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Canadian Energy Systems Analysis Research (CESAR) Initiative • www.cesarnet.ca

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CESAR (Canada Energy Systems Analysis Research) is an initiative that was started at the University of Calgary in 2013 to understand and inform energy systems change in Canada. By building data resources and visualization tools, analyzing past and present energy systems and modeling energy futures, CESAR researchers work to inform policy and investment decisions regarding the transformation of Canada's energy systems towards sustainability. To carry out its work, CESAR brings researchers, disciplines and sectors together from across Canada.

Though its website (www.cesarnet.ca), CESAR provides visualizations that communicate a wealth of information on the energy systems of Canada, and it provinces. The data behind many of these visualizations have been made available through a cooperative agreement between CESAR and whatIf? Technologies Inc, an Ottawa, Ontario systems modeling company, and the owner and developer of the Canadian Energy Systems Simulator (CanESS) model.

In addition to generating publications in the traditional academic literature, CESAR produces detailed, timely Reports / Discussion Papers under the 'CESAR Scenarios' publication series. These reports are made available for free download on the cesarnet.ca website.

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About the authors

Bastiaan Straatman has been modelling complex systems throughout his career, but since early 2012, he has been focused on developing and using the Canadian Energy Systems Simulator (CanESS) model to study the past, present and possible future energy systems of Canada. His past work has involved spatial decision support models, models of evolutionary dynamics in economics and models depicting greenhouse gas emissions in municipalities. Bastiaan holds a Master degree in Mathematics and a PhD in Geography.

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Mark Lowey lives in Calgary, where he has worked as a professional journalist for 35 years. He is the publisher and managing editor of *EnviroLine*, a business publication for western Canada's environmental industry. From 2006 to 2013, he worked as the communications director for the Institute for Sustainable Energy, Environment and Economy (ISEEE) at the University of Calgary. His journalism has garnered numerous awards, including: two national science writing awards from the Canadian Science Writers' Association; a Governor General's Michener citation; the first Alberta Science Technology Foundation award for science journalism; the first Canadian Petroleum Association/Banff Centre national award for environmental reporting; and the 2016 Award of Journalism Excellence from Engineers Canada.

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We also appreciate the valuable comments and criticisms from the reviewers of this work, and the work of Benjamin Israël in formatting the final version.

Executive Summary

Driven by climate change concerns, the world's energy systems are under pressure to transform and significantly reduce fossil fuel-related greenhouse gas (GHG) emissions. In Canada, this pressure especially affects Alberta, a province that both burns coal to generate electricity and produces and exports natural gas and oil to meet energy demands across Canada and in the United States.

We describe here the assumptions and some high-level results from two different Business-As-Usual (BAU) scenarios for the energy systems of Alberta. BAU scenarios incorporate existing technologies, trends and policies that define demand for fuels and electricity in all parts of the economy. The scenarios are useful in determining the province's future energy use and greenhouse gas (GHG) emissions if there are no changes in technologies, policies or human behaviour. In effect, BAU scenarios are the benchmark / reference to use in exploring the implications of alternative policy, technology or behavioural changes that will impact energy systems.

Defining a 'Business-As-Usual scenario' requires, first and foremost, making calculated assumptions about future growth in population and Gross Domestic Product (GDP). For energy resource economies, like Alberta's, it is clear that population and GDP projections are strongly correlated to the rate of growth in oil and gas development, and thus we first need to make assumptions about what will happen in those sectors.

Over the past 18 months, the global price for oil has changed dramatically, impacting Alberta's outlook for the growth rate of the oil sands sector. Our High Oil Sands Growth (HOSG) scenario assumes an oil price of about $US100/barrel that would stimulate both population growth and GDP in the province. Alternatively, our Low Oil Sands Growth (LOSG) scenario assumes an oil price of less than $US50/barrel, resulting in much lower projection for future population and GDP growth in the province.

Along with different projections of energy use and associated GHG emissions in Alberta, this report examines some of the possible impacts that a high versus low oil sands growth scenario are likely to have on the electricity, transportation and residential sectors.

It is important to note that the two BAU scenarios explored here – HOSG and LOSG – are defined by economic and market forces that are external to the province of Alberta and Canada. Also note that these scenarios are not predictions of the future, but projections of what Alberta's energy systems will look like if the existing trends, technologies and policies continue in either a HOSG or LOSG future.

Both scenarios have been generated using version 6 of the CanESS model[1] from whatIf? Technologies Inc., but incorporate some modifications and customizations.

Variable	Current (2014-15)	HOSG in 2040	LOSG in 2040
a) Oil production* (million barrels per day)	3.0	5.4	3.6
b) Natural gas production* (Exajoules/yr)	3.6	3.0	2.0
c) Population* (millions)	4.1	6.2	5.0
d) Per capita GDP* (2002$/capita)	$52,000	$61,000	$54,000
e) Provincial GDP (billion 2002$)	$205	$380	$270
f) Energy demand (petajoules/yr)	3,150	5,824	4,331
g) Provincial GHGs (Mt CO2e/yr)	265	409	307
h) Per capita GHGs (tCO2e/capita/yr)	66	65.7	62
i) Electricity demand (TWh/yr)	75	122	94
j) Personal travel per capita (km/capita/yr)	21,400	22,400	22,400
k) Residential housing stock (million dwellings)	1.7	2.5	2
l) Residential energy use (PJ/yr)	215	335	269

Table 1. Assumed (denoted with *) and Projected outcomes for Alberta in 2040 under Scenarios for both High Oil Sands Growth (HOSG) vs. Low Oil Sands Growth (LOSG) futures.

Highlights of the results (presented Table 1), and some potential implications, include:

a) Oil Production: In the High Oil Sands Growth (HOSG) Business-As-Usual (BAU) scenario, total oil production in Alberta is assumed to grow to 5.4 million barrels per day (Mb/d) in 2040, up from approximately 3 Mb/d in 2014-15. But in the Low Oil Sands Growth (LOSG) BAU scenario, only those new oil sands operations already in development were assumed to be built, so total oil production grows to only 3.8 million b/d in 2021 and then declines gradually to 3.6 million b/d in 2040.

1 Canadian Energy Systems Simulator (CanESS) Model from whatIf? Technologies Inc. (www.caness.ca)

> **Implications:** A slower growth in oil production in the LOSG scenario will impact Alberta's future revenues and spending compared to the HOSG scenario, unless the province can diversify its energy systems and economy and become less dependent on oil revenues. Less oil production will mean lower greenhouse gases than in a high oil sands growth scenario, but it will also mean less stimulation to the provincial economy from this sector and not as much oil for export.

b) Natural Gas Production: In the HOSG BAU scenario, production from 'tight' natural gas in Alberta was assumed to grow, partly compensating for a reduction in conventional gas production, and resulting in total natural gas production of 3.0 exajoule (EJ) per year in 2040 – down from 3.6 EJ/yr in 2014. In the LOSG BAU scenario, production from tight natural gas was assumed to grow more slowly, resulting in a steeper decline in total natural gas production to 2.0 EJ/yr in 2040.

> **Implications:** A decline in total natural gas production in the future will mean lower royalties for government from this sector, less economic stimulus in the sector and less gas for export. On the other hand, less natural gas production will mean a reduction in GHG emissions from this sector.

c) Population: In the HOSG scenario, Alberta's population was assumed to increase to 6.2 million in 2040, from the current 4.1 million. In the LOSG, however, the province was assumed to have a slower population increase to 5 million. This slower increase reflects an average population growth rate of about 0.78% per year, similar to that in Alberta over the period 1983-1989 (or in Quebec over the 2000-2015 period).

> **Implications:** A slower-than-expected population growth in Alberta will affect many areas, including health care, transportation, urban infrastructure and taxes. A smaller population may result in less government spending in some areas but may also lead to greater spending in others (e.g. more health care spending if a greater percentage of the future population is seniors).

d) Per Capita GDP: In the HOSG scenario, Alberta's GDP growth was assumed to continue the trend of recent years, reaching $61K per capita by 2040 – up from $52K per capita in 2015 (values in Cdn2002$). In the LOSG, GDP growth was assumed to deviate from the trend of recent years, reaching $54K per capita by 2040 – a small increase from $52K per capita in 2015.

> **Implications:** The LOSG assumption of an increase in per capita GDP may be overly optimistic, especially when one considers that the per capita GDP in oil and gas-rich Alberta has been about 1.7 times that of provinces like Ontario and British Columbia[2]. In a low oil price future, a case could be made that Alberta will experience a decline in per capita GDP. In the models used here, the more optimistic LOSG assumption would result in a slightly higher energy use and GHG emissions than what would be seen with a more pessimistic assumption for per capita GDP.

e) Provincial GDP: When per capita GDP growth assumptions were combined with those for population, they result in significantly different GDP 'futures' for Alberta. In the HOSG scenario, the province's GDP was projected to grow to $380 billion in 2040 – a substantial increase from the current $205 billion. In the LOSG, the province's GDP increases to a much smaller $270 billion (all values in Cdn 2002 dollars).

> **Implications:** Smaller-than-anticipated increases in both per capita GDP and provincial GDP will impact consumer spending along with government revenues and spending. Albertans and their government generally will have fewer dollars to spend, certainly on discretionary and luxury items.

f) Energy Use: Using the CanESS model in the HOSG scenario, Alberta's energy use was projected to increase to 5,824 petajoules per year (PJ/yr) in 2040 – up from 3,150 PJ/yr in 2014, with most of the increase being associated with oil and gas extraction and processing. In contrast, in the LOSG, the province's energy use showed a much smaller increase, to 4,331 PJ/yr in 2040.

> **Implications:** Compared to the HOSG scenario, the lower projected energy use in the LOSG scenario was mostly associated with lower energy inputs needed for oil and gas extraction; however, the lower population and GDP growth also resulted in downward pressure on energy use in other sectors.

g) Provincial Greenhouse Gas Emissions: In the HOSG scenario, Alberta's total greenhouse gas (GHG) emissions were projected to increase to 409 million tonnes carbon dioxide equivalent per year (Mt CO2e/yr) in 2040, up significantly from 265 Mt CO2e/yr in 2014. The HOSG projected that the oil and gas sector would be responsible for 46% of Alberta's GHG emissions by 2040. In contrast, in the LOSG, Alberta's total GHG emissions was projected to increase to 'only' 307 Mt CO2e/yr in 2040, with the oil and gas sectors responsible for 41% of those emissions.

2 https://en.wikipedia.org/wiki/List_of_Canadian_provinces_and_territories_by_gross_domestic_product

> **Implications:** Despite the Alberta governments policies to 'green' the electrical grid by phasing out coal power and introducing more renewables (technology changes implemented in both HOSG and LOSG models), the provincial GHG emissions are still projected to rise significantly over the next 25 years. Clearly, to meet climate change commitments, additional policy and technology changes will be needed.

h) Per Capita Greenhouse Gas Emissions: In the HOSG scenario, projected emissions are 66 tonnes (t) CO2e/capita/yr in 2040, similar to the 65.7 t CO2e/capita/yr in 2014. In the LOSG scenario, per capita emissions are slightly lower, at 62 t CO2e/capita/yr) in 2040. This is still more than three times the approximately 20 t CO2e/capita/yr for the average Canadian.

> **Implications:** Alberta will have less of an increase in total provincial greenhouse gas emissions in a LOSG scenario, but the oil and gas sector will still be responsible for 41% of all total GHGs in 2040. Per capita GHG emissions in the province wouldn't be much different in 2040 than they are now, and would still be three times higher than the per capita emissions for the average Canadian. Neither of these scenarios do anything significant to address the climate change challenge that the province or country faces over the next 25 years.

i) Electricity Demand: In the HOSG scenario, Alberta's demand for electricity is projected to increase to 122 terrawatt-hours (TWhr) per year in 2040, up substantially from about 75 TWhr/yr in 2015. As demand increases and coal is slowly phased out, and since much of the oil sands electricity generation is natural gas-based, much of the province's generation is projected to be natural gas-based in 2040. In the LOSG, Alberta's demand for electricity is significantly lower – reaching 94 TWhr/yr in 2040.

> **Implications:** The lower growth in electricity demand in the LOSG scenario than in the HOSG scenario would also reduce the need for new generation sources. However, the government's policies to retire coal plants and encourage renewables will mean that the majority of the provinces generation infrastructure will be replaced in the next 25 years. How this is done could lock in GHG emissions for decades beyond what is modeled here.

j) Personal Travel: In both scenarios the per capita annual distance travelled by the average Albertan is projected to increase slightly to 22,400 kilometres per year, from the current 21,400 km/yr, mainly due to an increase in intercity and international travel. As well, in both the HOSG and LOSG scenarios, light duty vehicles associated with commuter, non-commuter and intercity travel account for

64% to 68% of all personal travel. In the HOSG scenario, the demand for gasoline due mainly to vehicle fuel-efficiency standards. In the LOSG scenario, gasoline demand declines due to fuel-efficiency standards combined with a reduced population growth.

> **Implications:** Gasoline-powered light duty vehicles account for about two-thirds of all personal travel and have the largest carbon 'footprint' of all modes of personal transport. Therefore, it may make sense to focus on light duty vehicles in efforts to reduce GHG emissions (e.g. by improving public transit, encouraging car sharing and biking, increasing use of electric and hybrid vehicles, enhancing 'walkability' of urban neighbourhoods, etc.).

k) Residential Housing Stock: Driven by strong population growth in the HOSG, the residential housing stock is projected to grow to 2.5 million dwellings in 2040, from 1.7 million dwellings in 2015. The share of apartments remains constant at 21%, while the share of single attached dwellings increases slightly to 16% in 2040, from 12% in 2015. With slower population growth in the LOSG, the residential housing stock increases to 2 million dwellings in 2040.

> **Implications:** Per m2 of residential space, apartments have much lower energy use than attached or detached single-family dwellings. However, there has been no noticeable trend towards apartment dwelling, so that option has not been considered in either the HOSG or LOSG scenarios. Policies to encourage this transformation should be considered as a strategy for reducing provincial GHG emissions.

l) Residental Energy Use: In the HOSG, residential energy use is projected to increase to 335 petajoules per year (PJ/yr), from the current 215 PJ/yr. In the LOSG, residential energy use increases more slowly, to 269 PJ/yr in 2040. In both HOSG and LOSG scenarios, natural gas space heating and water heating make up the majority of residential energy use.

> **Implications:** To reduce residential energy use and/or GHG emissions within each type of residential housing, the focus must be on space and water heating. Alberta already has a policy in place that newly installed furnaces need to be of high efficiency. Besides this measure, policy makers should consider building code improvements, on-demand water heaters, reductions in housing size and energy-efficient retrofits. Eventually, when Alberta has a low carbon grid, electrification of space and water heating should be considered.

1. Introduction

Driven by climate change concerns, the world's energy systems are under pressure to transform and significantly reduce fossil fuel-related greenhouse gas (GHG) emissions. In Canada, this pressure especially affects Alberta, a province that both burns coal to generate electricity and produces and exports natural gas and oil to meet energy demands across Canada and in the United States.

Transforming energy systems will require policy and investment decisions that are informed by balanced, objective scientific analysis. Such analysis cannot be done well unless there is a thorough understanding of:

1. How Canada's provincial energy systems are similar to and different than each other;
2. The contribution that provincial energy systems make to the energy systems of Canada, North America and the world;
3. How energy systems are changing today and the forces driving those changes;
4. The nature and GHG emissions of provincial energy systems in a 'Business-As-Usual' (BAU) future; and
5. How changes in technologies or policies will modify the BAU scenario, altering demand for fuels and electricity and the emissions they generate.

What is a Business-As-Usual (BAU) Scenario?

BAU scenarios incorporate existing technologies, trends and policies that define demand for fuels and electricity in all parts of the economy, and therefore determine the resulting energy use and greenhouse gas emissions. As such, BAU models provide a 'benchmark' to examine and test the energy-systems implications of alternative future energy scenarios, driven by shifts in economics, policies or technologies.

While the Canadian Energy Systems Analysis Research (CESAR) initiative works in all five of these critical areas of study, this document is focused on item #4. We describe here the assumptions and some high-level results from two different BAU scenarios for Alberta. Both have been generated using the CanESS model .

Defining a 'Business-As-Usual scenario' requires, first and foremost, assumptions about future growth in population and Gross Domestic Product (GDP). For energy resource economies, like Alberta's, it is clear that population and GDP projections are strongly correlated to the rate of growth in oil and gas development, and thus we first need to make calculated assumptions about what will happen in those sectors.

Over the past 18 months, the global price for oil has changed dramatically, impacting Alberta's outlook for the growth rate of the oil sands sector. In Section 2, the High Oil Sands Growth (HOSG) scenario assumes an oil price of about $US100/ barrel that would stimulate both population growth and GDP in the province. Alternatively, a Low Oil Sands Growth (LOSG) scenario assumes an oil price of less than $US50/barrel, resulting in much lower projection for population and GDP.

2. Growth in oil and gas production

HOSG. The High Oil Sands Growth (HOSG) BAU scenario was based on a 2013 projection by the National Energy Board (NEB)[3], a time when the oil price was approximately $US100/barrel and expected to stay at that level into the foreseeable future.

In alignment with NEB projections, our HOSG BAU scenario projects total Alberta oil production in 2040 at 5.4 million barrels per day (b/d), up from approximately 3 million b/d today (Figure 1A).

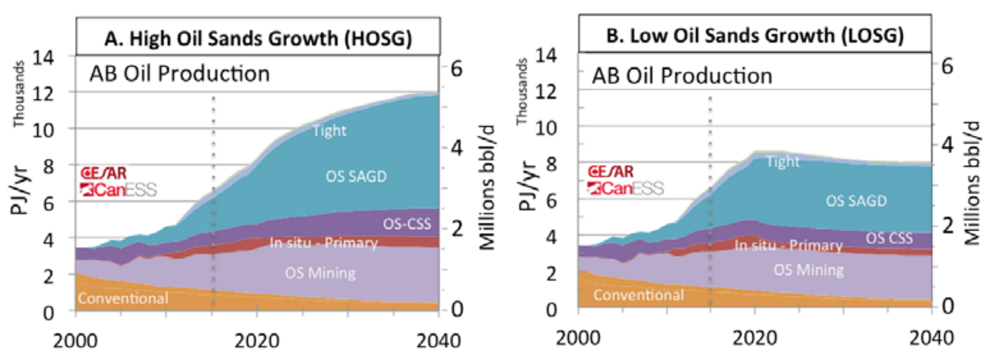

Figure 1. Comparison of the assumed rate of oil production in the high (HOSG, Panel A) vs. Low (LOSG, Panel B) Business-As-Usual (BAU) Scenario. The vertical dashed line separates historical data from future model projections.

Also in alignment with the NEB 2013 projection, Alberta's tight natural gas production in the HOSG scenario was assumed to grow to

3 NEB's Canada's Energy Future 2013 (https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/index-eng.html)

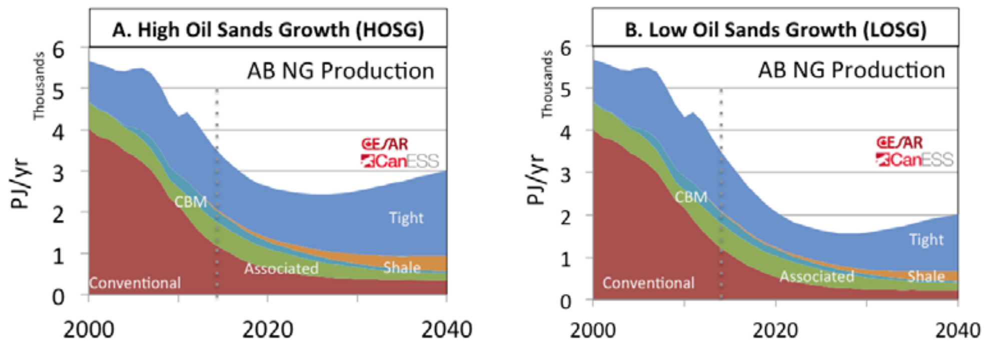

Figure 2. Comparison of the assumed rate of natural gas production in the high (HOSG, Panel A) vs. low (LOSG, Panel B) Business-As-Usual (BAU) Scenario. The vertical dashed line separates historical data from future model projections.

partly compensate for the reduction in conventional natural gas extraction (Figure 2A).

LOSG. The Low Oil Sands Growth (LOSG) scenario, on the other hand, was formulated around the concept of the low-growth scenario developed by the Alberta Electrical System Operator (AESO) in 2013[4] and by Alberta Treasury Board and Finance[5]. Such a scenario may occur if the 2016-2040 period were to be characterized by an extended period of low oil price (less than $US50/barrel) or if environmental or policy factors discouraged new oil sands developments (Figure 1B).

Like AESO, our LOSG BAU scenario assumed that only those oil sands projects that have already begun construction would be completed and go into production (Figure 1B). In this scenario, Alberta oil production in the LOSG was assumed to grow to 3.8 million b/d in 2021 and decline gradually to 3.6 million b/d in 2040. Over the same period, our LOSG projection for natural gas production (Figure 2B) was similar to that for the NEB 2013[6] low natural gas production projection.

4 AESO long-term outlook (http://www.aeso.ca/downloads/AESO_2012_Long-term_Outlook_bookmarked.pdf)

5 ATBF population projections (http://finance.alberta.ca/aboutalberta/population-projections)

6 NEB 2013 Natural Gas production (https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2013/ppndcs/pxgsprdctn-eng.html)

3. Population and GDP

HOSG. The strong oil and gas developments in Alberta highlighted in the 2013 NEB energy outlook would be a major factor in increasing the province's population to 6.2 million (Figure 3A). The average population growth rate between 2016 and 2040 in the HOSG scenario was 1.63% per year, about 80% of that experienced by Alberta over the 2000-2015 period.

In the HOSG scenario, GDP growth was projected to continue the trend of recent years, as was the case in NEB 2013[7], reaching $61K per capita by 2040, up from $52K per capita in 2015 (Figure 3A and Table 1).

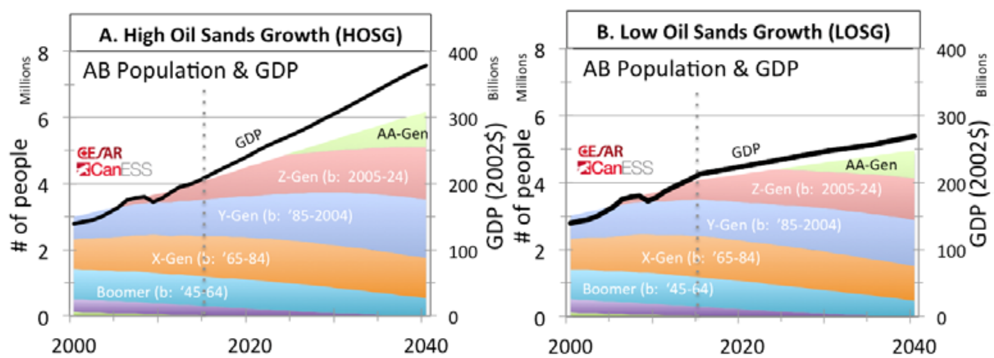

Figure 3. Comparison of the assumed population for Alberta in the High (HOSG, Panel A) vs. Low (LOSG, Panel B) Oil Sands Growth scenarios. The coloured bands show the age structure (by generation) making up the population in the province. The vertical dashed line separates historical data from future model projections.

	2000	2015	2020	2030	2040
HOSG	46,368	52,085	53,738	57,434	61,454
LOSG	46,368	52,085	52,612	53,625	54,262

Table 2. Comparison of the assumed values for Gross Domestic Product (GDP) per capita in the High (HOSG) vs. Low (LOSG) Oil Sands Growth scenarios.

LOSG. As a result of the suppressed Albertan economic drivers in the LOSG scenario, the province's population was projected to rise only to 5 million people in 2040[8] from the current 4.1 million in 2015 (Figure 3B). This reflects an average population growth rate of

7 National Energy Board 2013. (https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2013/ppndcs/pxmcrcnmc-eng.html)

8 Alberta Treasury Board and Finance2013 (http://fcssaa.org/sites/default/files/2013-2041-alberta-population-projections.pdf)

0.78% per year, similar to that in Alberta over the period 1983-1989 (or in Quebec over the 2000-2015 period).

In the LOSG scenario, GDP growth was projected to deviate from the trend of recent years with a change in growth rate in 2015, reaching $54K per capita by 2040, up from $52K per capita in 2015 (Table 2). When these per capita projections are combined with the population projections from above, they result in significantly different GDP projections for the province of Alberta. (From $205 billion (in 2002 dollars) currently to $270 billion (2002$) in 2040 for the LOSG, and $380 billion (2002$) in 2040 for the HOSG) (Figure 3B).

4. Energy use

When these assumptions for growth in oil sands production, population and GDP were incorporated into the CanESS model, detailed scenarios were generated for the energy systems of Alberta. The resulting projected total energy use in Alberta is shown in Figure 4.

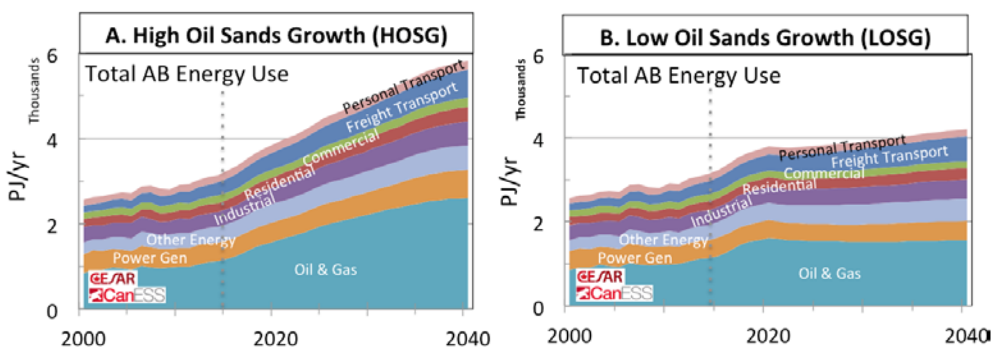

Figure 4. A comparison of total energy use (petajoules per year) in Alberta for two reference scenarios, one based on High Oil Sands Growth (A) and one based on Low Oil Sands Growth (B). Within each chart, historical (2000-2015) and projected (2015 to 2040) values are provided. Energy use has been allocated to a variety of business and household sectors.

HOSG. In the HOSG reference scenario, energy demand in the province was projected to increase from 3,150 petajoules per year (PJ/yr) in 2014 to 5,824 PJ/yr in 2040, with most of the increase being associated with oil and gas extraction and processing (Fig. 4A).

LOSG. In contrast, the LOSG reference scenario projected energy demand to increase to 4,331 PJ/yr in 2040 (Fig. 4B).

5. Greenhouse gas emissions

The GHG emissions associated with these two scenarios are provided in Figure 5.

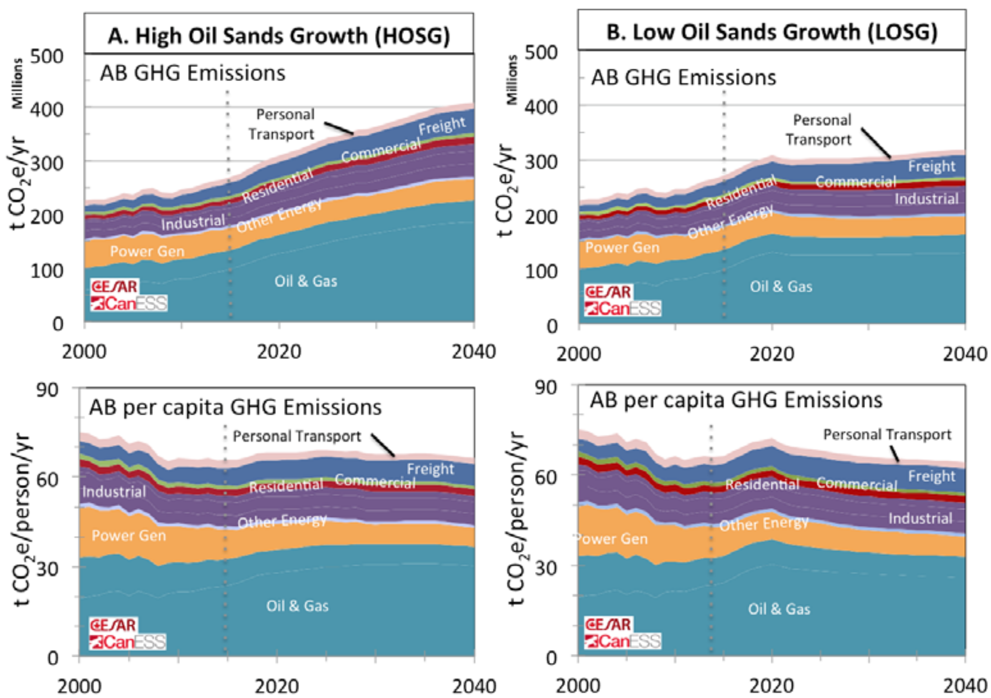

Figure 5. A comparison of greenhouse gas (GHG) emissions in Alberta for two reference scenarios, one based on High Oil Sands Growth (A) and one based on Low Oil Sands Growth (B). Within each chart, historical (2000-2015) and projected (2015 to 2040) values are provided. GHG emissions have been allocated to a variety of business and household sectors and the results are presented as total annual emissions (upper panels) and annual emissions per capita (lower panels).

HOSG. In 2014, total Alberta GHG emissions of 265 megatonnes (Mt) CO2e per year were projected to increase to 409 Mt CO2e/yr by 2040 in the HOSG Scenario (Figure 5A, upper panel). The HOSG projected that the oil and gas sector would be responsible for 46% of Alberta's total GHG emissions by 2040. Expressed on a per capita basis, 2014 GHG emissions in Alberta were 65.7 tonnes (t) CO2e per capita per year, a value more than three times that for an average Canadian (about 20 t CO2e/capita/yr). In 2040, the per capita emissions rate was projected to be similar (66 t CO2e/capita/yr) for the HOSG reference scenario (Fig. 5A, lower panel).

LOSG. In 2014, total Alberta GHG emissions of 265 megatonnes (Mt) CO2e/yr were projected to increase to 'only' 307 Mt CO2e/yr by 2040 in the LOSG scenario (Fig.5B, upper panel). The LOSG projected that the oil and gas sector would be responsible for 41% of Alberta's total GHG emissions by 2040, compared with 46% in the HOSG. Expressed on a per capita basis, 2014 GHG emissions in Alberta were 65.7 tonnes (t) CO2e/capita/yr, a value more than three times that for an average Canadian (about 20 tCO2e/capita/yr). In 2040, the per capita emissions rate was projected to be slightly lower (62 tCO2e/capita/yr) for the LOSG reference scenario (Fig. 5B, lower panel). In Alberta, emissions from the oil and gas and the primarily coal-fired power generation sectors have differentiated this province from most of the other provinces in the country.

6. Examples of other scenario details

6.1. Electricity generation

HOSG. In the HOSG scenario, with its strong population, GDP and oil sands growth, the demand for electricity is projected to increase from 75 terawatthour (TWh) in 2015 to 122 TWh in 2040. As demand increases and as coal is slowly phased out, and since much of the oil sands generation is natural gas-based, much of the province's generation is projected to be natural gas-based in 2040 (Fig 6A).

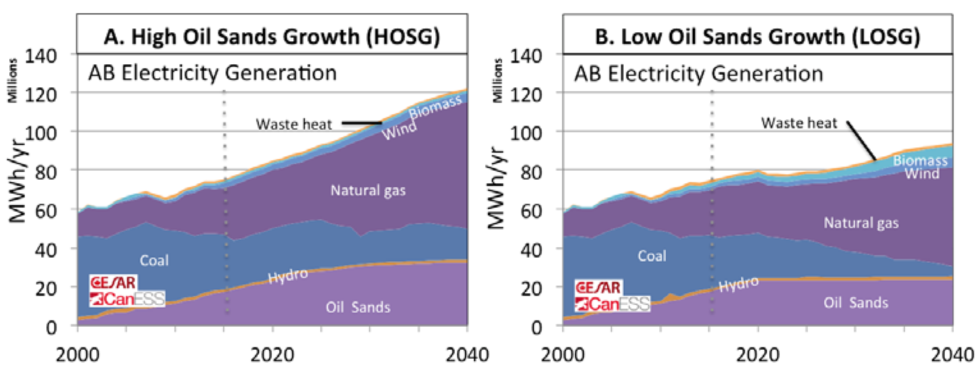

Figure 6. A comparison of electricity generation in Alberta for two reference scenarios, one based on High Oil Sands Growth (A) and one based on Low Oil Sands Growth (B). Within each chart, historical (2000-2015) and projected (2015 to 2040) values are provided. Both scenarios envision an increase in 'behind-the-fence' electricity generation in the oil sands (each in correspondence with their oil sands growth scenario), and a gradual replacement of coal-powered generation by natural gas generated electricity.

LOSG. With reduced economic activity and reduced population in the LOSG, the demand for electricity is substantially lower (94 TWh in 2040) than is the case for HOSG. Notice that coal does not get completely phased out in either scenario, as both scenarios adhere only to the federal regulations and not yet the recently announced Alberta climate plan. Similarly, renewables do not play a significant role in either of these BAU scenarios. Once the Alberta government comes out with a detail overview of their climate plan CESAR can develop a new BAU scenario to match the government's plans.

6.2. Personal travel

HOSG. Currently, the average Albertan travels about 21,400 kilometres per year, including all trip types (commuting, non-commuting within city, intercity and travel outside the country) by all modes. In the reference scenarios, the per capita annual distance travelled was projected to increase slightly to 22,400 km/yr by 2040, in response to a projected increase in intercity and international travel. About two thirds of the personal km travelled per year were projected to be through light duty vehicles (LDVs); one quarter is travel by air; and the remainder (about 7%) is travel by public transit and walking/biking. Figure 7 provides reference projections for the person-kilometres travelled per year by all Albertans. The higher values in the HOSG scenario (Fig. 7A) than in the LOSG scenario (Fig. 7B) can be attributed to differences in population between the two scenarios.

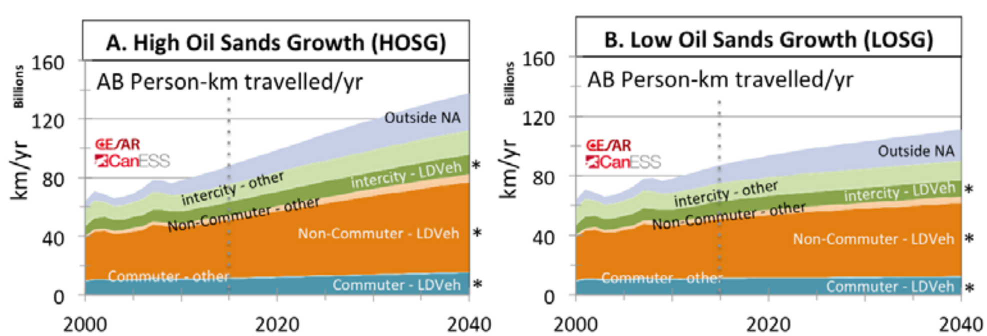

Figure 7. A comparison of person-km travelled (PKT) per year by Albertans, by purpose and mode of personal travel for two reference scenarios, one based on High Oil Sands Growth (A) and one based on Low Oil Sands Growth (B). Within each chart, historical (2000-2015) and projected (2015 to 2040) values are provided. Note that light duty vehicles associated with commuter, non-commuter and intercity travel accounts for 64 to 68% of all personal travel in both scenarios.

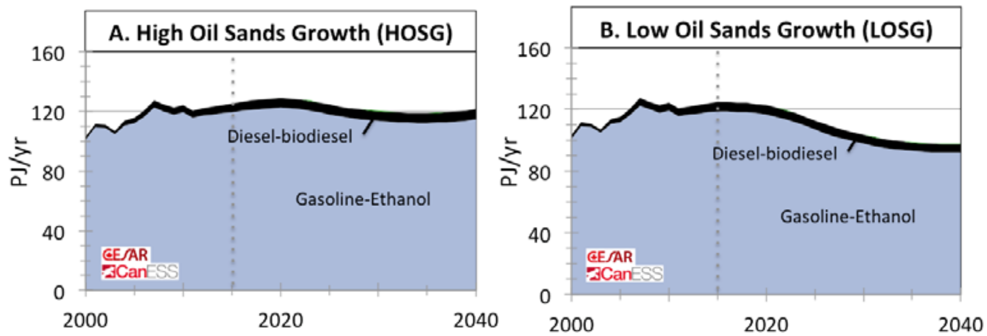

Figure 8. A comparison of the energy use for personal light duty vehicles in two reference scenarios, one based on High Oil Sands Growth (A) and one based on Low Oil Sands Growth (B). Within each chart, historical (2000-2015) and projected (2015 to 2040) values are provided.

Notice that due to the implementation of the Corporate Average Fuel Economy standards, even with strong population growth in the HOSG, the demand for gasoline is flat (Fig. 8A).

LOSG. The LOSG sees a significant reduction in Alberta person-km travelled (Fig. 7B) due to a reduced population growth. Combined with the implementation of the Corporate Average Fuel Economy standards, the demand for gasoline for personal vehicle use in Alberta is projected to decline in the LOSG scenario (Fig.8B).

6.3. Residential energy use

HOSG. Given the strong population growth to over 6 million by 2040, the residential housing stock is projected to grow from 1.7 million dwellings in 2015 to 2.5 million dwellings in 2040. The share of apartments is projected to remain constant at 21%, while the share of single-attached dwellings is projected to increase slightly from 12% in 2015 to 16% in 2040 (Fig. 9A). As can be seen in Fig 10, a considerable amount of energy in the residential sector is used by electric appliances and lighting. However, as Alberta's grid is becoming less carbon intensive, even in these BAU scenarios there is little gain – in terms of energy consumed – in improving the efficiency of electric service technologies.

LOSG. Given the reduced population in the LOSG scenario, the residential housing stock is projected to grow from 1.7 million dwellings in 2015 to only 2 million dwellings in 2040. As is the case for the HOSG scenario, natural gas space heating and water heating make up the majority of residential energy use. In order to reduce residential energy use in a meaningful way, those two end uses need to be addressed. Alberta already has a policy in place that newly

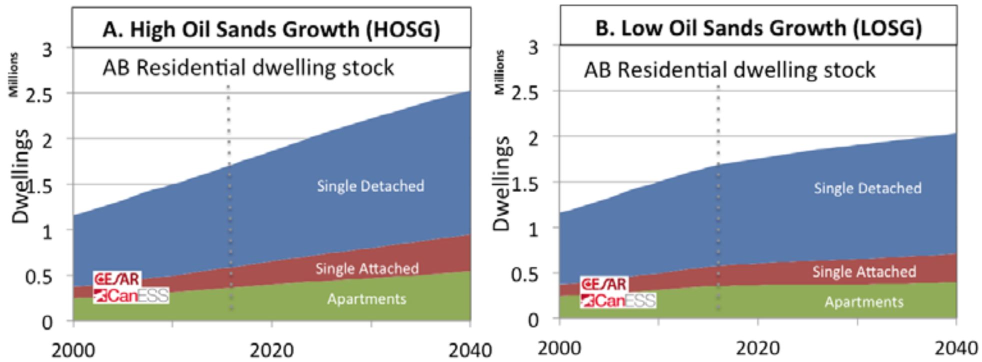

Figure 9. A comparison of the residential housing stock in two reference scenarios, one based on High Oil Sands Growth (A) and one based on Low Oil Sands Growth (B). Within each chart, historical (2000-2015) and projected (2015 to 2040) values are provided.

installed furnaces need to be of high efficiency. Besides this measure, the building code will be updated to reduce heat loss of residential buildings by improving insulation and sealing. On-demand generation of hot water would be a technology to address the inefficiency of natural gas-based hot water tanks.

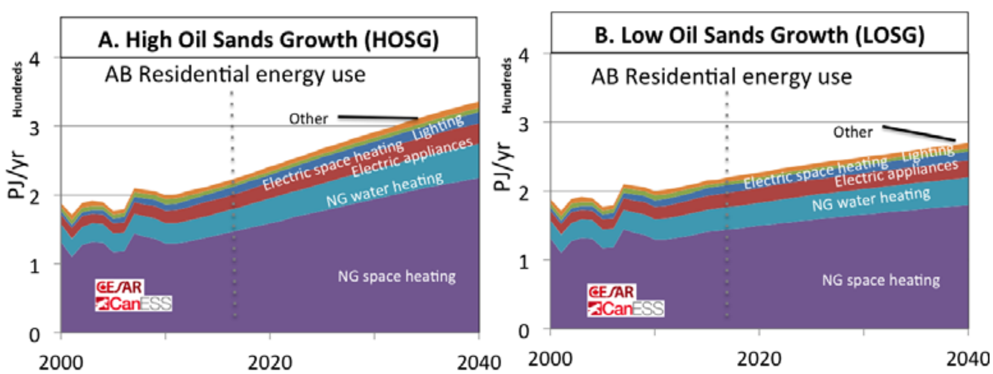

Figure 10. A comparison of the residential energy use in two reference scenarios, one based on High Oil Sands Growth (A) and one based on Low Oil Sands Growth (B). Within each chart, historical (2000-2015) and projected (2015 to 2040) values are provided.

The two BAU scenarios explored here – High Oil Sands Growth and Low Oil Sands Growth – were defined by economic and market forces affecting oil price that are external to Alberta, and over which neither Alberta nor Canada have any significant influence. What should be of more interest to Canadian policy makers is how policy and technology decisions made in this country could alter our energy systems and their impact on both greenhouse gas emissions and the economy of the province and nation. For this work, the BAU-LOSG scenario should probably be chosen as the 'benchmark' scenario and, in essence, become the 'key' that can be used to open a wide range of alternative energy systems scenarios.

Some of the scenario details presented in this backgrounder already provide some good leads for exploring possible alternative energy systems scenarios (e.g. What is the impact, using the LOSG scenario as the benchmark, on energy use and GHG emissions when policy around residential space heating, water heating and insulation gets updated? What if, on top of the Corporate Average Fuel Economy standards, at some point we start using many more self-driving, car-sharing electric vehicles? What if, on top of the introduction of electric vehicles, we reduce the carbon intensity of Alberta's grid by using renewables and some form of clean back-up capacity?). There are many doors to be opened, and CESAR has the key for opening them.