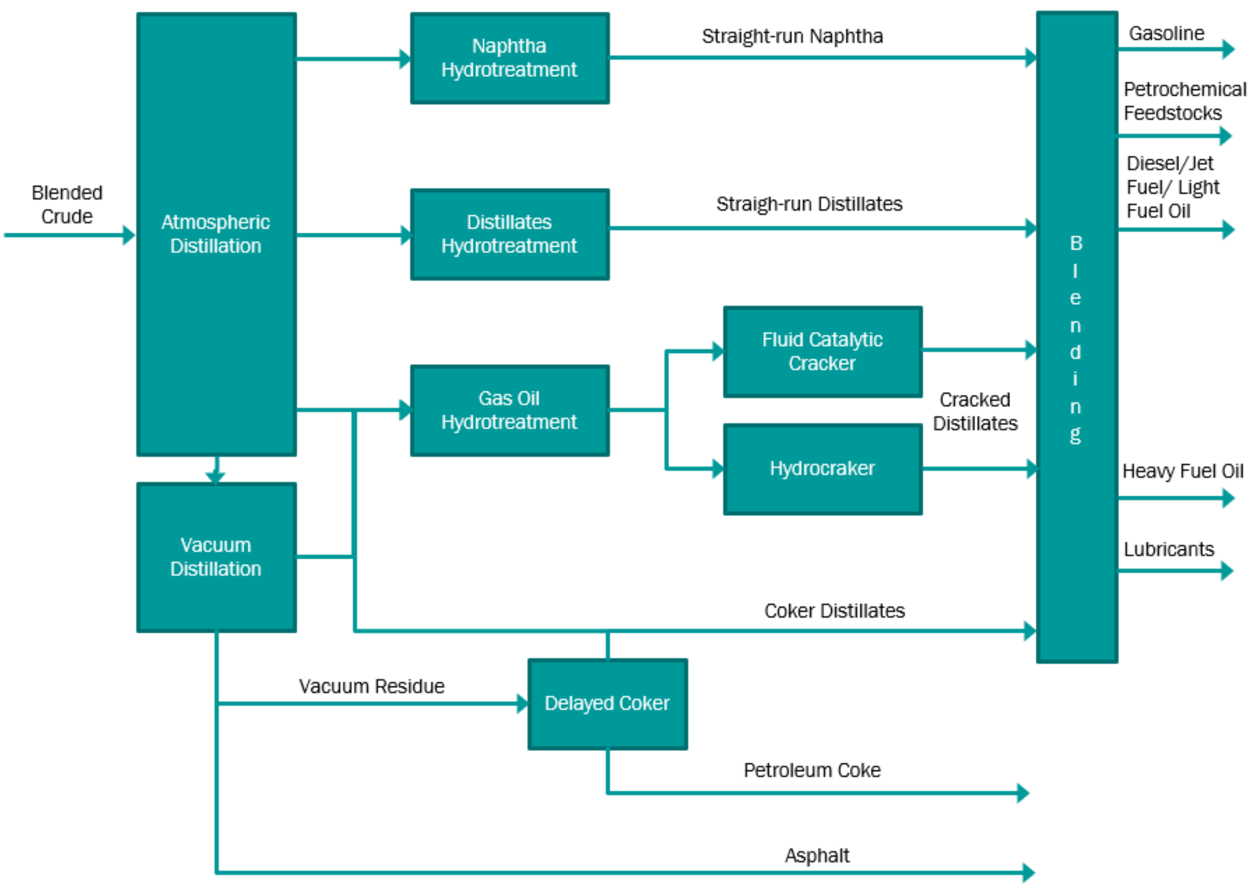
This new refining module allows refineries to respond to climate policy in two important ways:

- **Optimize their crude oil feedstock:** In previous versions of gTech, refineries consumed a single grade of oil which represented the average crude oil refined in Canada and the U.S. To account for the discount between light oil and bitumen, the oil and refining industries would "upgrade" bitumen into light oil. As such, upgraders were the only source of demand for bitumen and refiners could not change their crude oil feedstock in response to changing product demand.

  The new version of gTech explicitly models the distillation of four grades of crude oil into refining fractions and refineries can fully optimize their crude oil feedstock, subject to upstream constraints and their refinery configuration.

- **Change the suite of products produced:** Refineries can produce greater quantities of gasoline through fluid catalytic cracking (FCC), while they can produce greater quantities of light fuel oils (e.g., diesel) by installing a hydrocracker. Refineries can alter the products they produce, subject to the units available to them, thereby using their feedstock to produce a different product slate if demand changes with climate policy.

Figure 2: Structure of the refining module in gTech



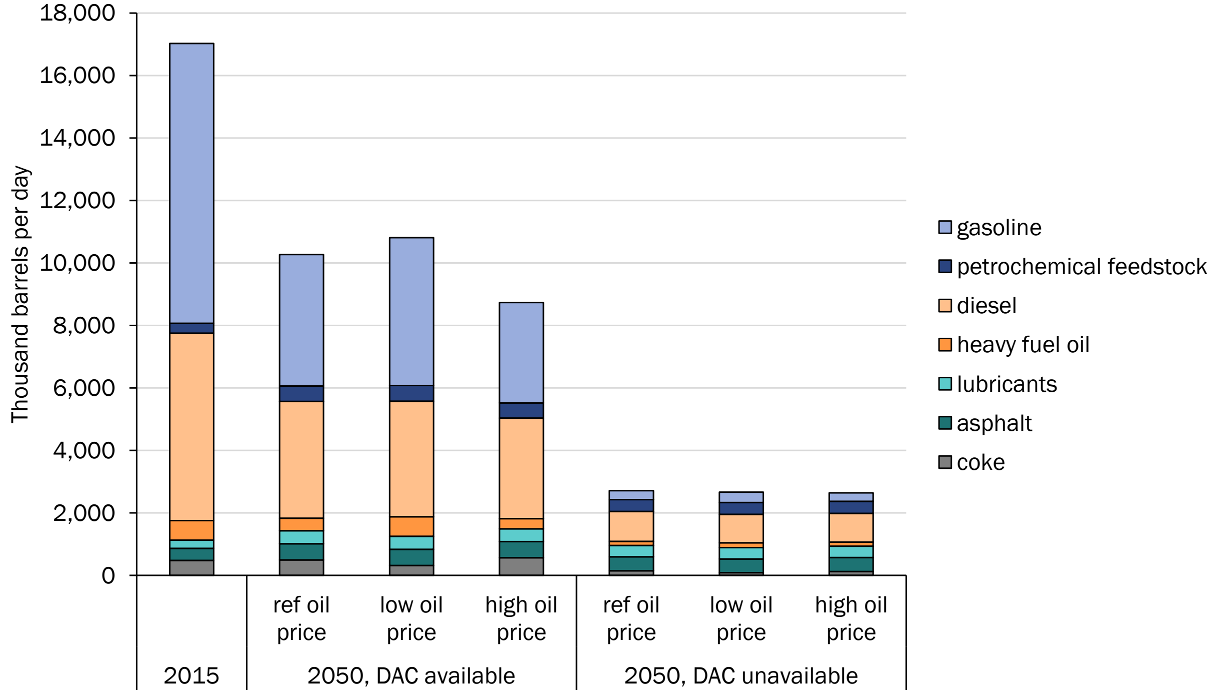
Modeling results

Modeling results indicate that under net zero policy, demand for lighter ends of a barrel of oil (gasoline and diesel) declines, while demand for heavy ends (asphalt, lubricants) remains. Figure 3 presents North American demand for oil products by type in gTech.

When net zero policy is simulated, demand for gasoline and diesel declines significantly by 2050, while demand for asphalt, lubricants and petrochemicals remains.

This change in demand is apparent in all modeling scenarios but is most apparent in scenarios without direct air capture (DAC) technology available. When this technology is not commercial, fewer offsets are available to allow for continued use of gasoline and diesel across the economy, so demand for these commodities declines more than scenarios in which DAC is available to offset the use of these commodities. In all cases, demand for asphalt, lubricants and petrochemicals remains in 2050.

Figure 3: North American demand for oil products (under different oil prices and direct air capture availability)

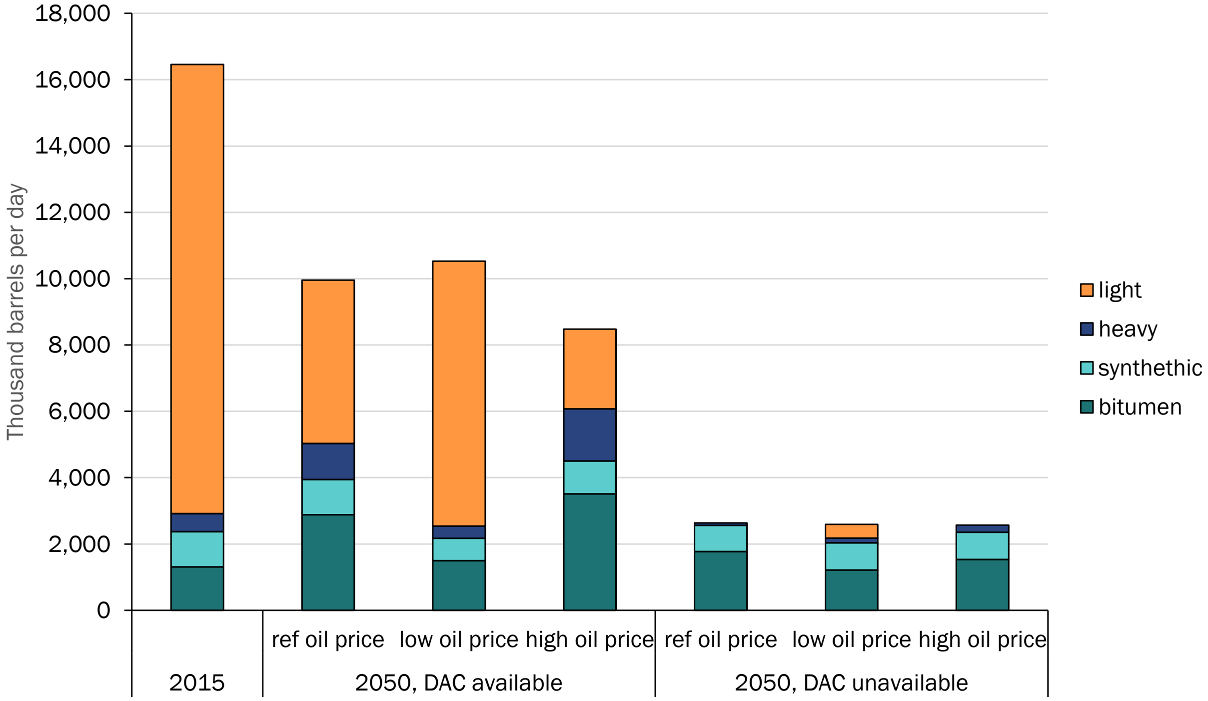


Heavier crudes (like bitumen) have a comparative advantage in producing products in the range for which demand remains in a net zero future. As a result, North American refinery input changes significantly under net zero policy. Figure 4 presents North American refinery input by crude type under net zero policy scenario.

Under net zero policy, refinery input changes from mostly light oil in 2020 to more heavy oil and bitumen by 2050.

For the reasons indicated above, a decline in demand for light and heavy oil is especially apparent in scenarios in which DAC technology is not available. However, all net zero scenarios indicate continued demand for bitumen in 2050.

Figure 4: North American refinery input under net zero policy (and different oil prices and direct air capture availability)

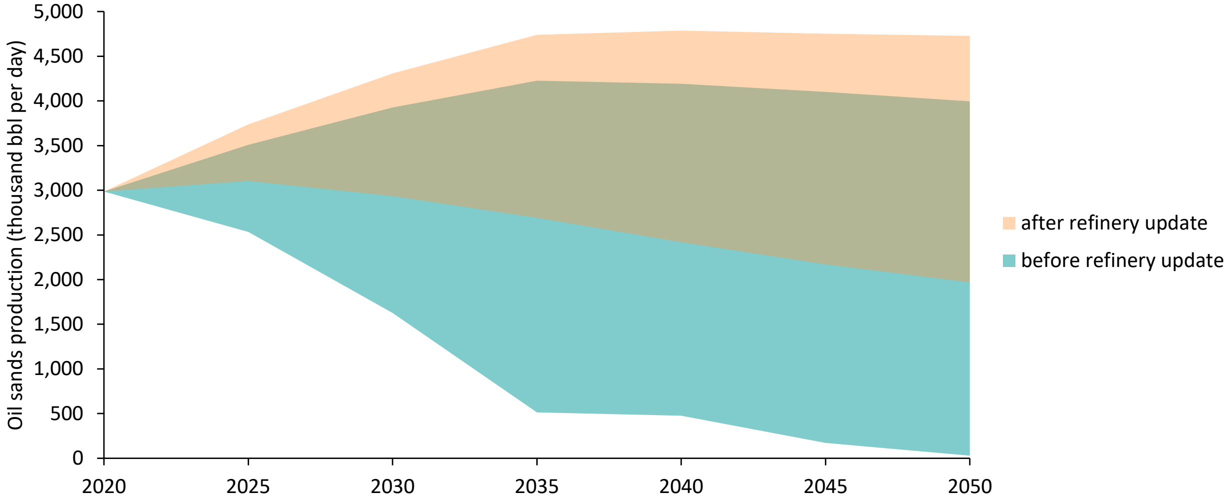


This has a significant impact on the role of oil sands in a net zero future.

Figure 5 below presents oil sands production in Alberta as a range across all net zero scenarios simulated both before and after model development was conducted to account for the comparative advantage that different grades of crude oil have in producing refined products.

Without accounting for this advantage, oil sands production declines significantly under net zero policy across many net zero scenarios. Production from Alberta's oil sands ranges from 29-3,996 thousand barrels per day in 2050 before bitumen beyond combustion was accounted for. However, when accounting for the comparative advantage of bitumen in producing non-combustion products, oil sands production plays a significantly larger role in a net zero future, ranging from 1,968-4,729 thousand barrels per day in 2050. When accounting for these advantages, results suggest that oil sands may be the “last barrel standing” in 2050 under net zero policy.

Figure 5: Oil sands production under net zero before and after refinery model update (range across net zero scenarios)[1]



The three figures below show oil sands production before and after the refinery update under a high, reference, and low global oil price. Across both versions of the model, production is highest when the global oil price is high, and lowest when the global oil price is low. Production from the oil sands sector remains higher in the version of the model with updated characterization of refineries to allow for bitumen beyond combustion across all three oil price scenarios.

[1] Please note that this graph provides an estimate of production impacts of allowing for bitumen beyond combustion by comparing the updated model with an older version. However, is not a perfect comparison as the two models are not identical.

Figure 6: Oil sands production under net zero before and after refinery model update (DAC available, **high global oil price**, reference technology costs)

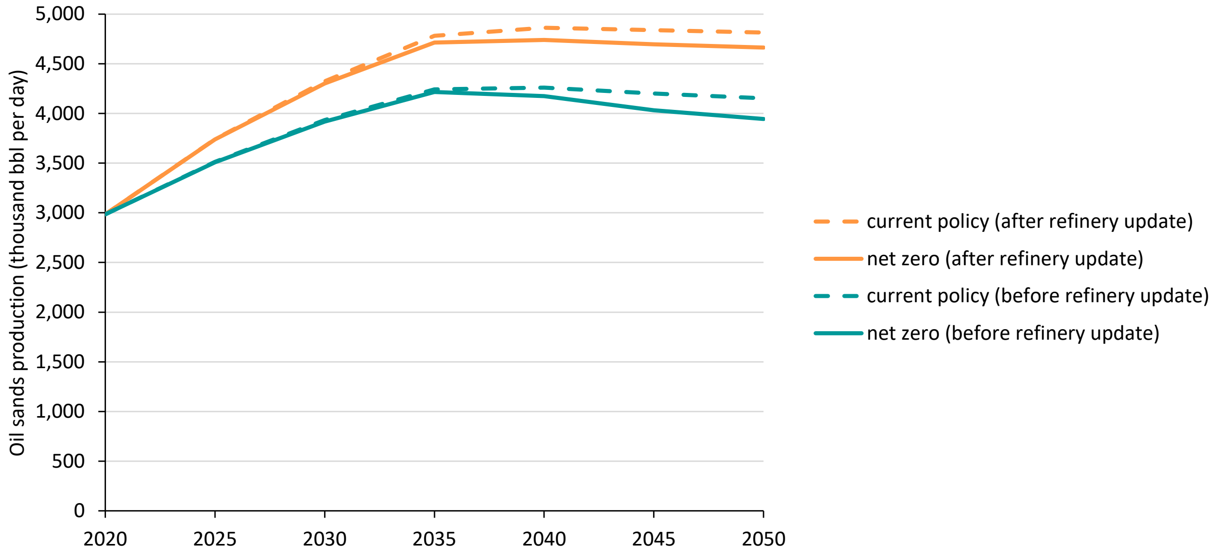


Figure 7: Oil sands production under net zero before and after refinery model update (DAC available, **reference global oil price,** reference technology costs)

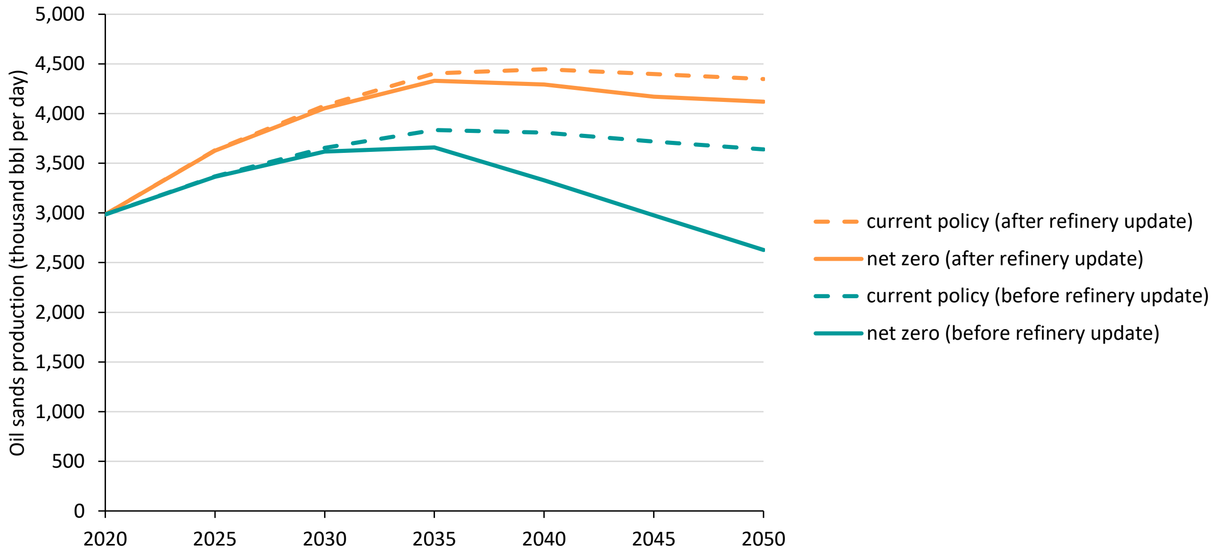
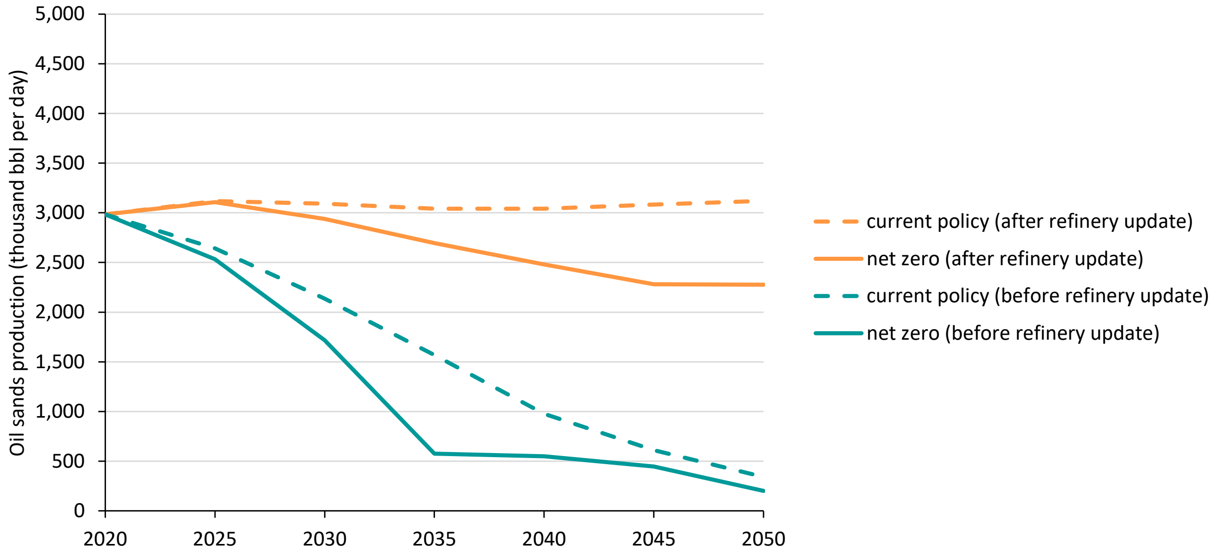
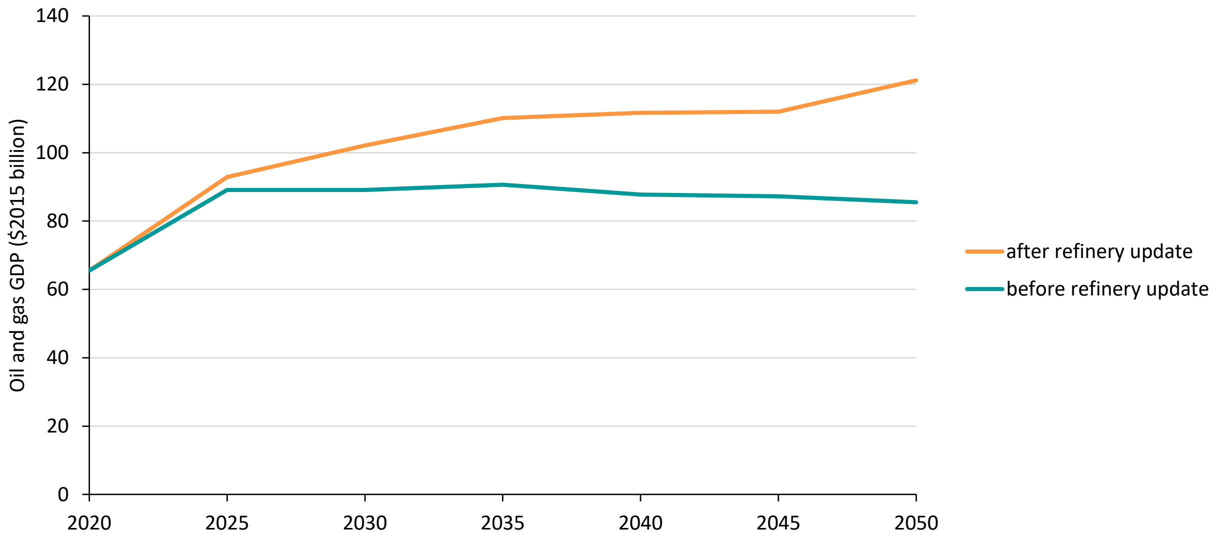


Figure 8: Oil sands production under net zero before and after refinery model update (DAC available, **low global oil price**, reference technology costs)



As a result of these changes, GDP is significantly higher in the oil and gas sector in a net zero future. Figure 9 presents Alberta's oil and gas sector GDP in a net zero scenario prior to introducing refinery detail to account for bitumen beyond combustion and a net zero scenario after the refinery updates. By 2050, GDP in the oil and gas sector is 42% higher because of the new model updates leading to continued bitumen production.

Figure 9: Oil and gas GDP under net zero before and after refinery model update[2]



[2] This net zero scenario assumes DAC is available, reference global oil price and reference low carbon technology costs.

Key sources and assumptions

A key assumption that drives the modeling results is the amount of refined petroleum required to produce a given value of asphalt products or lubricants, as this determines the demand for bitumen across Canada and the U.S. Model assumptions are currently aligned with refinery yields as reported by the U.S. Energy Information Administration.[3] Changes to this assumption, however, can have significant impacts on demand for bitumen in the model.

Another key source includes Statistics Canada Supply and Use Tables [4] which we use to calibrate the production of different refined products and types of crude consumed in different refineries in Canada. The Crude Monitor[5] is used to estimate the breakdown of a barrel of crude oil into fractions, and a report by Energetics Incorporated[6] is used to for the energy intensity of refining.

Limitations

The updates to modeling of Alberta's refining sector presented in this memo are a new addition to gTech. This model improvement has a significant impact on the future of Alberta's oil sands sector compared to previous net zero analyses, and as such warrants future research. In particular, peer review of the refining module would be beneficial, as well as exploration of current limitations to our approach, discussed in more detail below.

There are some dynamics important to the role of bitumen production in a net zero future that are not yet accounted for in gTech. These include both dynamics that may overestimate and dynamics that may underestimate the role of bitumen in a net zero future.

An important limitation is that gTech is specific to Canada and the U.S., so it does not account for international demand for asphalt, including growth in international demand over time. If Alberta was to export bitumen to supply this international market, this could increase the role for bitumen and oil sands production in a net zero future. However, the model also does not account for other potential suppliers of this market, including heavy oil from Venezuela which may compete with Alberta's bitumen.

Additionally, gTech does not account for the substitutability between asphalt and concrete for road infrastructure, or using alternative feedstocks to produce asphalt,

---

[3] U.S. Energy Information Administration. (2022). Refinery Capacity Report. Available from: https://www.eia.gov/petroleum/refinerycapacity/

[4] Statistics Canada. Supply and Use Tables. Available from: www150.statcan.gc.ca/n1/en/catalogue/15-602-X

[5] https://www.crudemonitor.ca/

[6] Energetics Incorporated (2007). Energy and Environmental Profile of the US Petroleum Refining Industry. Available at: https://www1.eere.energy.gov/manufacturing/resources/petroleum_refining/pdfs/profile.pdf

such as biocrude. If concrete is used for road infrastructure, or alternative feedstocks are used to produce asphalt, this could reduce the demand for bitumen in a net zero future.

Another limitation is that gTech does not account for the use of bitumen in producing other non-combustion products, such as carbon fibre. If demand for carbon fibre increases, the value and demand for bitumen could increase. Similarly, bitumen has a comparative advantage over lighter oils in producing sulfur, which is a biproduct of oil and gas production and an important element used in many applications, including chemical manufacturing and fertilizer production. If oil and gas production declines in a net zero future, the supply of sulfur from the oil and gas sector will decline while demand remains. As a result, supplying the sulfur market could be another important role for bitumen. Since gTech does not include carbon fibre or sulfur, this could underestimate the role of bitumen in a net zero future in the model results.