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Department of Economics

Memorial University

+1 (709) 864-4089

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COLLABORATION FOR APPLIED RESEARCH IN ECONOMICS

IMPACT OF THE ENERGY EAST PIPELINE ON THE OIL AND GAS INDUSTRY IN NEWFOUNDLAND AND LABRADOR – DEMONSTRATION OF A NEW SOFT-LINKING MODEL FRAMEWORK

Prepared by ESMIA Consultants for CARE

November 17th, 2015

Impact of the Energy East pipeline on the oil and gas industry in Newfoundland and Labrador –

Demonstration of a new soft-linking model framework

Final report

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ESMIA Consultants

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ESMIA
Energy Super Modelers and International Analysts

PROJECT TEAM

Kathleen Vaillancourt *, ESMIA Consultants, Montreal, Quebec, Canada

Yuri Alcocer, Intelligent Energy Consulting (IEC), St-John's, Newfoundland, Canada

Olivier Bahn, GERAD and Department of Decision Sciences, HEC Montreal, Quebec, Canada

* Contact information:

Kathleen Vaillancourt, Ph.D. MBA
President, ESMIA Consultants
Tel.: +1-514-794-5645
Email: kathleen@esmia.ca
Website: www.esmia.ca

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ABSTRACT

It is expected that, by 2030, Canada will produce a total of 6.4 million bbl/d, with over 90% of this increase coming from bitumen (CAPP, 2014b). However, to achieve the forecasted production levels, producers of Western Canadian oil must find a market that will yield a reasonable price for their product. Eastern Canada and USA regions are one of these potential markets. The objective of this study is to develop a soft-linking model framework and demonstrate its potential application with preliminary analyses on the domestic oil supply-demand dynamic in Canada under three economic growth scenarios and the impacts of the TransCanada Energy East pipeline on the oil supply-demand dynamic in Eastern provinces, Newfoundland and Labrador especially. The soft-linking framework combines three complementary modeling techniques: 1) the macroeconomic model NALEM (Newfoundland and Labrador Econometric Model), 2) a forecasting model of the oil production profile and, 3) the optimization LP energy model NATEM (North American TIMES Energy Model).

The results of the optimization model suggest that the pipeline would be used at its maximum capacity (1100 k bbl/d) starting around 2030 for both international exports and domestic uses in Eastern refineries, representing up to 98% of the crude used in Newfoundland and Labrador. While the oil prices are reaching 128$/bbl by 2050 in this case, blocking the access to WCSB oil in Newfoundland and Labrador brings the offshore oil price up by 10$/bbl in 2035 and 4$/bbl in 2050. The results of the forecasting model show higher production levels between 5% and 14% on average for the 2013-2050 period using these oil prices compared with those of the National Energy Board. The results illustrate well the potential of the model framework to analyse such supply-demand dynamics; this is a first step toward a broader and deeper analysis.

EXECUTIVE SUMMARY

The oil industry plays a major role in the Canadian economy with over $69 billion of private investment in 2013 and generates over $18 billion for governments in taxes and revenues (CAPP, 2014a). In 2013, Canada's crude oil production reached about 3.5 million barrel/day (bbl/d). It is expected that, by 2030, the country will produce a total of 6.4 million bbl/d, with over 90% of this increase coming from bitumen (CAPP, 2014b). However, to achieve the forecasted production levels, producers of Western Canadian oil must find a market that will yield a reasonable price for their product. This report focuses on one of the markets considered to enable a significant increase in oil production: Eastern Canada and USA. Two pipeline projects are key to open these markets, the Enbridge Line 9 A and B reversal, and the TransCanada Energy East Pipeline. They would add respectively 300,000 bbl/d and 1 million bbl/d of capacity.

The objective of this study is to develop a soft-linking model framework and demonstrate its potential application with preliminary analyses on: 1) the domestic oil supply-demand dynamic in Canada under different economic growth scenarios; and 2) the impacts of the TransCanada Energy East pipeline on the oil supply-demand dynamic in Eastern provinces, Newfoundland and Labrador especially.

To analyze the interactions between oil supply and demand on a 2050 time horizon, a soft-linking framework, mixing three complementary modeling techniques, is proposed:

- The macroeconomic model NALEM (Newfoundland and Labrador Econometric Model) is a macroeconomic model representing the structure of the provincial economy and capturing the major relationships between socioeconomic variables (Department of Finance, 2015).
- A forecasting model is used to define a production profile for the Newfoundland and Labrador oil sector to 2050 by considering both economic variables (prices) and physical variables (production and infrastructure) and by establishing a link between well count, oil price, and oil production (Alcocer et al., 2015).
- The optimization LP energy model NATEM (North American TIMES Energy Model) was developed using the MARKAL/TIMES model generator (ETSAP, 2015; Loulou et al., 2005). NATEM-Canada is a technology-rich model that represents, in details, the whole integrated energy sector of the 13 Canadian jurisdictions from primary to useful energy. The oil sector is described in great details for reserves, extraction, upgrading and refining activities.

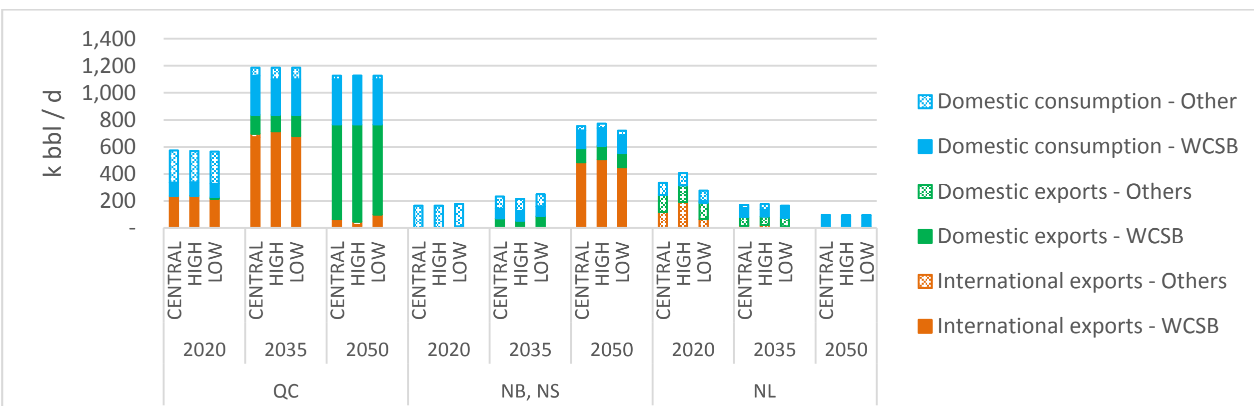
The work requires the following main steps: 1) Prepare three baseline scenarios with the NALEM model; 2) Derive reserves and oil production profiles for Newfoundland and Labrador using the forecasting model; 3) Project the end-use demand for energy services in the NATEM model using the macroeconomic drivers coming from NALEM; 4) Calibrate the NATEM model with offshore oil production profiles for Newfoundland and Labrador coming from the forecasting model; 5) Run the NATEM model for the three baseline scenarios and four scenarios on pipeline capacity; 6) Run the forecasting model back with the new oil prices as given by NATEM to derive convergence on oil production levels.

There are three baseline scenarios (CENTRAL, HIGH, LOW) and four pipeline capacity scenarios to supply the Western Canadian Sedimentary Basin (WCSB) oil to Eastern provinces (S1, S2, S3, S4). The three baseline scenarios utilize three coherent sets of oil prices and socio-economic growth rates coming from official sources (NEB, 2013), in general, and from the NALEM model for Newfoundland and Labrador, in particular. These scenarios are characterized by a WTI oil price reaching 123$/bbl (US$$_{2012}$) by 2050 in the CENTRAL scenario, 147$/bbl in the HIGH scenario and 87$/bbl in the LOW scenario. The same sets of oil prices were used to derive the oil production profiles with the forecasting model. These four scenarios utilize different assumptions about the pipeline capacity available to supply the Western Canadian Sedimentary Basin (WCSB) oil to Eastern provinces:

- **S1**: The maximum capacity is available up to Quebec and New Brunswick/Nova Scotia (domestic refineries and international exports) and then up to Newfoundland and Labrador via marine tankers.
- **S2**: The maximum capacity is available for Quebec, New Brunswick/Nova Scotia (domestic refineries and international exports), but not for Newfoundland and Labrador.
- **S3**: The maximum capacity is available for Quebec, New Brunswick/Nova Scotia (domestic refineries only), leaving more access to the WCSB oil for Newfoundland and Labrador.
- **S4**: The TransCanada pipeline project would be cancelled, which would preclude WCSB oil from reaching domestic refineries in Eastern Canada or international markets from Eastern provinces.

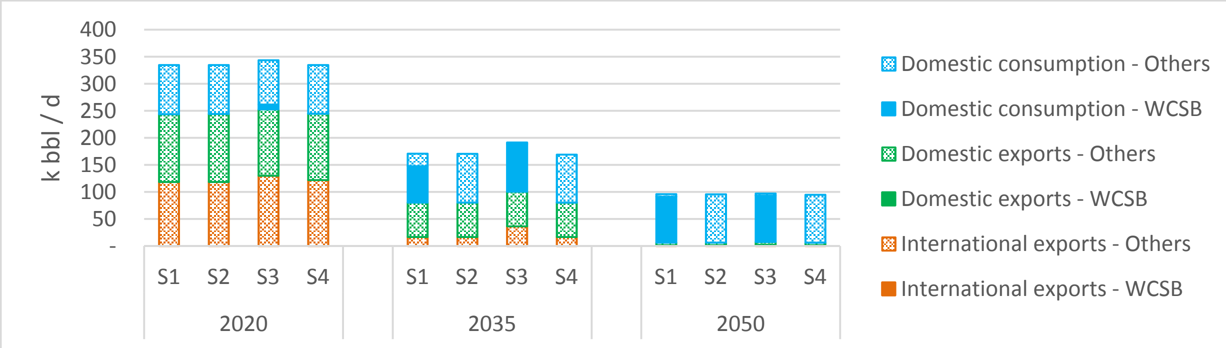
In S1, oil imports from the WCSB start as soon as the TransCanada pipeline becomes available in 2020 and reach its maximum capacity (1100 k bbl/d) around 2030. Synthetic oil is replacing a significant portion of the imported crude oil used in Quebec's refineries: between 75-82% in 2035 and 92% in 2050 (Figure ES-1). Since the needs of the province are small compared with the size of the TransCanada East pipeline, the vast majority of the synthetic oil coming through is exported to the USA toward 2035. An interesting change occurring between 2035 and 2050 is related to the destination of the WCSB oil: direct exports from Quebec to USA toward 2035 are decreasing to the profit of domestic exports to New Brunswick and Nova Scotia for international exports to Rest of the World – East where the oil prices are expected to be higher. In Newfoundland and Labrador, the synthetic oil from the WCSB is replacing the majority of the offshore oil in the refinery (between 90% and 98% by 2050). The offshore production is mainly exported on international markets.

Figure ES-1. Oil demand by province in Eastern Canada in S1



In S2, when Newfoundland and Labrador does not have access to synthetic oil, more of this oil is available for domestic use in Quebec and New Brunswick. The impact results in Newfoundland and Labrador being a greater user of its own domestic production for refining to the detriment of international exports (Figure ES-2). The limitation of international exports in Quebec and New Brunswick in S3, promotes a larger use of synthetic oil in domestic refineries in all provinces. Newfoundland and Labrador can increase its refining activities, its exports of refined products as well as international exports of its offshore oil. However, this has much less effect on the trade movement between Western and Eastern Canada than the international demand for WCSB oil. The effects of having less access to WCSB oil in Eastern Canada in S4 is clearly a decrease in activities both domestically and internationally. Interestingly, the impacts on the total production levels in the WCSB is light as more synthetic is exported directly to the USA.

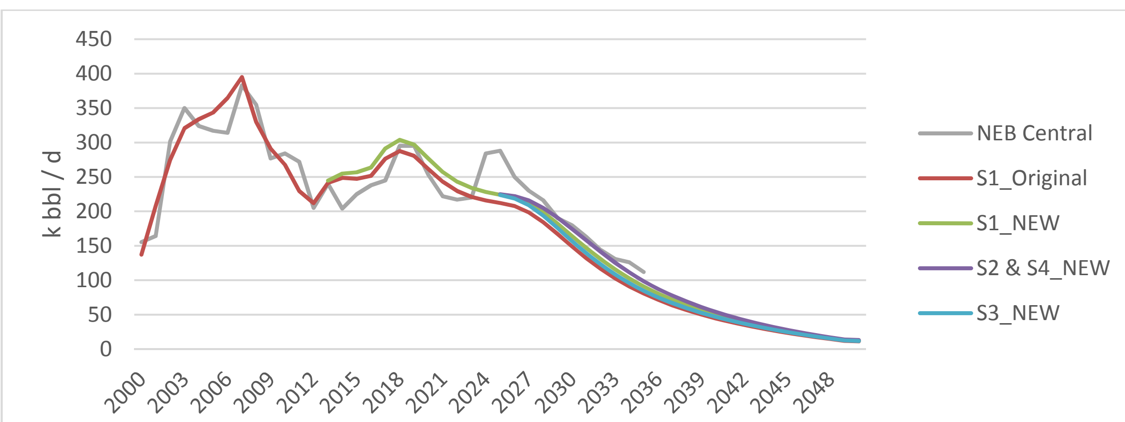
Figure ES-2. Oil demand in Newfoundland and Labrador in S1, S2, S3 and S4



In S1, there is more competition between different crude types and oil prices are converging at 128$/bbl by 2050 in all three baselines. Blocking the access to WCSB oil in Newfoundland and Labrador, such as in S2 and S4, brings the offshore oil price up by 10$/bbl in 2035 and 4$/bbl in 2050. In S3, the prices are going down by 8$/bbl in 2050 with an excess of WCSB oil coming to Newfoundland and Labrador.

After the first iteration with the forecasting model, the oil production is higher (S1_NEW) than in the original profile (S1_Original) due to higher marginal prices in the NATEM scenarios than in the central case of the NEB (Figure ES-3). The oil production difference peaks in 2036, showing a 13% higher level. In addition, S1 shows 8% more available reserves in 2013 due to the incentive of higher oil prices. Indeed, this new pattern in higher oil prices creates an incentive to drill more wells when the field oil production profile is higher compared to the original case. The impact is more significant up to 2030, since the contribution of each well is higher when the field is younger. The S2 scenario leads to the biggest benefits in terms of offshore production since there is no competition with Western oil: the oil production difference peaks in 2034, showing up to a 23% increase in production. For S3, the highest difference occurs in 2032, at 6% higher than the NEB.

Figure ES-3. Oil production in Newfoundland and Labrador after an iteration with the forecasting model



The results discussed in the report illustrate well the potential of the model framework to analyse such supply-demand dynamics and to provide insights on market trends. This is a first step toward a broader and deeper analysis. Future works will allow to improve this analysis from several points of view: 1) extend the methodology to cover more aspects of the problem and to improve the representation of the oil sector in the NATEM model, 2) refine data and assumptions to bring the definition of the problem closer to the reality and 3) consider multiple scenarios to analyse the problem in all its dimensions.

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1. Introduction

1.1. Context

The oil industry plays a major role in the Canadian economy with over $69 billion of private investment in 2013 and generates over $18 billion for governments in taxes and revenues (CAPP, 2014a). In 2013, Canada's crude oil production reached about of 3.5 million barrel/day (bbl/d), of which 1.9 were produced from oil sands. It is expected that by 2030, the country will produce a total of 6.4 million bbl/d. The crude oil coming from bitumen will represent over 90% of this increase (CAPP, 2014b). Although new technologies improve the actual life expectancy of conventional oil reserves, most of the growth in oil production levels in Canada is related to oil sands. Indeed, oil sands represented 90% of 339 billion barrels (bbl) of crude oil resources by the end of 2012 (NEB, 2013). All of Canada's bitumen resources can be found in Alberta and Saskatchewan. Canada owns the third largest reserves of oil in the world, just after Saudi Arabia and Venezuela (NEB, 2013).

However, to achieve the forecasted production levels, producers of Western Canadian oil must find a market that will yield a reasonable price for their product. Without access to tidewater ports, Alberta and Saskatchewan need to develop their transportation capacity to export this expected production. It is now becoming a political, economic and national security matter that this oil finds access to tidewater and export opportunities (McKenna, 2013)[1]. As for their actual markets, maintenance on existing pipelines and the necessity of upgrading refineries to process this crude oil from Western Canada, create bottlenecks upstream of Cushing that furthermore puts pressure on expected growth. This surplus and the inability to reach external markets already have negative effects on oil prices for Western Canadian producers. From 2007 to 2010, the Western Canadian Select (WCS), the price reference for Canadian heavy crude, traded US$16.64/bbl below West Texas Intermediate (WTI) (NEB, 2013). This price differential used to reflect the difference in the transportation costs of shipping and in quality between the two products, WCS been more corrosive and requiring additive and dilution in order to be transported. However, this gap in prices augmented to US$19/bbl between 2011 and 2012 with a high volatility: up to US$30/bbl of differential for some monthly average (NEB, 2013).

According to all projections (NEB, 2013, CAPP, 2014b), it is expected that production will soon exceed current pipeline capacity and only long term solutions may help supporting this projected growth. In the short term, transportation by rail cars may provide a temporary solution. In fact, rail cars shipping is expected to increase in Canada from about 200,000 bbl/d in late 2013 to 700,000 bbl/d by the end of 2016 (CAPP, 2014c). This is about the capacity of a major pipeline. However, even with this rapid expansion, the incremental capacity to export via rail cars will not be sufficient in the long term; there must be a dramatic increase in export capacity. In summary, it is necessary for Western Canada to find and open new markets to enable a significant increase in oil production. In this study, three markets are therefore considered for analysis: 1) Central and South USA markets, 2) Canadian and USA West coasts and Asia, and 3) East Canada and Eastern USA.

[1] This is even more critical considering that the Keystone XL pipeline has been declined permission by the Obama administration to proceed within the United States (Plumer, 2015).

1.2. Objectives

This research builds on a previous study (Vaillancourt et al., 2015), which focuses on different crude oil exportation scenarios based on existing capacity expansion and new pipeline projects exiting the Western Canadian Sedimentary Basin (WCSB) to reach North American, Asian or domestic markets. This report focuses specifically on the impact of the Energy East TransCanada pipeline on the oil and gas industry in Newfoundland and Labrador.

Indeed, Western producers are considering new markets on the other side of the country among others. Refineries in Québec and the Atlantic Provinces import more than 80% of their crude oil (642,000 bbl/d) from international markets, which makes them perfect targets for the expanding production in Western Canada. Supplying East refineries with Western crude will contribute to the country's energy security. These regions' four refineries can start using synthetic oil or handling blends with heavier crude without much modification to their installation. Their products could therefore be exported to Eastern USA. There is the additional advantage of an existing, but incomplete, network of pipelines that could be used to transport large amounts of crude to these regions. In Ontario, the refineries processed 380,300 bbl/d of crude oil from Canadian producers (representing 94% of capacity) in 2013. The first phase of the Enbridge Line 9 reversal is facilitating this internal transportation. PADD I district[2] is also a potential market that, if reached, may want to change its international imports to a more local and secure supply. Two pipeline projects are key to open these new markets, the Enbridge Line 9 A and B reversal, and the TransCanada Energy East Pipeline. If they were to be accepted in their actual form, they would add respectively 300,000 bbl/d and 1 million bbl/d to Québec's and Atlantic refineries.

Consequently, the main objective of this work is to develop a soft-linking model framework and to demonstrate its potential application with preliminary analyses on: 1) the domestic oil supply-demand dynamic in Canada under different economic growth scenarios; and 2) the impacts of different pipeline projects on the oil supply-demand dynamic in Eastern provinces, Newfoundland and Labrador especially. It is important to mention that the focus of this work has been on developing the framework using recent data as well as a coherent sets of assumptions. However, although the potential application of the proposed framework was successfully demonstrated to analyse oil demand and supply dynamics, we do not pretend to bring final answers to these issues. Indeed, a thorough review of the main data and assumptions, their validation with key players in the industries, as well as a deeper analysis of results would be necessary to bring robust solutions to these issues.

This paper is organized as follows. Section 2 gives an overview of the soft-linking framework using three models that are proposed to assess the oil supply-demand dynamics under different economic growth scenarios and different pipeline capacity scenarios for supplying Canadian oil to Eastern provinces. Section 3 details the scenario definition. Section 4 contains the analysis of all scenarios, namely the impacts for Eastern provinces of having a larger access to Western oil in terms of oil prices and offshore production, international and domestic trade movements. In Section 5, we conclude on the main outcomes of the study.

[2] In the United States, the Petroleum Administration for Defense Districts (PADDs) are geographic aggregations of States that allows regional analysis of crude oil and oil products supply and movements. PADD 1 is the East Coast.

2. Methodology

2.1. General framework

To analyze the interactions between oil supply and demand, a soft-linking framework, mixing three complementary modeling techniques is proposed. These include macroeconomic, forecasting and optimization (Figure 1).

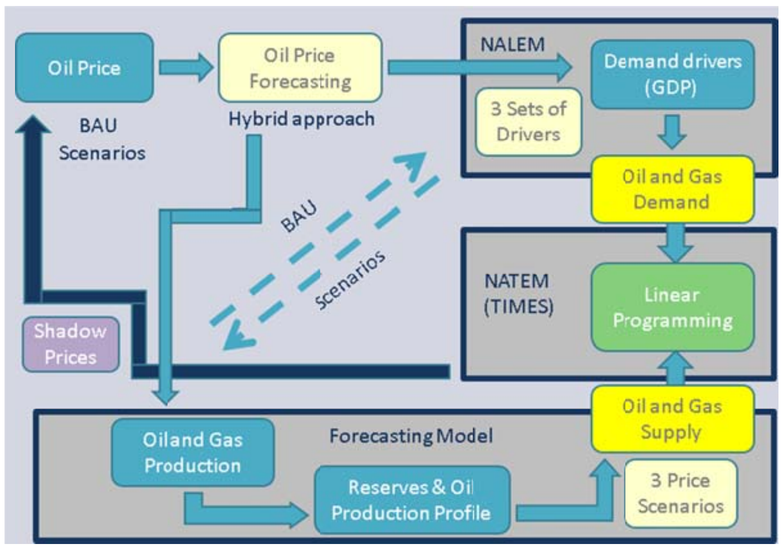
- The macroeconomic model NALEM (Newfoundland and Labrador Econometric Model) is a macroeconomic model representing the structure of the provincial economy and capturing the major relationships between socioeconomic variables. In addition, NALEM is able to capture and quantify the impacts of structural changes such new programs, tax reforms, evolution of the oil and gas industry, etc. "NALEM is organized into 10 different sectors: consumer spending, residential construction, business investment, government spending, exports, and imports comprise the six expenditure sectors essential to the determination of GDP and other key economic indicators. The remaining four sectors cover income and output, demographic and labour market activity, prices and wages, and government revenue. NALEM produces annual forecasts of all main indicators of provincial economic activity including GDP, personal income, labour force, employment, Consumer Price Index (CPI), and population." (Department of Finance, 2015).
- A Forecasting model is used to define a production profile for the Newfoundland and Labrador oil sector to 2050. The model considers both economic variables (prices) and physical variables (production and infrastructure) by establishing a link between well count, oil price, and oil production (Alcocer et al., 2015). Indeed, the well count is used in the oil industry as a key component of planning and decision-making in matters such as capital and operational expenditures. The approach is combined with the Hubbert logistic function to take into account the impact of the age of the producing wells. Calibration is done using a Canadian database of historical production data and records come from numerous Eastern Canada offshore and Canadian oil sands projects.
- The optimization LP model NATEM (North American TIMES Energy Model) is an energy model that has been developed using the most advanced energy optimization modeling framework: The Integrated MARKAL-EFOM System (TIMES). The MARKAL/TIMES model generators are supported by the Energy Technology Systems Analysis Program (ETSAP, 2015) of the International Energy Agency (IEA) and are currently used by more than 80 institutions in nearly 70 countries. This is a technology-rich optimization model that represents, in details, the whole integrated energy sector of Canada from primary to useful energy.

The work requires the following main preparation steps, namely data work, model settings, calibration and linking:

- Prepare three baseline scenarios. This task requires the preparation of three different baselines scenarios using the NALEM model, i.e. three different storylines consistent in terms of projections for oil prices as well as macroeconomic drivers (GDP, population, etc.). These projections will be used as drivers in both the forecasting and the energy optimization NATEM models. This model will help to understand the impact of variations in oil prices on provincial GDP.
- Derive reserves and oil production profiles (conventional and non-conventional) for Newfoundland and Labrador using the forecasting model. This task involves reviewing and updating reserves and oil production figures for Eastern offshore Canada.
- Project the end-use demand for energy services in the NATEM model using the macroeconomic drivers coming from the NALEM model.

- Calibrate the NATEM model with offshore oil production profiles for Newfoundland and Labrador coming from the forecasting model.
- Run the NATEM model for the three different baseline scenarios and analyzing alternate scenarios on pipeline capacity bringing more or less oil from Western Canada to Newfoundland and Labrador. For each scenario, the model will provide optimal technology and fuel mix to meet the end-use demand for energy services as well as partial supply-demand equilibrium. The NATEM model is used to study the relation between oil prices and quantities between the West and East Canadian coasts.
- Run the forecasting model back with the new oil prices as given by NATEM in the different pipeline capacity scenarios and performing iterations to derive convergence on oil production levels.

Figure 1. Soft-linking three models



While the macroeconomic NALEM model was developed by the Department of Finance of the Government of Newfoundland and Labrador, both the NATEM optimization energy model and the oil forecasting models are developed and managed among our team. Consequently, more details are provided regarding the structure and the assumptions behind these two models; the NATEM model is described in Section 2.2 and the forecasting model is described in Section 2.3.

2.2. The NATEM model

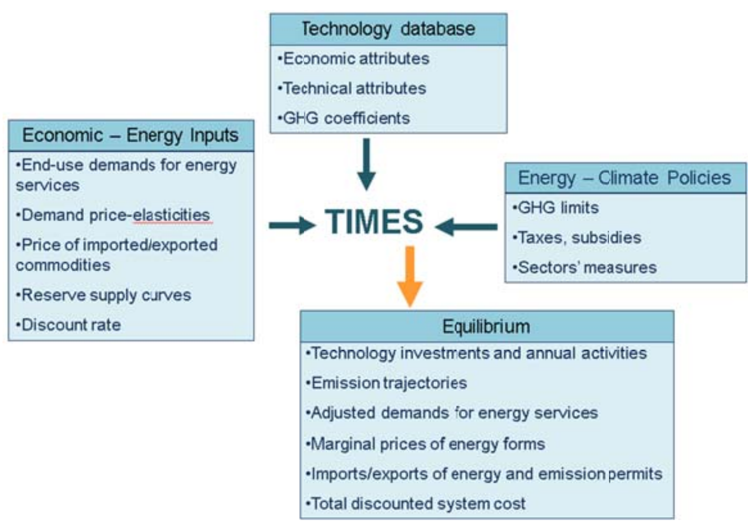
It is worth providing more information on the modeling philosophy and the economic rational of TIMES model, in general, as well as on the database structure of NATEM-Canada, in particular, in order to better understand the meaning of the results presented in this report.

2.2.1. The TIMES model generator

The TIMES model generator combines all the advanced features of the MARKAL models (Fishbone and Abilock, 1981) and to a lesser extent the ones of the EFOM (Energy Flow Optimization Model) model (Van der Voort, 1982), as well as various new features developed over time (Loulou et al., 2005). A TIMES model represents the entire energy system of a country or region. Such a system typically includes extraction, transformation, distribution, end-uses, and trade of various energy forms and materials. Each stage is described by means of specific technologies characterized by economic and technological parameters. The model also tracks GHG and criteria air contaminant emissions from fuel combustion and processes. In baseline scenarios, end-use demands are exogenously specified in terms of socio-economic needs (e.g., transportation, expressed in vehicle-kilometres) over a future horizon. A TIMES model is cast as a dynamic linear programming model. Under the assumption that energy markets are under perfect competition, a single optimization, which searches for the maximal net total surplus, simulates market equilibrium. Maximizing the net total surplus (i.e. the sum of producers' and consumers' surpluses) is operationally done by minimizing the net total cost of the energy system that includes investment costs, operation and maintenance costs, plus the costs of imported fuels, minus the incomes of exported fuels, minus the residual value of technologies at the end of the model horizon, plus welfare losses due to endogenous demand reductions. The main model outputs are future investments and activities of technologies at each period of time. Important additional outputs of the model are the implicit price (shadow price) of each energy material and emission commodity, as well as the reduced cost of each technology (i.e. reduction required to make a technology competitive).

In addition, TIMES models acknowledge that demands are elastic to their own prices contrary to traditional bottom-up models. This feature makes possible the endogenous variation of demands in policy scenarios compared to the baseline, thus capturing the vast majority of structural changes in demands and their impacts on the energy system. In climate policy scenarios, emission reduction is brought about by technology and fuel substitutions, which lead to efficiency improvements and process changes, by carbon capture and sequestration and by endogenous demand reductions. Figure 2 gives a schematic view of the main inputs and outputs associated with TIMES models.

Figure 2. Schematic view of information flows in TIMES models

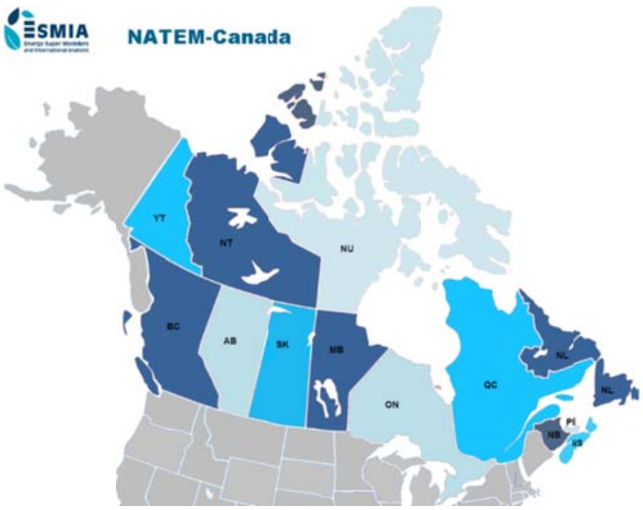


2.2.2. The NATEM-Canada database

The model covers the energy system of the 13 Canadian provinces and territories which are grouped into four main geographical regions for reporting purposes (Figure 3). The model spans 90 years (2011 to 2100) and this study will cover the 2011-2050 time frame through nine time periods. For each period, 16 time slices are defined uniformly across Canada, with four seasons a year (spring, summer, fall and winter) and four intraday periods (day, night, morning peak, evening peak). All costs are in 2011 Canadian dollars ($).

The global annual discount rate has been set to 5% for this study; additional works would be relevant to assess the impact of different discount rates on the evolution of the Canadian energy system.

Figure 3. Provinces and Territories of Canada



Code	Province/Territory	Region
AB	Alberta	West
BC	British Colombia	West
MB	Manitoba	West
NB	New Brunswick	East
NL	Newfoundland	East
NS	Nova Scotia	East
NT	Northwest territories	North
NU	Nunavut	North
ON	Ontario	Central
PE	Prince Edward Island	East
QC	Quebec	Central
SK	Saskatchewan	West
YT	Yukon	North

Overall, the model database includes more than 4,500 specific technologies and 800 commodities in each province and territory, logically interrelated in a reference energy system (Figure 4).

- *Final energy consumption*. The model is driven by a set of 70 end-use demands for energy services in five sectors: agriculture (AGR), commercial (COM), industrial (IND), residential (RSD) and transportation (TRA). In each sector and module of the database, a repository includes a large number of new technologies that are in competition to satisfy each end-use demand, including existing technologies, improved versions of existing technologies, as well as new technologies.
- *Conversion to secondary energy.* This covers all energy conversion technologies such as power plants (thermal with and without carbon capture options, nuclear, renewables, etc.), fossil fuels transformation plants (refineries, coke plants) and biofuels/biomass plants. There are separate modules for a potential future hydrogen economy and liquefied natural gas (LNG) industry.
- *Primary energy supply*. The database compiles all Canadian primary energy sources, such as both conventional and unconventional fossil fuels reserves (oil, gas, coal), renewables potentials (hydro, geothermal, wind, solar, tidal and wave), uranium reserves and biomass (various solid, liquid and gaseous sources).
- *Energy trade*. All primary and secondary forms of energy can be traded within and outside Canada. The domestic trade module deals with energy exchanges between the Canadian provinces and territories. The international trade module covers all energy exchanges between Canada and other countries, including USA.
- GHG emissions. The model tracks carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from fuel combustion, fugitive emissions (from processes, flaring and venting) from the energy sector as well as process emissions from the agriculture sector.
- *Carbon capture and sequestration*. Capture options are available in the electricity sector for the new coal plants. Future works will allow the addition of carbon capture options with biomass power plants. In addition to the regular emission reduction options available in the model (technology and fuel substitutions, endogenous demand reductions), a module is also covering

sequestration potentials for various options, including: enhanced oil recovery, enhanced coal bed methane, afforestation, oil and gas fields (onshore and offshore), deep saline aquifers.

As a result of our calibration process, TIMES-Canada yields for 2011 energy production and consumption consistent with official statistics (NEB, 2013; Statistics Canada, 2011; 2012; OEE 2011; Environment Canada, 2013) for the different province and territories.

In particular, Figure 5 gives a simplified representation of the oil sector in the model.

Reserves. Supply curves have been built from the latest data available from NEB (2013) and CAPP (2013) for the different types of oil (conventional light, tight, heavy and non-conventional bitumen), reserves (located reserves, enhanced recoveries and new discoveries) and extraction techniques (mined and in situ). Most of the Canadian oil reserves (93%) are located in the WCSB spread in four main provinces (Alberta, Saskatchewan, British Columbia, Manitoba).

Extraction. Extraction technologies are modeled for each type of oil and reserves. In particular, there are different technologies for bitumen extraction from either mined or in situ methods. While most of the bitumen have been extracted from mining techniques (e.g. the truck and shovel approach), the use of in situ processes is expected to growth considerably in the future as only a minor portion of the bitumen reserves are closed to the surface. Finally, two different technologies for in situ extraction: the first method called cyclic steam stimulation (CSS) and a more recent method steam assisted gravity drainage (SAGD). Both technologies use injection of steam into oil-sands deposits to reduce its viscosity and allow the bitumen to be moved to the well, but the SAGD method allow a better oil recovery factor and a better steam to oil ratio. Most of the mined bitumen (95%) is currently upgraded into synthetic oil, while the in situ bitumen is mixed with condensates to produce a diluted bitumen appropriate for transport by pipeline. All these technologies are characterized by different costs and energy requirements.

Figure 4. Simplified representation of the reference energy system of each Canadian jurisdiction

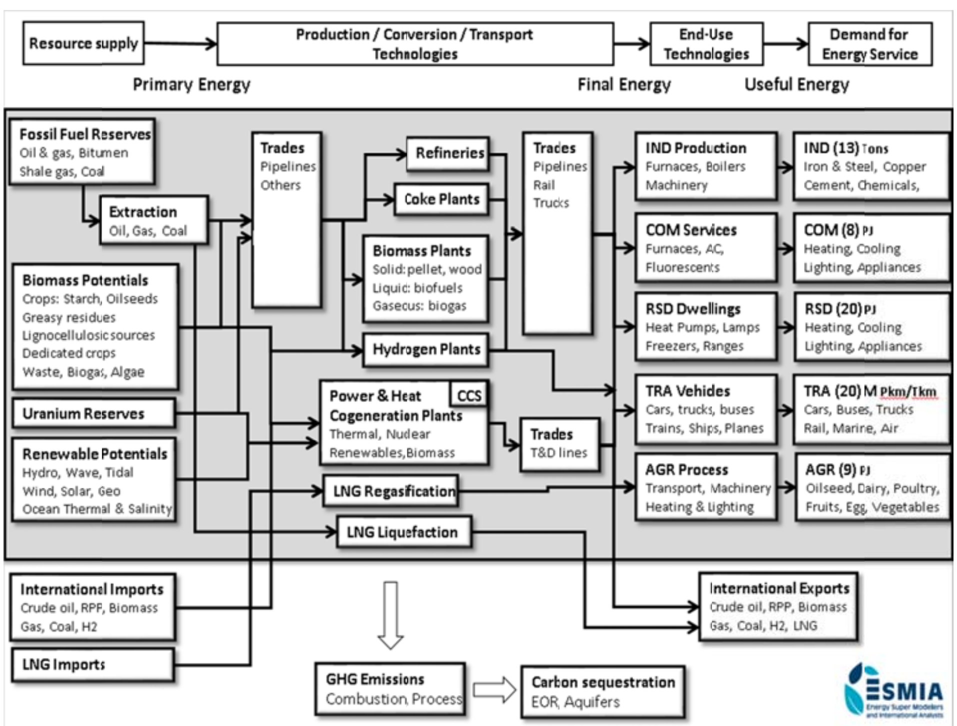
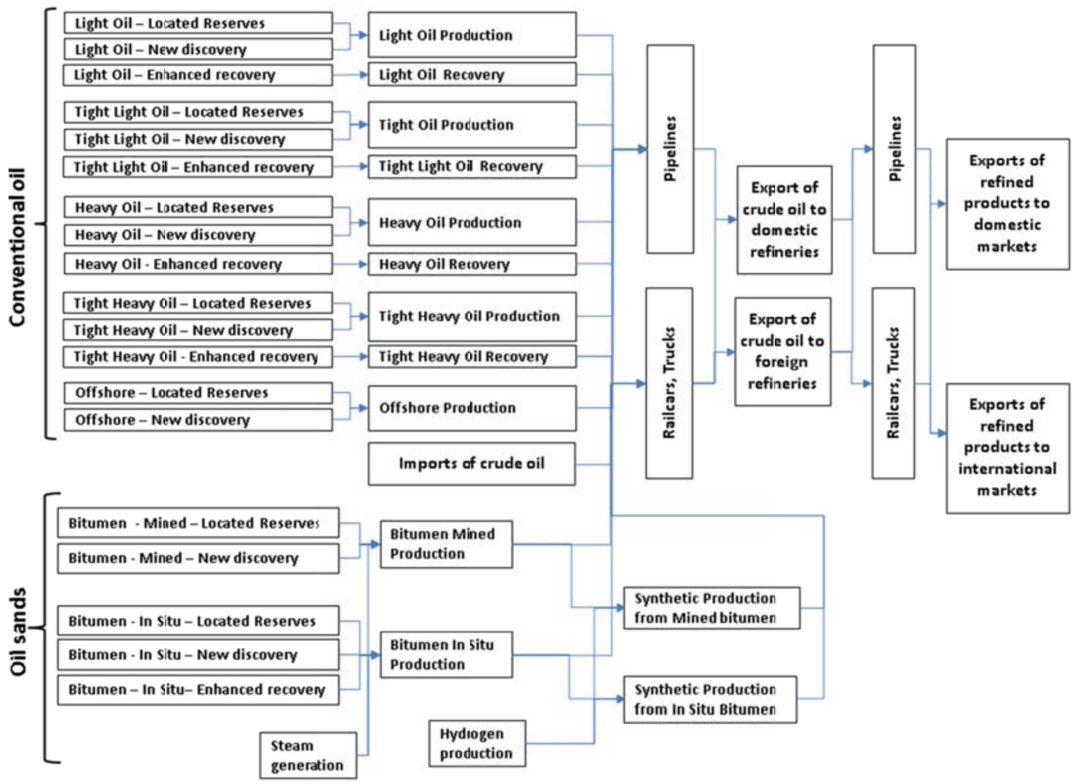


Figure 5. Simplified representation of the oil supply sector



Exploration and development costs are shown in Table **1**. The costs vary with the oil types as their exploration is associated with different levels and require different technologies for their development, but are assumed to be constant in time. The variation in costs in the WCSB (min-max) is related to the location of wells: costs are normally lower in Alberta than in the rest of the region. Table 2 contains the annual well maintenance and operation costs by type of oil and extraction methods (CERI 2013a; 2013b). Costs decrease at a yearly rate of 0.075% until 2035 (CERI 2011) and stay constant thereafter.

Table 1. Exploration and development costs for conventional and unconventional oil

2011 $ / bbl	WCSB-Min	WCSB-Max	Offshore East	Northern Territories
Conventional light				
Light crude oil located reserves	12.57	29.11		47.25
Light crude oil enhanced recovery	18.76	35.30		53.45
Light crude oil new discovery (step 1)	24.96	41.49		59.64
Light tight oil located reserves	18.76	35.30		
Conventional heavy				
Heavy crude oil located reserves	15.54	22.42		
Heavy crude oil enhanced recovery (step 1)	21.74	28.61		
Heavy crude oil new discovery (step 1)	27.93	34.80		
Heavy tight oil located reserves	21.74	28.61		
Offshore				
Offshore oil located reserves			29.42	47.25
Offshore oil new discovery			41.80	59.64

2011 $ / bbl	WCSB-Min	WCSB-Max	Offshore East	Northern Territories
Unconventional – Oil sands				
Mined bitumen located reserves	23.04			
Mined bitumen new discovery	29.23			
In situ bitumen located reserves	25.27			
In situ bitumen enhanced recovery	31.46			
In situ bitumen new discovery	37.65			

Source: CERI 2013a; 2013b; expert assumptions

Table 2. Well maintenance and operation costs for conventional and unconventional oil

2011 $ / bbl	2011	2012	2013	2015	2050
Light crude oil	7.93	7.87	7.80	7.68	6.63
Light enhanced recovery	14.12	14.00	13.93	13.69	11.77
Light tight oil	14.12	14.00	13.93	13.69	11.77
Heavy crude oil	7.93	7.87	7.80	7.68	6.63
Heavy enhanced recovery	14.12	14.00	13.93	13.69	11.77
Heavy tight oil	14.12	14.00	13.93	13.69	11.77
Offshore oil	20.90	20.73	20.61	20.27	17.43
Mined bitumen	17.90	17.77	17.59	17.34	14.93
In situ bitumen	9.35	9.23	9.17	9.04	7.80
Mined bitumen with upgrading	24.59	24.40	24.21	23.84	20.50
In situ bitumen with upgrading	15.98	15.85	15.73	15.48	13.31

Source: CERI 2011; 2013a; 2013b

Upgrading and refining. Downstream activities includes six upgraders with a total capacity of 1.2 million bbl/d and 19 refineries with a total capacity of 2.06 million bbl/d and producing a full range of refined products (CAPP, 2014b). Only a small number of refineries in Ontario and Alberta are currently configured to upgrade bitumen directly. All technologies are characterized by different costs and energy requirements. An important quantity of natural gas is use for steam generation (bitumen recovery) and hydrogen production (bitumen upgrading). Corresponding GHG emissions from fuel combustion and fugitive emissions are accounted at each step of the supply chain as well as flaring and venting emissions.

Transportation. The database includes the current existing transportation capacity as well as planned projects for existing capacity expansion or new infrastructure. Due to the location of the main production centers in the WCSB and of the major markets in the USA Midwest and Gulf Coast regions, the pipeline network in North America has a strong North-South linkage. There are actually four main pipelines exiting the WCSB with a total capacity of 3.67 million bbl/d. The existing pipelines as well as planned projects are listed in Table 3 for exports from the WCSB to international destinations; they can all be visualized on maps in CAPP (2014b). In addition, rail transportation capacity has evolved quickly from 46 thousand bbl/d in 2012 to 300 thousand bbl/d in 2014 (CAPP, 2014b). The growth in rail capacity is assumed to slow down and reach a maximum of 945 thousand bbl/d day in 2050.

Table 3. Existing and proposed pipelines for international exports

Pipeline	Target In-Service	Capacity (k bbl/day)	Capacity (PJ)
Enbridge Mainline	1950	2500	5,651
Kinder Morgan Trans Mountain	1953	300	678
Spectra Express	1997	280	633
TransCanada Keystone	2010	591	1,336
Total Existing Capacity		**3,671**	**8,298**
Enbridge Alberta Clipper Expansion	2015	120	271
Enbridge Alberta Clipper Expansion	2016	230	520
TransCanada Keystone XL	2020	830	1,876
Trans Mountain Expansion	2017	590	1,334
Enbridge Northern Gateway	2017	525	1,187
Total Proposed Capacity		**2,295**	**5,188**
Total Capacity		**5,966**	**13,486**

As for domestic trade, two major new projects are proposed and they are considered as future investment options in the model (Table 4) (CAPP, 2014b). These projects would allow synthetic oil from the WCSB to be exported to Eastern refineries since they are not equipped to process bitumen. This provides an opportunity for Quebec and Atlantic provinces to reduce their imports from foreign countries. In average, the existing transportation capacity between Canadian jurisdictions are assumed to be used at 85% of their maximum capacity. This means that for export increases of more than 15% from current level required new investments in transportation capacities.

Table 4. New pipelines for domestic exports

Pipeline	Target In-Service	Capacity (k bbl/day)	Capacity (PJ)
Enbridge Line 9 reverse	2015	300	678
TransCanada Energy East	2018	1,100	2,486

The model allows increase in exportation levels in three phases: 1) until 100% of the existing capacity is reached (i.e. the least cost option) ; 2) until 100% of the committed new capacity (e.g. expansion plan) is reach by 2020; and 3) by investing in new transportation infrastructure such as pipeline and rail tracks (i.e. the highest cost option).

Cost assumptions are presented in Table 5. The total investment cost for new pipeline projects vary between 16.6$/bbl to 34.2$/bbl. For the TransCanada Energy East project in particular, the cost was estimated at 11.3 billion $ (Deloitte, 2013) or roughly 28.1 $/bbl. Due to lack of precise data in the appropriate format, the investment cost for new rail is assumed to be 75% of the new pipeline cost. For the modeling exercise, the total investment costs of building new transportation capacity was allocated to the different provinces on a distance basis from Alberta in order to adequately account for the transportation costs for each province and to capture the effect on the endogenous oil commodity prices. Similarly, although the maintenance and operation costs are constant on a barrel basis (approximately 0.7$/bbl using assumptions in Karangwa (2008); Statistics Canada 2015a; 2015b), they vary with the distance between provinces. In the model database, the maintenance and operation costs of the rail transportation mode are assumed to be higher than those of the pipeline mode, although this difference is reduced over time. The final transportation cost for Newfoundland and Labrador for the synthetic oil coming from Alberta by pipeline amount to 9.5$/bbl.

Table 5. Cost assumptions by transportation mode

$/bbl	Pipeline		Rail	
	Min	Max	Min	Max
Investment costs for new projects by province	$1.5	$3.8	$1.1	$2.8
Annual operation costs for existing and new transportation mode 2011-2019	$0.7	$4.1	$1.0	$6.1
Annual operation costs for existing and new transportation mode 2020-2050	$0.7	$4.1	$0.8	$4.9

Exports. The model captures six types of oil commodities (light oil, heavy oil, bitumen, synthetic oil, condensates and pentanes) that can be transported by pipelines and/or other means (trucks, trains and tankers) from primary production wells to different types of destinations: domestic refineries, USA refineries and export terminals (e.g. Kitimat in BC) reaching two aggregated international regions (Rest of the World – East and Rest of the World – West). While international trade movements are modeled using fix prices and limits on quantities by origins and destinations, domestic trade movements within Canada are determined endogenously (i.e. prices and quantities are determined by the model based on the available infrastructure capacities and cost of investing in new capacities).

Table 6 shows the price for exported oil (and import oil) on international markets. These prices were first based on oil price forecast given by NEB (2013) with a constant different of 7$/bbl for Brent over WTI until 2035 following assumptions: exports to USA (Brent price -5$/bbl), to ROW - West (Brent price), to ROW-East (Brent price +2$/bbl). Due to the excess of oil supply in North America and the lack of pipeline to reach demand markets, the oil prices are lower than on international markets.

Table 6. Exported oil prices by destination, 2011-2050

Destination	Unit	2012	2013	2020	2025	2030	2050
USA	$/bbl	$98	$ 97	$104	$107	$110	$115
ROW - West	$/bbl	$ 103	$102	$109	$112	$115	$120
ROW- East	$/bbl	$ 105	$104	$111	$114	$117	$122

Energy uses and emissions. All energy requirements for oil extraction, transformation and transportation is accounted in the model. In particular, an important quantity of natural gas is use for generating the steam used for bitumen extraction as well as for producing the hydrogen used for bitumen upgrading at wells or at the refineries. This natural gas consists in both purchased gas (two-third) and the co-products generated during the in situ extraction and upgrading operations. Corresponding GHG emissions from fuel combustion and fugitive emissions are accounted at each step of the supply chain as well as flaring and venting emissions from oil, gas and coal production.

2.3. The forecasting model

The forecasting model considers both economic variables (prices) and physical variables (production and infrastructure) by establishing a link between well count, oil price and oil production (Alcocer et al., 2015). The approach is combined with the Hubbert logistic function to take into account the impact of the age of the producing wells. The model is described in Alcocer et al., (2015) and summarized here.

Oil production. We assume that yearly production of oil ($P_{o,n}$) of a given oil type *o* (e.g., onshore, offshore, or oil sands) in a given field or region *n* is a linear function of the new investments ($I_{o,n}$) that correspond to the number of newly drilled wells (i.e., the well count); the field average production rate ($f_{o,n}$) per well; the time-indexed performance (i.e., production) for individual wells ($w_{o,n}$), which is assumed to be identical for the new wells drilled in a given year (i.e., as a vintage); and the average life ($l_{o,n}$) of the assets (i.e., wells) :

$$P_{o,n}(t) = \sum_{i=t-l_{o,n}}^{t} \left(I_{o,n}(i).\, f_{o,n}(i).\, w_{o,n}(t-i) \right) \qquad (1)$$

where t is a (discrete) time index corresponding to the year considered. Note that the field average production rate ($f_{o,n}$) could be either a constant (i.e., average production) or a function of time for the quantity produced. In the latter case, it could account for learning effects (i.e., either improving with time or as more oil is produced). It can also represent the maturity of the oil field.

Investments in new wells. Under some (strong) microeconomic assumptions (Jukić, Scitovski, and Sabo, 2005) that define a perfect competitive market (such as perfect information, a large number of buyers and sellers, free entry and exit, homogeneous goods, perfect factor mobility, and zero transaction costs), one can postulate an upward relationship between oil price (p) and the production ($P_{o,n}$) at time t. We assume here that the new investments follow this rationale as described below:

$$I_{o,n}(t) = k_o + k_1.\, p(t) + k_2.\, P_{o,n}(t) \qquad (2)$$

where k_0, k_1, and k_2 are calibration parameters.

Equations (1) and (2) are based on supplier behaviour according to specific microeconomic principles as well as practices in the oil industry. More precisely, oil-producing firms typically use an approach similar to Eq. (2) as a planning tool to help them decide what new wells to drill. In this case, the price and production levels (to be used in Eq. (2)) are based on expert estimations. We have statistically tested the correlation between oil prices and well counts for Canada; see Alcocer et al., (2015).

Production of individual wells. To predict the future oil production, we use the Hubert peak approach that uses a logistic function to explain the decline in the production of oil wells and fields over time (Hubbert, 1956). This function is based on empirical observations made by the American geophysicist M. King Hubbert as he successfully predicted the evolution of American oil production around 1965–1970. This can be expressed as follows:

$$w_{o,n}(t) = \frac{h_0 \cdot e^{-h_1 \cdot t}}{\left(1 + \cdot e^{-h_1 \cdot t}\right)^2} \qquad (3)$$

where h_0 is the maximum production that one individual oil well can achieve and h_1 is a factor describing the steep of oil production decline over time. These two parameters are adjusted to match the total production for a specific oil type and region.

Alcocer et al., (2015) also describe in details how the calibration was done for the different types of oil production (conventional onshore, offshore, and oil sands) in two Canadian regions (Eastern and Western Canada) for the period 1980–2007. In this work, the forecasting model was used to define production profiles for the oil sector in Newfoundland and Labrador under different oil price scenarios up to 2050.

3. Scenarios

3.1. Baseline scenarios

3.1.1. Demand projections from NALEM drivers

TIMES models compute the optimal energy configuration that satisfies future demands for energy services that have been exogenously assumed from 2011 levels. The approach used in this work build on Vaillancourt et al., (2014) where different baselines were developed using coherent sets of growth rates, characterized by different assumptions on oil prices or economic growth. It covers a large range of uncertainties related to possible future trends. Concretely, growth rates of various socio-economic drivers up to 2050 are applied to the 2011 base year demand for energy services in NATEM, in conjunction with coefficients capturing service demand sensitivity to these drivers.

$$\boldsymbol{Demand_t} = \boldsymbol{Demand}_{\boldsymbol{t-1}} \times \left(\mathbf{1} + \left(\frac{\boldsymbol{Driver_t}}{\boldsymbol{Driver_{t-1}}} - \mathbf{1}\right) \times \boldsymbol{Sensitivity_t}\right) \quad (4)$$

In summary, this approach requires: 1) the definition of a coherent sets of socio-economic driver growth rates for all end-use demands in all provinces and territories, 2) the allocation of a particular socio-economic driver to each end-use demand in each province and territory and 3) the definition of a sensitivity series for each drivers allocated to each end-use demand.

Similarly, we have developed three baseline scenarios, which utilize three coherent sets of oil prices and socio-economic growth rates coming from official sources (NEB, 2013), in general, and from the NALEM model for Newfoundland and Labrador, in particular; a CENTRAL scenario and two other baselines, a LOW and HIGH scenarios. Main assumptions are shown in Table 7 for Canada and Newfoundland and Labrador in terms of average annual growth rates.

Table 7. Main assumptions in the three baseline scenarios

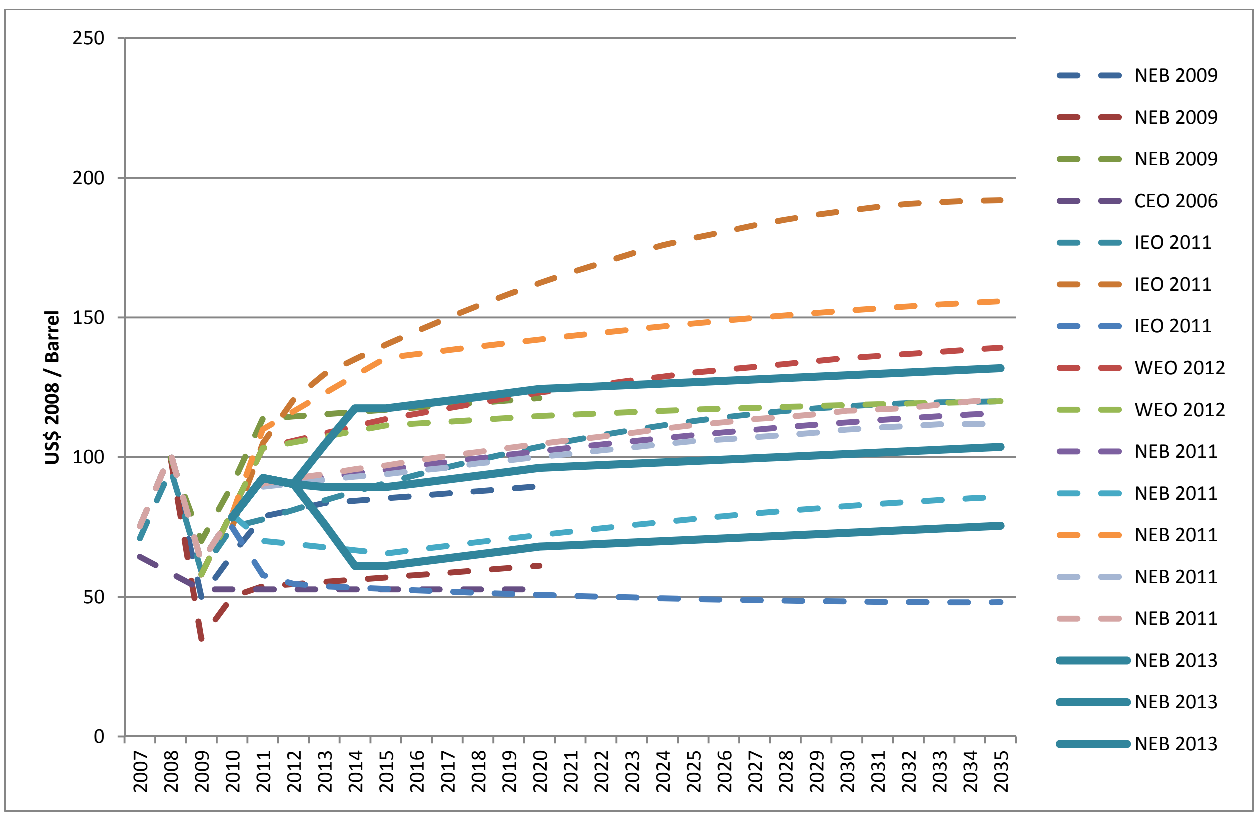
Scenario	Canada		Newfoundland and Labrador	
	2011-2035	2035-2050	2011-2035	2035-2050
Total GDP*				
Central	1.78%	1.54%	0.87%	1.01%
High	1.74%	1.70%	0.96%	0.85%
Low	1.84%	1.51%	0.79%	0.30%
Population				
Central	0.94%	0.81%	0.04%	-0.04%
High	0.94%	0.81%	0.09%	-0.13%
Low	0.94%	0.81%	-0.02%	0.05%
Household Floor Space				
Central	1.32%	1.25%	0.39%	1.04%
High	1.32%	1.25%	0.39%	1.04%
Low	1.32%	1.25%	0.39%	1.04%
Personal Disposable Income				
Central	2.30%	1.60%	3.22%	0.64%
High	2.36%	1.66%	3.43%	0.64%
Low	2.28%	1.60%	3.00%	0.64%

* Correspond to the adjusted real GDP at market prices for Newfoundland

The CENTRAL scenario is characterized by a WTI oil price starting at 96$/bbl (US$$_{2012}$) in 2011 and reaching 110$/bbl by 2035 and 123$/bbl by 2050. The oil price remains flat until 2016 and slowly increases afterward due to the assumption that strong oil demand from developing countries offset the growth in unconventional oil and gas supplies. In the LOW and HIGH cases, the oil price is assumed to be below and above the reference price by 30$/bbl in 2035. The oil price reaches 147$/bbl by 2050 in the HIGH scenario and 87$/bbl by 2050 in the LOW scenario. As for the socio-economic drivers, they come mainly from NEB (2013), but GDP, GDP per capita and population figures for Newfoundland and Labrador were adjusted based on the NALEM forecast for the three baselines between 2011 and 2035. For information purpose, Figure 6 compares the three NEB forecasts (bold lines) to those of other national and international organisations (dash lines).

A driver has been allocated to each end-use demand following a specific logic in each sector. The allocation is identical in all provinces and territories. As for sensitivity series, they were derived from past observations regarding the evolution of the end-use demands compared with the evolution of the drivers. Energy demand in different sectors is influenced by different factors. End-use demands for energy services in the residential sector (e.g. space heating) will be affected by drivers such as population and the number of households with slower growth rates, while those of the commercial sector will be affected by drivers with higher growth rates such as of the GDP for service industries or GDP per capita. In the agriculture sector however, the end-use demands are projected using the original drivers of NATEM (Frenette, 2013). This choice was motivated by the fact that these drivers result from a comprehensive study on agri-food policy and, consequently, are more detailed and more appropriate for the structure of the model.

Figure 6. Comparison of oil price forecasts from different national and international organisations



The resulting end-use demands for energy services in Newfoundland and Labrador are presented in Table 10 in Annexes for the CENTRAL scenario at milestone years. An example is provided regarding end-use demand projections for passenger transportation in million passengers-kilometres for Canada in Figure 7 and for Newfoundland and Labrador in Figure 8 in the three baselines.

Figure 7. End-use demand projections for passenger transportation in Canada

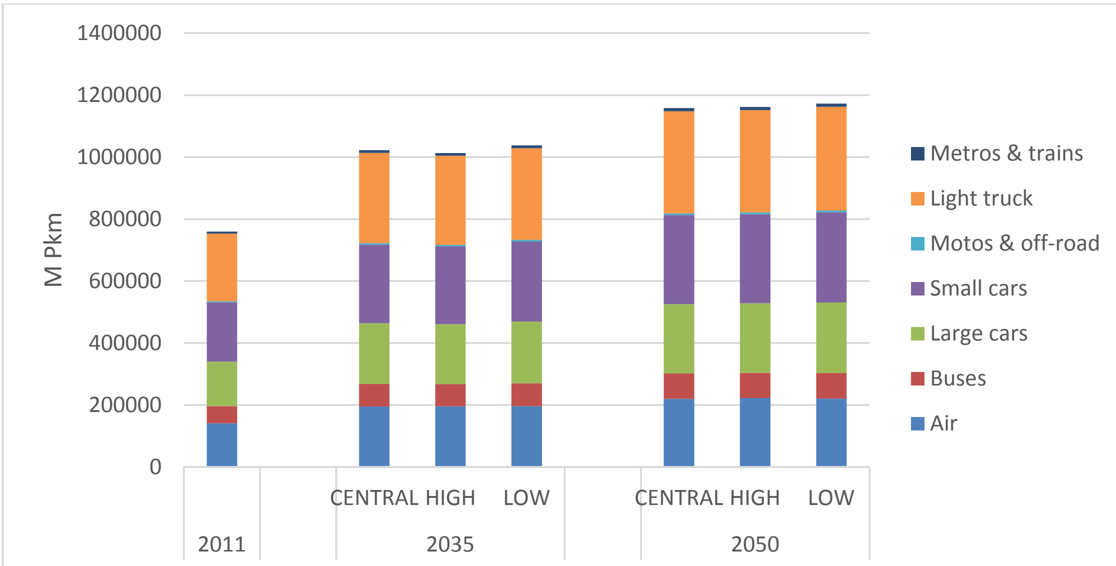
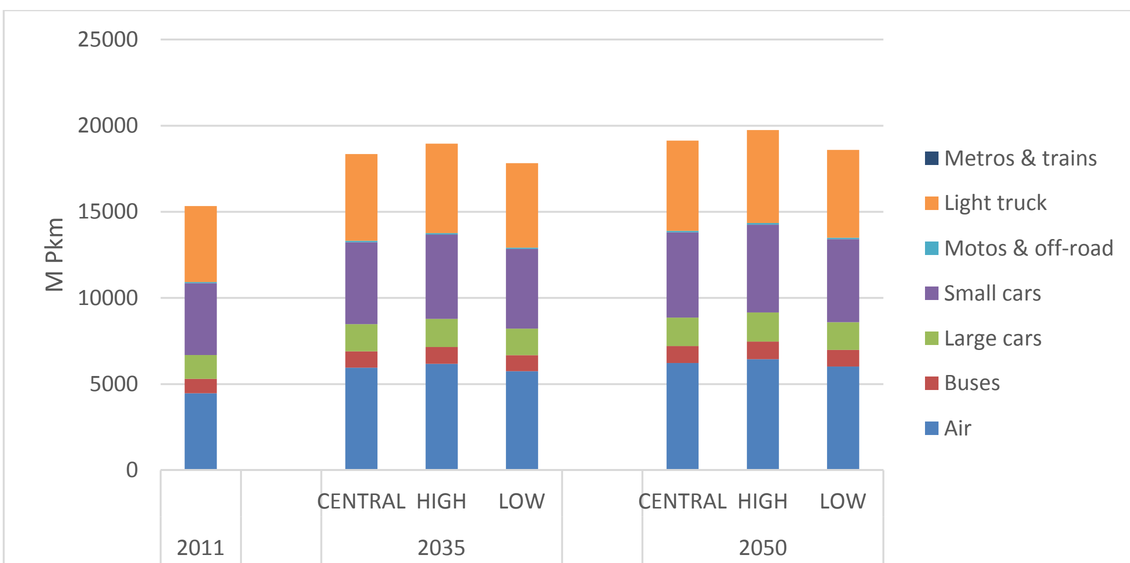


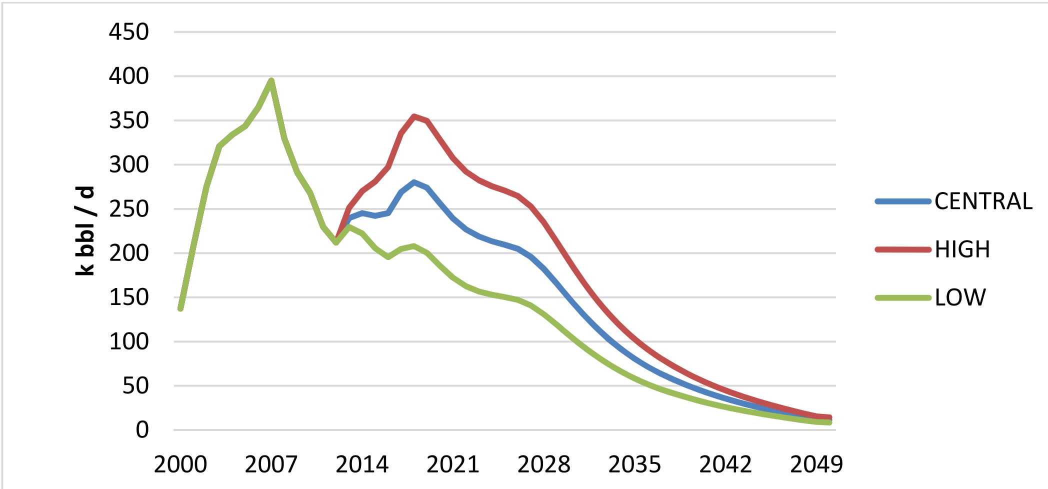
Figure 8. End-use demand projections for passenger transportation in Newfoundland and Labrador



3.1.2. Oil production from the forecasting model

Using the same sets of oil prices (NEB, 2013), the oil production profiles as given by the forecasting model are illustrated in Figure 9. These production profiles are used as the starting point in the TIMES model, which is calibrated to generate the same oil production levels in the corresponding three baseline scenarios. The comparison of each baseline scenarios are compared with the NEB forecast in Figure 31, Figure 32 and Figure 33 in Annexes.

Figure 9. Offshore oil production in Newfoundland and Labrador



3.2. Scenarios on pipeline capacities

3.2.1. Pipeline capacities for international exports from the WCSB

In all scenarios, the international export capacity as defined in the model illustrates the situation where all new pipeline projects would take place (as in Table 3). A set of assumptions was described in Vaillancourt et al. (2015) to define the real availability of pipelines for international exportation from the WCSB. These assumptions take into account the portion of each pipeline not available due to their current use for domestic exports or due to the competition with the oil entering pipelines on the other side of the USA border (CAPP, 2014b). Given these assumptions, the remaining available capacity is 4,858 PJ and is expected to be doubled by 2020 with an additional 4,986 PJ of capacity (Table 8).

A breakdown by type of destinations gives a better illustration of the saturation levels and potential for increases. Most of the existing capacity (97%) is used to export oil to Southern markets, while only a marginal portion (15%) is sent to Western markets. The addition of new capacity will allow current exportation levels to the Southern markets to increase by 1.79 times and to the Western markets by 65 times.

Table 8. Available pipeline capacity for international oil exports by destination

	Existing capacity	New capacity	Total capacity	Exports in 2011	% of capacity in 2011
	PJ	PJ	PJ	PJ	%
Southern markets	4,679	3,448	8,127	4,546	97%
Western markets	179	1,538	1,717	27	15%
Total international	4,858	4,987	9,844	4,573	

The objective of a previous study (Vaillancourt et al., 2015) was to analyze scenarios with different assumptions about the pipeline capacity available to supply the WCSB oil on various markets: for example with and without the most important projects such as TransCanada Keystone XL (1,876 PJ of additional capacity for international trade) and/or the Enbridge Northern Gateway (1,187 PJ of additional capacity for international trade). These scenarios were tested in order to view the impacts on the Canadian oil production levels and trade movements both within and outside Canada. The impacts was shown on the oil sector specifically and on the overall energy system in general. However, this work build on that baseline assuming that all projects would be available to export WCSB oil to international markets.

3.2.2. Pipeline capacities for domestic exports

The objective of the current study is to analyze four scenarios with different assumptions about the pipeline capacity available to supply the WCSB oil to Eastern provinces, Newfoundland and Labrador in particular:

- **S1**: This scenario represents the reference situation where all new pipeline projects would take place allowing WCSB oil to reach refineries in Central and Eastern Canada: Enbridge Line 9 reverse (PJ up to Ontario and Quebec) and TransCanada Energy East (2,486 PJ up to Quebec and New Brunswick and then up to Newfoundland and Labrador via marine tankers or barges). The NATEM model will optimize Western oil imports for Eastern refineries as all as for further international exports from Eastern provinces.
- **S2**: This scenario represents a situation where the TransCanada Energy East pipeline would reach the province of Quebec, New Brunswick and Nova Scotia for uses in refineries and further direct exports to international markets. Consequently, Newfoundland and Labrador would not have access to the oil coming from the WCSB.
- **S3**: This scenario represents a situation where the TransCanada Energy East pipeline would reach Quebec, New Brunswick and Nova Scotia refineries, but would not include further direct export options to international markets. Consequently, Newfoundland and Labrador would have more access to the oil coming from the WCSB.
- **S4**: This scenario represents a situation where the TransCanada Energy East pipeline project would be cancelled, which would preclude WCSB oil from reaching either refineries in Central and Eastern Canada or international markets from Eastern provinces.

In summary, there are three baseline scenarios (CENTRAL, HIGH, LOW) and four pipeline capacity scenarios for exporting oil West to East (S1, S2, S3, S4). Scenario S1 is a complete flexible scenario where the model optimizes the investment options in TransCanada Energy East pipeline as well as the energy flows between Western Canada and Eastern Canada. Scenario S2 aims at showing the impacts of not having this pipeline option for Newfoundland and Labrador. Scenarios 3 and 4 are more extreme cases, created mainly to test the methodology. See Table 9 for maximal pipeline capacities in Eastern Canada.

Table 9. Available maximal pipeline capacity for domestic oil exports

	QC, NB, NS	NL
S1	Full capacity: 2,486 PJ	Full capacity minus the portion exported to USA and ROW: 2,486 PJ - X PJ
S2	Full capacity: 2,486 PJ	No link up to NL: 0 PJ
S3	Full capacity: 2,486 PJ	Full capacity that remain available up to NL: 2,486 PJ
S4	No pipeline: 0 PJ	No pipeline: 0 PJ

4. Results

4.1. Baseline scenarios

From the end-use demands for energy services up to 2050 and using the reference scenario S1 for pipeline capacity, the NATEM model computes the optimal solution satisfying the final energy demand in each of the three baseline scenarios: CENTRAL, HIGH and LOW. Below, details are provided on the corresponding energy consumption and production pathways required to meet the projected end-use demands. Results are reported on a national and provincial basis, i.e. for Newfoundland and Labrador essentially and compared with Canadian averages when relevant.

4.1.1. Final energy consumption

Figure 10 shows the breakdown of final energy consumption by end-use sector in the three baseline scenarios in Canada. The total Canadian final energy demand is expected to increase by 23% in the CENTRAL scenario on the 2050 horizon, with 50% of the additional demand coming from the central region (Quebec and Ontario) and another 35% coming from Western provinces (mainly British Colombia and Alberta). One third of the final energy is consumed by transportation (32%), which also account for 20% of the additional demand in 2050. Important growth is also coming from the commercial and industrial sectors, which accounts for 30% and 32% of the additional demand and represent 49% of the final demand in 2050.

Regarding the breakdown of final energy consumption by fuel type (Figure 11), fossil fuels and oil products in particular will continue to dominate the markets on the long term. In 2050, the fuel mix is characterized by 39% of oil products and 25% of natural gas in the CENTRAL scenario. However, the highest growth is observed for electricity due to the higher growth in the end-use sectors relying on these fuels (e.g., commercial) and the large variety of options available for electricity generation in Canada. Electricity accounts for 52% of the additional energy demand up to 2050. The shares of biomass in the total energy consumption remains small (8% in 2050).

Figure 10. Final energy consumption by end-use sector in Canada

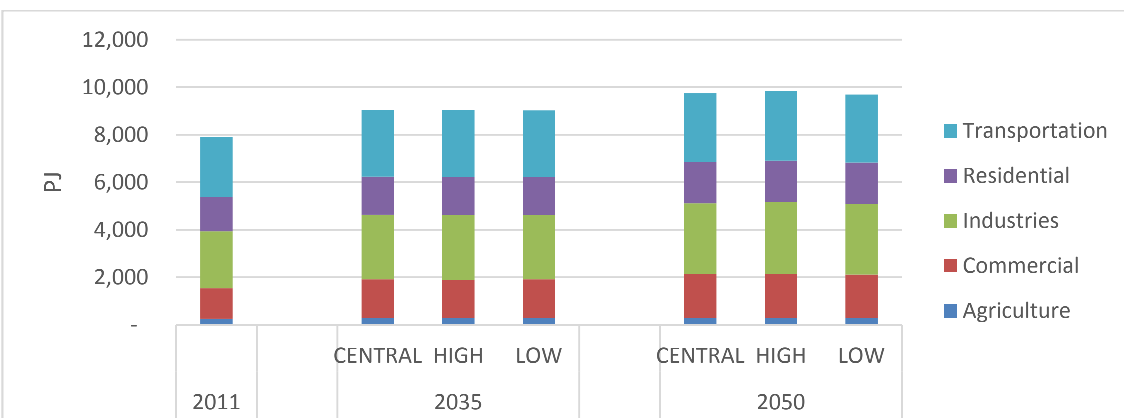
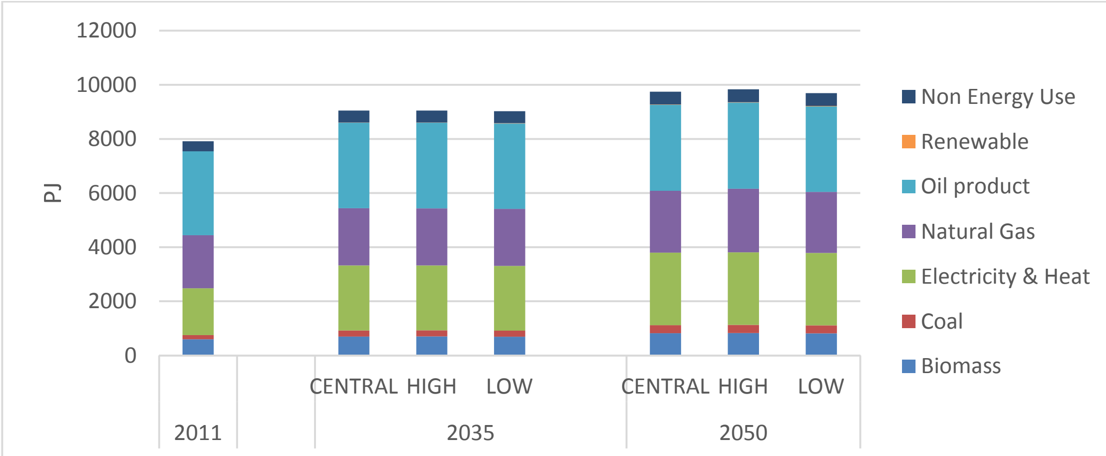


Figure 11. Final energy consumption by fuel type in Canada



For Newfoundland and Labrador specifically, Figure 12 shows the breakdown of final energy demand by end-use sector in the three baseline scenarios. The total final energy demand is expected to increase by 12% through 2050 in the CENTRAL scenario, a growth that is lower than the Canadian average (23%). Regarding the relative proportion of each sector in the total final energy demand, there are structural difference when comparing Newfoundland and Labrador to the national average. Specifically, the transportation sector represents a higher share for Newfoundland and Labrador (46% in 2011 compared with 32% for Canada), while industries represent a much lower proportion in Newfoundland and Labrador then in Canada as a whole (17% in 2011 compared with 30% for Canada). However, higher growth in the industrial sector minimizes these differences toward 2050, where industries account for 28% of the final energy demand in Newfoundland and Labrador.

The breakdown of final energy consumption by fuel type in the three baseline scenarios as illustrated in Figure 13 indicates that fossil fuels will continue to dominate the markets on the 2050 horizon as in Canada generally. However, there is a decreasing trend for oil products (from 63% in 2011 to 48% in 2050) in favour of electricity (from 28% to 37% on the same period). As for the national average, the use of biomass remains flat through 2050 (below 8%).

Figure 12. Final energy demand by end-use sector in Newfoundland and Labrador

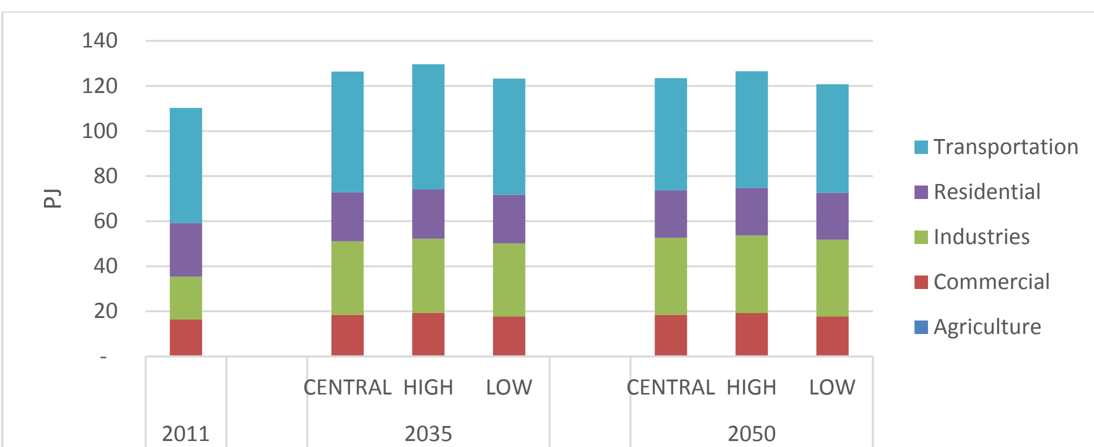
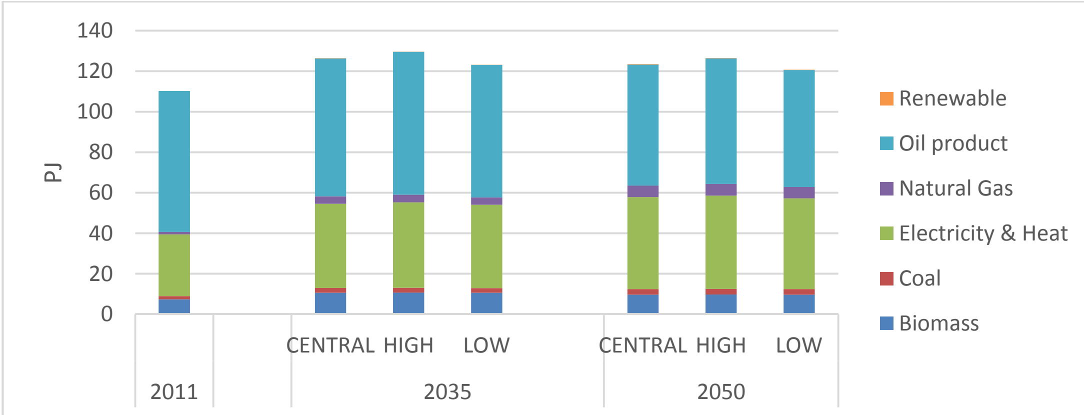


Figure 13. Final energy demand by fuel type in Newfoundland and Labrador



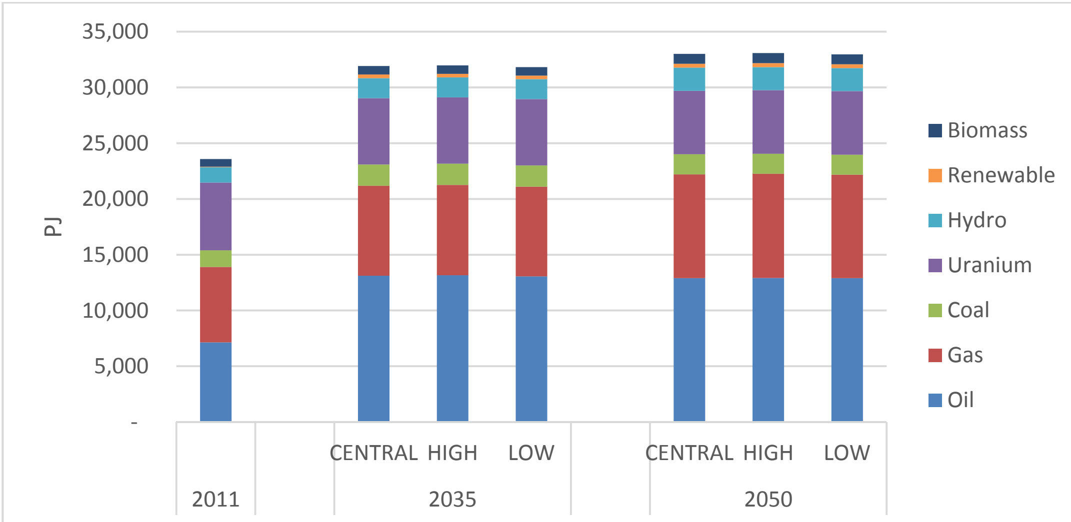
The variation of results across the different baselines is consistent with the NEB (2013) assumptions regarding the evolution of socio-economic trends. In some provinces, the final energy demand is increasing faster in the LOW scenario compared with the CENTRAL case and vice versa for the HIGH scenario due to the fact that higher oil prices put higher pressure on the final energy demand growth. However, in oil producing provinces, this trend is offset by the fact that the oil and gas sector is increasing with oil prices, which create more GDP and leads to higher growth in final energy demand. For instance, in Newfoundland and Labrador, the HIGH scenario leads to only a more significant growth in the final energy demand (14.8%) compared to the CENTRAL scenario (12.0%), while the LOW scenario leads to a lower growth (9.5%) by 2050. This range in the final energy consumption will be useful to analyse the impact of the pipeline capacity scenarios on oil prices in Newfoundland and Labrador.

4.1.2 Primary energy supply

This section presents more details regarding the optimal energy production paths required to meet the final energy demand, both for domestic consumption and for international exports. Figure 14 shows the energy production by type in the three baseline scenarios. In the CENTRAL scenario, most of the growth in oil production (84%) is occurring between 2011 and 2035, before slowing down between 2035 and 2050 (-2%). Gas production grows by 38% in the 2050 horizon due to its significant reserves, with a larger penetration of unconventional gas compensating for the decline in conventional gas production. Conventional gas sources are mainly concentrated in the Western region (76% in Alberta). The production starts decreasing with the extra supplies of unconventional gas on the markets and continues to decline on the long term due to the lower well production rates (NEB, 2013). With technological progress for unconventional gas extraction (i.e., horizontal drilling and hydraulic fracturing) as well as conventional gas reserve depletion, the production from unconventional gas wells is becoming more profitable and allows the overall gas production to increase again from 2020 after a decline in the total gas extraction activities. Most of the unconventional gas production (mainly tight and shale gas, but also coalbed methane) is located in British Colombia and Alberta. Frontier gas reserves from the Northern and the offshore Eastern regions are not included in the model.

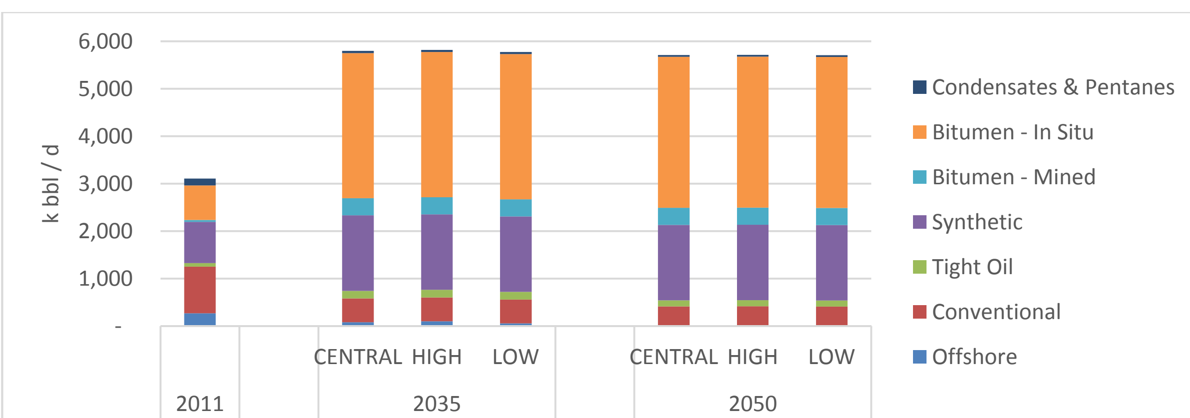
Due to coal power phase out in many provinces, coal production grows by only 20% for domestic uses in industries and international exports. Uranium extraction follows a decreasing trend (-6% between 2011 and 2050) following nuclear plant closures. Hydro follows a constant increase representing a 50% growth between 2011 and 2050. Finally, although other renewable production increase by a factor 7, its proportion in the overall production mix remains around 1%. Overall, the primary energy production remains between 39.8% and 40.3% for the three baseline scenarios.

Figure 14. Primary energy production by type in Canada



In particular, Figure 15 compares the breakdown of crude oil production by type in the three baseline scenarios. The large majority of the oil production is exported on international markets and the international demand for Canadian crude is the main driver for oil production levels. In this work, we have assumed that the international demand for Canadian crude is constant across scenarios both for simplification reasons and for the minor expected effect on domestic consumption. More precisely, the international demand for Canadian crude is limited in a way that the oil production levels do not excess those forecasted by the NEB (2013) as shown in Figure 16. After the limit on the pipeline capacity to exports crude from the WCSB is reached (Section 3.2.1), additional exports can occurred from the Eastern provinces, since the TransCanada East pipeline capacity exceeds the capacity needed to supply refineries in Quebec and Atlantic provinces. The maximum production levels as taken from the NEB (2013) are reached in all scenarios.

Figure 15. Oil production by type in Canada



In relation to the stability of the domestic demand for oil across the different baseline scenarios, it is not surprizing to see in Figure 15 that domestic economic trends have very little impact on oil production levels. Oil production increases by 1.8 time from 2011 level and is expected to reach 5,710k bbl/d in 2050.

The production shows constant increase with the highest growth rates being between 2013 and 2025, when most of the new pipeline capacities are becoming available.

Most of the oil production is coming from the WCSB, with conventional oil representing only 10% of the total production in Canada in 2050. The WCSB is a mature basin, where conventional oil production declines at significant faster rates between 2025 and 2050. The 19% increase between 2011 and 2020 is due to the availability of enhanced oil recovery options, extending the life of some wells and the extraction of tight oil. The two sources of new project developments come from Western oil sands and Newfoundland offshore production. While oil sands (mined and in situ extraction, plus synthetic production from both types) represented already half of the total oil production in 2011, it is expected to represent 90% of the production in 2050. The proportion of oil sands extracted via in situ techniques is expected to represent 58% of the overall production in 2050, as the mined activities for oil sands extraction should increase only slightly (from 28% to 32% in 2050). A significant portion of this oil sands production via mined or in situ techniques is converted to synthetic oil. Synthetic oil production from oil sands upgrading is expected to provide 28% of the total production in 2050.

Figure 16. Oil production by type in Canada compared with the NEB (2013) forecasts

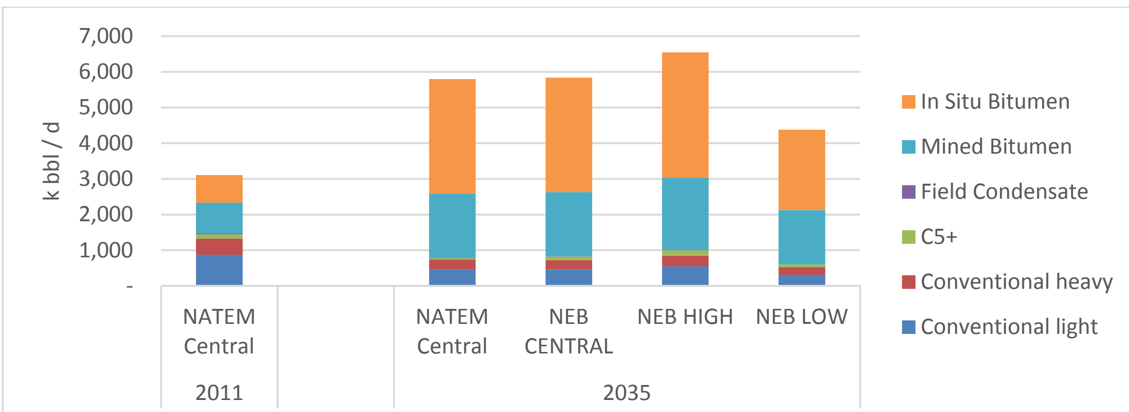
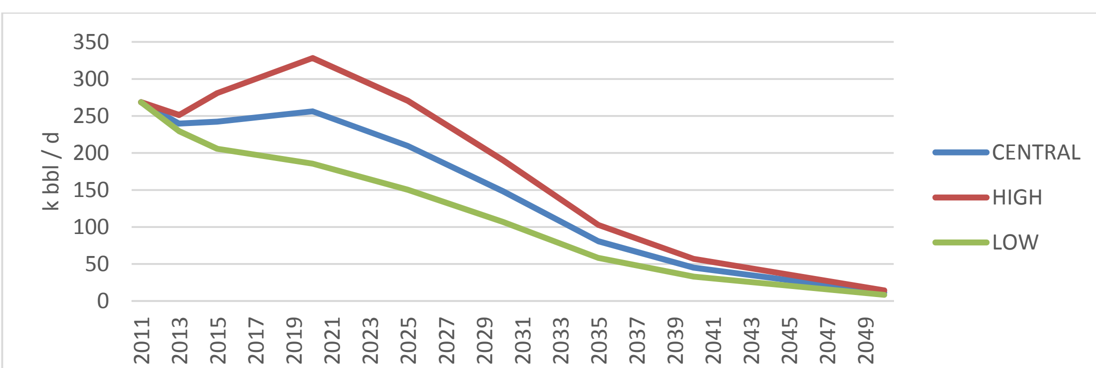


Figure 17 show the evolution of the total offshore oil production in Newfoundland and Labrador through 2050 to meet both the domestic demands and international exports in the three baseline scenarios. The outcomes of the forecasting model for the three different oil price scenarios (Figure 9) are used as fixed production levels in NATEM. Note, however, that NATEM uses longer time period than the forecasting model which is annual. Oil production peaks around 2020 (328 kbbl/d in the HIGH scenario) before starting to decline.

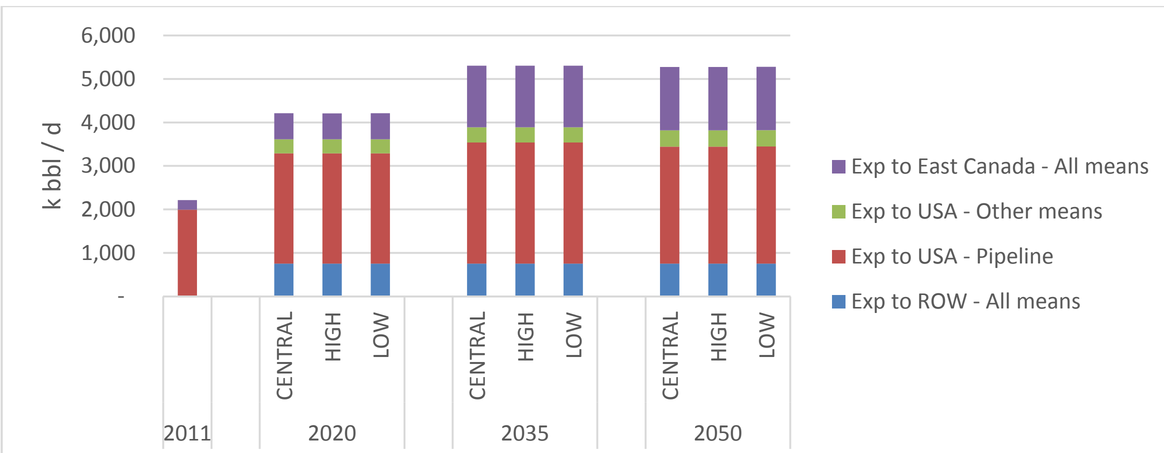
Figure 17. Oil production in Newfoundland and Labrador– original from the forecasting model



4.1.3 International and domestic exports from WCSB

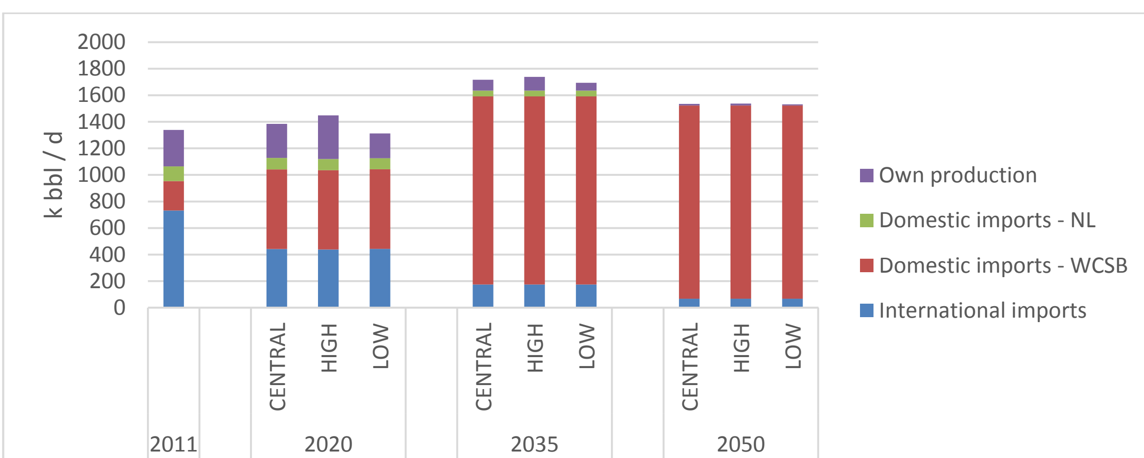
Before analyzing the supply-demand dynamics in Eastern Canada for the different pipeline capacity scenarios, it is relevant to have a look at the supply-demand dynamics in Canada as a whole. Figure 18 shows the oil exports by destination from Western Canada, while Figure 19 shows the oil imports by origin in Eastern Canada. Oil exports are almost exclusively oriented to USA markets by pipeline in 2011 (98%), but they start to be diversified both in terms of transportation means and other destinations in the rest of the world due to higher oil prices (Table 6). In addition, Western provinces start to move synthetic oil to Eastern provinces via the TransCanada East pipeline from 2020 and the pipeline is used at full capacity from 2030. It is important to note that an important portion of that oil is further exported to international markets and that not all is used in Eastern refineries. Trading movements from the WCSB to Ontario through the existing Enbridge pipeline are also included in the domestic export numbers.

Figure 18. Oil exports by destination from Western Canada



As for the origin of the oil supply in Eastern Canada, it is apparent that imports through the TransCanada East pipeline represent the majority of the mix when this option becomes available. Since the oil production in Newfoundland and Labrador is decreasing to almost zero in 2050 (assuming no new field will be discovered and developed), all refineries in Eastern Canada will need to rely on domestic imports from the WCSB and on international imports in a lesser manner. The next section presents more details on the origin of imports and the use of crude oil by province.

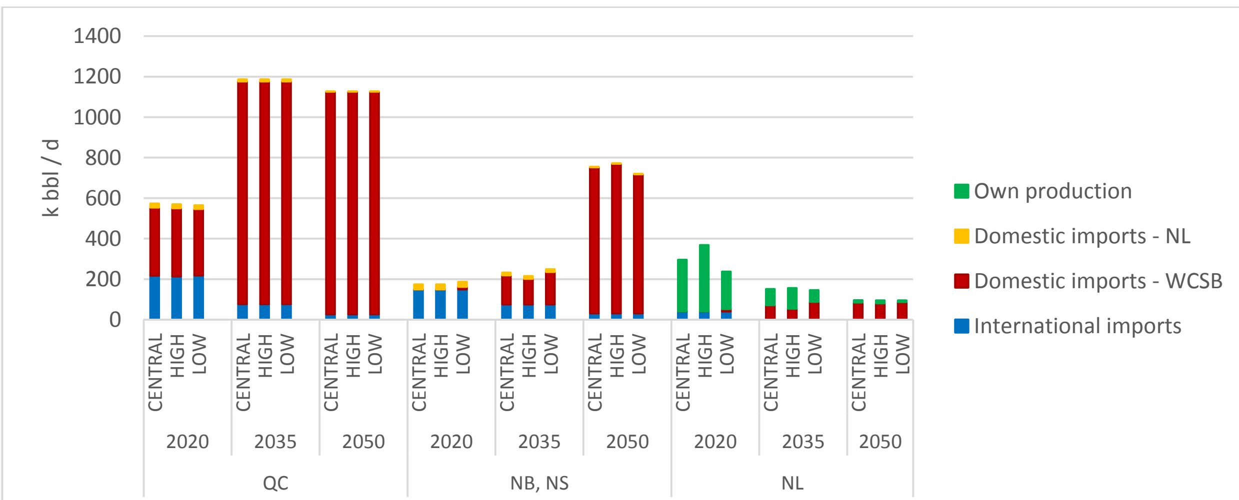
Figure 19. Oil imports by origin in Eastern Canada



4.2. Pipeline capacity scenarios

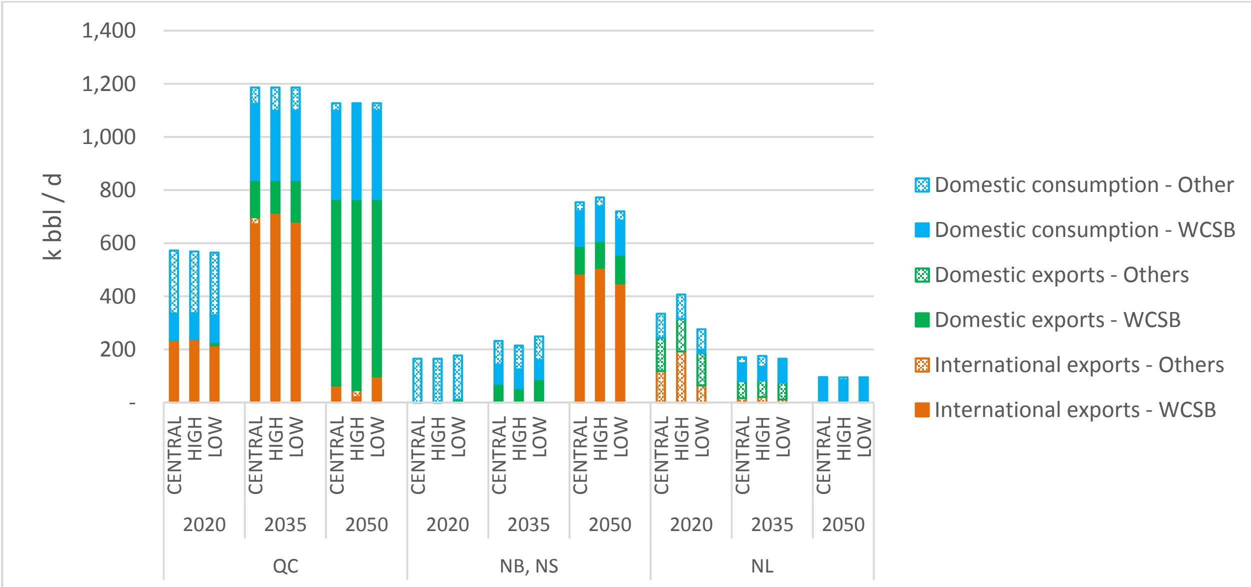
This section looks at the supply-demand dynamics in Eastern provinces in particular for the different pipeline capacity scenarios. Figure 20 shows the same type of information as in Figure 19 for the three baseline scenarios, albeit at a provincial level, in order to better understand the trade movements in Eastern Canada. As mentioned earlier, oil imports from the WCSB start as soon as the TransCanada pipeline becomes available in 2020 and reach its maximum capacity (1100 k bbl/d) around 2030. Quebec, New Brunswick and Nova Scotia have access to synthetic oil from the WCSB for use in domestic refineries or exports to USA and/or Rest of the World. In Newfoundland and Labrador, the synthetic oil from the WCSB is used solely in the refinery since there are no option assumed in the model for further exports of synthetic oil to international markets. Synthetic oil is assumed to replace the offshore oil as its production decreases over time.

Figure 20. Oil imports by origin and by province in Eastern Canada



More details are given in Figure 21 regarding the different uses of the WCSB synthetic oil as well as other types of crude oil that reach or is being produced in Eastern provinces. Synthetic oil is replacing a significant portion of the imported crude oil used in Quebec's refineries: between 75-82% in 2035 and 92% in 2050. The remaining portion represents the imported light oil from Africa, the North Sea and the Middle East. It is important to note, however, that this crude mix is strongly dependent on the assumptions about the imported light oil prices and quantities. Since the needs of the province are small compared with the size of the TransCanada East pipeline, the vast majority of the synthetic oil coming through is exported to the USA toward 2035. An interesting change occurring between 2035 and 2050 is related to the destination of the WCSB oil: direct exports from Quebec to USA toward 2035 are decreasing to the profit of domestic exports to New Brunswick and Nova Scotia for international exports to Rest of the World – East where the oil prices are expected to be higher (Table 6). In Newfoundland and Labrador, the WCSB oil is replacing the majority of the offshore oil in the refinery (between 90% and 98% by 2050). The offshore production is mainly exported on international markets.

Figure 21. Oil demand by province in Eastern Canada



The remaining part of the section looks at the effects of the different pipeline capacity scenarios on the supply and demand dynamics of each province. The oil imports by origin and by province in Eastern Canada as shown in Figure 20 and the oil demand by province in Eastern Canada as shown in Figure 21 represent the reference situation in terms of pipeline capacity (S1); the same complete results are shown in Annexes for oil imports in S2 (Figure 34), S3 (Figure 35) and S4 (Figure 36) as well as for oil demand in S2 (Figure 37), S3 (Figure 38) and S4 (Figure 39).

Since the different assumptions underlying the three baseline scenarios do not affect the results in a significant manner, the comparison analysis focuses on the central scenario for each pipeline capacity scenarios. The variations in oil import patterns according to the different pipeline capacity scenarios are illustrated subsequently for Quebec (Figure 22), New Brunswick/Nova Scotia (Figure 23) and for Newfoundland and Labrador (Figure 24). The S2 does not have a significant effect on the oil supply mixes in Quebec and New Brunswick/Nova Scotia for their own use. However, since it assumes that the WCSB oil will not reach Newfoundland and Labrador, less synthetic oil is imported through New Brunswick in 2035 to reach Newfoundland and Labrador.

Figure 22. Oil imports by origin in Quebec in the pipeline scenarios

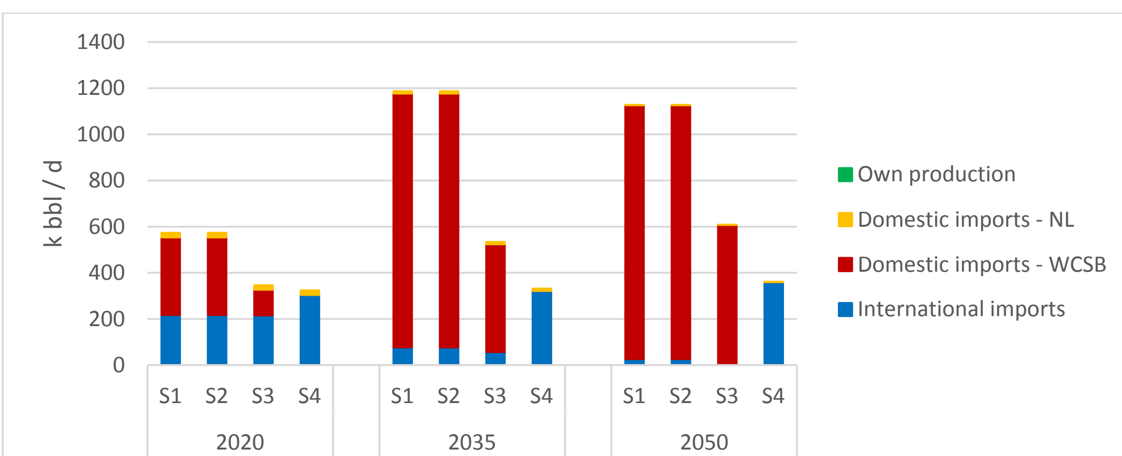


Figure 23. Oil imports by origin in New Brunswick/Nova Scotia in the pipeline scenarios

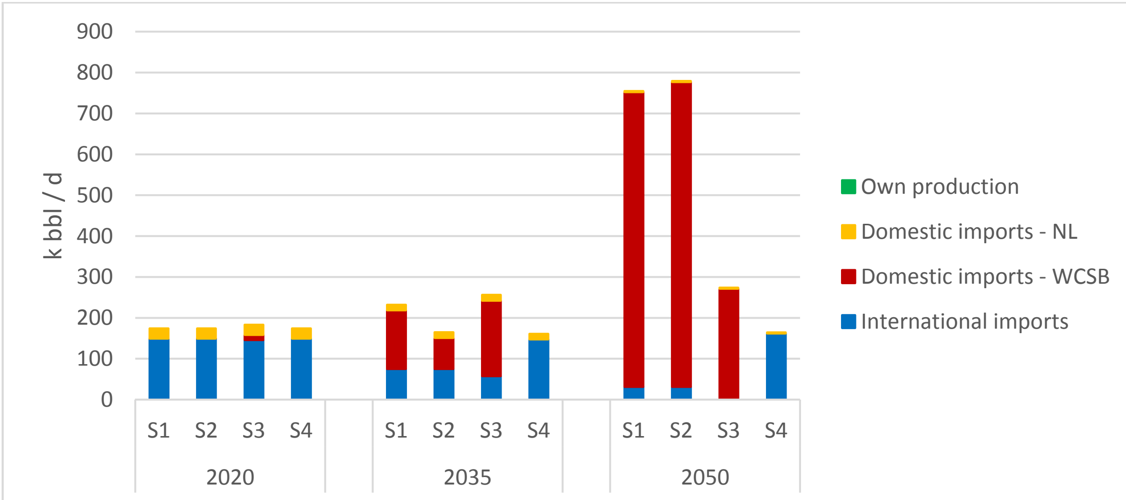
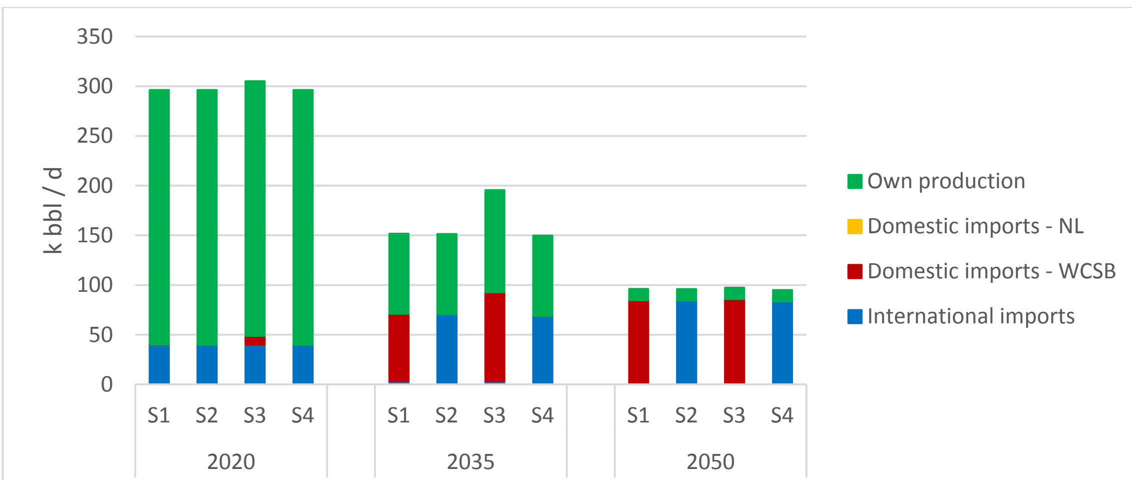


Figure 24. Oil imports by origin in Newfoundland and Labrador in the pipeline scenarios



As for S3, which assumes that there will be no international exports from Quebec and New Brunswick/Nova Scotia, it affects the oil supply mixes in a more significant manner in all provinces. As a larger proportion of the WCSB oil imported in Eastern Canada is for international exports, the trading flows between Western and Eastern Canada in general are much reduced. However, Quebec can reduce its imports from international markets and this leaves larger amount of the WCSB oil available for exports to Newfoundland and Labrador. Finally, there are no access at all to WCSB oil for Quebec and Atlantic provinces in S4. This situation requires some provinces to import more oil from other markets (international as well as from Newfoundland and Labrador) although the changes are minor. The biggest impacts are on the demand side.

The variations in oil demand patterns according to the different pipeline capacity scenarios are illustrated subsequently for Quebec (Figure 25), New Brunswick/Nova Scotia (Figure 26) and for Newfoundland and Labrador (Figure 27). In S2, when Newfoundland and Labrador does not have access to synthetic oil, more of this oil is available for domestic use in Quebec and New Brunswick. The impact results in Newfoundland and Labrador being a greater user of its own domestic production for refining to the detriment of international exports. The limitation of international exports in Quebec and New Brunswick in S3, promotes a larger use of synthetic oil in domestic refineries in all provinces. Newfoundland and Labrador can increase its refining activities, its exports of refined products as well as international exports of its offshore oil. However, this has much less effect on the trade movement between Western and Eastern Canada than the international demand for WCSB oil.

Figure 25. Oil demand in Quebec in the pipeline scenarios

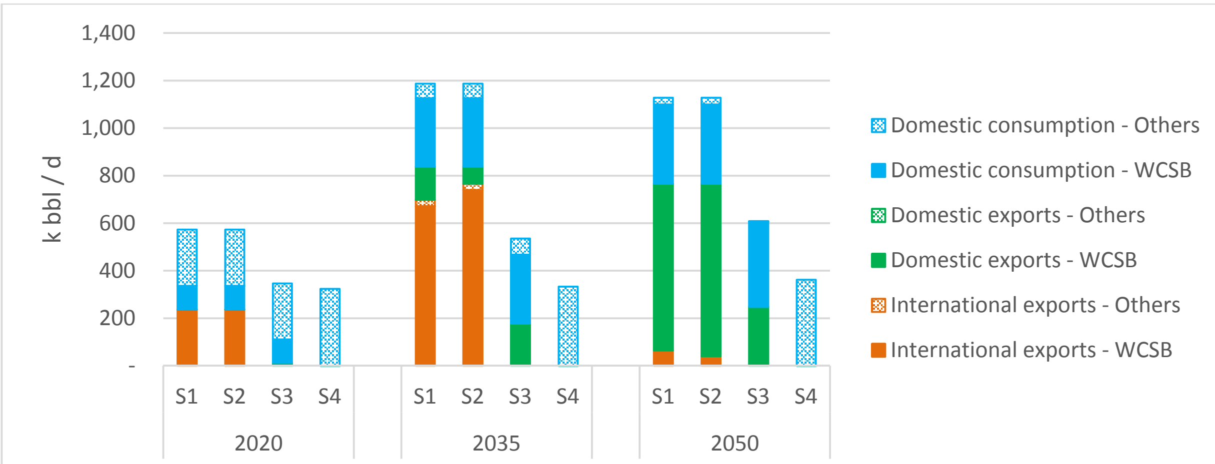
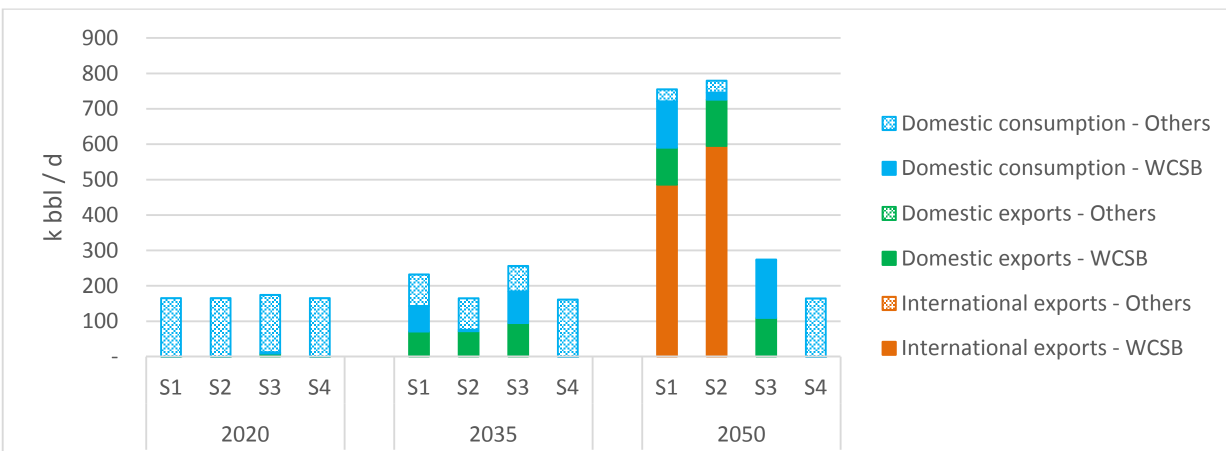
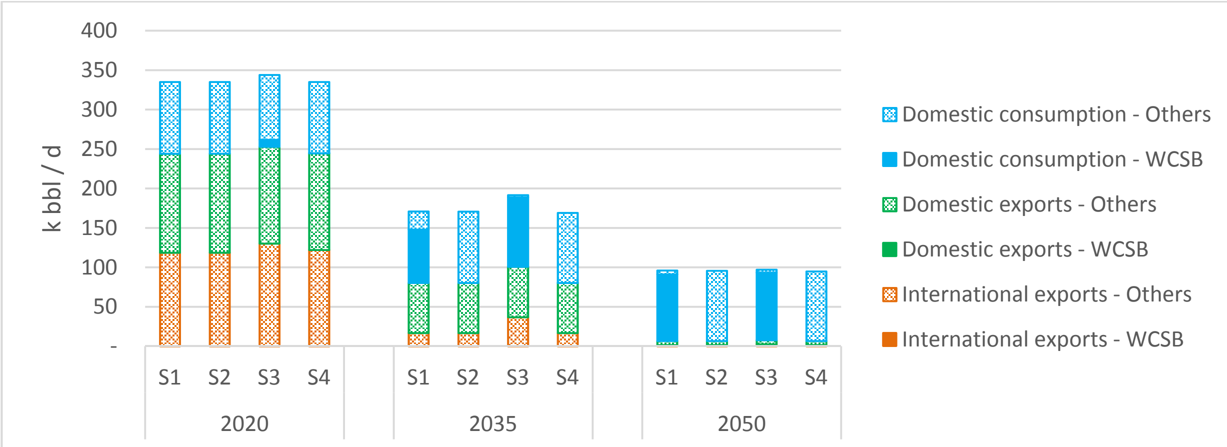


Figure 26. Oil demand in New Brunswick/Nova Scotia in the pipeline scenarios



The effects of having less access to WCSB oil in Eastern Canada in S4 is clearly a decrease in activities both domestically and internationally. Interestingly, the impacts on the total production levels in the WCSB is light as more synthetic is exported directly to the USA.

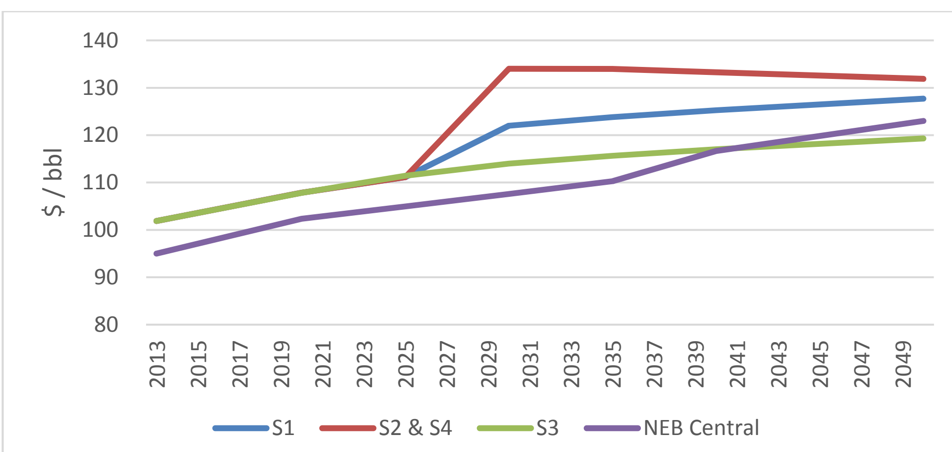
Figure 27. Oil demand in Newfoundland and Labrador in the pipeline scenarios



4.3. Impact on oil prices and production levels

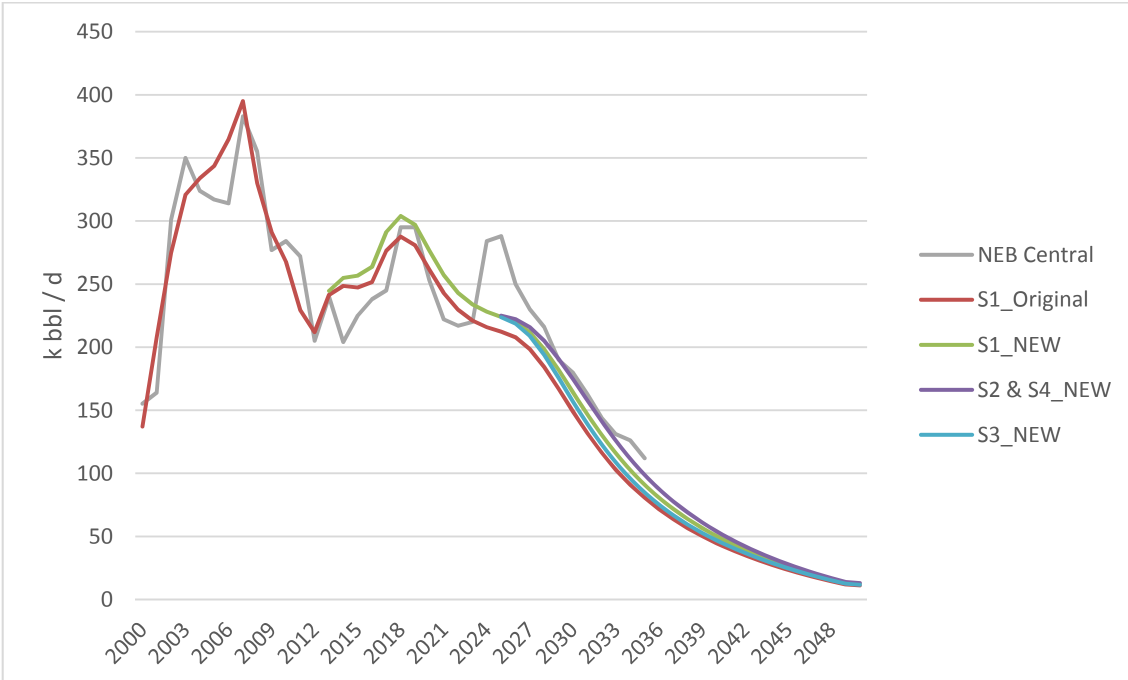
This section shows the effects of the pipeline capacity and the access to WCSB oil on the offshore oil commodity prices and production in Newfoundland and Labrador (Figure 28), using the first iteration between the forecasting model and NATEM. When the model can optimize the quantities of synthetic oil coming from the WCSB up to the maximum TransCanada East pipeline capacity, such as in S1, there is more competition between different crude types. This allows prices to converge at 128$/bbl by 2050 in all three baselines. Blocking the access to WCSB oil in Newfoundland and Labrador, such as in S2, brings the offshore oil price up by 10$/bbl in 2035 and 4$/bbl in 2050. As for the other two scenarios, there are more extreme and perhaps less realistic, but they illustrates well the utility of the proposed framework to analyse supply-demand dynamics in Eastern Canada. In S3, the prices are going down further with an excess of WCSB oil coming to Newfoundland and Labrador, while they remain high in S4, when the whole pipeline project is cancelled (this scenario has impacts on the oil prices in other Eastern provinces). The comparison of these prices with those of the NEB (2013) in their central scenario shows that their assumptions on the availability of crude oil on all Canadian markets are optimistic.

Figure 28. Marginal oil commodity prices in Newfoundland and Labrador in the pipeline scenarios



Finally, the forecasting model is also used to show the impacts of new oil prices in our optimal scenario (S1) compared with a situation where Newfoundland and Labrador would have more or less access to synthetic oil from WCSB (S2, S3 and S4) on oil production levels (Figure 29).

Figure 29. Oil production in Newfoundland and Labrador after an iteration with the forecasting model



The oil production is higher in the new production profile (S1_NEW) than in the original profile (S1_Original) due to higher marginal prices in the NATEM scenarios than in the central case of the NEB (Figure 28). The oil production difference peaks in 2036, showing a 13% higher level than in the NEB. Considering the average increase between 2013 and 2050, S1 is about 9% higher levels than the central case of the NEB overall. If we consider the reserves available in 2013, S1 shows 8% more reserves than in the NEB case due to the incentive of higher oil prices. Indeed, this new pattern in higher oil prices creates an incentive to drill more wells when the field oil production profile is higher compared to the original case. The impact is more significant up to 2030, since the contribution of each well is higher when the field is younger. Afterwards, the contribution is much less significant as the field is maturing and the contribution of each new well becomes smaller.

At first sight, it seems there is not much differences in the oil production profiles between the different pipeline capacity scenarios as the impacts of having more or less access to the TransCanada East pipeline is only possible beyond 2020. However, after looking more closely to the different production profiles, it becomes apparent that the differences are meaningful and require some considerations. The S2 scenario leads to the biggest benefits in terms of offshore production since there is no competition with Western oil. For this case, the oil production difference peaks in 2034, showing up to a 23% increase in production compared with the central case of the NEB. The average increase between 2013 and 2050 is about 14%. Regarding the available reserves in 2013, S2 shows 10% more reserves than the NEB. For S3, the highest difference occurs in 2032, at 6% higher than the NEB. The average increase between 2013 and 2050 is 5% and the available reserves are 6% higher.

In summary, the access to Western oil would allow the Eastern provinces to maintain crude oil prices at lower level than if they would need to import crude oil for international markets.

5. Conclusion

This report focuses specifically on the impact of the TransCanada pipeline on the oil and gas industry in Newfoundland and Labrador. A soft-linking model framework was presented and applied to a specific case study to generate insights on: 1) the domestic oil supply-demand dynamic in Canada under different economic growth scenarios; and 2) the impacts of different pipeline projects on the oil supply-demand dynamic in Eastern provinces, Newfoundland and Labrador especially. The NATEM model database was presented into more details for the oil sector. The results discussed in the report illustrate well the potential of the model framework to analyse such supply-demand dynamics and to provide insights on market trends. This should be seen as a first step toward a broader and deeper analysis. Indeed, these are complex issues that would require more works in order to bring robust conclusions.

Future works will allow to improve this analysis from several point of view: extend the methodology to cover more aspects of the problem, refine data and assumptions to bring the definition of the problem closer to the reality and consider multiple scenarios to analyse the problem in all its dimensions.

From a methodological perspective, the next step would be to complete the loop by looking at the impact of oil prices changes on socio-economic growth forecasts in Newfoundland and Labrador using the NALEM model. This requires the collaboration of the Department of Finance – Government of Newfoundland and Labrador. We also think that the study would benefit from using a fiscal model to analyze the impact of marginal prices due to changes in pipeline capacities (or other changes in the oil sector) on GDP, taxes and profits per barrel (price-cost). In addition, the following improvements are considered to improve the representation of the oil sector in the NATEM optimization model:

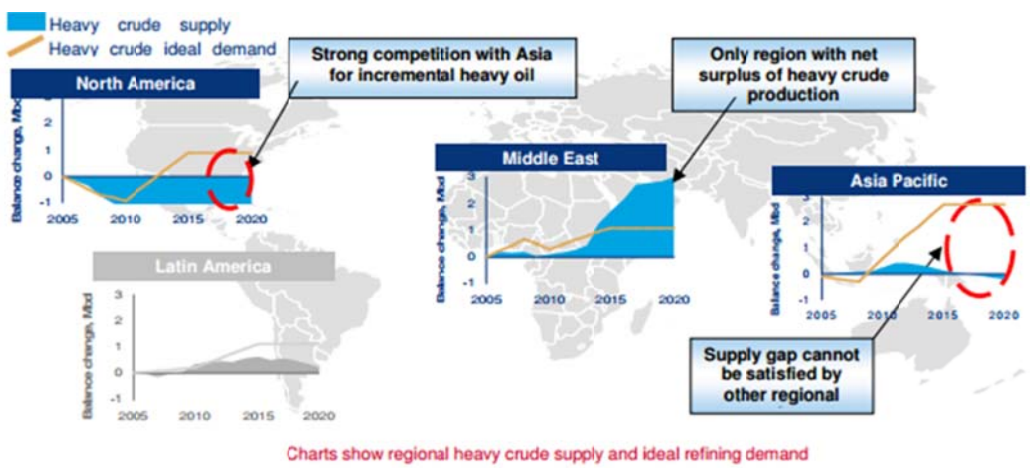
- Give more flexibility to the model in order to optimize investments between 1) upgrading activities in the WCSB for synthetic oil exports in Eastern Canada, and 2) exports of diluted bitumen directly from the WCSB with additional upgrading activities in Eastern refineries (and, further diluted bitumen to USA and ROW).
- Increase the level of details in terms of transportation options as well as for international markets for different crude oil types and refined products.
- Refine the representation of refineries taking into account crude quality, blending options and corresponding output mix options.
- Add other sources of crude oil that can compete with Canadian crude such as the shale oil from North Dakota (USA), the new Statoil oil discovery in Newfoundland that could yield up to 600 million barrels of additional reserves.

On the data, assumptions and scenario analysis aspects, it would be important to update the cost data as the information becomes available in the literature and to validate the most uncertain values with key players in the industry. Moreover, sensitivity analysis on the most critical factors is necessary to bring more robustness to the study such as transportation costs between different provinces. Finally, numerous additional scenarios would be relevant to address the most significant uncertainties impacting the evolution of the Canadian oil sector, namely:

- Scenarios with variations to demands for different types of crude oil in North American refineries: This is to study the future evolution of the refining sector with the possibility of both Valero and Irving building new refineries in North East America and Europe or facing possible refinery closures as the US refineries are becoming more competitive thanks to their access to cheaper oil supply.

- Scenarios with variations to the Brent over WTI differential: This differential is a relative new phenomenon due to the oversupply of North American crude oil and the limitations to access international markets. As more pipeline projects are concluded and political constraints are eliminated (e.g. the Jones Act) such limitations will decreased giving North American crude oil access to new markets willing to pay higher international prices.
- Scenarios with variations to the oil price assumptions by transportation route: the original assumption of a higher netback for the East (ROWE) route than for the West (ROWW) route needs to be challenged as other regions in the world evolve to produce and process heavy oil. As it can be seen on Figure 30, the Canadian bitumen is starting to have more competition from the heavy crude coming from Middle East. On the other side, Asian demand will also increase, giving more advantage to the West route as time approaches 2020.

Figure 30. Heavy crude oil supply change versus heavy crude oil ideal demand change



Source: Wood Makenzie (2011).

To conclude, we expect that this extended framework will shade lights with a greater level of robustness on uncertainties around:

- The availability of resources, capital cost of projects and planning process by companies as well as policy design by governments.
- Increasing oil price volatility.
- Connections and evolution of exploitation, transportation and refining under different oil prices and pipeline capacity scenarios.
- Geographical issues specific to the Canadian oil sector: imports and offshore production in Eastern Canada versus exports and oil sands production in Western Canada.

ANNEXES

Table 10. Projection of end-use demands for energy services in Newfoundland and Labrador

Demand	Unit	2011	2013	2015	2020	2025	2030	2035	2040	2050
Beef	Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dairy	Mt	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Eggs	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fruit	Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grains and Oilseeds	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hog	Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	PJ	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Poultry	Mt	-	-	-	-	-	-	-	-	-
Vegetables	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Auxiliary Equipment	PJ	3.11	3.31	3.48	3.55	3.63	3.64	3.65	3.70	3.80
Auxiliary Motors	PJ	1.24	1.32	1.39	1.42	1.45	1.45	1.46	1.48	1.52
Lighting	PJ	6.89	7.35	7.73	7.87	8.06	8.07	8.09	8.21	8.42
Other Services	PJ	4.26	4.76	5.09	5.78	6.19	6.54	6.86	7.03	7.19
Space Cooling	PJ	0.25	0.27	0.28	0.29	0.29	0.29	0.29	0.30	0.31
Space heating	PJ	4.00	4.27	4.49	4.57	4.68	4.69	4.70	4.77	4.89
Street lighting	PJ	0.25	0.27	0.28	0.28	0.29	0.29	0.29	0.30	0.30
Water heating	PJ	0.60	0.64	0.68	0.69	0.71	0.71	0.71	0.72	0.74
Ammonia	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Chlorine	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other chemicals	Mt	-	-	-	-	-	-	-	-	-
Iron and steel	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cement	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other mining	PJ	2.59	2.66	2.72	2.73	2.85	2.85	2.86	2.92	3.02
Aluminium	Mt	-	-	-	-	-	-	-	-	-
Copper	Mt	-	-	-	-	-	-	-	-	-
Other non-ferrous metals	Mt	-	-	-	-	-	-	-	-	-
Other manufacturing industries	PJ	2.11	2.21	2.27	2.38	2.69	2.93	3.16	3.27	3.37
Other industries	PJ	6.01	6.29	6.46	6.78	7.65	8.35	8.99	9.32	9.61

Demand	Unit	2011	2013	2015	2020	2025	2030	2035	2040	2050
High quality paper	Mt	0.56	0.57	0.58	0.59	0.61	0.61	0.61	0.62	0.65
Low quality paper	Mt	0.56	0.57	0.58	0.59	0.61	0.61	0.61	0.62	0.65
Space cooling - Attached Houses	PJ	-	-	-	-	-	-	-	-	-
Space cooling - Apartments	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Space cooling - Detached Houses	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cloth drying	PJ	0.66	0.71	0.73	0.79	0.83	0.88	0.93	0.96	0.98
Space cooling - Mobile Homes	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	PJ	0.49	0.50	0.50	0.49	0.49	0.50	0.50	0.50	0.50
Cloth washing	PJ	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09
Dish washing	PJ	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06
Freezing	PJ	0.24	0.26	0.27	0.29	0.30	0.32	0.34	0.35	0.36
Space heating - Attached Houses	PJ	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Space heating - Apartments	PJ	0.81	0.82	0.83	0.84	0.84	0.84	0.84	0.84	0.83
Space heating - Detached Houses	PJ	11.66	11.82	11.96	12.03	12.07	12.06	12.04	12.03	12.00
Space heating - Mobile Homes	PJ	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lighting	PJ	1.68	1.75	1.80	1.82	1.88	1.88	1.89	1.91	1.96
Other electric equipements	PJ	1.29	1.38	1.44	1.55	1.62	1.73	1.83	1.88	1.93
Refrigeration	PJ	0.48	0.51	0.53	0.58	0.60	0.64	0.68	0.70	0.71
Water heating - Attached Houses	PJ	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Water heating - Apartments	PJ	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Water heating - Detached Houses	PJ	2.46	2.47	2.47	2.46	2.46	2.47	2.47	2.47	2.48
Water heating - Mobile Homes	PJ	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Air, Freight, All	MTKms	16.35	17.86	18.84	20.86	22.31	23.57	24.75	25.37	25.94
Air, Passenger, Domestic	MPKms	2,184.83	2,299.06	2,390.78	2,427.02	2,486.02	2,488.38	2,493.31	2,529.77	2,596.43
Air, Passenger, International	MPKms	2,283.78	2,494.99	2,631.41	2,914.16	3,117.17	3,293.44	3,457.83	3,544.53	3,623.67
Marine, generic	PJ	4.58	5.01	5.28	5.85	6.26	6.61	6.94	7.11	7.27
Road, Freight, Heavy Trucks	MTKms	4,548.04	4,968.64	5,240.32	5,803.41	6,207.70	6,558.72	6,886.11	7,058.76	7,216.36
Road, Freight, Medium Trucks	MTKms	150.47	164.39	173.38	192.01	205.38	217.00	227.83	233.54	238.75
Road, Freight, Light Trucks	MTKms	414.75	453.11	477.88	529.23	566.10	598.11	627.97	643.71	658.08
Road, Passenger, School Buses	MPKms	449.65	473.16	492.04	499.50	511.64	512.13	513.14	520.65	534.36

Demand	Unit	2011	2013	2015	2020	2025	2030	2035	2040	2050
Road, Passenger, Intercity Buses	MPKms	100.13	105.36	109.57	111.23	113.93	114.04	114.27	115.94	118.99
Road, Passenger, Large Cars, Long distance	MPKms	623.11	655.69	681.85	692.19	709.01	709.69	711.09	721.49	740.50
Road, Passenger, Large Cars, Short distance	MPKms	761.58	801.40	833.37	846.01	866.57	867.39	869.11	881.82	905.06
Road, Passenger, Motorcycles	MPKms	67.97	71.52	74.38	75.50	77.34	77.41	77.56	78.70	80.77
Road, Passenger, Off road vehicles	PJ	3.07	3.23	3.36	3.41	3.50	3.50	3.51	3.56	3.65
Road, Passenger, Small Cars, Long distance	MPKms	1,875.39	1,973.44	2,052.17	2,083.28	2,133.92	2,135.95	2,140.18	2,171.48	2,228.69
Road, Passenger, Small Cars, Short distance	MPKms	2,292.14	2,411.98	2,508.21	2,546.23	2,608.12	2,610.60	2,615.77	2,654.03	2,723.96
Road, Passenger, Light Trucks	MPKms	4,411.72	4,642.38	4,827.58	4,900.76	5,019.89	5,024.66	5,034.61	5,108.24	5,242.83
Road, Passenger, Urban Buses	MPKms	284.68	299.57	311.52	316.24	323.93	324.24	324.88	329.63	338.31
Road, Passenger, Subways	MPKms	-	-	-	-	-	-	-	-	-
Rail, Freight	MTKms	-	-	-	-	-	-	-	-	-
Rail, Passenger	MPKms	-	-	-	-	-	-	-	-	-

Figure 31. Comparison of oil production levels in NL to the NEB forecast in the CENTRAL scenario

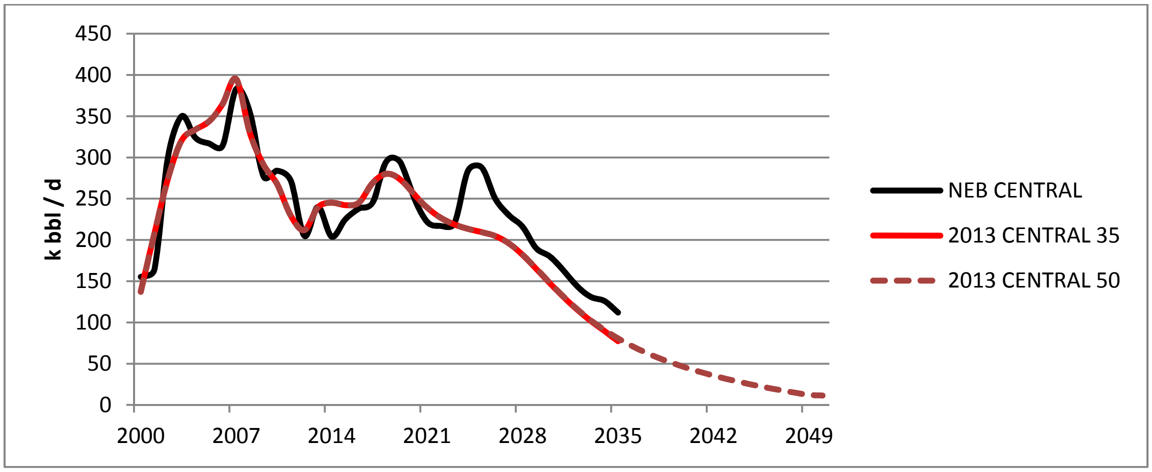


Figure 32. Comparison of oil production levels in NL to the NEB forecast in the HIGH scenario

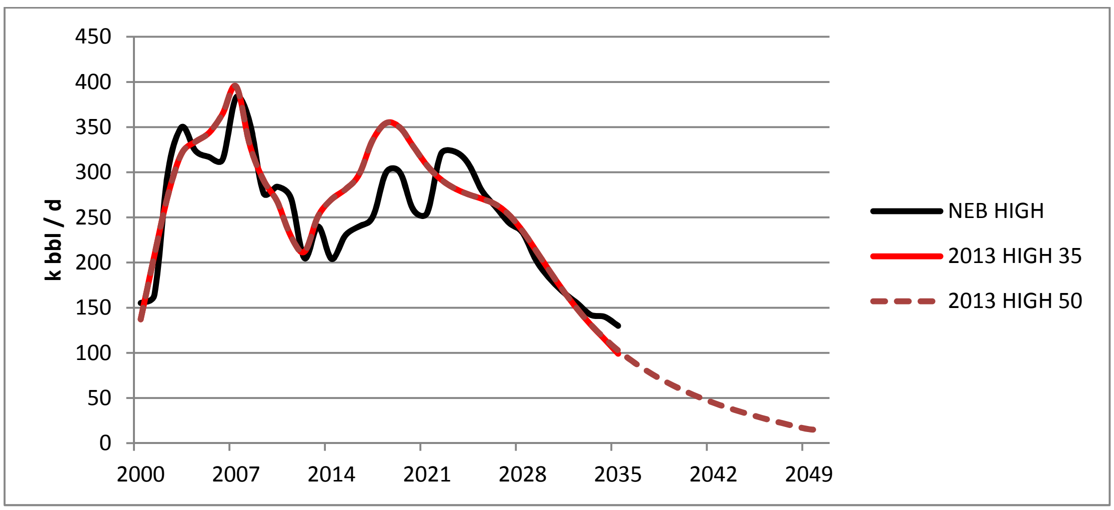


Figure 33. Comparison of oil production levels in NL to the NEB forecast in the LOW scenario

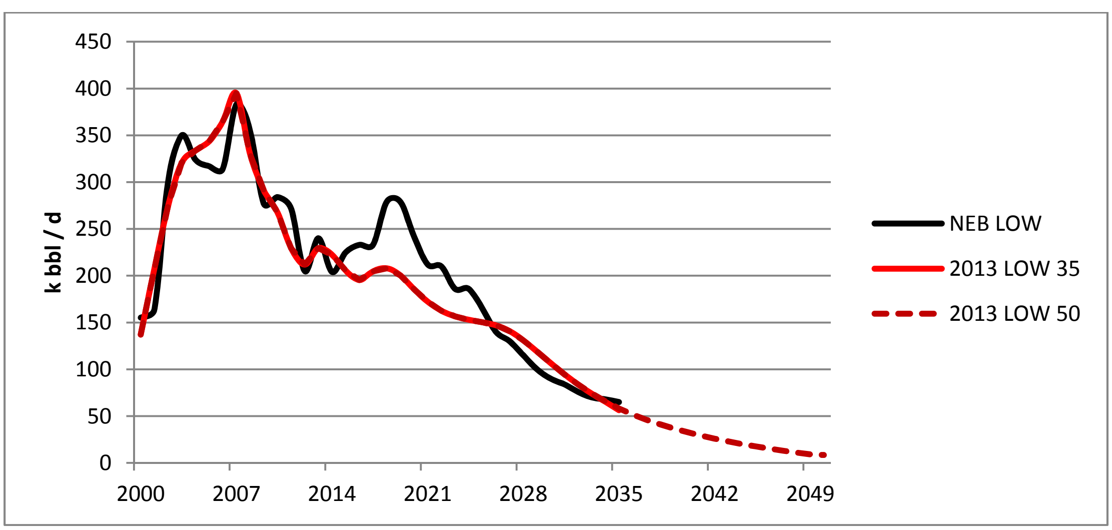


Figure 34. Oil imports by origin and by province in Eastern Canada in S2

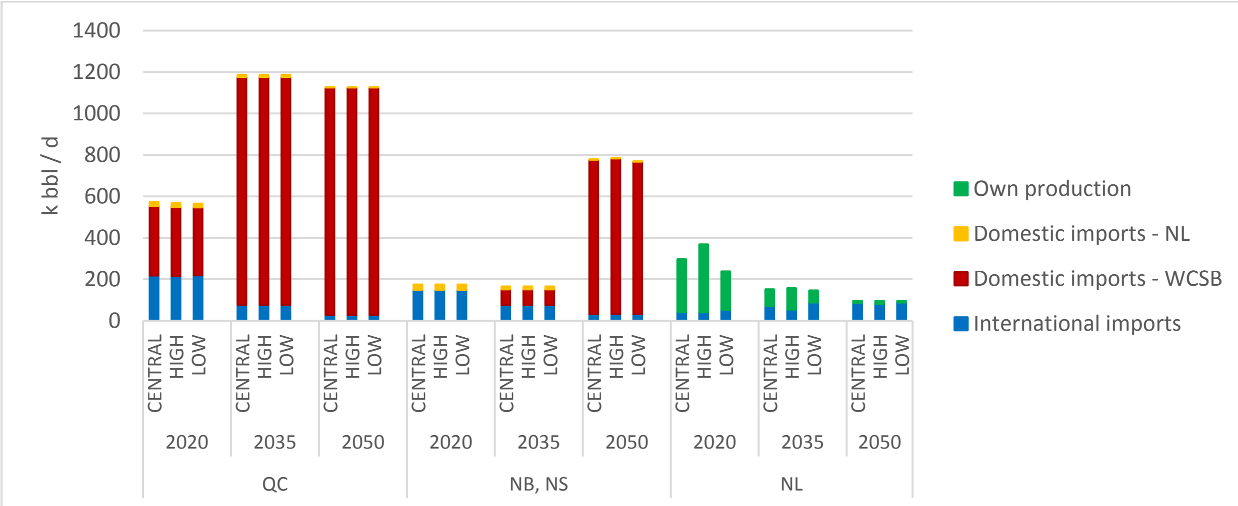


Figure 35. Oil imports by origin and by province in Eastern Canada in S3

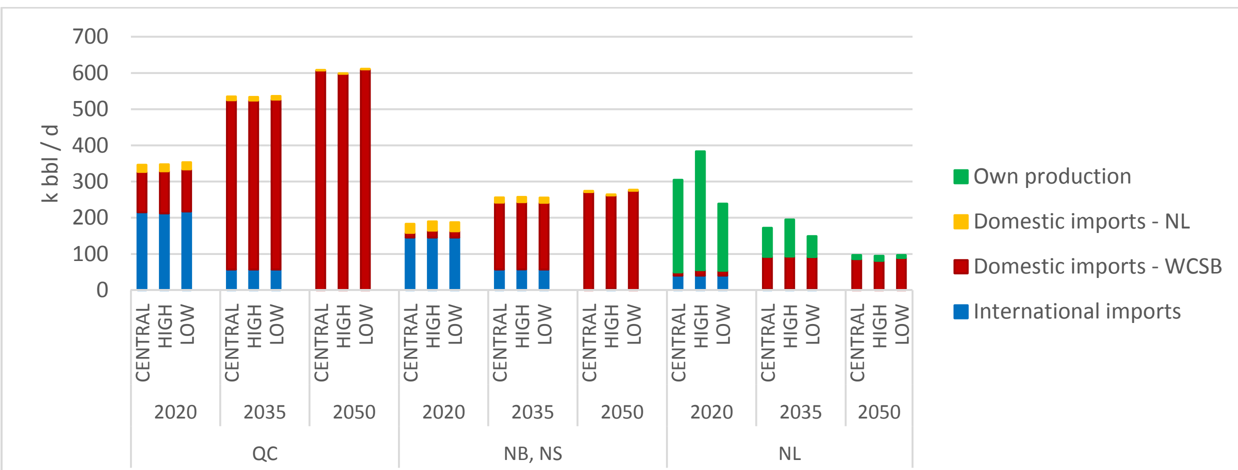


Figure 36. Oil imports by origin and by province in Eastern Canada in S4

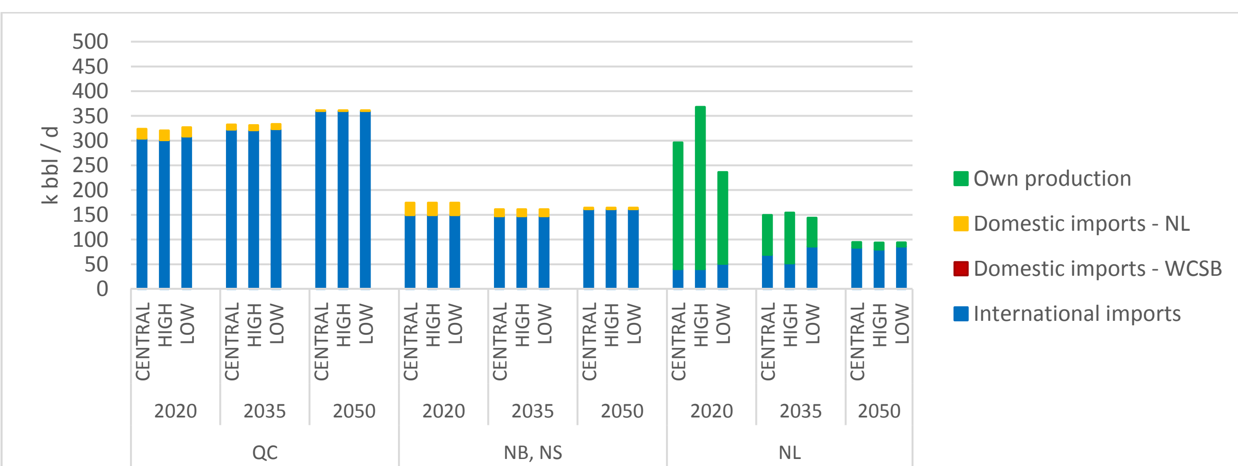


Figure 37. Oil demand by province in Eastern Canada in S2

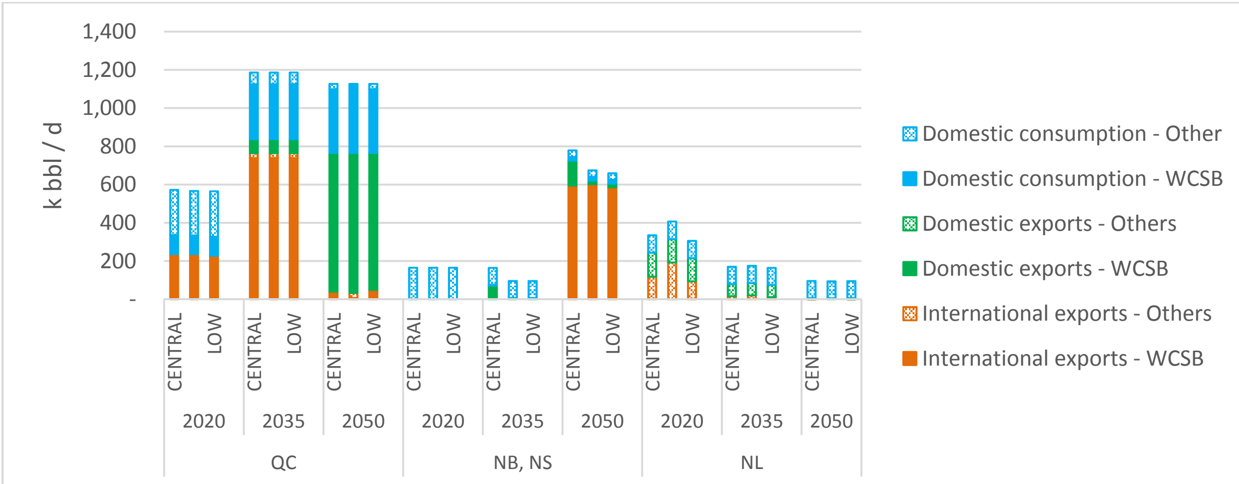


Figure 38. Oil demand by province in Eastern Canada in S3

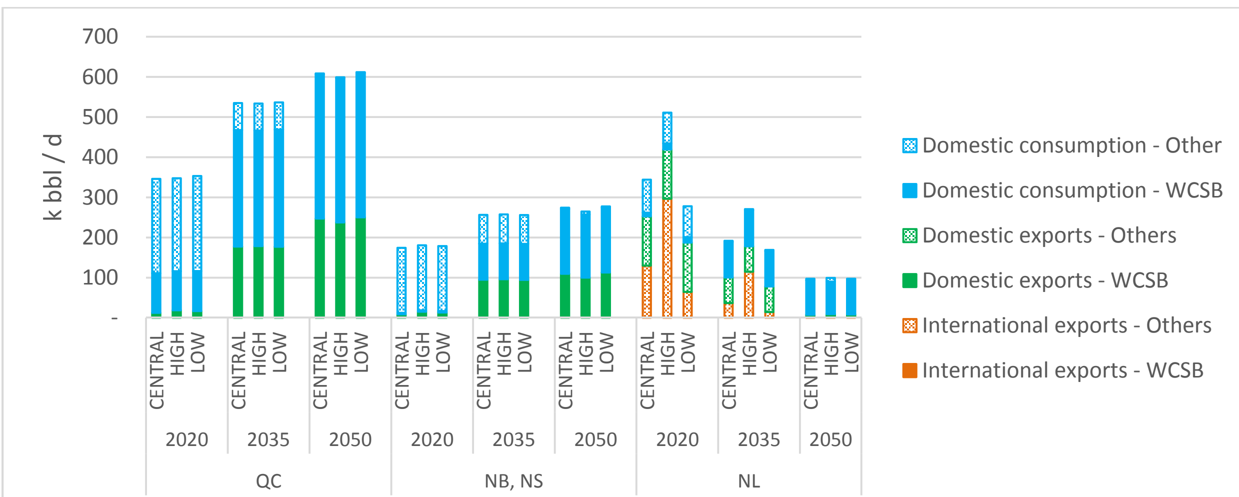
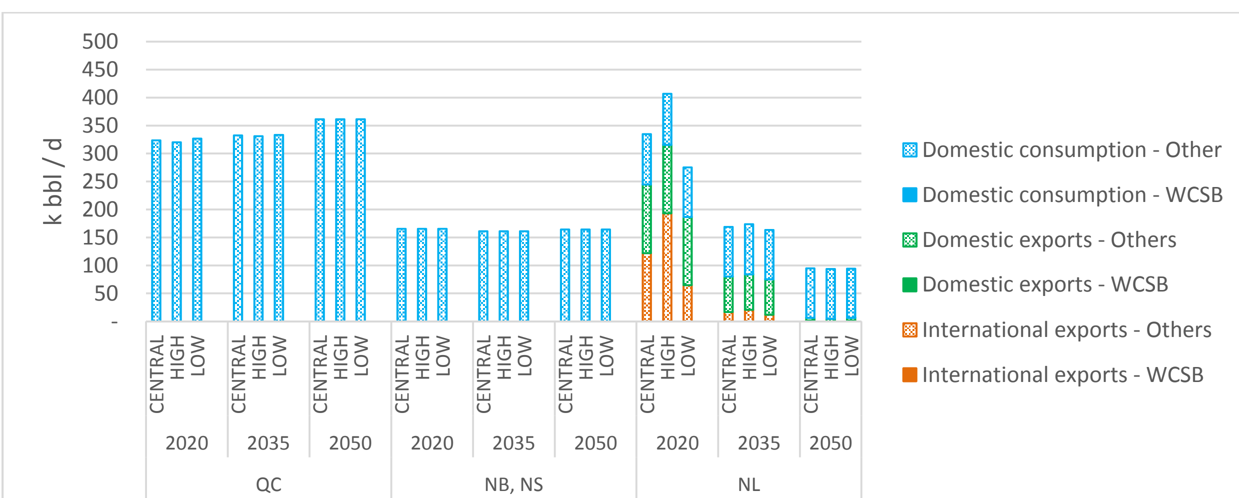


Figure 39. Oil demand by province in Eastern Canada in S4



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