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COMPETITIVE ANALYSIS OF THE CANADIAN PETROCHEMICAL SECTOR

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COMPETITIVE ANALYSIS OF THE CANADIAN PETROCHEMICAL SECTOR

Competitive Analysis of the Canadian Petrochemical Sector

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Executive Summary

This study examines the availability of petrochemical feedstock in Canada for the C1 through C3 value chains through 2030, and expands on CERI's September 2015 study, "Examining the Expansion Potential of the Petrochemical Industry in Canada" to assess Canada's competitive position in comparison to other petrochemical producing jurisdictions.

Globally, petrochemicals are frequently looked to as a means of economic diversification in economies who rely heavily on oil and gas revenues. As the Canadian economy has been negatively affected by the fall in oil and gas prices, Canada's petrochemical sector is an interesting one to look to for potential future growth.

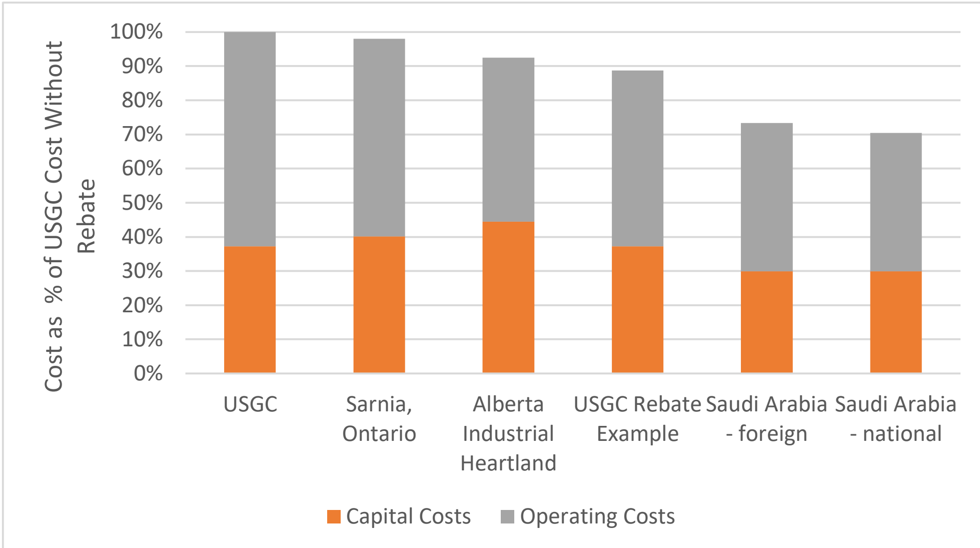
Canada's main source of petrochemical feedstock includes natural gas liquids (NGLs) from processing plants and off-gas plants for facilities in Alberta's Industrial Heartland area and Ontario's Chemical Valley.

There is potential for increased availability of petrochemical feedstock in Canada. Alberta is positioning itself to take advantage of this as it implements its Petrochemicals Diversification Program in order to capitalize on excess propane and methane.

CERI completed plant gate cost calculations for a new liquids and solids petrochemical facility in Alberta, Ontario, the US Gulf Coast (USGC) and Saudi Arabia in order to consider the competitiveness of Canada's petrochemical sector against some of its competitors. CERI also completed sample netback calculations, bringing in the cost of moving the product to market, comparing product sent to China from Alberta versus the US Gulf Coast.

Within the plant gate cost calculations, raw material inputs and facility systems and equipment are shown to represent the majority of the costs to construct and run petrochemical facilities across all jurisdictions for both liquids and solids facilities, with corporate taxes being significant for solids facilities. Raw material inputs and corporate taxes also see the most variability across jurisdictions, making them differentiators. A significant factor in making comparisons across jurisdictions is also the willingness of government, whether federal or regional (state/provincial/municipal), to providing incentives for investment. Taking project-specific incentives into consideration, relative costs of new liquids petrochemical facilities is shown in Figure E.1.

Figure E.1: Relative Costs of a New Liquids Petrochemical Facility, Including USGC Project-Specific Rebate

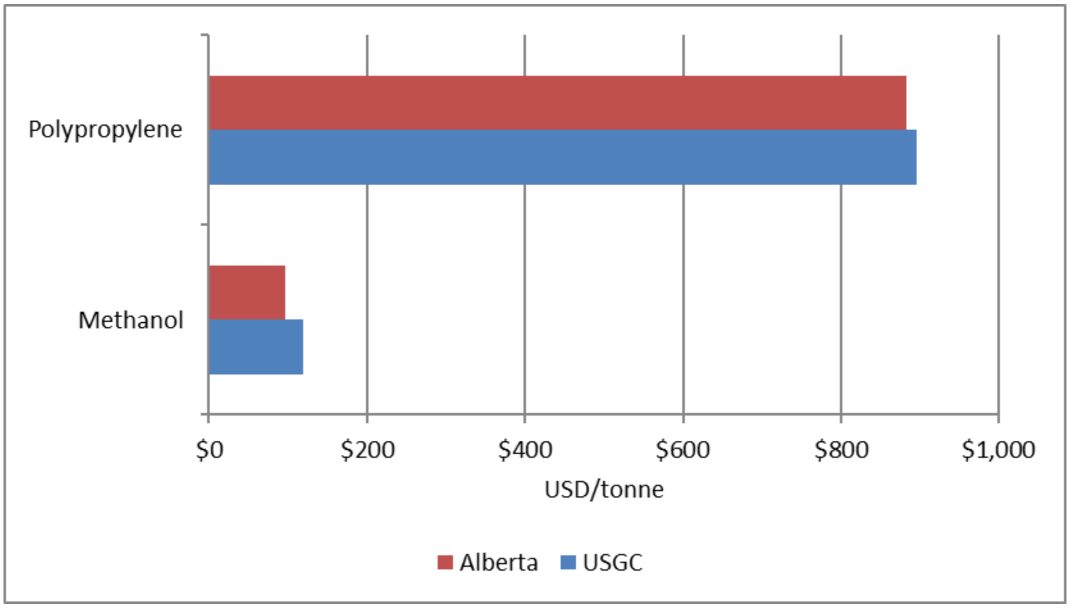


Source: CERI

While the USGC is initially shown to be the most expensive jurisdiction in which to construct and operate a petrochemical facility, it is actually positioned as less expensive than either Canadian jurisdiction once the project-specific rebate is taken into consideration. Saudi Arabia is consistently the least expensive jurisdiction in this comparison, both for a foreign and Saudi-owned company.

The USGC's competitive advantage against Canadian producers is also illustrated when looking at sample netback calculations, assuming polypropylene and methanol production from Alberta or the USGC going to Asia. The results of this calculation are shown in Figure E.2.

Figure E.2: Sample Netback Calculations



Source: CERI

CERI also considered variables that may not be reflected in either plant gate cost or netback calculations, including regulatory climate, integration of a region's petrochemical sector and access to market. Canadian regulation is viewed by industry as being clear and stable, although not as fast to work through as compared to US regulation. The Canadian petrochemical clusters in Alberta and Ontario, while integrated, do not see the same level of integration as other competing jurisdictions, which potentially serves as a deterrent to investment. Finally, the Canadian petrochemical industry does not have issues with access to market. Overall, the Canadian petrochemical industry is well positioned to compete favourably in the absence of government support in other regions.

Chapter 1: Canadian Petrochemical Feedstock Availability, Canadian and Global Clusters

Introduction

With Canada's GDP being negatively impacted by the low oil prices since mid-2014,[1] the issue of what opportunities exist for economic diversification is highly relevant. While Canada has an established petrochemical sector, this report looks at what conditions could make it more attractive to additional investment, as well as ranks competing petrochemical jurisdictions on various factors that contribute to investment appeal. In 2015, petrochemicals contributed 0.86 percent to Canada's GDP.[2] This report expands on the analysis done in CERI Study 153, "Examining the Expansion Potential of the Petrochemical Industry in Canada" published in August 2015, to break down plant gate costs across various petrochemical jurisdictions and examine Canada's competitive advantage.

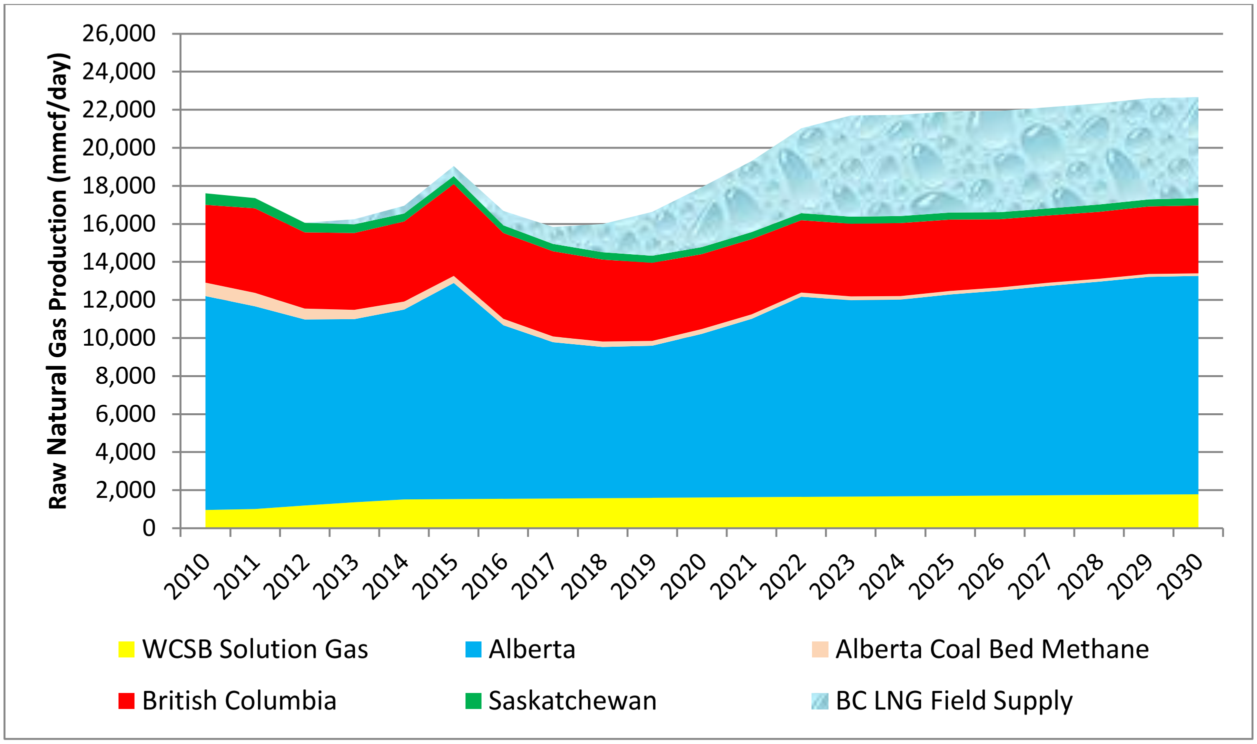
Feedstock Availability in Canada

In the Canadian context, the main sources of petrochemical feedstock include natural gas liquids (NGLs) from processing plants and off-gas plants as a feedstock for olefins or ethylene crackers in Alberta and Ontario. Crude bitumen, crude oil, and condensates processed at refineries are another feedstock, which yield Liquid Petroleum Gases (LPGs), as well as refinery naphtha and gas oils for steam crackers. This study looks at petrochemicals derived from NGLs stripped from a natural gas stream.

CERI modeled the availability of raw gas produced in the Western Canadian Sedimentary Basin (WCSB) from 2010 through 2030 and the results are shown in Figure 1.1.

[1] CERI, "Low Crude Oil Prices and Their Impact on the Canadian Economy", February 2016
[2] Statistics Canada, CANSIM Table 379-0031, accessed September 2016.

Figure 1.1: Raw Natural Gas Production in the WCSB: 2010-2030



Source: CERI, AER, BCOGC

This projection assumes that British Columbia will see an increase in natural gas production driven by demand from new Liquefied Natural Gas (LNG) facilities. This LNG demand will ramp up to 5.3 Bcf/day by 2022. Separate from the demand from LNG projects, the WCSB sees reduced production of natural gas from 2015 through 2019 as reduced drilling due to low natural gas prices works with high decline rates to lower production. Without new LNG production facilities, natural gas production flattens at around 17 Bcf/day.

A factor not taken into account in the modeling, but important to consider, is the potential for increase in production out of the WCSB due to new, lower, tolling agreements as TransCanada launches an open season on its Mainline.[3] Lower tolls would allow gas from the WCSB to flow into eastern markets currently serviced by the Dawn Hub in Ontario.

Methane

Methane, the simplest hydrocarbon, is the main component of natural gas. While the exact composition of natural gas can vary, the Alberta Energy Regulator (AER) estimates that methane makes up approximately 92 percent of raw natural gas.[4] NGLs are typically separated from raw natural gas in a gas processing facility, leaving methane to be used as a heating fuel. If methane is used as a petrochemical feedstock through a gas-to-liquids process, the resulting product is

[3] Daily Oil Bulletin, TransCanada Launches Open Season on New Mainline Tolling Option, October 13, 2016
[4] Alberta Energy Regulator, Natural Gas, accessed September 2016, http://www.aer.ca/data-and-publications/statistical-reports/natural-gas

methanol. Methanol can be used as an antifreeze or to produce biodiesel, or can be further processed into methyl methacrylate, polymethyl methacrylate, formaldehyde or methyl tert-butyl ether.

The methane in a natural gas stream can also be used as feedstock in order to create ammonia, an important component for fertilizers. While ammonia production is not considered elsewhere in this report, it is important to keep in mind as the industry has the potential for growth given the availability of natural gas. In 2008, the fertilizer industry used approximately eight percent of natural gas used within Canada.[5] Canada currently sees production of ammonia in Alberta, Saskatchewan, Manitoba and Ontario. Table 1.1 shows Canadian production of ammonia from 2006 through 2016.[6]

Table 1.1: Canadian Production of Ammonia: 2006-2016

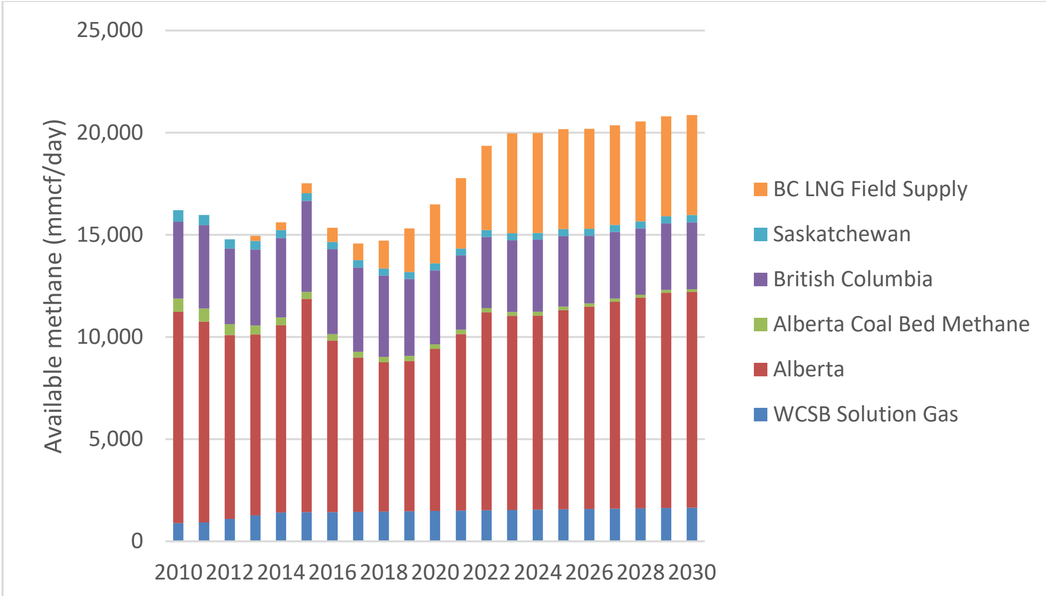
Year (July to June)	Volume (thousand tonnes)
2006/2007	4674
2007/2008	4614
2008/2009	4522
2009/2010	4440
2010/2011	4683
2011/2012	4749
2012/2013	4783
2013/2014	4545
2014/2015	4801
2015/2016	4919

Source: Statistics Canada, CANSIM Table 001-0067.

Figure 1.2 shows the methane available based on CERI's projection of natural gas production through 2030.

[5] Natural Resources Canada, Canadian Ammonia Producers: Benchmarking Energy Efficiency and Carbon Dioxide Emissions, 2008, http://publications.gc.ca/collections/collection_2009/nrcan/M144-155-2007E.pdf, p. 1.
[6] Statistics Canada, CANSIM Table 001-0067, accessed October 2016.

Figure 1.2: Available Methane: 2006-2030



Source: CERI, AER, BCOGC

By 2030, just over 15 Bcf/day of methane will be available in the absence of any new LNG projects. Reflecting the projected production of natural gas, volumes of available methane will decrease from 2015 through 2019 as low natural gas prices depress drilling rates. With current feedstock requirements for the Methanex Medicine Hat plant of 48 mmcf/day, there would be no shortage of available methane if economics dictated that the natural gas stream be diverted to methanol production.

The 2010 Canadian demand for methanol is shown in Table 1.2.[7]

Table 1.2: Canadian Demand for Methanol (2010)

Application	% of Total Canadian Demand
Formaldehyde (resins)	60-70%
Oil and Gas Field Chemical	10-15%
Chlorine Dioxide (Wood Pulp Bleaching)	10-15%
Windshield Washer	10-15%
Fuels (Biodiesel)	1-5%
Paints and Coatings, Adhesives, Sealants, Cleaning, other	<5%
Total (kilotonnes, 2010)	**600-700**

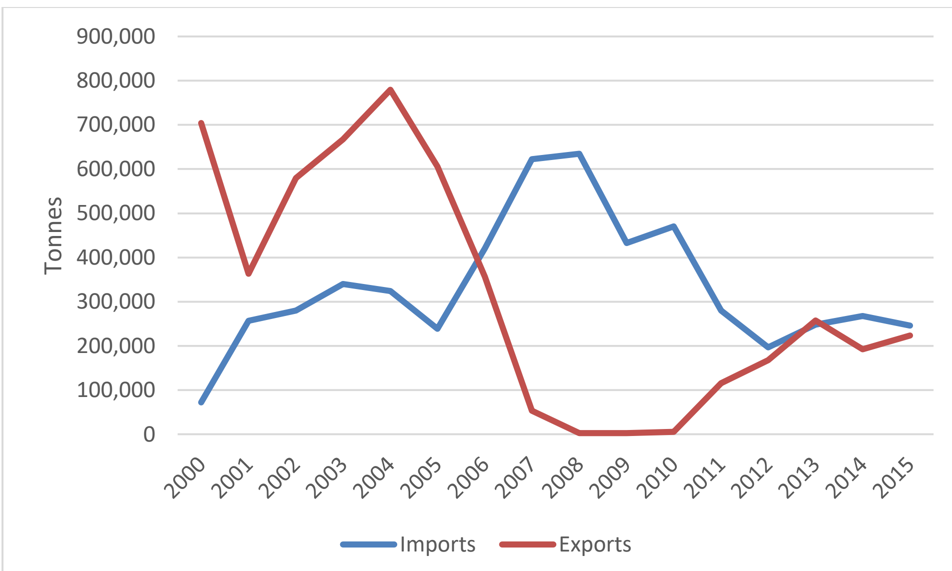
Source: ChemInfo, Bio Based Chemical Import Replacement Initiative, January 2014.

[7] ChemInfo, Bio Based Chemical Import Replacement Initiative, January 2014, https://www.albertacanada.com/files/albertacanada/BioBased-Chemical-Import-Replacement-Report_Full-Report(237_pages).pdf, pp. 162

While in the past Canada was a more active player in methanol production, four producing plants were closed between 2001 and 2006[8] when the price of natural gas feedstock was as high as $12/MMBtu. Canadian methanol production is now ramping up again, both as a biofuel and using natural gas as feedstock. In 2010, Methanex Corporation announced that it would restart its previously closed methanol plant in Alberta,[9] and the facility now produces 0.6 million tonnes of methanol annually.[10] From a 2014 report done for the Government of Alberta by Cheminfo, "Imports and exports of methanol in Alberta clearly show when the Alberta Methanex facility began production. Prior to 2011, when the Methanex facility was not operational, there were substantial imports of methanol (79,820 tonnes [T] in 2010) and a negative trade balance. However, in 2011, as the Methanex facility began production, this trade balance shifted. In 2012, Alberta exported 136,370 tonnes more methanol than they imported."[11]

Canada's imports and exports of methanol over the past 15 years, as reported by Statistics Canada in the Canadian International Merchandise Trade Database are shown in Figure 1.3:

Figure 1.3: Canada's Imports and Exports of Methanol: 2000-2015



Source: Statistics Canada, Canadian International Merchandise Trade Database, Trade Commodity 290511

Global demand for methanol is expected to rise as it is a clean-burning energy source. Canadian players have already started to position themselves in preparation for this increase in demand,

[8] Alberta Oil, A methanol renaissance in Canada refuels the biofuels debate, September 22, 2014, http://www.albertaoilmagazine.com/2014/09/refueling-biofuels-debate/

[9] Methanex website, Methanex Plans to Restart its Methanol Plant in Medicine Hat, Alberta, September 8, 2010, https://www.methanex.com/news/methanex-plans-restart-its-methanol-plant-medicine-hat-alberta

[10] Methanex website, Medicine Hat, accessed September 2016, https://www.methanex.com/location/north-america/medicine-hat

[11] ChemInfo, Bio Based Chemical Import Replacement Initiative, January 2014, https://www.albertacanada.com/files/albertacanada/BioBased-Chemical-Import-Replacement-Report_Full-Report(237_pages).pdf, pp. 165

with Canadian Methanol Corporation planning a methanol plant for British Columbia with an expected output of 5,000 T per day.[12] Primus Green Energy has also announced plans to invest in a 160 T per day methanol plant in Alberta in June of 2016.[13]

Alberta's recently announced Petrochemicals Diversification Program is a relevant factor in possible new investment in methanol production in the province. The program, announced on February 1, 2016, will see $500 million in total royalty credits awarded to up to three new petrochemical facilities.[14,15] These credits, to be paid out over three years after the facility has started producing, can be traded to an oil or natural gas producer, facilitating an agreement for reduced feedstock costs for the petrochemical producer in return for reduced royalty payments from the oil or natural gas producer. The Government of Alberta intends to encourage investments in methane and propane upgrading, specifically, due to the abundance of the commodities in the province. At the time of writing, the Government had not announced the winning projects; 16 applications were received,[16] with Primus Green Energy's methanol plant being one of the applicants.[17]

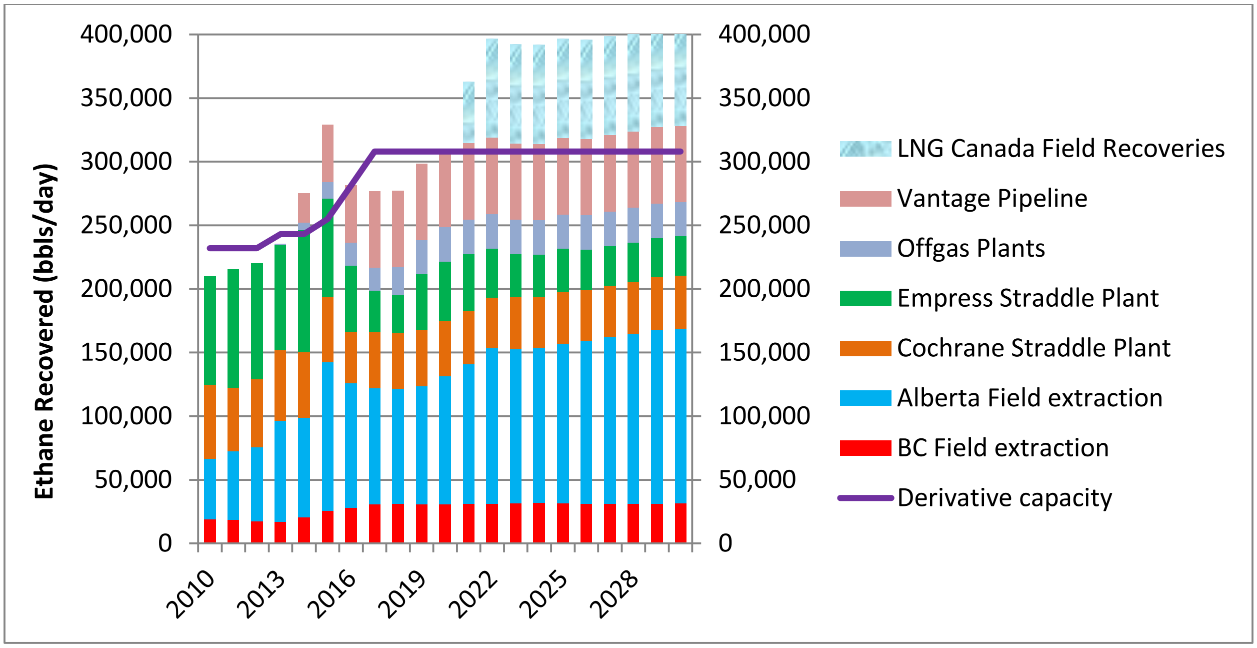
Ethane

Ethane is the smallest-chain NGL that is separated from a natural gas stream. It can be used to produce ethylene, which has a large variety of possible derivatives, including ethylbenzene, polyethylenes, ethanol, acetaldehyde and ethylene oxide, which can all further be processed into plastics, rubbers, solvents and polyesters. During the 1980s and 90s some ethane volumes were also used for enhanced oil recovery (EOR).

Figure 1.4 shows the volume of ethane with the potential to be recovered from the natural gas stream in the WCSB between 2010 and 2030. The figure illustrates that there might be excess ethane beyond the derivative capacity in Alberta and British Columbia if gas is produced to meet LNG demand. In other words, if this excess ethane is not recovered it might be rejected (i.e., left in the gas stream).

[12] Yahoo! Finance, Primus Green Energy Announces Launch of Second North American Methanol Plant Project, Slated for 2018 Delivery in Alberta, June 21, 2016, http://finance.yahoo.com/news/primus-green-energy-announces-launch-130000511.html
[13] http://www.newswire.ca/news-releases/primus-green-energy-announces-launch-of-second-north-american-methanol-plant-project-slated-for-2018-delivery-in-alberta-583776231.html
[14] Government of Alberta, Alberta takes significant step toward diversifying economy, February 1, 2016, http://www.alberta.ca/release.cfm?xID=401612BEB9080-C4D9-B4D5-F7DD7DFD99A7D80C
[15] Government of Alberta, Department of Energy, Diversifying Alberta's petrochemicals sector, February 2016, http://www.energy.alberta.ca/Org/pdfs/FSpetrochemPDP.pdf
[16] Government of Alberta, Petrochemicals Diversification Program attracts significant interest from global investors, June 6, 2016, http://www.alberta.ca/release.cfm?xID=4187883D09635-B916-78DF-DB31D033C5201F5A
[17] Edmonton Journal, Primus Green Energy planning new methanol plant in northwestern Alberta, June 21, 2016, http://edmontonjournal.com/business/energy/primus-green-energy-planning-new-methanol-plant-in-northwestern-alberta

Figure 1.4: Recovered Ethane: 2010-2030



Source: CERI, AER, BCOGC

As with methane, volumes of produced ethane will drop from 2015 through 2019. A rise in ethane volumes will be seen after 2019 as drilling rates start to overcome the high decline rates that the natural gas wells see. By 2030, approximately 320,000 bbls/day of ethane will be supplied, including Vantage imports, in the absence of new LNG projects in BC. Including additional ethane from natural gas additions to satisfy new LNG plants, approximately 400,000 bbls/day of ethane will be available by 2030. This leaves 80,000 to 100,000 bbls/day of ethane that potentially might be rejected.

The Government of Alberta implemented its Incremental Ethane Extraction Program (IEEP) in 2006 which saw the government give $250 million in Fractionation Credits to petrochemical companies upgrading ethane and ethylene. The primary purpose of the program was to encourage more value-added industry in Alberta by addressing the tight supply of ethane feedstock in order to fully utilize existing petrochemical capacity in the province. The program was designed to encourage investments in ethane extraction facilities as well as to attract possible future investment in petrochemical derivative plants.[18] In CERI Study 139, "Natural Gas Liquids (NGLs) in North America – An Update: Part II – Midstream and Downstream Infrastructure",[19] CERI estimated that close to 90 kb/d of incremental C2 was approved under

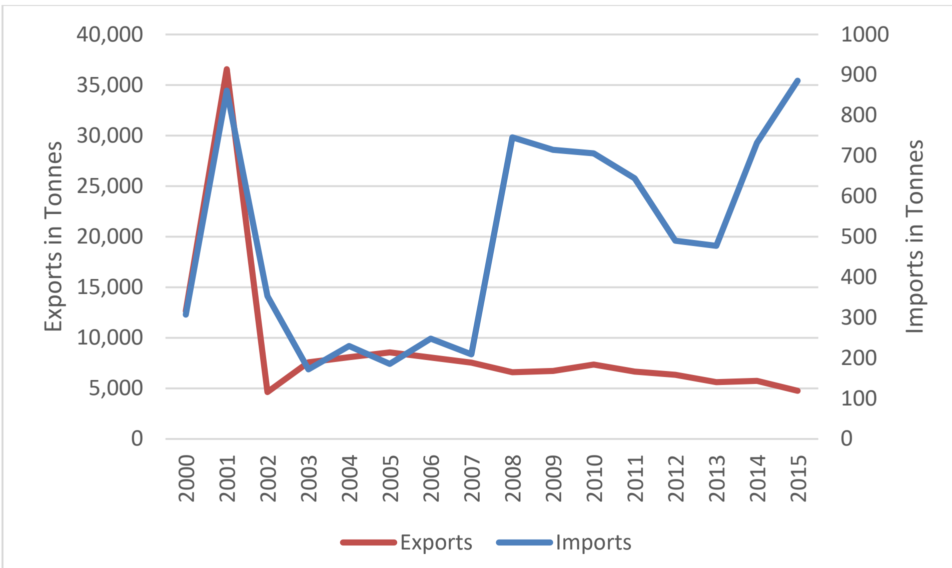
[18] For more on the IEEP see: http://www.energy.alberta.ca/Org/pdfs/IEEP_Guidelines_June_1_2011.pdf
[19] CERI, Natural Gas Liquids (NGLs) in North America – An Update: Part II – Midstream and Downstream Infrastructure, May 2014.

the program between 2008 and 2012, with $4B in investment tied directly[20] (45 percent) and indirectly[21] (55 percent) to the program.

Ethane demand comes primarily from olefin crackers in Alberta. However, historically, ethane has moved from Alberta to Ontario to satisfy demand in the Sarnia market, while some ethylene has also moved from Alberta to Ontario, thus reflecting the ethylene capacity surplus position in Alberta. Ethane and ethylene transfers from Alberta to Ontario stopped around the 2007-08 timeframe as the Cochin pipeline was forced to stop deliveries. This in turn led to the closure of Dow Chemicals' derivative plants in ON.[22]

In looking at Canadian imports and exports of ethylene from 2000 through 2015, as shown in Figure 1.5, Canada's growing imports of ethylene show opportunity to fill domestic demand if the economics dictate domestic production to be preferable to imports.

Figure 1.5: Canada's Imports and Exports of Ethylene: 2000-2015



Source: Statistics Canada, Canadian International Merchandise Trade Database, Trade Commodity 290121

Propane

Propane is an NGL that is separated from a natural gas stream and used as a fuel or further processed to produce propylene. Propylene can be further processed into a large number of derivatives, including acrylonitrile, cumene, propylene oxide, polypropylene, acrylic acid, butyraldehyde and isopropanol. These derivatives can be used to manufacture a number of consumer products including plastics, textiles, coolants, glass, adhesives, solvents and

[20] Extraction plant builds, modifications and expansions for incremental ethane extraction

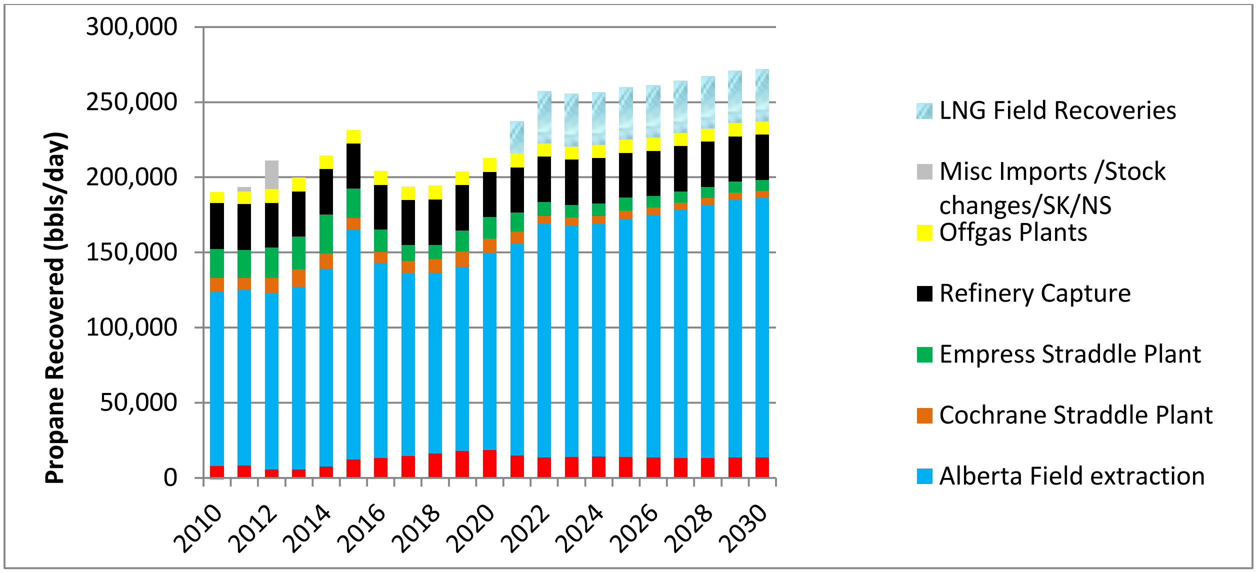
[21] Required expansions and modifications in pipeline and fractionation capacity to get incremental C2 volumes to end-users

[22] August 31, 2006, CBC News, Business: *Dow closing operations in Sarnia, Fort Saskatchewan*: http://www.cbc.ca/news/business/dow-closing-operations-in-sarnia-fort-saskatchewan-1.580276

pharmaceuticals. Propane is the most versatile of the NGLs. Its use in Canada is primarily as an energy source or a fuel.

Figure 1.6 shows the volume of propane recovered from the natural gas stream in the WCSB between 2010 and 2030.

Figure 1.6: Recovered Propane: 2010-2030



Source: CERI, AER, BCOGC

As with methane and ethane, volumes of produced propane will drop from 2015 through 2019. Increasing propane volumes will be seen after 2019, as increasing drilling rates outweigh the gas wells' high decline rates. By 2030, approximately 240,000 bbls/day of propane will be recovered in the absence of new LNG projects in BC. Including additional propane available from natural gas additions to satisfy new LNG plants, approximately 275,000 bbls/day of ethane will be recovered by 2030.

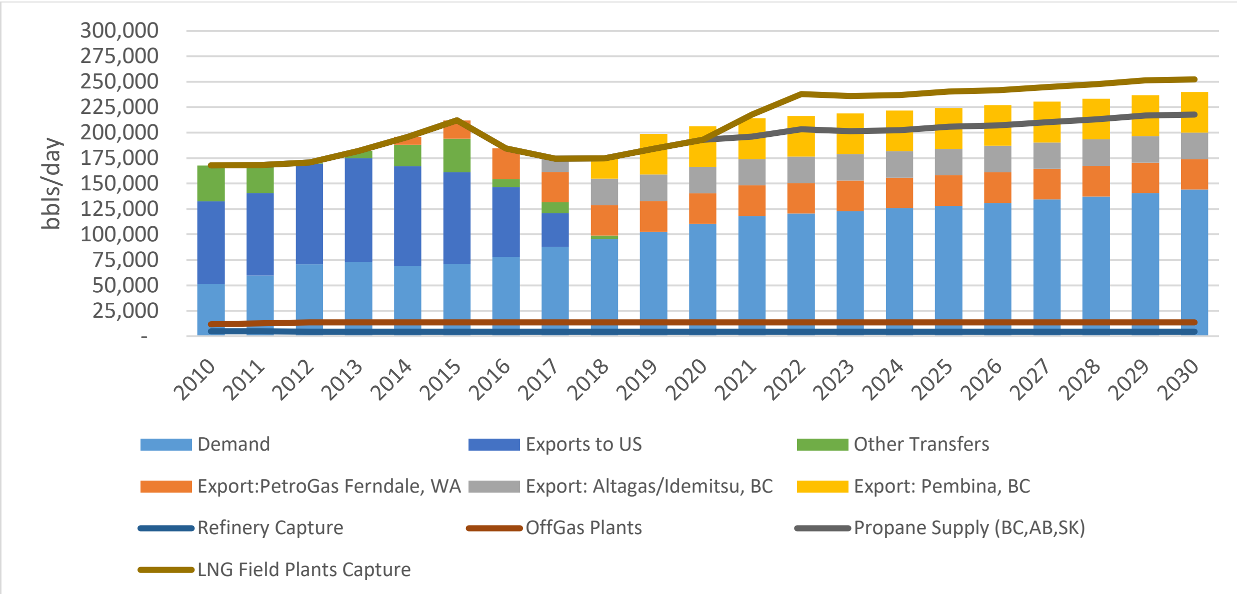
Propane production is almost evenly split between western[23] and eastern[24] Canada. Field extraction from both BC and Alberta shows the most variability, while propane recoveries from the Cochrane and Empress Straddle Plants show continuously decreasing volumes.

Propane use in the mining, oil and gas extraction sector as well as the manufacturing sector is primarily for the purposes of heating, equipment fuel, or power generation. Canadian production of propane is currently slightly greater than Canadian demand, and is likely to remain greater in

[23] Includes: British Columbia (BC), Alberta (AB), Saskatchewan (SK), and Manitoba (MB)
[24] Includes: Ontario (ON), Quebec (QC), New Brunswick (NB), Nova Scotia (NS), and Newfoundland (NFLD). The single largest production source in this region is the Sarnia fractionator which is fed with WCSB NGL mixes via the Enbridge system

the medium term. This imbalance of supply and demand was reflected by the negative spot prices seen in 2015 at Edmonton.[25] This is highlighted in Figure 1.7.

Figure 1.7: Propane Potential Disposition: 2010-2030



Source: CERI, AER, BCOGC

As Figure 1.7 illustrates, demand will exceed supply when Pembina's propane export terminal starts to operate, if LNG projects do not come online and increase the propane supply.

Alberta's Petrochemicals Diversification Program is intended to take advantage of the large quantity of propane (as well as methane) feedstock available and may dampen the supply and demand imbalance for the commodity. A propane dehydrogenation plant proposed by Williams prior to its being bought by Inter Pipeline is the subject of an application under the Program. The plant will have a capacity of 525,000 tonnes per year of propylene with an expected in-service date of 2019.[26] The facility will be built near Edmonton, Alberta, in close proximity to a fractionator which will provide the feedstock. Inter Pipeline expects a final investment decision to be made by the end of 2016, with an expected in-service date of 2020.[27] Pembina Pipeline Corp. announced in April of 2016 that it is examining the possibility of a propane dehydrogenation and polypropylene upgrading facility to produce polypropylene plastic pellets. The plant would have a capacity of 800,000 tonnes per year of polypropylene, for export to North American and international markets. The investment decision is expected to be made by 2017, with an expected in-service date of 2020.[28]

[25] https://rbnenergy.com/no-where-to-run-no-where-to-hide-the-great-edmonton-propane-givaway
[26] http://www.ogj.com/articles/2015/10/williams-advances-proposed-alberta-pdh-unit.html
[27] Inter Pipeline website, Inter Pipeline Announces $1.35 Billion Acquisition of Canadian NGL Midstream Business, August 8, 2016, http://www.interpipeline.com/news/news-releases.cfm?newsReleaseAction=view&releaseId=305
[28] http://www.pembina.com/media-centre/news-releases/news-details/?nid=135321

AltaGas is planning development of a propane export terminal off the west coast of BC at Prince Rupert.[29] The terminal will have a capacity of 1.2 million tonnes per year over 20 to 30 marine shipments. The final investment decision is expected to be made by the end of 2016, with operation to begin in 2018.

Canadian Regional Clusters

In Canada, there are three major petrochemical clusters. These are located in Alberta (Joffre and Fort Saskatchewan), Ontario (Sarnia-St. Clair), and Québec (East Montreal). Further details on these regional clusters are described below.

Alberta

In Alberta, the petrochemical industry is primarily based on ethylene cracking facilities (olefins) (about 92 percent of petrochemical production capacity), while there is also an aromatics-based facility (at the Shell Scotford site) and a methanol facility owned by Methanex in Medicine Hat. Steam crackers in Alberta are configured to use ethane as a feedstock with a small degree of flexibility to crack some volumes of propane when ethane supply is constrained or when propane offers a cost advantage. This highlights the fact that the petrochemical industry in Alberta is reliant on the supply of NGLs, primarily ethane, which is tied to production and processing of natural gas. For a more detailed description of petrochemical groups, one can refer to Chapter 1 of CERI's study 153, "Examining the Expansion Potential of the Petrochemical Industry in Canada", released in August 2015. The following information on petrochemical clusters in the country is based on the information released in that study, with updates on capacity additions as well as including the production of methanol from the natural gas stream.

Table 1.3 displays Alberta olefin facilities together with the respective ethylene derivative plants and aromatic plants (as parts of refining complexes) from where benzene, tolyene and xylenes are produced for end-use products.

[29] AltaGas website, Ridley Island Propane Export Terminal, accessed July 2016, http://www.altagas.ca/our-infrastructure/projects/ridley-island-propane-export-terminal

Table 1.3: Alberta Petrochemical Plant Information (2016)

ALBERTA						
Company	Facility	Location	Main Product	Plant Capacity (kt/yr)	Feedstock	Required Feedstock (kb/d)
Ethylene Crackers (Olefins)						
NOVA Chemicals	Ethylene 1 (E1)	Joffre Complex, AB	Ethylene	726	C2/ Some C3	45
NOVA Chemicals	Ethylene 2 (E2)	Joffre Complex, AB	Ethylene	816	C2/ Some C3	51
NOVA Chemicals (50%)/ Dow Chemicals (50%)	Ethylene 3 (E3)	Joffre Complex, AB	Ethylene	1,270	C2	79
Dow Chemicals	Dow Fort Saskatchewan (LHC1)	Fort Saskatchewan, AB	Ethylene	1,285	C2	80
Total Ethylene Crackers				***4,097***		***255***
Aromatics Plants						
Shell Canada	Shell Scotford Refinery	Scotford, AB	Benzene	370	Crude Oil	n/a
Total Aromatics				***370***		
Ethylene Derivatives						
						Required Feedstock (kt/yr)
Polyethylene and Similar Products						
NOVA Chemicals	Polyethylene 1 (PE1)	Joffre Complex, AB	LLDPE	1,112	Ethylene	949
NOVA Chemicals	Polyethylene 2 (PE2)	Joffre Complex, AB	LLDPE & HDPE	431	Ethylene	435
INEOS Oligomers	Joffre Linear Alpha Olefins (LAO) Plant	Joffre Complex, AB	LAO	250	Ethylene	253
Dow Chemicals	Prentiss PE	Red Deer, AB	LLDPE	500	Ethylene	505
Dow Chemicals	Fort Saskatchewan PE	Fort Saskatchewan, AB	LLDPE	850	Ethylene	859
Celanese (AT Plastics)	Edmonton EVA Manufacturing Plant	Edmonton, AB	LDPE, EVA	143	Ethylene	61
Total				***3,286***		***3,061***
Ethylene Glycol						
ME Global (50% owned by Dow Chemicals)	Prentiss I Ethylene Oxide/ Ethylene Glycol (EO/EG) Plant	Red Deer, AB	MEG	310	Ethylene	179
ME Global (50% owned by Dow Chemicals)	Prentiss II EO/EG Plant	Red Deer, AB	MEG	285	Ethylene	165
ME Global (50% owned by Dow Chemicals)	Fort Saskatchewan (FS) 1EO/ EG Plant	Fort Saskatchewan, AB	EO/EG	350	Ethylene	202
Shell Chemicals Canada Ltd.	Shell Chemicals Scotford Manufacturing Monoethylene Glycol (MEG) Plant	Scotford, AB	MEG	450	Ethylene	260
Total				***1,395***		***806***
Styrene Monomer						
Shell Chemicals Canada Ltd.	Shell Chemicals Scotford Manufacturing Styrene Monomer (SM) Plant	Scotford, AB	SM	450	Ethylene	121
					Benzene	365
Total				***450***		***486***
Other Facilities						
Keyera Corp.	Alberta EnviroFuels (AEF)	Edmonton, AB	Iso-octane	521	Field Butanes (f-C4)	n/a
Williams Canada	Redwater Fractionator/ Propylene Plant	Redwater, AB	PGP	68	SGLs Mix	n/a
Methanex	Medicine Hat Methanol Facility	Medicine Hat, AB	Methanol	600	Natural Gas	48,154 mcf/day
Total				***589***		***48,154 mcf/day***

Sources: Data from AED,[30] AIEM,[31] BMI,[32] CERI research,[33] MEI,[34] Industry data,[35,36] GOA[37], OGJ data,[38] and Sarnia-Lambton Economic Partnership.[39] Tables by CERI.

[30] Alberta Chemical Operations, Alberta Economic Development (AED), May, 2000: http://www.nelson.com/albertascience/0176289305/student/weblinks/documents/ChemicalOperationsDirectory.pdf

[31] Association Industrielle de l'est de Montreal (AIEM), Membres et types d'industries: http://www.aiem.qc.ca/index.php?option=content&task=view&id=11&Itemid=106

[32] Business Monitor International (BMI), Canada Petrochemicals Report, 2013: http://www.marketresearch.com/Business-Monitor-International-v304/Canada-Petrochemicals-7287960/

[33] Including: Canadian Energy Research Institute (CERI): The Sarnia Complex, Synergies and Strategies, Study No. 68. December, 1995

[34] Montreal Economic Institute (MEI), the Economic Benefits of Pipeline Projects to Eastern Canada: http://www.iedm.org/files/note0813_en.pdf

[35] Capacity for Nova Chemicals' PE1 facility includes expected additions from the PE1 expansion project, set to come online at the end of 2016, http://www.novachem.com/ExWeb%20Documents/joffre/PE1_Fact_Sheet.pdf,

[36] Methanex website, accessed September 2016, https://www.methanex.com/location/north-america/medicine-hat, required feedstock calculated using syngas production method, assuming natural gas at 92% methane

[37] Alberta Department of Energy, July 13, 2015, http://www.energy.alberta.ca/Org/pdfs/EthExtFacMap.pdf

[38] Oil & Gas Journal (OGJ), International Survey of Ethylene From Steam Crackers – 2013: http://www.ogj.com/articles/print/volume-111/issue-7/special-report-ethylene-report/international-survey-of-ethylene-from.html

[39] Sarnia-Lambton Petrochemical and Refining Complex, October 2013: http://www.sarnialambton.on.ca/medialibrary/5/S_L_PETROCHEM_BROCH.pdf

Ontario

Table 1.4 displays Ontario olefin facilities together with the respective ethylene derivative plants and aromatic plants from where BTX (benzene, toluene, xylenes) is produced for end-use products.

Table 1.4: Ontario Petrochemical Plant Information (2016)

ONTARIO						
Company	Facility	Location	Main Product	Plant Capacity (kt/yr)	Feedstock	Required Feedstock (kb/d)
Ethylene Crackers (Olefins)						
NOVA Chemicals	Corunna, Ethylene	Corunna, ON	Ethylene	839	C2,C3,C4,C5+	67
Imperial Oil Products & Chemicals	Imperial Sarnia	Sarnia, ON	Ethylene	300	C2,C3,C4,C5+	23
Total Ethylene Crackers				*1,139*		*90*
Aromatics Plants						
Benzene						
Imperial Oil	Imperial Sarnia	Corunna, ON	Benzene	110	Crude Oil/ NGLs	n/a
Nova Chemicals	Corunna, Ethylene	Sarnia, ON	Benzene	120	Crude Oil/ NGLs	n/a
Shell	Shell Sarnia	Sarnia, ON	Benzene	60	Crude Oil	n/a
Sunoco Chemicals (Suncor)	Suncor Sarnia	Sarnia, ON	Benzene	50	Crude Oil	n/a
Total Benzene				*340*		
Toluene						
Imperial Oil	Imperial Sarnia	Sarnia, ON	Toluene	85	Crude Oil/ NGLs	n/a
Shell	Shell Sarnia	Sarnia, ON	Toluene	130	Crude Oil	n/a
Sunoco Chemicals (Suncor)	Suncor Sarnia	Sarnia, ON	Toluene	207	Crude Oil	n/a
Total Toluene				*422*		
						Required Feedstock (kt/yr)
Ethylene Derivatives						
Polyethylene and Similar Products						
NOVA Chemicals	St. Clair River, Corunna, ON PE	Corunna, ON	HDPE	204	Ethylene	194
NOVA Chemicals	Mooretown, ON PE	Mooretown, ON	HDPE	211	Ethylene	200
NOVA Chemicals	Mooretown, ON PE	Mooretown, ON	LDPE	170	Ethylene	161
Imperial Oil Products & Chemicals	Sarnia PE	Sarnia, ON	HDPE	470	Ethylene	446
Total				*1,055*		*1,002*
Styrene Monomer						
Styrolution	Styrolution Sarnia Production Site	Sarnia, ON	SM	431	Ethylene	116
					Benzene	339
Total				*431*		*455*
Other Facilities						
Lanxess Inc.	Sarnia Site	Sarnia, ON	Butyl Rubber	150	Mixed C4's, Butylene, Butadiene, Styrene,	n/a
Total				*150*		

Sources: Data from AED,[40] AIEM,[41] BMI,[42] CERI research,[43] MEI,[44] Industry data, OGJ data,[45] and Sarnia-Lambton Economic Partnership.[46]

[40] Alberta Chemical Operations, Alberta Economic Development (AED), May, 2000: http://www.nelson.com/albertascience/0176289305/student/weblinks/documents/ChemicalOperationsDirectory.pdf

[41] Association Industrielle de l'est de Montreal (AIEM), Membres et types d'industries: http://www.aiem.qc.ca/index.php?option=content&task=view&id=11&Itemid=106

[42] Business Monitor International (BMI), Canada Petrochemicals Report, 2013: http://www.marketresearch.com/Business-Monitor-International-v304/Canada-Petrochemicals-7287960/

[43] Including: Canadian Energy Research Institute (CERI): The Sarnia Complex, Synergies and Strategies, Study No. 68. Dec, 1995

[44] MEI, the Economic Benefits of Pipeline Projects to Eastern Canada: http://www.iedm.org/files/note0813_en.pdf

[45] Oil & Gas Journal (OGJ), International Survey of Ethylene From Steam Crackers – 2013: http://www.ogj.com/articles/print/volume-111/issue-7/special-report-ethylene-report/international-survey-of-ethylene-from.html

[46] Sarnia-Lambton Petrochemical and Refining Complex, October 2013: http://www.sarnialambton.on.ca/medialibrary/5/S_L_PETROCHEM_BROCH.pdf

In Ontario, about 60 percent of the province's petrochemical capacity is based on olefins and 40 percent on aromatics (toluene and benzene). Historically, feedstock for olefin facilities have been sourced from western Canada (NGLs and crude oil/condensate),[47] and local refineries (LPG). Aromatics-based facilities sourced their feedstock from local refineries (which in turn source their crude oil from western Canada and overseas) and local olefin crackers. More recently, NGLs (primarily ethane and propane) are being imported from the United States to feed steam crackers. Increased connectivity with western Canada has diminished crude oil refining and aromatics-based facilities' dependence on crude oil imports.

Québec

In Québec, the industry is based on aromatics (benzene and toluene) primarily produced at the Suncor refinery. In 2008, the Petromont ethylene cracker, the only olefins-based facility, was closed down. Table 1.5 displays Québec facilities together with the respective derivative plants.

Table 1.5: Québec Petrochemical Plant Information (2016)

QUEBEC						
Company	Facility	Location	Main Product	Plant Capacity (kt/yr)	Feedstock	Required Feedstock (kt/yr)
Aromatics Plants						
Benzene						
Suncor	Suncor Refinery/ Petrochemicals	Montreal, QC	Benzene	350	Crude Oil	n/a
Total				***350***		
Toluene						
Suncor	Suncor Refinery/ Petrochemicals	Montreal, QC	Toluene	240	Crude Oil	n/a
Total				***240***		
Other Facilities						
Aromatics Derivatives						
p-Xylene						
ParaChem Chemicals (Suncor)	Montreal Site	Montreal, QC	p-Xylene	350	Benzene & Toluene	n/a
Total				***350***		
Xylene/PTA Derivatives						
Interquisa Canada (CEPSA Chimie)	Montreal Site	Montreal, QC	PTA	500	p-Xylene	350
Selenis	Montreal Site	Montreal, QC	PET	150	PTA	345

Sources: Data from AED,[48] AIEM,[49] BMI,[50] CERI research,[51] MEI,[52] Industry data, OGJ data,[53] and Sarnia-Lambton Economic Partnership.[54]

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[47] Nova Chemicals had a refining facility to separate light crude and condensate into LPG, naphtha, and aromatic fractions

[48] Alberta Chemical Operations, Alberta Economic Development (AED), May, 2000: http://www.nelson.com/albertascience/0176289305/student/weblinks/documents/ChemicalOperationsDirectory.pdf

[49] Association Industrielle de l'est de Montreal (AIEM), Membres et types d'industries: http://www.aiem.qc.ca/index.php?option=content&task=view&id=11&Itemid=106

[50] Business Monitor International (BMI), Canada Petrochemicals Report, 2013: http://www.marketresearch.com/Business-Monitor-International-v304/Canada-Petrochemicals-7287960/

[51] Including: Canadian Energy Research Institute (CERI): The Sarnia Complex, Synergies and Strategies, Study No. 68. Dec. 1995

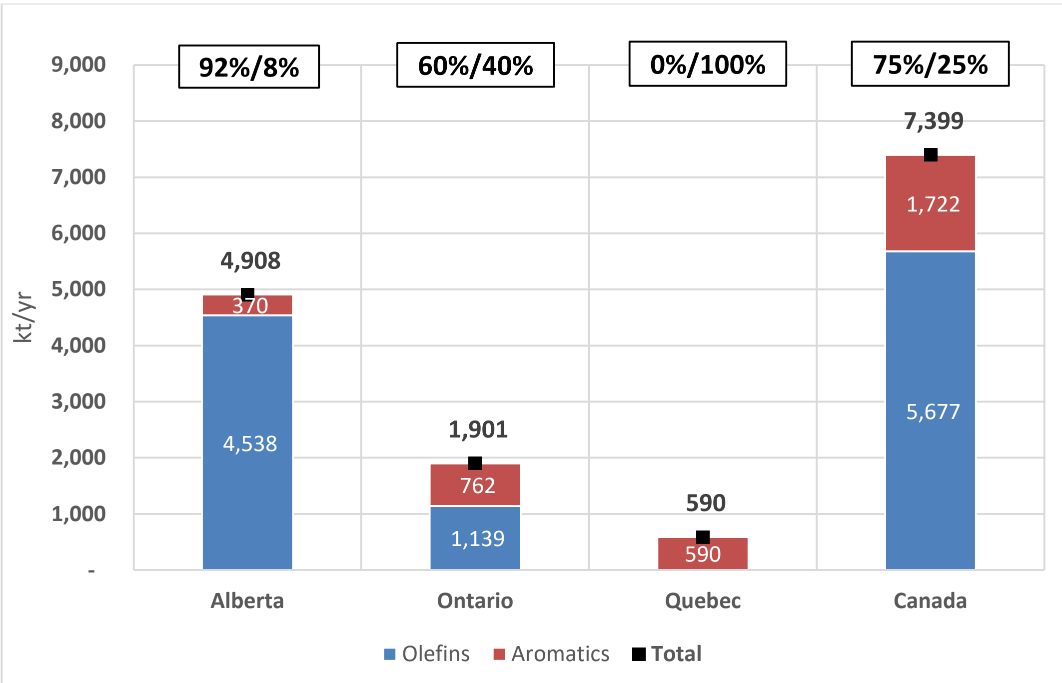
[52] MEI, the Economic Benefits of Pipeline Projects to Eastern Canada: http://www.iedm.org/files/note0813_en.pdf

[53] Oil & Gas Journal (OGJ), International Survey of Ethylene From Steam Crackers – 2013: http://www.ogj.com/articles/print/volume-111/issue-7/special-report-ethylene-report/international-survey-of-ethylene-from.html

[54] Sarnia-Lambton Petrochemical and Refining Complex, October 2013: http://www.sarnialambton.on.ca/medialibrary/5/S_L_PETROCHEM_BROCH.pdf

Figure 1.8 shows the split between olefin and aromatic production capacity and the percentage of olefin production for Canada at approximately 75 percent.

Figure 1.8: Petrochemical Manufacturing Regions and their Olefin and Aromatic Production (kt/yr)



Source: CERI

Table 1.6 provides a summary of the three major Canadian petrochemical clusters and the interaction between the steam crackers, aromatic plants, and their derivative plants.

Eighty percent of ethylene cracking capacity is in Alberta, with the largest concentration around the Joffre complex. CERI calculates that Canadian facilities have the capacity to produce 5,677 thousand tonnes (kt) of ethylene per year.

Table 1.6: Major Petrochemical Clusters in Canada, Summary

ALBERTA

From: Petrochemical Plants			To: Derivative Plants	
Type	Capacity (kt/yr)		Feedstock Req. (kt/yr)	Type
Olefins Plants				
Ethylene Crackers	4,538	71%	3,236	Polyethylene/LAO/EVA Plants
		18%	806	MEG Plants
		3%	121	SM Plant
	Total	**92%**	**4,163**	**Total Derivative Plants**
	Balance	8%	375	Excess Capacity
Aromatics Plants				
Benzene	370	99%	365	SM Plant
	Total	**99%**	**365**	**Total Derivative Plants**
	Balance	1%	6	Gasoline Blend, Industrial Chemicals, Solvents, Resins & Fibers

ONTARIO

From: Petrochemical Plants			To: Derivative Plants	
Type	Capacity (kt/yr)		Feedstock Req. (kt/yr)	Type
Olefins Plants				
Ethylene Crackers	1,139	88%	1,002	Polyethylene Plants
		10%	116	SM Plant
	Total	**98%**	**1,118**	**Total Derivative Plants**
	Balance	2%	21	Excess Capacity
Aromatics Plants				
Benzene	340	100%	339	SM Plant
	Total	**100%**	**339**	**Total Derivative Plants**
	Balance	0%	1	Gasoline Blend, Industrial Chemicals, Solvents, Resins & Fibers
Toluene	422	100%	422	Gasoline Blend, Industrial Chemicals, Solvents, Resins & Fibers
	Total	**100%**	**422**	**Total Derivative Plants**
	Balance	0%	-	

QUEBEC

From: Petrochemical Plants			To: Derivative Plants	
Type	Capacity (kt/yr)		Feedstock Req. (kt/yr)	Type
Aromatics Plants				
Benzene	350	100%	350	Benzene Derivatives (Including p-X plant) & Refinery Feedstocks
	Total	**100%**	**350**	**Total Derivative Plants**
	Balance	0%	-	
Toluene	240	100%	240	Toluene Derivatives (Including p-X plant) & Refinery Feedstocks
	Total	**100%**	**240**	**Total Derivative Plants**
	Balance	0%	-	

CANADA

From: Petrochemical Plants			To: Derivative Plants	
Type	Capacity (kt/yr)		Feedstock Req. (kt/yr)	Type
Olefins Plants				
Ethylene Crackers	5,677	75%	4,238	Polyethylene/ LAO/EVA Plants
		14%	806	MEG Plants
		4%	237	SM Plants
	Total	**93%**	**5,281**	**Total Derivative Plants**
	Balance	7%	396	Excess Capacity
Aromatics Plants				
Benzene & Toluene Plants	1,722	41%	704	SM Plants
	Total	**41%**	**704**	**Total Derivative Plants**
	Balance	59%	1,018	Other Benzene & Toluene Derivatives (Including p-X plant) & Refinery Feedstocks

Source: CERI

World Markets

This section provides a brief description of world markets, including some of the world's important players in petrochemical production. This section is divided into three parts: the US, Middle East and the Asia-Pacific region. The US section highlights the US Gulf Coast (USGC) and reviews briefly the up and coming US Northeast, the area of the US most characterized by the shale gas revolution. Within the Middle East discussion, Saudi Arabia and Iran are reviewed while the Asia-Pacific section examines Japan, South Korea and China.

This section delves into what these nations produce, who they export their products to and what feedstock they utilize. With regard to the latter, feedstock price and availability determines the producer's profit margins. There are generally three feedstocks utilized: 1) methane, ethane, propane and butane, 2) naphtha, and 3) benzene, toluene and xylenes (BTX). Methane, ethane, propane and butane is obtained from natural gas processing plants while naphtha and BTX is obtained from petroleum refineries.

United States (USGC and US East Coast)

The US shale gas and tight oil (shale oil) revolution has had a profound impact on oil and natural gas production. The Marcellus and Utica Shales in Pennsylvania, West Virginia, Ohio and New York have fueled a resurgence in natural gas production in the US, while the Bakken Formation in North Dakota and Montana has done the same for oil. While well documented, the growth of natural gas liquids (NGLs) lies outside of the glare of the media spotlight; its impact on the energy landscape is tremendous.

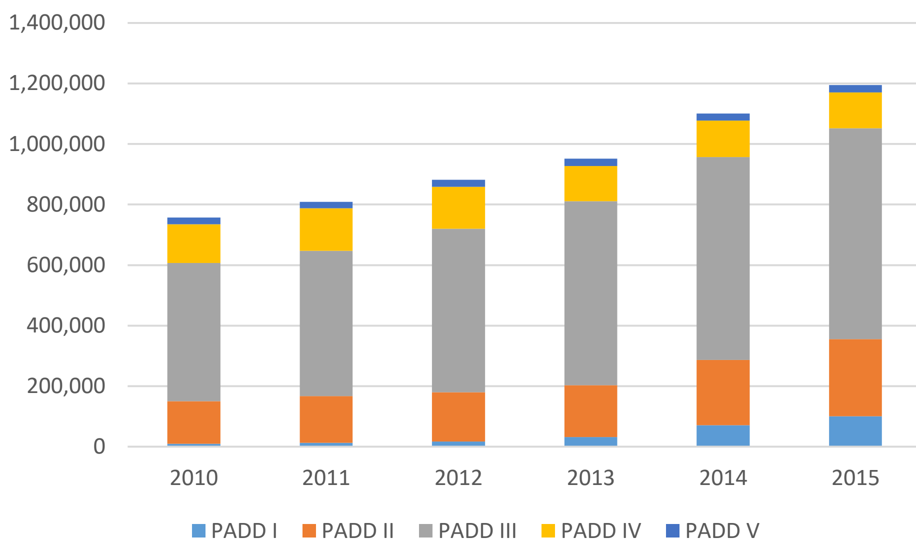
The growth of shale gas and tight oil production are impacting NGL production. Petrochemical producers, who account for over half of NGL consumption, are paying attention. The petrochemical industry has shifted away from naphtha and currently consumes nearly all ethane produced in the US, approximately 35 percent of US propane and 25 percent of US butane. Unsurprisingly, the US is the top country for gas plant NGL production, followed by Saudi Arabia, Qatar, Russia and the United Arab Emirates.[55] The US has historically been a net importer of NGLs, but the proliferation of shale gas production and the associated NGL production has turned them into a net exporter.

Figure 1.9 illustrates US NGL production between 2010 and 2015 by PADD.[56,57] NGL production increased from 757 million barrels in 2010 to 1,195 million barrels in 2015. This production is led by PADD III (Gulf Coast), followed by PADD II (Midwest) and PADD IV (Rockies). More specifically, the Texas Inland region produced 478 million barrels in 2015, followed by Oklahoma, Kansas and Missouri at 129 million barrels in 2015 and the Appalachian No. 1 region at 101 million barrels in 2015. Illustrating the growth of NGL production in PADD I (East Coast), the Appalachian No. 1 region produced only 9.7 million barrels in 2010. Without doubt, fractionation capacity will

55 CERI Study No. 153, "Examining the Expansion Potential of the Petrochemical Industry in Canada", pp. 44.
56 EIA, Natural Gas Liquids Production Data, https://www.eia.gov/dnav/pet/pet_pnp_gp_a_EPL0_FPF_mbbl_a.htm
57 PADDs are geographically defined as follows: PADD I (East Coast), PADD II (Midwest), PADD III (Gulf Coast), PADD IV (Rockies) and PADD V (West Coast).

increase in the Marcellus/Utica area as the region will become a more important NGL hub in North America. It is important to note that when the Texas Gulf Coast and the Louisiana Gulf Coast are accrued, they account for 151,030 thousand barrels of NGL production. That is why the majority of petrochemical facilities are located around the Gulf Coast.

Figure 1.9: NGL Production, 2010-2015 (thousand barrels per year)

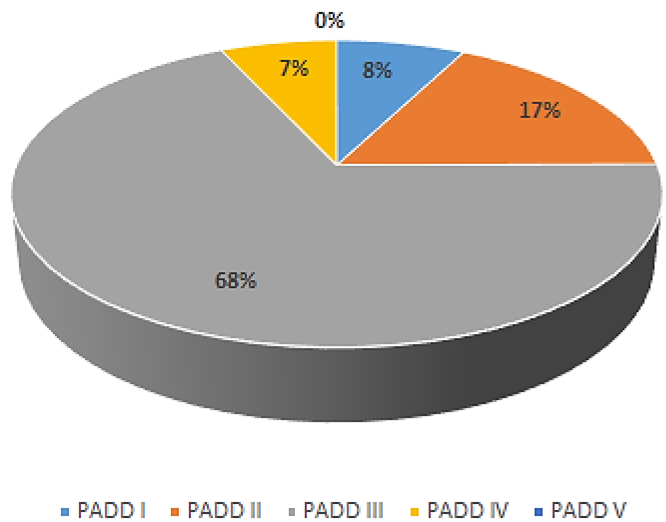


Source: EIA[58]

Ethane is used almost exclusively as a petrochemical feedstock to produce ethylene, which in turn can be used as a building block for plastics, packaging materials, and other consumer products. Figure 1.10 illustrates ethane production in the US in 2015 by PADD. The majority of ethane supply in the US is in PADD III (Gulf Coast) at 68 percent, followed by PADD II at 17 percent and PADD I at 8 percent. It is also interesting to note that PADD I (East Coast) ethane production, while still quite small, has increased from 96 thousand barrels in 2010 to 31 million barrels in 2015 – mostly due to the Appalachian No. 1 zone, located near the prolific Marcellus/Utica Shale.

[58] EIA, Natural Gas Liquids Production Data, Natural Gas Liquids Production Data, https://www.eia.gov/dnav/pet/pet_pnp_gp_a_EPL0_FPF_mbbl_a.htm

Figure 1.10: Ethane Production, 2015 (thousand barrels)



Source: EIA[59]

Pipelines transport ethane around the US. The US historically has had no imports and exports of ethane however this is changing as dedicated ethane pipelines are built from producing areas in the US to petrochemical facilities in Canada.[60] There are two in particular: the Vantage pipeline, originating in the Bakken, and the Mariner West pipeline which crosses Canada from west to east. As previously mentioned, US petrochemical facilities are able to absorb some of the increased supply of ethane as they switch away from other NGLs and heavier petroleum-based naphtha feedstock in ethylene crackers to lighter feedstock, however there is still some excess ethane.

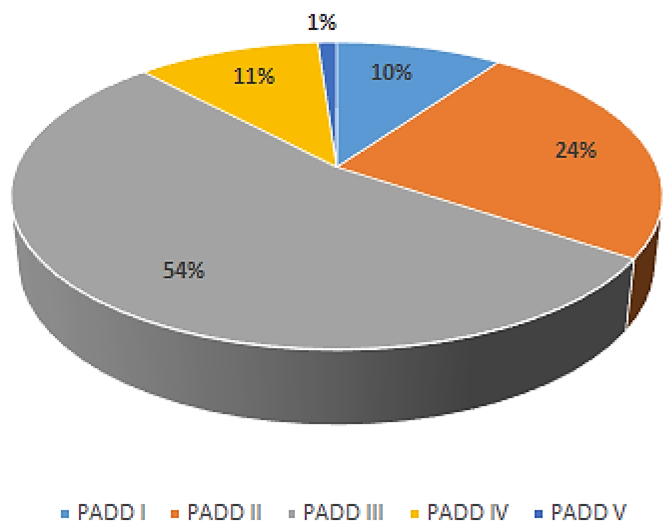
The market for propane is more dynamic. Propane can be transported by pipeline, truck, rail and barge. Its uses range from residential heating to transportation fuel for forklifts, to petrochemical feedstock for ethylene and propylene production. As a result, it is often used as a fuel for heating in remote areas and demand is highly seasonal, peaking in the winter months. While production of propane has been increasing over the past five years, consumer demand has been falling, leading producers to seek alternative domestic markets, such as an alternative fuel and for agricultural use. Demand for propane is down in the petrochemical markets as it has been less competitive than ethane.

Figure 1.11 illustrates propane production in the US in 2015 by PADD. Propane production, like natural gas production, comes mostly from PADD III. The latter makes up 54 percent of the supply

[59] EIA, Ethane Production Data, https://www.eia.gov/dnav/pet/pet_pnp_gp_a_EPL0_FPF_mbbl_a.htm
[60] It should also be noted that the United States has started exporting ethane by tanker to overseas locations via export terminals in Pennsylvania and Texas (http://www.eia.gov/todayinenergy/detail.php?id=28052&src=email)

of propane, followed by 24 percent in PADD II and 11 percent in PADD IV. PADD 1 accounts for 10 percent.

Figure 1.11 Propane Production, 2015 (thousand barrels)



Source: EIA[61]

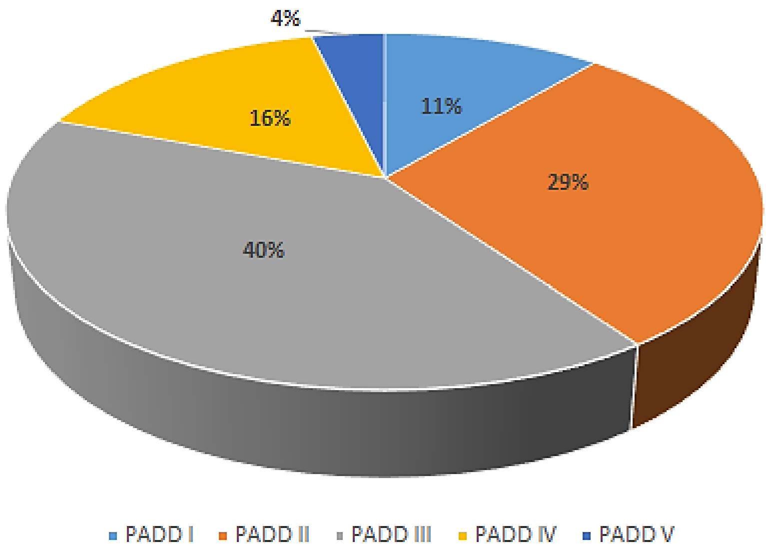
In 2011 the US became a net exporter of propane. These exports primarily occur from PADD III reflecting that the Gulf Coast market for propane/propylene was not large enough to absorb the increased supply that was a combination of increasing PADD III supply and transfers from PADDs II and IV.

Butanes are produced in smaller quantities and are utilized in refining, particularly for gasoline blending or alkylation, or as a petrochemical feedstock. Not as competitive as ethane for production of ethylene, the demand for normal butane has fallen in recent years in the petrochemical sector. Butane can also be used for other petrochemicals, including butadiene, used for making synthetic rubber for tires, belts and hoses. Demand for these products, however, continues to increase.

Figure 1.12 illustrates the total butane production in the US in 2015 by PADD. Like ethane and propane, it is dominated by PADD III, at 40 percent. This is followed by 29 percent in PADD II and 16 percent in PADD IV.

[61] EIA, Propane Production Data, https://www.eia.gov/dnav/pet/pet_pnp_gp_a_EPL0_FPF_mbbl_a.htm

Figure 1.12: Butane Production, 2015 (thousand barrels)



Source: EIA[62]

The USGC, or PADD III, is the largest petrochemical cluster in North America, accounting for approximately 47 percent of total US refining. The stretch along the Gulf Coast, in Texas alone has 27 petroleum refineries processing more than 5.1 million barrels of crude oil per day. They are located in the Houston area, Port Arthur and Corpus Christi, the highest concentration of petrochemical plants. Other major centers include Beaumont-Port Arthur-Orange, Brownsville, Corpus Christi, Victoria, and Seadrift. Texas leads the US in total energy production, primarily crude oil and natural gas production.[63] The state has many energy-intensive industries, including petroleum refining and chemical manufacturing. More than one-fourth of the nation's total refining capacity is located in Texas. These coastal refineries have access to local Texas production, foreign imports, and crude oil produced offshore in the Gulf of Mexico. This high level of integration is a key factor in the competitiveness of the region. Many of the Texas refineries are sophisticated facilities that use additional refining processes beyond simple distillation to yield a larger quantity of lighter, higher-value products, such as motor gasoline.

Not surprisingly, Texas leads the nation in total petroleum consumption, and it is first among the states in the consumption of distillate fuel oil and liquefied petroleum gases (LPG). Nearly all of the LPG is consumed by the industrial sector where it is used as a chemical feedstock in petrochemical plants.

Texas' petroleum products exports in 2014 were valued at US$59 billion[64] while the state's basic chemical products exports in 2014 were valued at US$24.9 billion, including cyclic hydrocarbons,

[62] EIA, Butane Production Data, https://www.eia.gov/dnav/pet/pet_pnp_gp_a_EPL0_FPF_mbbl_a.htm
[63] EIA, Texas Analysis, http://www.eia.gov/state/analysis.cfm?sid=TX
[64] Government of Texas, Wide Open for Business, Petroleum Production Manufacturing, http://gov.texas.gov/files/ecodev/profilepetroleumandcoal.pdf, pp. 1.

acyclic ethers and acrylonitrile.[65] Texas exports basic chemicals to Mexico (42 percent), Canada (14 percent), Brazil (12 percent), Belgium (11 percent), South Korea (11 percent) and the Netherlands (10 percent).[66]

Home to six refineries and petrochemical plants, Louisiana is also a major producer, processor and transporter of domestic energy. There are more than 300 major chemical plants located in Louisiana. Roughly 88 percent of the country's offshore oil rigs are located off Louisiana's coast, and has 50 million tons of crude oil refined and distributed throughout the United States.[67] Louisiana is able to refine more than 2.9 million barrels of gasoline per day, which is the second largest capacity in the US,[68] making it the second largest petroleum product producing state, after Texas.

The energy, petrochemicals and plastics industry in the Greater New Orleans region benefits from a complex transportation infrastructure such as ports, highways, railroads and pipelines, providing easy access to the rest of the world.

The US possesses a cost advantage as nearly half of the world's capacity is configured to operate on heavier feedstock such as naphtha – the single largest feedstock or 45 percent of global capacity. This is followed by ethane at 27 percent, propane, gas oil, butane and other non-specified feedstock to make up 17 percent, and other feedstock at 11 percent. The latter generally refers to NGL and LPG mixes, as well as refinery gases or a mix of various feedstock types. It is important to note that facilities using naphtha have gained an advantage in the past 18 months, as the price is based on crude oil, which has dropped substantially after mid-2015, certainly shrinking the cost advantage for North American ethylene production. Supply availability is also an advantage for the petrochemical industry.

The future evolution of NGL supply and demand balances in the USGC (and the rest of the US) will rest on the ability of the industry to build enough infrastructure in a timely fashion to deliver increasing supply from existing and emerging areas to both expanding domestic industries, such as petrochemicals, and also increasingly to Canada (most NGLs) and the global LPG market.[69]

Middle East (Saudi Arabia and Iran)

About two thirds of NGLs are produced by countries outside the Organization of Petroleum Exporting Countries (OPEC), where approximately 80 percent of production volumes come from

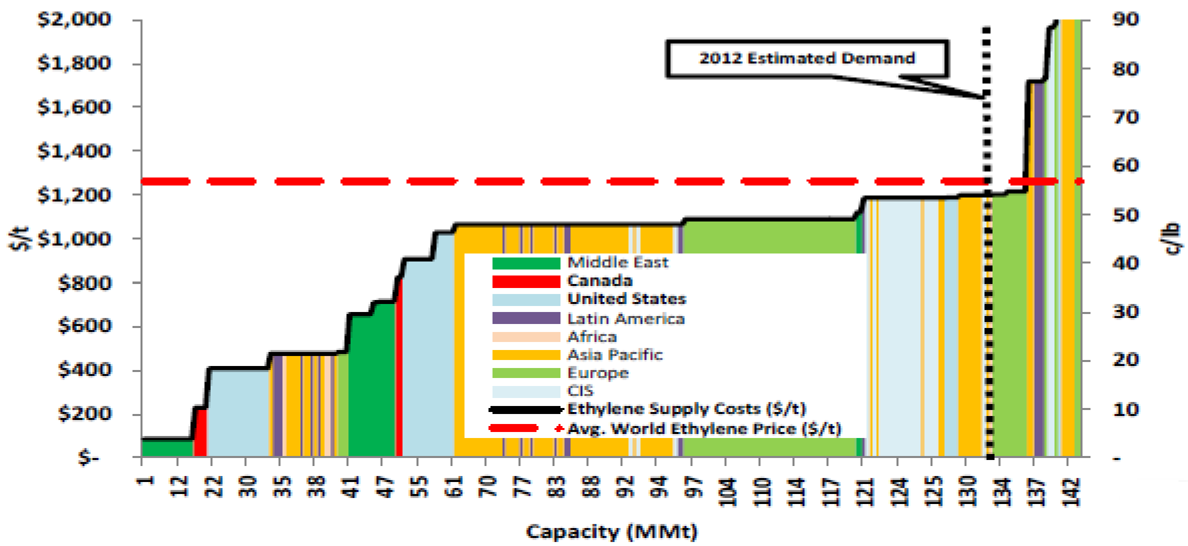
[65] Government of Texas, Wide Open for Business, Basic Chemicals, http://gov.texas.gov/files/ecodev/profilebasicchemicals.pdf , pp. 1.
[66] ibid
[67] Greater New Orleans Regional Economic Development, Energy/Petrochemicals/Plastics, http://gnoinc.org/industry-sectors/energypetrochemicalsplastics/
[68] STI Group, The Louisiana Oil and Gas Industry Growth: Refineries & Petrochemical Plants, http://setxind.com/downstream/louisiana-oil-gas-industry-growth-refineries-petrochemical-plants/
[69] Energy Information Administration, April 2013, Annual Energy Outlook 2013, with Projections to 2040, http://www.eia.gov/forecasts/aeo/pdf/0383(2013).pdf

refineries.[70] The remaining volumes of NGLs and naphtha are produced by OPEC countries, with the largest portion (around 84 percent in 2011) coming from gas plants by a handful of OPEC's members including Saudi Arabia, Qatar, the United Arab Emirates (UAE), Iran, Algeria, and Nigeria.[71]

While it is not realistic to discuss all the major players in this region, it is prudent to review Saudi Arabia and Iran. The former is one of the most important players in the petrochemical industry while the latter is a nation who is quickly becoming an important player in the petrochemical industry in the Middle East.

Abundant and inexpensive oil and natural gas give the Middle East a great cost advantage, as petrochemical feedstocks such as ethane are plentiful. Figure 1.13 illustrates the production costs for petrochemicals by region and shows that the lowest petrochemical feedstock costs in the world are experienced in the Middle East, followed by North America. Producers experience high margins and are able to re-invest profits to expand production. However, lower crude oil prices, as well as lower naphtha prices, are narrowing the price advantage.

Figure 1.13: Cost Comparison of Ethylene Supply Costs (2012)



Source: CERI[72]

It is, however, important to mention that part of the cost advantage in the Middle East is due to incentives making their feedstocks artificially low. Many state-owned enterprises in Saudi Arabia,

[70] CERI Study, "Examining the Expansion Potential of the Petrochemical Industry in Canada", August 2015, pp. 43.
[71] ibid
[72] CERI Presentation, Understanding natural gas markets, NGLs markets, and petrochemical feedstock availability in Canada, Alberta Petrochemical Development Opportunities Seminar, Carlos Murillo, May 2015, pp. 36.

for example, benefit from subsidies on water, power and feedstock, further reducing the price of natural gas.[73]

The premier producer of NGLs in the Middle East is Saudi Arabia, the region's largest petrochemical producer with an annual 86.4 million tons of capacity. With the world's second largest proven oil reserves and a strategic location, Saudi Arabia is becoming a hub for the expanding petrochemical industry. The country's geographical proximity to the high growth market, expanding production capacity and absolute feedstock cost advantage position Saudi Arabia to become an even bigger player in petrochemicals.[74]

According to the Royal Commission for Jubail & Yanbu National Petrochemical Company (Yansab), Saudi Arabia produces over 50 unique petrochemical products. Saudi Arabia is the world's largest producer of ethylene, accounting for 11 percent of global ethylene production. Ethane is the preferred petrochemical feedstock among OPEC members, although Saudi Arabia's petrochemical facilities use small volumes of LPG and naphtha as well. It is important to note that Saudi Arabia's petrochemical industry was initially based on naphtha and began incorporating ethane, propane and butane in the early 2000s, with dramatic diversification occurring within the last decade.[75]

The industry is led by Saudi Arabian Oil Company (ARAMCO), Saudi Basic Industries Corporation (SABIC), Saudi Petrochemical Company (SADAF), Saudi Kayan Petrochemical Company (YANPET) and Yanbu National Petrochemical Company (Yansab).

ARAMCO and SABIC are the major players in the sector. Saudi Arabia has eight domestic refineries, with a combined crude throughput capacity of about 2.5 million bbl/d[76] of which ARAMCO's share is approximately 1.8 million bbl/d.[77] SABIC is a public company based in Riyadh and is ranked among the world's largest petrochemical manufacturers.

SADAF was established as a joint venture between SABIC and Shell in 1980. Beginning with the complex at Jubail, the company expanded in 2005 and 2012, with production in two styrene plants. The latter offered a combined 1,160,000 tpa.

YANPET was founded in 1980 by SABIC and ExxonMobil Corporation to develop a petrochemical complex in Yanbu. The facility opened in 1985 with an initial capacity of 500,000 (tpa) of ethylene, 200,000 tpa of linear low-density polyethylene (LLDPE), 220,000 tpa of ethylene glycol and 96,000 tpa of high-density polyethylene (HDPE). Yansab was established in 2004 to develop the Yanbu Petrochemicals Complex by SABIC holding 55 percent shares, Saudi investors holding another 10

[73] ODI website, Fossil fuel exploration subsidies: Saudi Arabia, Shelagh Whitney and Shakuntala Makhijani, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9268.pdf, pp. 2.
[74] Saudi Petrochemical Sector Al-Jazira Capital Research Department Sector Reports, July 2011.
[75] Saudi Gazette, Saudi Petrochemical Sector Growth Prospects Excellent, http://saudigazette.com.sa/business/saudi-petrochemical-sector-growth-prospects-excellent/
[76] Oil and Gas Journal, Worldwide Refining Capacity Details, January 1, 2014.
[77] Saudi Aramco website, Annual Review 2013, pp. 30.

percent and 35 percent garnered from other various private investors.[78] In 1985, total production was 6.3 million metric tons (mmt); by the end of 2014 it had reached 69.7 mmt.[79]

Iran's petrochemical sector is of great interest, particularly with the lifting of sanctions in early 2016. Once OPEC's second largest producer, three years of isolation have hurt its oil and natural gas industry. However, Iran appears to be rebounding quickly. Oil production reached pre-sanction levels of 3.6 million bpd by mid-2016. Iran's petrochemical industry can draw on its large natural gas reserves.[80]

At the heart of its petrochemical sector is the National Petrochemical Company (NPC). The Tehran-based company was founded in 1964, initially operating a small fertilizer plant in Shiraz.[81] The NPC generated US$20.4 billion in 2015 producing chemicals and intermediaries, industrial polymers, fertilizers and metals. Iran exported US$5.68 billion worth of petrochemical products in the first four months of 2016, primarily to China, the UAE, South Korea, Turkey and India.[82] NPC has several holding companies, including Persian Oil and Gas Development Group, Pasgarad Energy Development Company, Persian Gulf Petrochemical Industries Company and Tamin Petroleum & Petrochemical Investment Company.[83]

Iran is currently seeking funding – approximately US$40.1 billion – to complete 67 projects that sit partially built as a result of years of sanctions.[84] These projects have a designed capacity of 61.1 million tons per year.[85] The company suggests new investments in the petrochemical industry to total US$21.4 billion in another 36 projects by 2026.[86]

Iran's planned growth in its petrochemical industry will likely make it a significant rival to Saudi Arabia.

Asia-Pacific (Japan, South Korea and China)

After the US and China, Japan is the third largest petroleum consumer.[87] Due to limited oil reserves, Japan maintains government-controlled oil stocks to ensure against a supply

[78] SABIC website, Manufacturing Affiliates, Yansab, http://www.sabic.com/corporate/en/ourcompany/manufacturingaffiliates/yansab.aspx
[79] SABIC website, Our Company, Corporate Profile, https://www.sabic.com/corporate/en/ourcompany/corporate-profile
[80] Fuelfix website, Iran's recovery could sputter with cash, http://fuelfix.com/blog/2016/06/16/irans-recovery-could-sputter-without-cash-wider-trade/
[81] Iran's Petrochemical Industry Report 2014, International Affairs Department, http://nipc.ir/uploads/annualreport_2014_22893.pdf?fkeyid=&siteid=71&fkeyid=&siteid=71&pageid=3235, pp. 6
[82] The Iran Project, $5.679bn worth petchem products exported in 1st 4 months, http://theiranproject.com/blog/2016/07/29/5-679bn-worth-petchem-products-exported-1st-4-months/
[83] Iran's Petrochemical Industry Report 2014, International Affairs Department, http://nipc.ir/uploads/annualreport_2014_22893.pdf?fkeyid=&siteid=71&fkeyid=&siteid=71&pageid=3235, pp. 2.
[84] ibid, pp. 18.
[85] ibid
[86] ibid, pp. 19.
[87] EIA, Japan January 30, 2015, Full Report.

interruption. Of the 420 million barrels of total strategic crude oil stocks, 73 percent are government stocks and 27 percent are commercial stocks.[88] The majority of Japan's domestic oil supply is obtained in the form of refinery gain, resulting from the country's large petroleum refining sector. The country has 148 producing oil wells in over a dozen fields.[89] On the supply side, production of petroleum and other liquids was an estimated 136,000 bbl/d, of which only 18,000 bbl/d was from crude oil and NGLs.

Production of non-OPEC refinery LPG and naphtha has increased rapidly over the last decade, primarily due to increases in production from the Asia-Pacific region, given increased crude oil and overall energy demand in the region. Condensate refining is the last significant source of NGLs and naphtha demand among non-OPEC countries. Demand for condensate as a refinery feedstock is high in the Asia-Pacific region, primarily in Japan.

Japan's strengths include a high level of specialization and value-added, which enables producers to stay ahead of competition from low-cost Asian and Middle Eastern producers. Japan's weaknesses include high debt, lack of domestically produced naphtha feedstock, high dependence on imports, and high cost of transport and machinery.[90]

Despite being highly dependent on naphtha and low-sulfur fuel oil imports, the Japanese petrochemical industry benefits from convenient access to foreign markets.

South Korea is one of the top energy importers in the world and relies on fuel imports for 97 percent of its primary energy demand, lacking domestic energy reserves. The country has no international oil or natural gas pipelines, relying instead on tanker shipments of LNG and crude oil to meet its demand. The majority of South Korea's total oil production of 60,000 bbl/d is based on refinery processing gains and a small portion of biofuel production.

South Korea is one of Asia's largest petroleum product exporters with about 19 Mt of oil products exported in 2014.[91] The country has the sixth largest refining capacity in the world. Major oil refineries include South Korea Innovation, GS Caltex Corporation and S-Oil Corporation Hyundai Oil Refinery. It is one of the prominent petrochemical producers in the world, with overall annual ethylene capacity of 7.6 million tons per year (Mt/year) and various accompanying downstream plants.[92] Within the Asia-Pacific region, countries such as China and Indonesia suffer from a

[88] International Energy Agency, October 2015.
[89] Oil and Gas Journal, Worldwide Production, December 1, 2014.
[90] Business Monitor International – Japan Petrochemical Report 2015.
[91] International Energy Agency, Key world energy statistics, 2016, https://www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf
[92] The Chemical Industry of South Korea: Progress and Challenges, Il Moon and Jae Hyun Cho, https://www.aiche.org/sites/default/files/cep/20111240.pdf, pp. 2.

deficit of ethylene and propylene's main derivatives, polyethylene and polypropylene, South Korea continues to produce levels above and beyond their domestic needs.[93]

Petrochemical production facilities are located at three main centers in South Korea: Ulsan, Yeochun and Daesan, and a smaller complex in Onsan.[94] Ulsan accounts for around 35 percent of Korea's total production and for US$45.3 billion in exports in 2013 – 40 percent of the nation's chemical industry. Ulsan is also home to Asia's largest chemical industrial complex, as well as some of the leading chemical companies in the world such as South Korea Energy, S-oil, Solvay, Eastman, Rhodia, BP, ExxonMobil and DuPont.[95] The main cracker operators are Hanwha Chemical, Honam Petrochemical, LG Petrochemicals, Samsung, and SK Corporation. Others include Lotte Chemical, LG Chemical, GS Caltex, KPIC, and Samsung Total Petrochemicals.[96]

Naphtha, which is used for South Korea Petrochemical and industrial sectors, accounts for about 44 percent of total oil product demand and is the primary driver of domestic demand growth. Outside of the petrochemical sector, oil demand growth is limited in the long term due to declining population growth, energy efficiency measures, and competition from other fuels (natural gas, nuclear, renewables).

Demand for naphtha, which is used as the country's sole petrochemical feedstock, is increasing with the development of naphtha-based aromatics capacity. Naphtha's share in South Korean total refined oil production rose from about 17.9 percent in 2009 to 22 percent in 2013.[97]

South Korea's strengths include large refining and olefins capacity and their ideal position to take advantage of growing Chinese demand. Its weaknesses include hydrocarbon feedstock that needs to be imported, making it highly reliant on overseas supply. The petrochemical industry in South Korea is diversifying feedstock sources and aiming to reduce naphtha feedstock usage to LPG.

With most of its chemical production feeding domestic demand, China's government has pursued a policy of petrochemical self-sufficiency. Currently the world's largest chemical producer, the country rapidly increased its share of global production from 8.1 percent in 2001 to over 25 percent in 2011.[98]

China's quick ascendance as a chemical producer has certainly amplified the competition for this market. Japan and South Korea are in competition with North America for the Chinese market,

[93] CERI study "Natural Gas Liquids (NGLs) in North America: An Update; Part IV – Global Markets and Opportunities", May 2014
[94] KPIA (Kora Petrochemical Industry Association), Industry Information, http://www.kpia.or.kr/eng/industry/pcind_01.html
[95] Invest Korea, Industry Information, http://www.investkorea.org/ikwork/reg/eng/co/index.jsp?l_unit=90202&m_unit=90309&code=1410302
[96] Business Monitor international – South Korea Petrochemicals Report 2015
[97] ibid
[98] The University of York, The Chemical Industry, http://www.essentialchemicalindustry.org/the-chemical-industry/the-chemical-industry.html

where their proximity allows these nations to compete based on low transportation costs. The economic slowdown in China has, however, certainly impacted the petrochemical industries in neighbouring countries. It is important to note that China's petrochemical industry was impacted negatively by the recession in 2008, decreasing by 10 percent in profits, or a total of US$73 billion.[99] However, while China's economic growth has slowed recently, imports are still required in order to supply their growing demand.

China is led by Sinopec, the third largest company by chemical sales in 2014, behind German-based BASF and US-based Dow Chemical. Sinopec, or China Petroleum and Chemical Corporation, is a subsidiary of Sinopec Group, or China Petrochemical Corporation. The latter is the second largest company in the world in terms of revenue.[100] Interestingly, China National Petroleum Corporation is the third largest company in terms of revenue,[101] followed by Saudi Aramco.

China, like its Asia-Pacific counterparts, utilizes more expensive feedstock, like naphtha. China also utilizes its abundant and low-cost coal resources, operating coal-based polyethylene plants, although these plants are struggling to compete against more cost-effective naphtha-based plants.[102] China is adding 2.47 million mt/year of new coal-based polyethylene plants by end-2016, higher than the 1.8 million mt/year installed in 2015.[103] China is also adding significant capacity of coal-based methanol.[104] It is interesting to note that SABIC and Chinese producer Shehua Ningxia Coal Industry Group (SNCG) are planning to develop a petrochemical complex utilizing locally-available coal feedstocks.[105]

Industry pundits look towards China's vast shale gas resources to play a future role in their petrochemical industry, similar to that of the US. Its technically recoverable shale gas resources are the largest in the world, at 1,112 Tcf.[106] Rounding out the top 5 are: Argentina (802 Tcf), Algeria (707 Tcf), US (665 Tcf) and Canada (573 Tcf). The country certainly possesses a vast

[99] Asian Economic Institute website, CHINA'S PETROCHEMICAL INDUSTRY RESPONDS POSITIVELY TO STIMULUS PACKAGE http://www.asiaecon.org/special_articles/read_sp/12490
[100] Sinopec Group website, Annual Report, http://www.sinopecgroup.com/group/Resource/pdf/20140917e.pdf, pp. 14.
[101] CNPC website, Annual Report 2014, http://www.cnpc.com.cn/en/xhtml/features/AnnualReport2014online/images/00-2014%20Annual%20Report.pdf, pp. 43.
[102] Platts, Runs at China's coal-based PE plants likely to remain below 70% this year: sources, May 26, 2016, http://www.platts.com/latest-news/petrochemicals/singapore/runs-at-chinas-coal-based-pe-plants-likely-to-27591575
[103] ibid
[104] Global Petrochemical Market Outlook: Balancing the push from regional supply with the pull from global demand, IHS, 9th Annual GPCA Forum, Mark Eramo, November 23, 2014 http://www.gpcaforum.net/wp-content/uploads/2016/04/ihs4.pdf, pp. 19.
[105] SABIC eyes coal-based China petchem complex joint venture, May 31, 2016, http://www.icis.com/resources/news/2016/05/31/10002998/sabic-eyes-coal-based-china-petchem-complex-joint-venture/
[106] Macquarie Commodities Research, Global petrochemical industry outlook – shifting trade flows, https://www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2013/ga001/presentations/26Sept_09.45_James%20Yong.pdf, pp. 24.

resource base, but its infrastructure to produce the shale gas is currently lacking. In addition, the NGL opportunity is less defined, as the resource is considered dry.[107]

[107] Macquarie Commodities Research, Global petrochemical industry outlook – shifting trade flows, https://www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2013/ga001/presentations/26Sept_09.45_James%20Yong.pdf, pp. 25.

Chapter 2: Competitive Comparisons Between Jurisdictions

This chapter compares four petrochemical producing jurisdictions, including two in Canada, on their competitiveness across varying factors. CERI completed plant gate facility costs for each of the jurisdictions, considered netbacks, as well as examined variables that may not be fully represented in a project economics calculation.

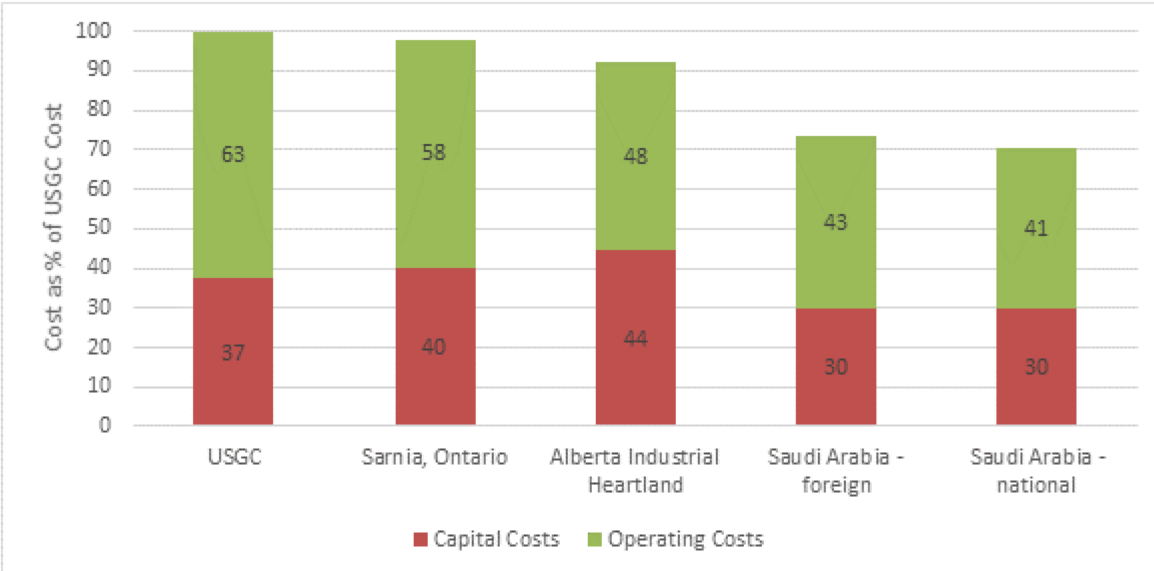
CERI Study 153, "Examining the Expansion Potential of the Petrochemical Industry in Canada"[1] introduced a comparative analysis between different global regions. This report concluded that challenges facing expansion of Canada's petrochemical sector included the development of offshore markets for natural gas to increase the supply of NGLs, the addition of infrastructure for separating ethane from incremental natural gas production, and logistical support for moving the products to market. In the year since Study 153 was released, significant factors in the competitiveness of Canada's petrochemical sector have been the sustained low price of natural gas for feedstock, the continuously growing high volumes of natural gas production out of the Marcellus and the introduction of Alberta's Petrochemical Diversification Program, discussed in Chapter 1.

As an update to the analysis done in Study 153, CERI completed plant gate cost calculations looking at the cost of construction and operation of a new petrochemical facility for both a liquid (methanol) and solid (polypropylene) product in various regions over an 18-year lifespan. The analyses were divided between liquid and solid end products to align with the Lang factors, which describe cost relationships between equipment and capital cost for petrochemical facilities.[2] CERI used a cash flow NPV-based model which is described in more detail in Appendix B. The relative costs for a new petrochemical facility between Canada's major petrochemical clusters in Alberta and Ontario to the US Gulf Coast and Saudi Arabia are shown in Figures 2.1 and 2.2. The methodology for these calculations can be found in Appendix A.

[1] CERI, "Examining the Expansion Potential of the Petrochemical Industry in Canada", August 2015

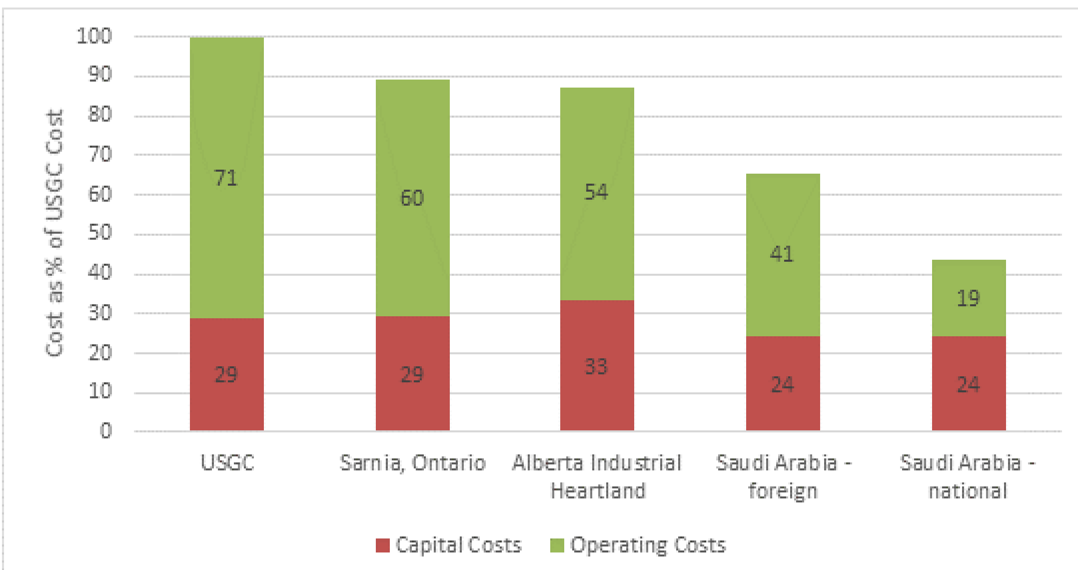
[2] Lang, Hans, Cost Relationships in Preliminary Cost Estimation, Chemical Engineering, 1947.

Figure 2.1: Relative Costs of a New Liquids Petrochemical Facility in Various Regions



Source: CERI

Figure 2.2: Relative Costs of a New Solids Petrochemical Facility in Various Regions



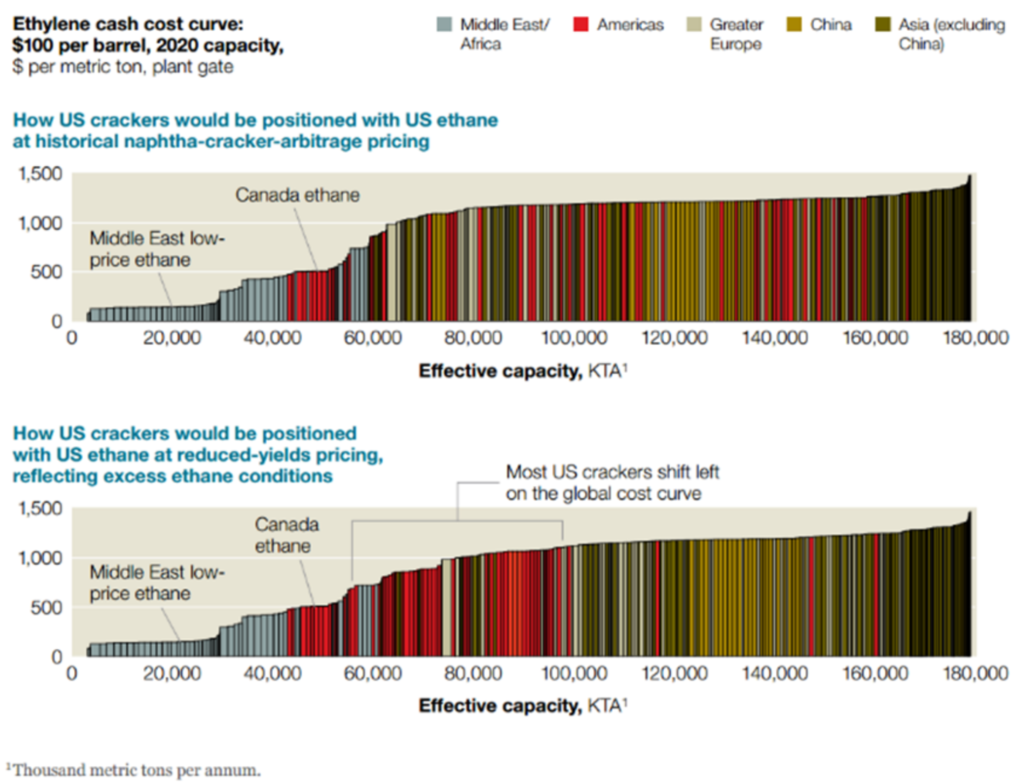
Source: CERI

At a high level, the US Gulf Coast seems to be the most expensive jurisdiction to build and operate a petrochemical facility for both a liquid and solid product, with the Canadian clusters appearing more attractive and very similar to each other, and Saudi Arabia coming in at approximately half of the cost of the US Gulf Coast. While CERI's Study 153 looked at Canada as a whole, this analysis breaks down the country into its two main petrochemical producing areas: Alberta, represented mainly in the Alberta Industrial Heartland, and Ontario, represented mainly in Sarnia. The province of Quebec does have petrochemical activity centered around Montreal, however the industry is not on the same scale as that in Alberta and Ontario.[3] It is also important to note that Montreal uses crude oil as a feedstock for its petrochemical production, making comparisons against other provinces difficult.

CERI's study 153 also considered Northeast Asia (Japan and Korea) in its comparison. These jurisdictions were not considered in the plant gate cost analysis as, like Montreal's industry, crude oil/naphtha is used as a feedstock. The regions considered in Figure 2.1 – Sarnia, the US Gulf Coast, the Alberta Industrial Heartland and Saudi Arabia – all use natural gas/NGLs as their petrochemical feedstock, making comparison between the jurisdictions possible.

CERI's analysis of plant gate costs and the findings that Canadian producers are competitive with US producers are consistent with other analyses. The results from a 2012 McKinsey analysis of ethane cracker plant gate costs under the condition of low feedstock prices are shown in Figure 2.3, placing Canadian costs above those in the Middle East, but lower than those in the US.

Figure 2.3: Sample Cost Curves: Ethane Cracking



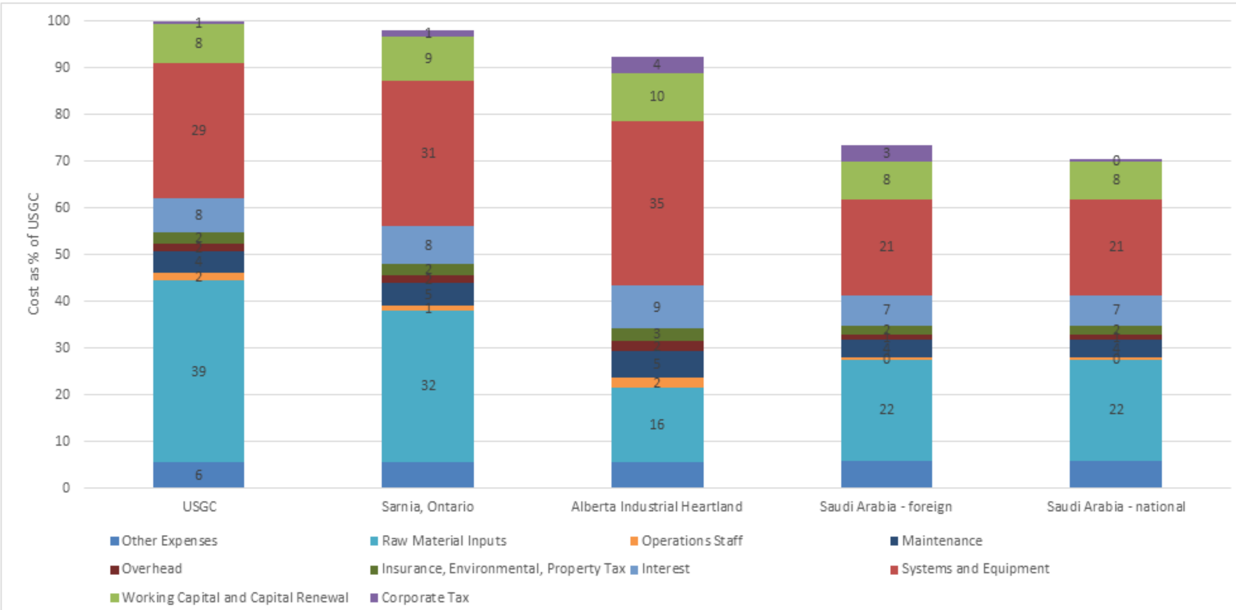
Source: McKinsey&Company[4]

[3] Government of Canada, Petrochemicals Industrial Profile, accessed August 2016, https://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01135.html

[4] McKinsey&Company, McKinsey on Chemicals, "Using microeconomics to guide investments in petrochemicals", Spring 2012, page 51.

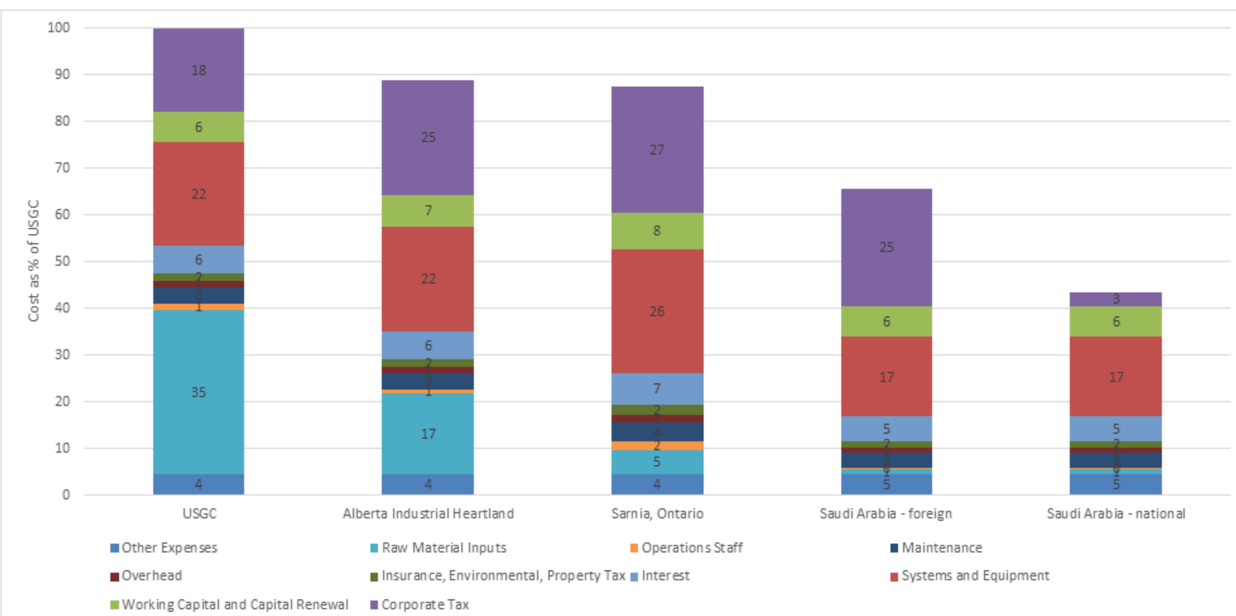
While Figures 2.1 and 2.2 offer a high level overview of the costs of building and operating a solid and liquid petrochemical facility in various regions, Figures 2.4 and 2.5 break down the relative net present value calculations into various components.

Figure 2.4: Relative Costs of a New Liquids Petrochemical Facility – Component Breakdown



Source: CERI

Figure 2.5: Relative Costs of a New Solids Petrochemical Facility – Component Breakdown



Source: CERI

Raw material inputs and facility systems and equipment are shown to represent the majority of the costs to construct and run petrochemical facilities across all jurisdictions for both liquids and solids facilities, with corporate taxes being significant for solids facilities. Raw material inputs and corporate taxes also see the most variability across jurisdictions, making them differentiators. It should be noted that transportation costs are significant also, however their costs in Saudi Arabia were unknown and were estimated to be the same as those in the USGC.

Systems and Equipment are comprised of Inside Battery Limits (ISBL) and Outside Battery Limits (OSBL), whose values are broken down by region in Table 2.1. The Construction Industry Institute defines ISBL as "all equipment and associated components (piping, etc.) that act upon the primary feed stream of a process",[5] whereas OSBL is defined as "utilities, common facilities, and other equipment and components not included in the ISBL definition… typical OSBL equipment includes cooling towers, water treatment facilities, tank farms, etc."[6] The values for ISBL and OSBL for the USGC were estimated based on published numbers of known projects, application of Lang factors (see Appendix B) and other completed analyses. The values for the competing jurisdictions were based on cost markups between regions as calculated by Compass International.

Table 2.1: ISBL and OSBL Values for Various Jurisdictions (million US$)

	USGC	Alberta Industrial Heartland	Sarnia	Saudi Arabia
ISBL (liquids)	340	410	350	245
OSBL (liquids)	170	205	200	115
ISBL (solids)	340	400	330	260
OSBL (solids)	170	200	180	120

Source: CERI

Raw material inputs consist of feedstock (natural gas or propane), chemicals, power and water. Feedstock represents 94 percent, 86 percent, 72 percent and 85 percent of the total raw material input cost for liquids production in the US Gulf Coast, Alberta, Ontario and Saudi Arabia, respectively. It is important to note that the cost of natural gas to a petrochemical producer in Saudi Arabia was recently increased by over 100 percent,[7] making feedstock a more significant part of project cost than in the past. Using propane as a feedstock changes the proportion of costs: feedstock is far cheaper, while returns are higher, leading to larger amounts in corporate taxes being paid over the calculated period.

[5] The Construction Industry Institute, CII Glossary, accessed September 2016, https://www.construction-institute.org/scriptcontent/glossary.cfm?section=Orders

[6] Ibid.

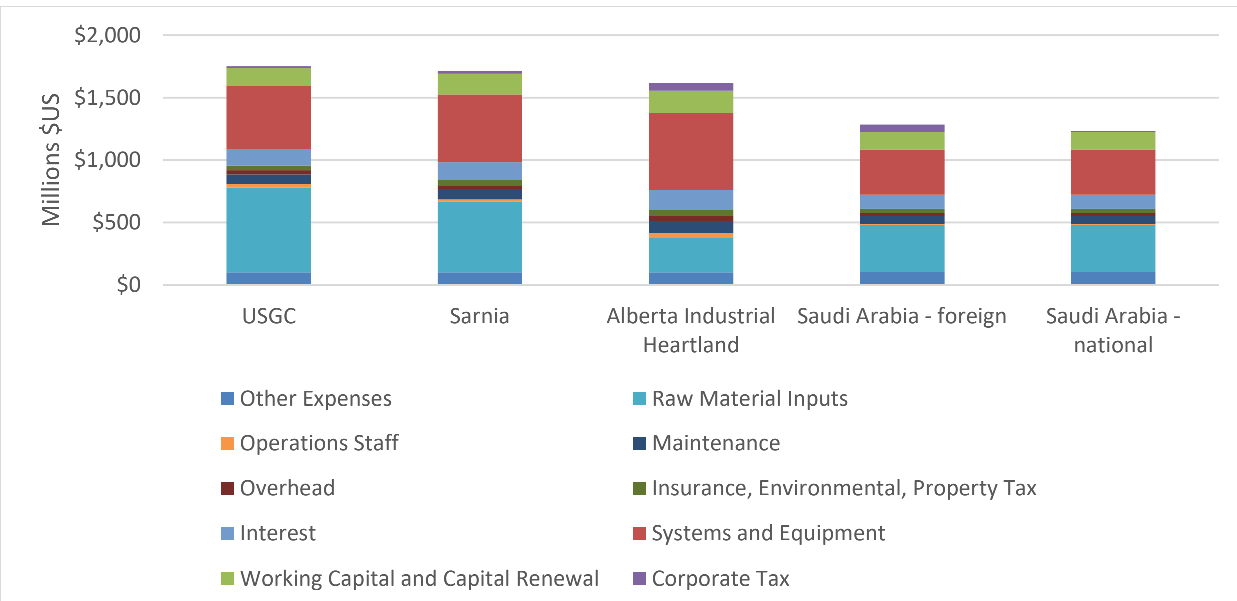
[7] Platts, "Saudi Arabia hikes price of gas for power production, ethane, gasoline in 2016 budget", December 29, 2015, http://www.platts.com/latest-news/natural-gas/dubai/saudi-arabia-hikes-price-of-gas-for-power-production-26323825

A factor of importance in assessing input costs is the cost of power and the potential for negotiation. In Ontario, power costs are more significant than in any of the competing jurisdictions. Through industry interviews, CERI was told that petrochemical producers in Ontario are looking for reduced power tariffs in order to increase the sector's competitiveness.

It is important to note the limitations of an assessment that generalizes petrochemical facilities into solids and liquids plants. One of the driving factors in assessing the economic viability of a petrochemical investment is the spread between feedstock and produced product pricing. Many of the contracts for feedstock pricing, such as propane or ethane, are arranged confidentially. Potential investors would complete project economics knowing the discounts they would expect to receive on feedstock.

While costs can be highly variable, the net present value costs of designing, constructing and operating a liquids petrochemical facility over an 18-year period are shown in Figure 2.6.

Figure 2.6: Net Present Value Costs of a New Liquids Petrochemical Facility – Component Breakdown



Source: CERI, BOC, Centre for Study of Living Standards, Compass International, Bureau of Labour Statistics, Government of Alberta, CRA, IRS, Louisiana Department of Revenue, AESO, EPCOR, Fortis Alberta, StatsCan

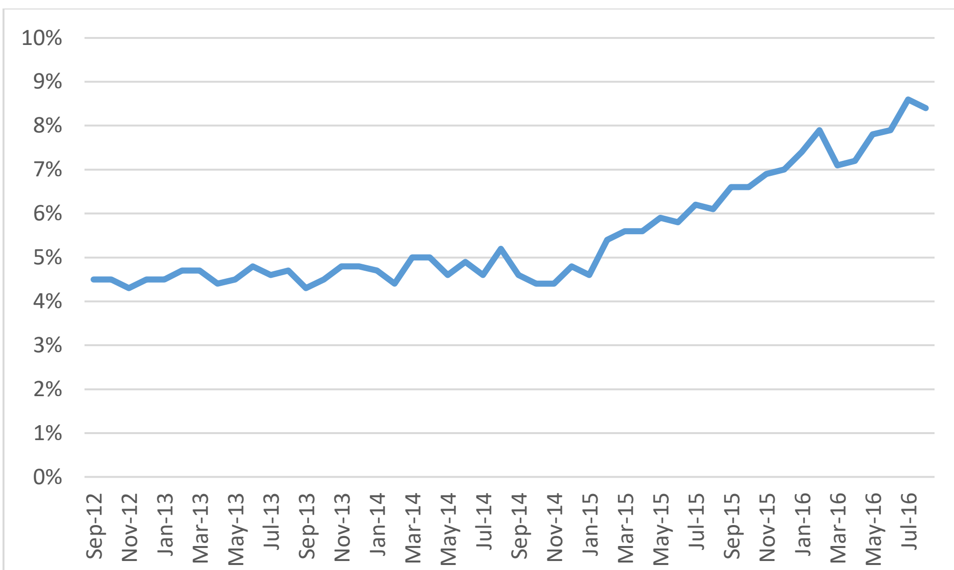
These costs are based on known cost data in the various jurisdictions, such as the price of feedstock and other raw material inputs, the cost of labour, corporate tax rates and financial conditions as well as known cost comparisons between jurisdictions.

Feedstock costs are driven by two factors: the cost of the product, and wellhead to plant gate logistics, including transportation, processing and storage. The location of Alberta's petrochemical facilities in proximity to its natural gas producing areas helps keep these costs low. As mentioned in Chapter 1, the United States is seeing petrochemical activity in close proximity to the highly active Marcellus shale in order to take advantage of available feedstock. The cost associated with transport logistics tends to be where Alberta loses its competitive advantage, with less market flexibility when compared to the US Gulf Coast.

The cost of labour, while not explicitly shown in Figures 2.1, 2.2, 2.4 and 2.5, is a significant part of the facility systems and equipment cost as well as the operations staff cost. Labour costs impact the cost of project design, plant construction and plant operation. The local demand for skilled tradespeople and engineers has a significant impact on not only the labour rate, but the labour efficiency. Historically in Alberta, for example, a high demand for workers meant employees could command a higher wage. Labour shortages also meant that less experienced and less productive staff could be hired, driving down efficiency. Compass International lists the following factors as contributors to poor productivity: “overcrowded or tight work areas, a work force with limited skills, extreme weather conditions, inadequate or poor supervision, complex work items or sophisticated specifications, fast-track construction requirements, extensive overtime, materials and equipment not stored close to the work areas and small or scattered items of work.”[8]

The decline in crude oil prices that has occurred since 2014 has caused changes in labour markets, particularly in Alberta. The unemployment rate in the province has risen sharply from under five percent in recent years, to over 8 percent as of August 2016, as shown in Figure 2.7.

Figure 2.7: Unemployment Rate in Alberta: September 2012 – August 2016



Source: CANSIM[9]

Higher rates of unemployment mean that workers can no longer command high wages. A larger labour pool means labour efficiencies are also increased. The construction of a new

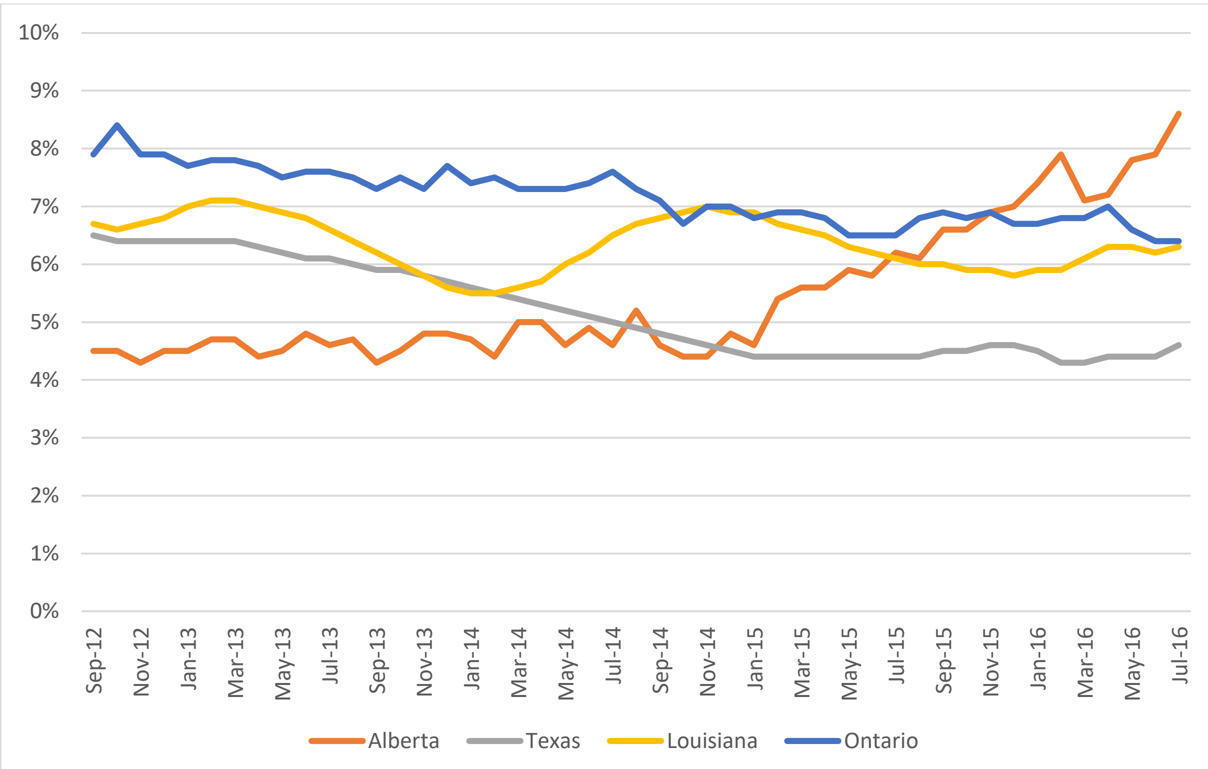
[8] Compass International, 2016 Global Construction Costs Yearbook, pp 116.

[9] Statistics Canada, CANSIM Table 282-0087, accessed September 2016

petrochemical facility in Alberta in the current low-oil price environment would have lower labour costs and be more efficient.

Figure 2.8 compares unemployment rates seen in Texas, Louisiana, Alberta and Ontario, in order to illustrate the relative shock that Alberta's economy has undergone since late-2014.

Figure 2.8: Unemployment Rate in Multiple Jurisdictions: September 2012 – August 2016



Source: CANSIM,[10] Bureau of Labor Statistics[11,12]

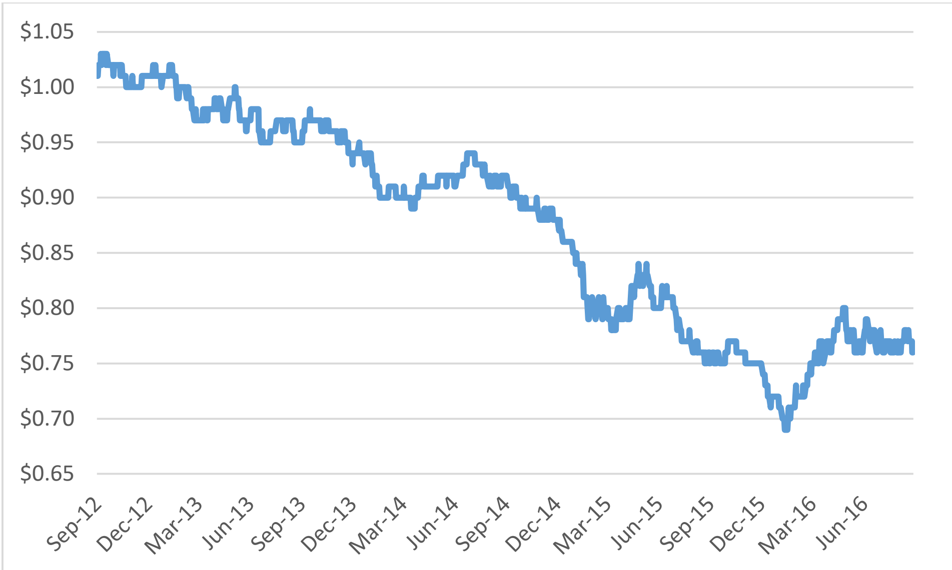
As can be seen in Figure 2.8, the decline in the price of oil has not impacted the other jurisdictions in the same manner. In fact, the unemployment rates in both Texas and Ontario have dropped while Alberta's has risen. The effects on efficiency seen from a rising unemployment rate will not be observed in these other jurisdictions.

Another factor to be considered is the position of the Canadian dollar against the US dollar. Similar to low unemployment rates, a historically higher Canadian dollar worked against the competitiveness of hiring labour in Canada. Since September 2012, the Canadian dollar has

[10] Statistics Canada, CANSIM Table 282-0087, accessed September 2016
[11] Bureau of Labor Statistics, Texas, accessed September 2016, http://www.bls.gov/eag/eag.tx.htm
[12] Bureau of Labor Statistics, Louisiana, accessed September 2016, http://www.bls.gov/regions/southwest/louisiana.htm#eag

dropped from a value higher than that of the US dollar (USD) to its current value of $0.76USD. The value of the Canadian dollar against the US dollar is shown in Figure 2.9:

Figure 2.9: Value of CAD against USD: September 2012 – August 2016



Source: Bank of Canada[13]

For a company operating chiefly in US dollars, paying an employee in Canadian dollars has become far more attractive as the value of Canadian currency has fallen. In Alberta specifically, both the higher rate of unemployment and the value of the Canadian dollar has acted in favour of labour competitiveness.

CERI used the results from the Government of Alberta's 2015 Alberta Wage and Salary Survey[14] to populate labour costs for various positions required for the construction and operation of a petrochemical facility. CERI also used the results from the United States Department of Labor's Bureau of Labor Statistics' Occupational Employment Survey (May 2015)[15] to populate similar labour costs for the states of Texas and Louisiana. CERI used data from Compass International's 2016 Global Construction Costs Yearbook for professional engineering salaries in Alberta and Texas, as well as specific positions in Saudi Arabia. Select positions and their salaries are shown in Table 2.2. All values are shown in Canadian dollars; wage rates in USD were converted at the rate of 1 CAD = 0.76 USD.

[13] Bank of Canada, 10-Year Currency Converter, accessed September 2016, http://www.bankofcanada.ca/rates/exchange/10-year-converter/

[14] Government of Alberta, Wages and Salaries, 2015, http://occinfo.alis.alberta.ca/occinfopreview/info/browse-wages.html

[15] United States Department of Labor, Occupational Employment Statistics, May 2015, http://www.bls.gov/oes/current/oes_nat.htm

Table 2.2: Select Positions/Salaries: Alberta, Texas, Saudi Arabia

Alberta	
Chemical Plant Machine Operators	$41.04/hour, $86,271/year
Supervisors, petroleum, gas and chemical processing and utilities	$61.43/hour, $127,567/year
Manufacturing Managers	$50.57/hour, $105,167/year
Construction trades helpers and labourers	$25.89/hour, $58,644/year
Construction Managers	$51.40/hour, $110,284/year
Professional Engineer	$130-200/hour[16]
Texas	
Chemical Equipment Operators and Tenders	$38.2/hour, $79,482/year
First-Line Supervisors of Production and Operating Workers	$41/hour, $85,254/year
Industrial Production Managers	$69.71/hour, $144,976/year
Construction Labourers	$18.29/hour, $38,038/year
First-Line Supervisors of Construction Trades and Extraction Workers	$42.77/hour, $88,972/year
Professional Engineer	$112-164/hour[17]
Saudi Arabia	
Senior Superintendent	$39-52/hour[18]
Common Labourer	$17.55-$23.4/hour[19]
Professional Engineer	$52-73/hour[20]

Source: Compass International's 2016 Global Construction Costs Yearbook.

The salaries highlighted in Table 2.2 show Alberta as a slightly more expensive jurisdiction to operate in, from a labour cost perspective, than Texas, even with the exchange rate favouring salaries in CAD. The salaries in Saudi Arabia are significantly less expensive than those in North America. Compass International notes that as many as 90 percent of construction workers in Saudi Arabia are non-Western Expatriates, which command a much smaller salary than their Western Expatriates or Saudi national counterparts.[21]

Salary data for employees in Ontario is not available at the level of granularity as for the province of Alberta, so knowledge of relative wage rates was used as a proxy when calculating labour cost burdens for a petrochemical facility in Sarnia. Relative wage rates were also used for calculating salaries of positions unknown in Saudi Arabia. Statistics Canada reports that manufacturing salaries in Ontario are 70 percent of those in Alberta, while trades and equipment operators'

[16] Compass International, 2016 Global Construction Costs Yearbook, pp 111.
[17] Based on $95-140/hour in Washington D.C. Compass International page 491, at 0.9 calibration factor for Texan cities (page 500)
[18] Compass International, 2016 Global Construction Costs Yearbook, pp 373.
[19] ibid
[20] Based on estimate of 80% of workers being paid non-western expat rates, Compass International, 2016 Global Construction Costs Yearbook, pp 372.
[21] Compass International, 2016 Global Construction Costs Yearbook

salaries in Ontario are 84 percent of those in Alberta, all as of August 2016.[22] Hays Oil & Gas Global Salary Guide 2015[23] reports that Middle Eastern Operator/Technician wage rates are 70 percent of those in North America.

As the factors impacting labour competitiveness in Alberta are dynamic, it is important to note that the timeline for construction of a petrochemical facility could be four years, with two years of design and regulatory approval prior to that. The current pressures on labour rates may not look the same throughout the duration of planning, construction or operating a facility. The petrochemical industry, like any other industry, is not in a position to set labour rates so as to be competitive against other jurisdictions. Knowledge of trends and the dynamic factors at play can help in adjusting other factors within the industry's control in the context of long-term planning.

Payable corporate taxes are a significant component of total project cost and vary between jurisdictions. The rate applicable to a petrochemical facility in Ontario is 11.5 percent provincially[24] plus 15 percent federally,[25] in Alberta it is 12 percent[26] provincially plus 15 percent federally and in Louisiana it is 8 percent at the state level[27] and 35 percent federally.[28] The state of Texas is not subject to a state corporate tax and pays only the 35 percent federal tax rate.

Taxation in Saudi Arabia is not straightforward, with different types of taxes and rates applying, depending on whether the corporation in question is a Saudi Arabian corporation. Saudi companies are subject to a 2.5 percent religious tax, known as a zakat, on its income and profits.[29] Foreign-owned corporations see a tax rate of 20 percent.[30] The analysis shown in Figure 2.2 lists project costs for both foreign and nationally-owned companies operating in Saudi Arabia.

The total corporate tax rates seen in the various jurisdictions are shown in Table 2.3.

[22] Statistics Canada, Average hourly wages of employees by selected characteristics and occupation, unadjusted data, by province, September 2016, http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/labr69a-eng.htm
[23] Hays, Oil & Gas Global Salary Guide, 2015, http://hays.com/cs/groups/hays_common/@og/@content/documents/promotionalcontent/hays_1429953.pdf
[24] Canada Revenue Agency, Corporation Tax Rates, July 2016, http://www.cra-arc.gc.ca/tx/bsnss/tpcs/crprtns/rts-eng.html
[25] ibid
[26] Government of Alberta, Competitive Corporate Taxes, July 2016, http://www.albertacanada.com/business/overview/competitive-corporate-taxes.aspx
[27] Louisiana Department of Revenue, Corporation Income & Franchise Taxes, accessed July 2016, http://revenue.louisiana.gov/CorporationIncomeAndFranchiseTaxes
[28] IRS, Internal Revenue Manual, January 1, 2016, https://www.irs.gov/irm/part3/irm_03-012-016r-cont02.html#d0e11486
[29] National Industrial Clusters Development Program, Taxation, accessed July 2016, http://ic.gov.sa/index.php?option=com_content&view=article&id=17&Itemid=117
[30] Ibid.

Table 2.3: Corporate Tax Rates

Jurisdiction	Total Rate
Alberta	27%
Ontario	26.5%
Louisiana	43%
Texas	35%
Saudi Arabia – national	2.5%
Saudi Arabia - foreign	20%

Source: Various Federal, Provincial and State government websites.

In practice, foreign corporations looking to invest in Saudi Arabia may do so by setting up a joint venture with a national Saudi corporation. In the case of a joint venture, the lifespan costs of constructing and operating a petrochemical facility would not be reflected by either of the totals (Saudi Arabia – foreign or Saudi Arabia – national) shown in Figures 2.1 through 2.5.

With corporate taxes representing such a significant share of total project costs, the corporate tax rate can be a determinant in whether or not an investment is made. In order to incent investment, governments can offer concessions that offset corporate taxes payable.

Referring back to Figures 2.1, 2.2, 2.4 and 2.5, the whole story is not told without considering concessions given by governments to specific projects. All told, the USGC is often more competitive than both the Alberta Industrial Heartland and Sarnia.

The USGC is the largest petrochemical cluster in North America, accounting for approximately 47 percent of total US refining. The energy, petrochemical and plastics industry in the USGC region certainly benefits from a complex production and transportation infrastructure, such as ports, highways, railroads and pipelines, providing easy access to the rest of the world. In addition, Texas and Louisiana both benefit from an abundance of low-cost feedstock. Without a doubt, the USGC petrochemical sector has really taken off in the past decade, fueled in part by the shale gas boom. The same is true for petrochemical facilities in other parts of the US, absorbing much of the increased supply of ethane, as they switch from other NGLs and heavier petroleum-based naphtha feedstock.

Alberta's Industrial Heartland, however, is also fueled by abundant and low-cost feedstock, leading to lower production costs. With four world-class ethylene plants producing approximately 8.6 billion pounds of ethylene annually,[31] Alberta is capitalizing on ethane feedstock, as is Ontario's petrochemical hub. In this sense, petrochemical industries in Canada and the US, not located just in PADD III (Gulf Coast) are structured in a similar way – they possess a cost advantage as nearly half of the world's capacity is configured to operate on heavier feedstock such as naphtha. The latter is still the single largest feedstock globally for the petrochemical sector, accounting for 45 percent. This is followed by ethane at 27 percent,

[31] Government of Alberta, Alberta's Energy Industry: An Overview, June, 2010, pp. 3.

propane, gas oil, butane and other non-specified feedstock at 17 percent, and other feedstock[32] at 11 percent.

Yet, the USGC region is experiencing something of a petrochemical boom or resurgence. In Texas alone, the American Chemistry Council has estimated that 100 petrochemical projects worth US$50 billion will be completed within ten years.[33]

When comparing jurisdictions, in actuality the USGC is more competitive than both Alberta and Ontario and one of the reasons are subsidies or incentives. Further spurring the attractiveness of investing in the region are local or state subsidies and incentives in Texas and Louisiana, and other parts of the US. It is also important to note that Saudi Arabia's costs are lower, in part due to incentives making their feedstocks artificially low. An element to consider in all jurisdictions is the existence of "backdoor deals"; that is, agreements to incent investment that are done on a personal level, with the details left unadvertised. Comparisons can only be made between projects whose incentives have been published or otherwise relayed. This section only discusses the relationship with subsidies in the US, Canada's largest competitor.

The USGC is also home to federal, state and local incentives available to the energy, petrochemical and plastics industry. It is also interesting to note that the subsidies and corporate incentives received in the USGC and in other regions tend to be more project specific, rather than a program such as Alberta's C$500 million Petrochemicals Diversification.[34]

Incentives such as the Texas Enterprise Fund (TEF) offers tax abatement to companies investing in the region and provides money for job-creating ventures.[35] Dow Chemical applied for the fund in April 2012, receiving a US$1 million grant while Kuraray America, a US chemical company, is receiving a similar amount; 19 projects across various sectors received a total grant amount for US$56.7 million, in just the Houston/Gulf Coast region.[36] Between 2003 and 2014, the TEF gave out approximately US$500 million in return for job-creating investment.[37] The fund is drawing attention from various sectors.

[32] The Other Feedstock category generally refers to NGLs and LPG mixes, as well as refinery gases or a mix of various feedstock types.
[33] Houston Chronicle, Houston prepares for its plastics and chemicals export boom, August 25, 2016, http://www.houstonchronicle.com/business/energy/article/Houston-prepares-for-its-plastics-and-chemicals-9185520.php
[34] Alberta Energy, Petrochemicals Diversification Program, http://www.energy.alberta.ca/EnergyProcessing/4130.asp
[35] NY Times website, Boo, Promises 20,000 New Jobs but Shortages Too, http://www.nytimes.com/2012/07/15/us/texas-oil-boom-promises-20000-new-jobs-but-also-water-and-electricity-shortages.html?_r=0
[36] Government of Texas, Office of the Governor Economic Development and Tourism, Texas Enterprise Fund: Locations of Contract Awardees in the Houston/Gulf Coast Region, http://gov.texas.gov/files/ecodev/TEF_Gulf.pdf
[37] Government of Texas, Wide Open for Business, Texas Enterprise Fund, https://texaswideopenforbusiness.com/services/texas-enterprise-fund

Other incentives include Chapter 313, or 313 agreements. Under Chapter 313 of the Texas Tax Code, school districts may provide property "tax credits and an eight-year limitation on the appraised value of a property, for the maintenance and operations portion of the school district property tax".[38] In exchange for the value limitation and tax credit, the property owner must enter into an agreement with the school district to create a specific number of jobs and build or install specified types of real and personal property worth a certain amount.[39] The State of Texas reimburses the school districts that awarded the tax break, for lost tax revenue. This program has encouraged capital investment and job creation, but has also impacted Texas' annual budget. As of December 31, 2013, there were 242 executed agreements between 137 school districts and 174 businesses.[40] Petrochemical companies such as Dow Chemical, BASF Corporation, Air Liquide Large Industries, Phillips 66 Company and Freeport LNG Development have, for example, applied for tax breaks in the Brazosport ISD, in exchange for job-creating investment in the school district.[41] Petrochemical and the renewable energy sectors, as well as other manufacturing, such as Samsung and Hewlett-Packard, are attracted to these 313 agreements.

Similarly, Louisiana attracts capital investment via tax breaks and other incentives as well. South African-based Sasol is building a massive petrochemical project in the state. Worth US$8.1 billion, the project includes an ethane cracker and 6 petrochemical plants, located in the Lake Charles area.[42] The company will create 500 direct jobs, almost 2,400 indirect jobs and approximately 5,000 construction jobs.[43] Sasol will receive a performance-based grant of US$115 million from the state for land acquisition and infrastructure costs associated with the facility,[44] as well as will qualify for Louisiana's new Competitive Projects Payroll and the Louisiana Quality Jobs Program.[45] Louisiana Governor Bobby Jindal and Louisiana Economic Development were credited as factors for Sasol's investment in the location.[46] Also in Louisiana, $2.2 billion in reductions in owed property tax over ten years will be reduced from Sempra Energy's approximately $6 billion LNG facility.[47]

[38] Government of Texas, Chapter 28: Government Financial Subsidies, http://comptroller.texas.gov/specialrpt/energy/pdf/28-GovernmentFinancialSubsidies.pdf, pp. 371.
[39] ibid
[40] State Auditor's Office, An Audit on Selected Major Agreements Under the Texas Economic Development Act, November 2014, Report No. 15-009, https://www.sao.texas.gov/reports/main/15-009.pdf
[41] Texas Ahead website, Chapter 313 School Value Limitation Agreement Documents, http://www.texasahead.org/tax_programs/chapter313/applicants/
[42] PN website, Sasol to build $8.1 billion petrochemical complex in Louisiana, October 27, 2014, http://www.plasticsnews.com/article/20141027/NEWS/141029734/sasol-to-build-8-1-billion-petrochemical-complex-in-louisiana
[43] ibid
[44] ibid
[45] ibid
[46] ibid
[47] Reuters, After Jindal, Louisiana reels from corporate tax giveaways, March 8, 2016, http://www.reuters.com/article/us-louisiana-budget-politics-insight-idUSKCN0WA2OG

Tax breaks are a large factor in Shell Chemical's ethane and derivatives complex, located in Beaver County, Pennsylvania.[48] Home to the enormous Marcellus Shale and the underlying and rapidly growing Utica Shale, the US Northeast is an ideal location for the cracker plant. The facility was approved in June 2016 and will likely be on-stream in the 2020s, if construction starts within the next 18 months.[49] It will use 100,000 bpd of locally-produced ethane from the Appalachia Basin and have a 1.6 million tons per annum (Mtpa) of polyethylene capacity.[50]

In 2012, then Governor Corbett pushed through a tax break for Shell, a US$2.10 credit for every barrel of ethane it buys from Pennsylvania's oil and gas operators.[51] The company will also have 25 years of tax cuts and exemptions because the site is an expanded Keystone Opportunity Zone.[52] The tax incentives were an important part of the equation to move ahead with the project, according to Shell's Vice President of Pennsylvania Chemicals Project, Ate Visser.[53]

While Figures 2.1, 2.2, 2.4 and 2.5 give examples of what plant gate cost calculations for new petrochemical facilities could look like across various jurisdictions, knowing the dynamic nature of cost factors including shifting wage rates, changing feedstock prices, and opportunities for government assistance, whether through official programs or project-specific incentives, will help inform a more accurate cost outlook. Figure 2.10 shows an example of what project-specific subsidies may look like. Using information gathered on Sempra's LNG facility and its $2.2 billion rebate on operating expense with a capital expenditure of $6 billion, ratios between capital and operating expenditures for a liquids facility are modified. When looking at a USGC liquids petrochemical facility's costs, taking into account potential project-specific rebates, it comes in at less expensive than either Canadian jurisdiction on both capital and operating costs.

[48] Petrochemical Update, Location and tax breaks key to Shell's Pennsylvania cracker plant approval, July 8, 2016, http://analysis.petchem-update.com/engineering-and-construction/location-and-tax-breaks-key-shells-pennsylvania-cracker-plant-approval

[49] ibid

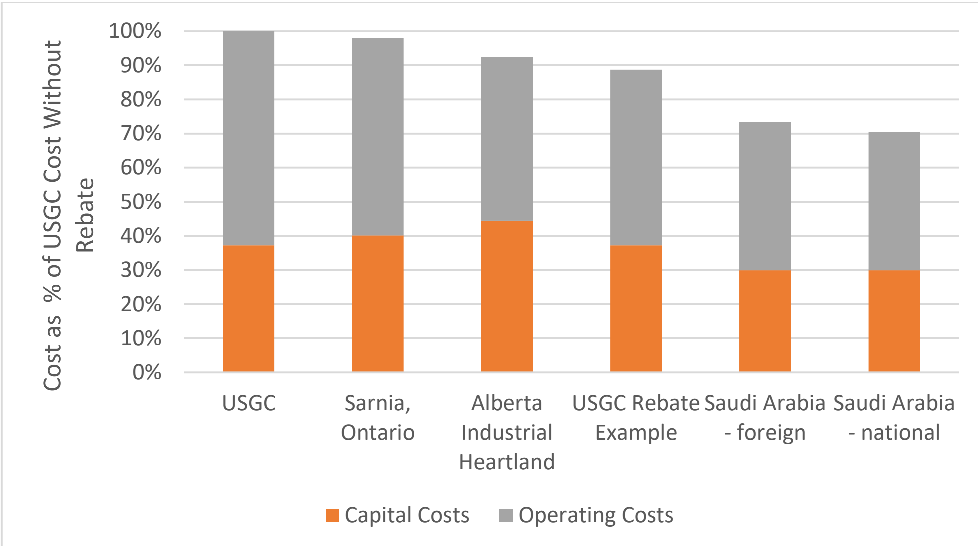
[50] Power Source, Shell cracker plant in Beaver County to provide 600 jobs when it opens, June 7, 2016, http://powersource.post-gazette.com/powersource/companies/2016/06/07/Shell-says-Marcellus-cracker-is-a-go-ethane-beaver-county-pennsylvania-pittsburgh/stories/201606070131

[51] ibid

[52] ibid

[53] Petrochemical Update, Location and tax breaks key to Shell's Pennsylvania cracker plant approval, July 8, 2016, http://analysis.petchem-update.com/engineering-and-construction/location-and-tax-breaks-key-shells-pennsylvania-cracker-plant-approval

Figure 2.10: Relative Costs of a New Liquids Petrochemical Facility, Including USGC Project-Specific Rebate



Source: CERI

In order to make a comprehensive comparison between jurisdictions, plant gate costs are a start but do not tell the entire story. It is necessary to consider the market for the product and incorporate the costs of transporting the product to the market. In a highly integrated petrochemical cluster, a product may be demanded locally which eliminates costs associated with transportation. For example, propylene produced in Alberta is consumed locally to make polypropylene. A project proponent will assess demand for its particular product and evaluate netbacks given its knowledge of product end destination, comparing netbacks to the end destination between potential project locations.

An advantage that the USGC has over Alberta's Industrial Heartland or the Sarnia region is its proximity to shipping channels for international export. When comparing exports to Asia, USGC products can be sent the short distance to export terminals along the Gulf Coast, while Alberta product must be shipped via rail to export terminals either off the coast of British Columbia or the west coast of the United States. It is likely that product produced in Ontario would not be sent to Asia but consumed in North America or sent to Europe. Transportation rates are negotiated confidentially between the shipper and freight company, however through industry and government interviews as well as publicly available data,[54,55,56] CERI estimated costs to ship petrochemicals from Alberta and the USGC to an Asian market. It is important to keep in mind

[54] Methanex, Methanex Investor Presentation, September 2016, https://www.methanex.com/sites/default/files/investor/MEOH%20Presentation_September2016.pdf, slide 9

[55] SeaRates, accessed October 2016, https://www.searates.com/

[56] Platts, The impact of rising freight rates on olefins/petrochemical industry, March 2014, http://www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2014/xc450/presentations/Day%202%20-%2011.30%20am%20Deavy%20Aron.pdf

that rates seen by individual shippers will vary according to their negotiated contracts. The rates assumed for this analysis, in USD, are shown in Table 2.4.

Table 2.4: Estimated Shipping Rates

	Liquid	Solid
AIH to Asia (via Vancouver)	$90/tonne	$60/tonne
USGC to Asia	$80/tonne	$50/tonne

Source: CERI

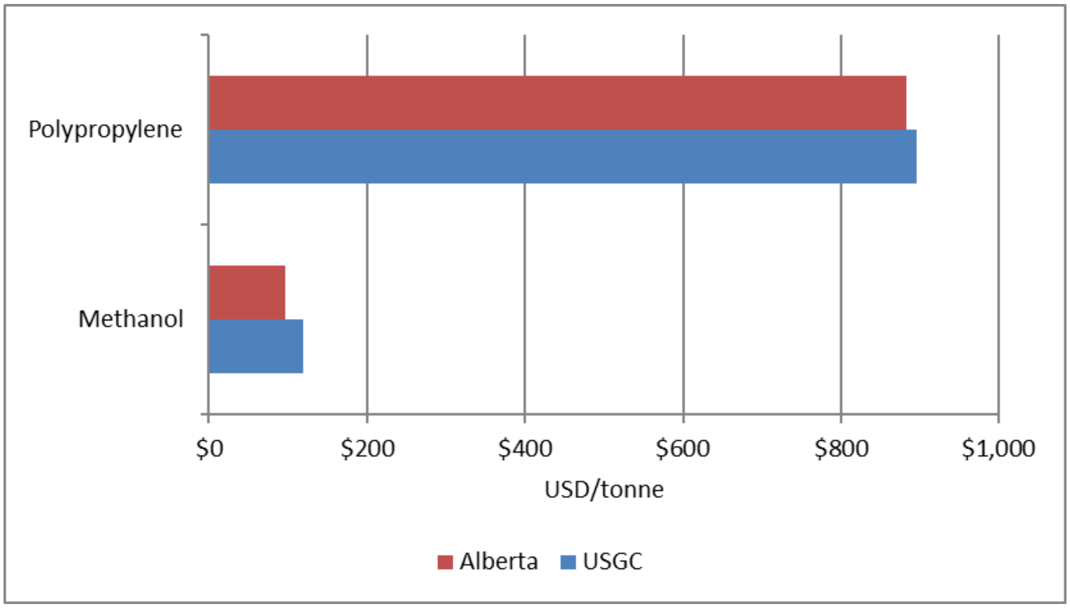
For methanol, using a posted contract price of USD$285/tonne in Asia Pacific,[57] the plant gate costs previously discussed (using the USGC values that take into account project-specific rebates, assuming production of 300 million gallons/year[58]), miscellaneous fees of approximately 20%[59,60] (duty, VAT, insurance, handling) and the transport costs in Table 2.4, the netbacks are $63/tonne from the USGC and $40/tonne from Alberta.

For polypropylene, using a price in China of 9500 Yuan/tonne[61] or USD$1,425/tonne,[62] the plant gate costs previously discussed (assuming production of 500,000 tonnes/year), fees of 20% as above and transport costs as in Table 2.4, the netbacks are $896/tonne from the USGC[63] and $882/tonne from Alberta.

The results of these calculated netbacks are shown in Figure 2.11.

[57] Methanex, Our Business, accessed October 2016, https://www.methanex.com/our-business/pricing
[58] 300 million gallons/year = 0.899 million tonnes/year at a density of 792 kg/m^3
[59] China Briefing, Import-Export Taxes and Duties in China, March 11, 2013, http://www.china-briefing.com/news/2013/03/11/import-export-taxes-and-duties-in-china.html
[60] Various industry interviews
[61] PolymerTrack, accessed September 2016, http://www.polymertrack.com/mypt.php?login_account_ref=18018&login_password=thewil123&action=menu_subs
[62] Using an exchange rate of 1CAD = 0.15 USD, October 2016
[63] While project-specific rebates were not calculated for a solids plant, for the purposes of netback calculations it was assumed that operating costs would be reduced by the same proportion as for the sample liquids plant.

Figure 2.11: Sample Netback Calculations



Source: CERI

A factor not represented in the netback calculation is freight time: shipping time from Vancouver to Shanghai is approximately 15 days versus approximately 30 days to ship from Houston to Shanghai.[64] An additional 4-5 days is required to bring product from Alberta to Vancouver via rail.[65]

Vitally important to netbacks is the availability of transportation infrastructure. Any bottleneck in a system will increase the cost to transport a good, thereby reducing the netback. A description of Canada's transportation infrastructure for NGLs is described in more detail in Chapter 3.

Further factors on jurisdictional competitiveness, whose impacts may not be necessarily directly quantified, will be discussed in Chapter 3.

[64] SeaRates, accessed September 2016, https://www.searates.com/
[65] Industry interviews

Chapter 3: Key Factors in Making a Competitive Investment in Canada

This chapter will discuss factors whose variability can help determine the attractiveness of investing in the Canadian petrochemical sector. As identified in Chapter 2, the cost of raw material inputs, facility systems and equipment and corporate taxes are large components of the project economics of a new petrochemical facility. Governments can impact corporate taxes through various incentive programs, as described in Chapter 2. Other factors, such as the regulatory environment and access to market are also crucial when considering investment.

Environmental Regulation

The regulatory environment, while not easily quantifiable, can be a determining factor when making an investment decision. Regulatory requirements, the length of time devoted to review, clarity of requirements and certainty around the regulatory process all factor into the regulatory environment's attractiveness to potential investors.

In conversations with industry, CERI consistently heard that the regulatory process in Alberta can take twice the amount of time to work through in comparison to US regulation, while the regulatory process in Ontario can take longer than in Alberta due to backlog. While the size of the project will, to an extent, dictate the length of time required for preliminary engineering and environmental approval, industry suggested 18-24 months as an appropriate estimated timeline for a new petrochemical facility in Alberta. Applying the factors mentioned above, a timeline for approval in the US may take 9-12 months, while in Ontario that process could take 20-30 months.

While the social acceptance and public confidence in the petrochemical industry will be discussed further in another section, it is important to note its impact on the regulatory process. The petrochemical industry, not only within Canada but in the US and globally, has not seen the issues relating to public confidence that other resource-based industries have, and therefore is comfortable with a certainty in regulatory proceedings. With this clarity of what the regulatory process will look like, corporations can accurately estimate the regulatory burden and incorporate it into project plans, encouraging investment.

The political stability enjoyed in both Canada and the United States is another factor that encourages investment. Potential investors are not concerned that feedstock will be cut off due to geopolitical reasons. In Saudi Arabia, for example, the sudden doubling of feedstock cost in 2015 will present significant impacts on operators currently in the country.

With the clarity and stability of the Canadian regulatory process in mind, industry has noted that the time required to gain regulatory approval is not always seen as a disincentive to investment. Construction on a petrochemical facility cannot start until the environmental application has been approved, but this allows for up-front scoping and design to be solidified prior to construction. Again, the certainty around the Canadian regulatory process allows corporations to be confident in investing in facility design while the environmental assessment is occurring.

In making a direct comparison between Canadian and US regulation, however, industry did note that the US regulatory environment can be friendlier towards investment, with shorter time required for environmental approval and less interplay between the different levels of government and various departments involved.[1]

Social Acceptance/Public Confidence

Key factors in determining whether an investment is competitive include production costs (including government incentives), market demand, access to market, and construction management and regulatory approvals. Social acceptance falls into the latter category, as public confidence is linked by many to the openness and efficiency of the regulatory process. While always having been an important factor in attracting investment, it is becoming more so in the past decade, particularly following several high-profile failures of similarly scaled energy projects.

Despite the fact that refineries, LNG terminals and oil terminals have experienced issues regarding social or public confidence, building new pipeline infrastructure has attracted the most attention. TransCanada Pipeline's (TCPL's) proposed Keystone XL expansion, Enbridge's Northern Gateway, Kinder Morgan's Trans Mountain Expansion (TMX) and TCPL's Energy East Pipeline have, to varying degrees, encountered opposition.

In terms of Alberta's petrochemical industry, its infrastructure is complex and includes gas processing plants (field plants), refineries, straddle plants, fractionation facilities, as well as pipelines for gathering and delivery, and various storage facilities and petrochemical plants. Fueled by abundant and low-cost feedstock, Alberta is the Canadian leader of petrochemical production, with annual sales exceeding C$14 billion.[2] For instance, four world-class ethylene plants are producing a combined annual capacity of ethylene production of approximately 8.6 billion pounds.[3]

When making comparisons between petrochemical producing regions, the level of integration within the sector is an important factor to consider. Elements listed above, such as field plants, refineries, straddle plants, fractionation facilities, storage facilities, production plants and transportation pipelines are all part of an integrated petrochemical cluster. It would be prohibitively expensive for an investor to invest in a standalone petrochemical facility without an existing industry in proximity. While both Alberta and Ontario do have existing integrated petrochemical industries, the level of integration is not to the extent of that seen in either the US

[1] A particular example of a regulatory delay that could lead to a quantifiable loss in revenue is delay in connecting a facility to the electrical grid.

[2] Government of Alberta, Alberta's Energy Industry: An Overview, June, 2010, pp. 3.

[3] ibid.

Gulf Coast or Saudi Arabia. An already high level of sector integration encourages further investment, which leads to a more robust collection of integrated elements.

An economy benefits from diversification as it reduces exposure to risk. Value-added processing increases revenue and employment in an economy that is struggling. In addition, today's low natural gas prices, declining labour costs and government subsidies further spur the attractiveness of the potential investments, in a part of the province that already has energy and petrochemical infrastructure investment totaling C$30 billion.[4] As previously mentioned, the province of Alberta is encouraging investment with a C$500 million Petrochemicals Diversification Program.[5] Announced on February 1, 2016, the program has received 16 applications from local and international companies.[6]

With the petrochemical industry being responsible for adding over 9,500 direct jobs in the province of Alberta,[7] communities hosting these petrochemical clusters, located primarily in Joffre and Fort Saskatchewan, certainly see them as value-adding job creators. These petrochemical facilities are seen as not only playing an important role in producing goods used for industrial and consumer products, but also in providing the province a unique opportunity to diversify its economy from simply being a producer and exporter of natural gas and oil.

The number of potential investments, totaling more than $29 billion in new investment,[8] from the Petrochemicals Diversification Program certainly reflects the positive investment climate and public confidence for these mega-projects.

While the petrochemical industry in Alberta is being viewed in a positive light, it is important to note that there is growing attention surrounding the petrochemical sector in Ontario. This was highlighted by a two-day protest in September 2015 in Sarnia's Chemical Valley, bringing attention to the pollution caused by local petrochemical industries.[9]

Access to Market

Integrated petrochemical complexes are located primarily in Joffre and Fort Saskatchewan, Alberta and Sarnia, Ontario. These petrochemical clusters play an important role in producing goods used for industrial and consumer products. The centers, along with the large petrochemical hubs in Texas (Mont Belvieu) and Kansas (Conway), are the four major NGL trading centers in North America. The petrochemical clusters in Texas and Kansas are located in close

[4] Alberta Oil Magazine, Why The First Canadian Hydrocarbons To Reach Asia Might Not Be Oil Or Gas, But Plastic Pellets, June 1, 2016, http://www.albertaoilmagazine.com/2016/06/first-canadian-hydrocarbons-reach-asia-might-not-oil-gas-plastic-pellets/

[5] http://www.energy.alberta.ca/EnergyProcessing/4130.asp

[6] ibid

[7] Government of Alberta, Petrochemicals, accessed September 2016, http://www.energy.alberta.ca/Org/pdfs/factsheet_Petrochemicals.pdf

[8] http://www.jwnenergy.com/article/2016/6/alberta-says-its-petrochemicals-incentive-program-has-received-double-investment-interest-expected/

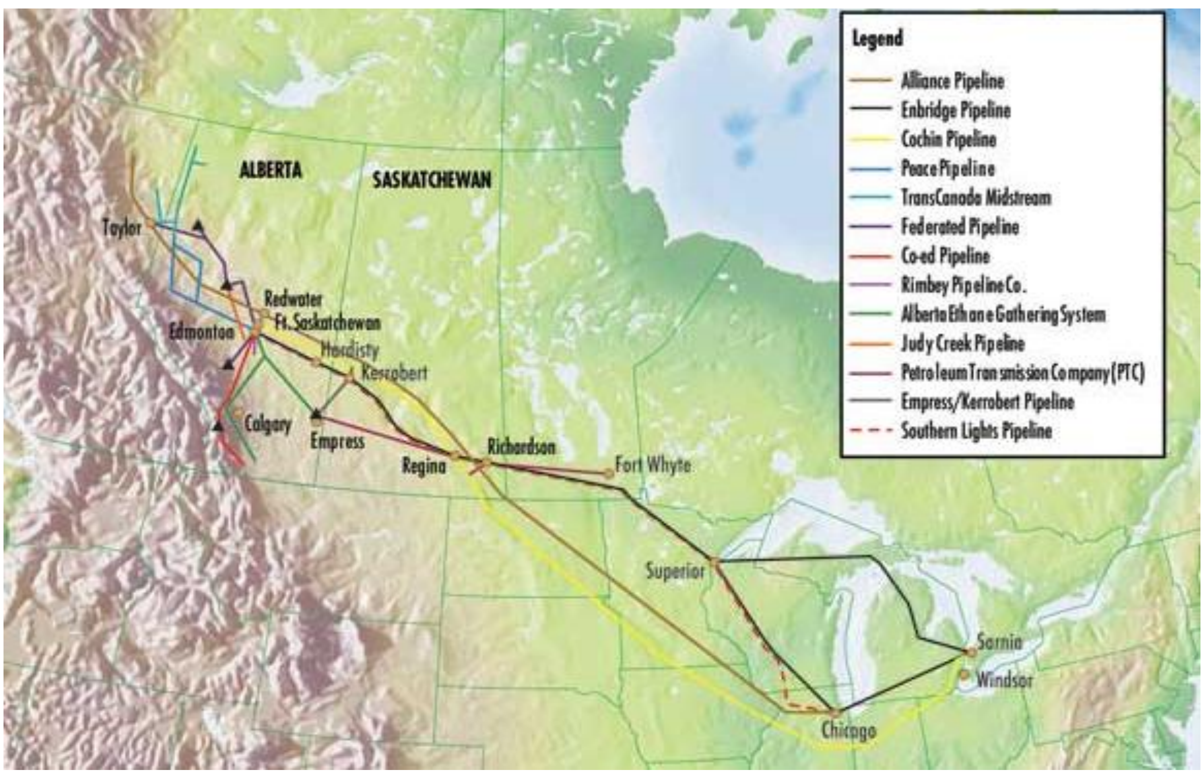
[9] The Observer website, Toxic Tour marches through Chemical Valley to raise awareness of local pollution, Terry Bridge, September 6, 2015.

proximity to market, with the former being the largest consuming region on the continent with strategic location to the US Gulf Coast, as well as significant storage, pipelines and proximity to refineries.[10] The clusters in Alberta and Ontario, however, are located further from consuming markets, whether North American or global.

This section explores access to market for petrochemical products in Canada, with a focus on origination from Alberta and Ontario. It is important to note that a third petrochemical cluster is located in Montreal (Montreal-East) but is quite small and not discussed in this section.

The NGL infrastructure in Canada, particularly in Alberta, is complex and extensive, including gas processing plants (field plants), refineries, straddle plants, fractionation facilities, as well as a spider web of pipelines for gathering and delivery, and various storage facilities and petrochemical plants. Figure 3.1 illustrates Canada's complex NGL network, from its pipelines, to fractionation facilities, to its petrochemical hubs.

Figure 3.1: Major NGL Infrastructure in Canada



Source: NEB[11]

[10] National Energy Board website, Natural Gas Liquids - How Canadian Markets Work, http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/prcng/ntrlgslqd/cndnmrkt-eng.html (accessed on September 22, 2012)
[11] National Energy Board website, Canada's Energy Future: Infrastructure Changes and Challenges to 2020 - Energy Market Assessment, http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2009/nfrstrctrchngchllng2010/nfrstrctrchngchllng2010-eng.html#s4 (accessed on September 22, 2012)

This figure illustrates major gas pipeline systems, or gathering lines, as well as main NGL delivery systems, including NGL export pipeline (Enbridge Mainline [Lines 1/5[12]], Empress-Kerrobert, the Alliance Pipeline and the Petroleum Transmission Company) and NGL import pipelines (Southern Lights/Line 13, Cochin Pipeline, Mariner West, Vantage Pipeline and UTOPIA Pipeline). The latter will provide additional feedstock capacity to the Sarnia area, likely in operation in 2018, importing NGLs from the Utica Shale in Harrison County, Ohio – hence the name of the pipeline: Utica to Ontario Pipeline Access (UTOPIA).[13]

In addition to the extensive pipeline network for exporting and importing NGLs, the clusters at Fort Saskatchewan, Alberta and Sarnia/St. Clair, Ontario require rail to deliver product to tidewater and consuming markets. Both centers are also linked to rail infrastructure that plays an important role in moving NGLs, particularly from the Western Canadian Sedimentary Basin to the end-users. Currently propane and butanes, as well as various refined petroleum products and chemicals, are transported from western Canada to central Canada and other consuming locations in the US. Diluent, on the other hand, is transported from various locations in the US to oil sands producers in Alberta.

Canada has two major rail lines that are available for transporting petrochemical products – Canadian National (CN) and Canadian Pacific (CP). Both railways are classified as Class 1 and are also major players in North America, possessing vast networks of rail extending across Canada and the US. Further description of the rail network can be found in Appendix C.

The existence of the two rail lines allows for competition however the existence of company-specific infrastructure dampens that possibility. Special loading/offloading rail terminals are required and usually a plant is only connected to one of the major rail carriers, resulting in significant incremental cost when multiple rail carriers need to be engaged in delivery. This is one of the major costs to petrochemical producers.

Federal rail regulation has introduced competitive mechanisms which serve to reduce the cost of transportation to markets. The two mechanisms are interswitching and arbitration, both of which are described below.

Interswitching is the practice of one rail carrier moving product along their line for a limited distance in order to facilitate long-distance transportation by its competitor carrier. The federal government mandates a maximum fee that the carrier can charge, depending on the distance required for the interswitch.[14] The practical implication on a petrochemical producer is that it has some flexibility in the location of its facility while still being able to ensure access to rail under competitive pressure.

[12] Net of Kerrobert

[13] 2b1st Consulting website, Kinder Morgan to connect USA and Canada through UTOPIA project, http://www.2b1stconsulting.com/kinder-morgan-to-connect-usa-and-canada-through-utopia-project/

[14] Government of Canada, Railway Interswitching Regulations, SOR/88-41, December 17, 1987, http://laws-lois.justice.gc.ca/eng/regulations/sor-88-41/FullText.html

In response to the backlog in grain shipping in 2014, the federal government extended the range of interswitching from 30 km to 160 km in Alberta, Manitoba and Saskatchewan.[15] This policy change helped reduce backlog by opening up shipping options, and was not intended to be a permanent change in regulation. In April of 2016, the extended interswitching range was extended for a year.[16] Unless petrochemical producers are assured of a permanent change in the regulation, it is unlikely that any further short-term extensions to the longer interswitching range will positively impact petrochemical investment.

The second mechanism in place is arbitration offered by the Canadian Transport Agency.[17] If the shipper wishes to negotiate transportation rates with the rail carrier and the two parties cannot come to an agreement, they can request that an arbitrator be assigned to settle the matter. The federal government will assign an arbitrator, with the cost of doing so split between the two parties. The arbitrator will settle on one of the two shipping rates being discussed – a compromise between the two rates will not occur. Both parties can recognize the inherent risk when calculating their expected cost, therefore both parties are incentivized to negotiate between themselves before requiring an arbitrator. From a practical standpoint, petrochemical producers can expect that their rail rates are ultimately lower overall due to this competitive mechanism being in place.

An important factor in the transportation of petrochemical products is the impact that the volatility of the product has on space for negotiation and ultimate transit pricing. Solid products such as polypropylene pellets do not pose a shipping risk. In the case of an incident involving a spill, the polypropylene can easily be collected without impacting the surrounding environment. The transportation of more volatile fluids, such as methanol which is highly toxic and flammable, carries a greater risk. Canadian law creates an obligation for rail carriers to carry product,[18] creating a need for assignment of liability and providing a basis for negotiating a higher cost of transportation.

From an investor standpoint, factors such as the regulatory climate, level of integration of the local petrochemical sector and access to market can be as critical in decision-making as the project economics. While Canadian regulation can take longer than its USGC counterpart, it is still considered to be clearly defined and not tied up with issues of public trust. Its levels of bureaucracy may serve as a deterrent when comparing to the simpler system in the US. The lack of integration in the two Canadian petrochemical sectors may serve as a deterrent, as a new facility must ensure the necessary tie-ins to feedstock and transportation infrastructure are in

[15] Government of Canada, Legislative Summary of Bill C-30: An Act to amend the Canada Grain Act and the Canada Transportation Act and to provide for other measures, April 1, 2014, http://www.lop.parl.gc.ca/About/Parliament/LegislativeSummaries/bills_ls.asp?ls=c30&Parl=41&Ses=2

[16] Government of Canada, Government of Canada intends to work with Parliament to extend certain provisions for rail in the Canada Transportation Act, April 22, 2016, http://news.gc.ca/web/article-en.do?nid=1055999

[17] Government of Canada, Canadian Transportation Agency, Arbitration: Rail Arbitration, July 6, 2016, https://services.otc-cta.gc.ca/eng/arbitration-rail-arbitration

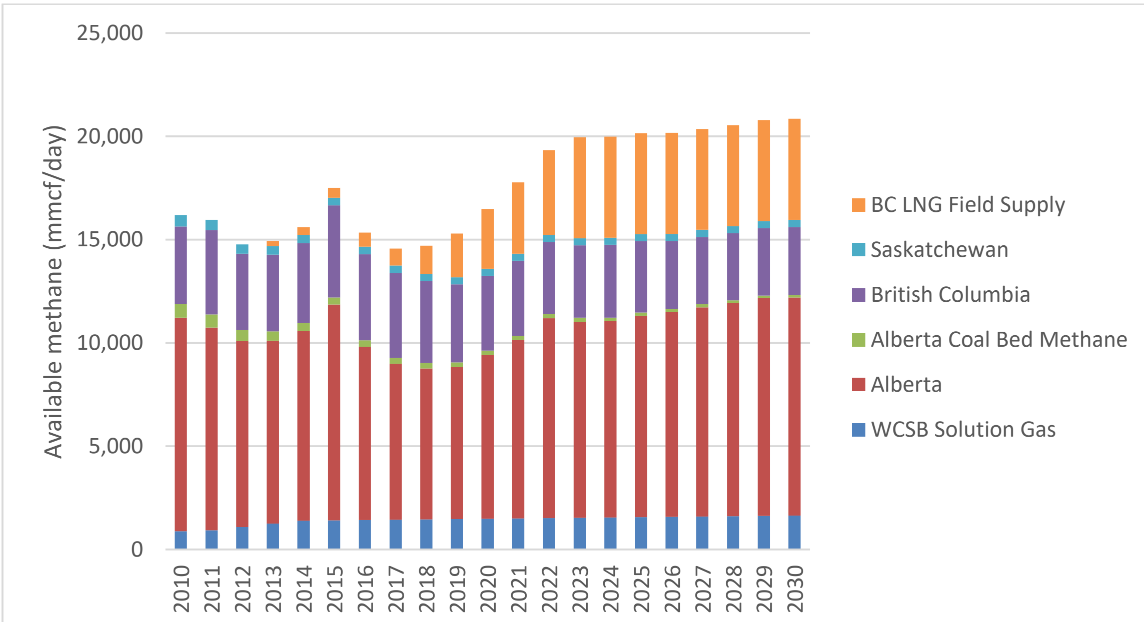
[18] Parliament of Canada, Rail Shipper Protection Under the Canada Transportation Act, August 25, 2015, http://www.lop.parl.gc.ca/content/lop/ResearchPublications/2015-57-e.html#txt11

place. Finally, access to market is a critical component in determining the attractiveness of a petrochemical investment. The Canadian petrochemical industry is well positioned with its transportation options at this point.

Chapter 4: Conclusions

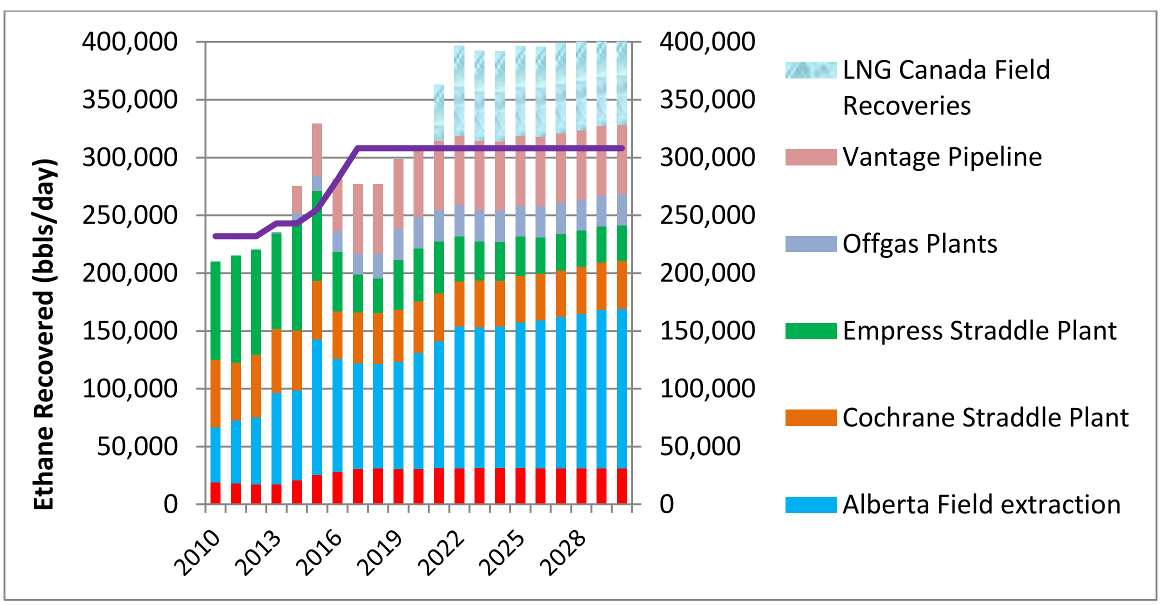
Canada's already active petrochemical sector has room for expansion, with projections of available feedstock from the WCSB. This is shown in Figures 4.1, 4.2 and 4.3.

Figure 4.1: Available Methane: 2010-2030



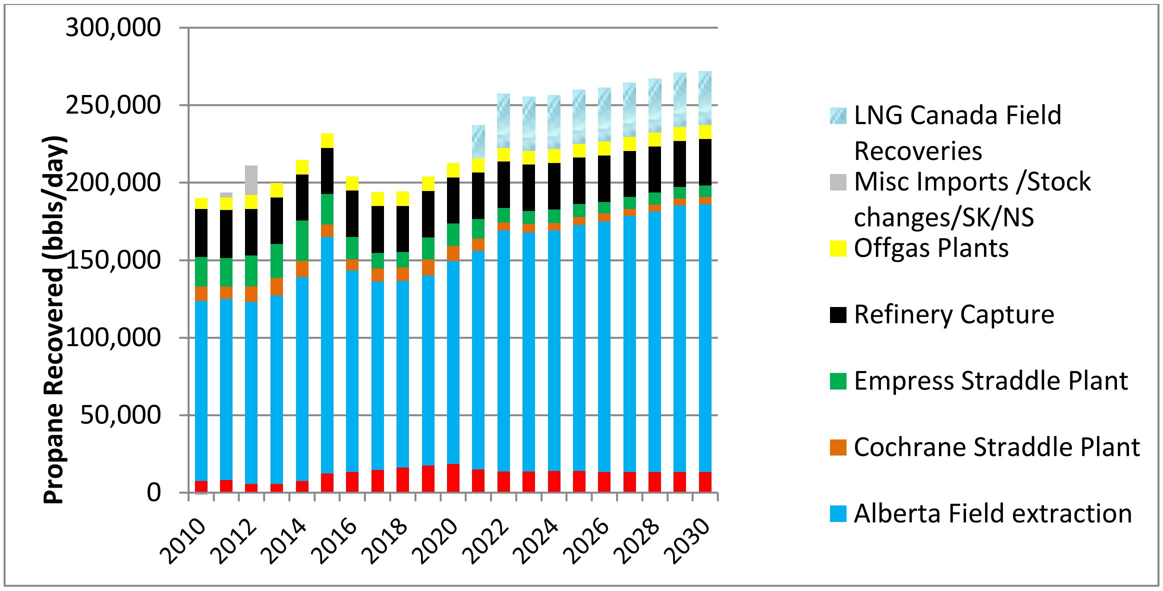
Source: CERI, AER, BCOGC

Figure 4.2: Recovered Ethane: 2010-2030



Source: CERI, AER, BCOGC

Figure 4.3: Recovered Propane: 2010-2030



Source: CERI, AER, BCOGC

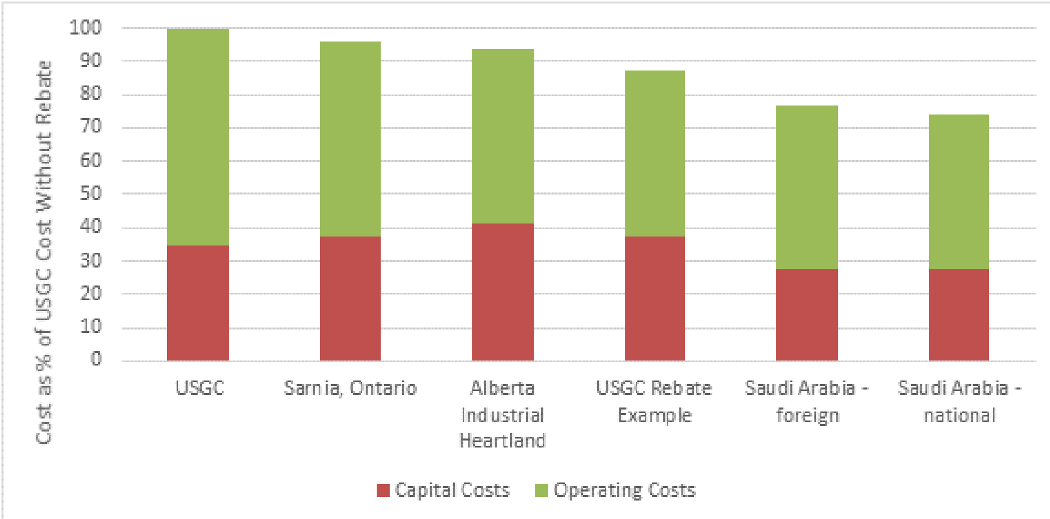
As is evident from Figures 4.1-4.3, feedstock availability is projected to rise through 2030 as production of natural gas increases out of the WCSB. The possibility of LNG development in BC adds the potential for significant volumes of ethane and propane recovery, as well as the possibility of methane recovery if the entirety of the new natural gas development isn't directed to LNG projects.

The Government of Alberta recognizes the availability of feedstock and is seeking to encourage investment in the methane and propane space through its Petrochemicals Diversification Program. While the winning projects have not been announced, with 16 applicants[1] the program will be fully subscribed. The program has the potential to attract investments as it makes Alberta a more competitive jurisdiction when compared to the competing areas in the USGC, Ontario and the Middle East, among other locations.

While initial plant gate cost calculations show the USGC to be the most expensive and Saudi Arabia to be the least expensive jurisdictions to invest in a petrochemical facility, both for a liquid and solid product, this is not reflective of the entire story. Figure 4.4 compares plant gate costs between jurisdictions, incorporating an example of project-specific incentives in the USGC to show Canadian jurisdictions as the most expensive within the scope of this study.

[1] Government of Alberta, Petrochemicals Diversification Program attracts significant interest from global investors, June 6, 2016, http://www.alberta.ca/release.cfm?xID=4187883D09635-B916-78DF-DB31D033C5201F5A

Figure 4.4: Relative Costs of a New Liquids Petrochemical Facility, Including USGC Project-Specific Rebate

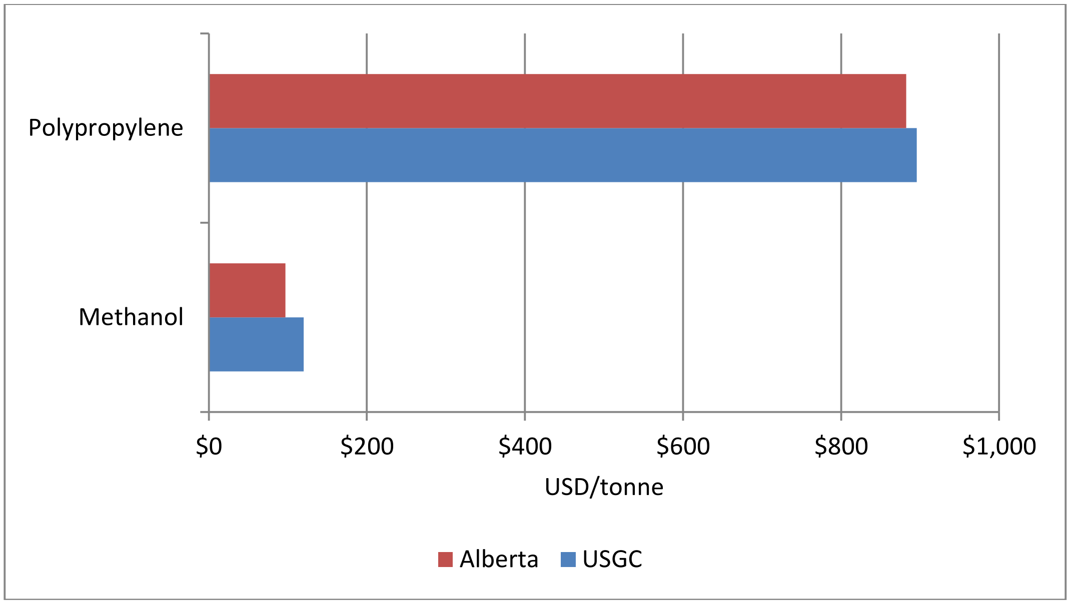


Source: CERI

Within the calculated costs, variables such as raw material inputs, the cost of labour and the corporate tax rate are subject to fluctuation, depending on economic conditions or willingness of governments to provide investment incentives. For example, the cost of labour in Alberta is currently more favourable than under normal conditions, as high levels of unemployment have encouraged more efficient labour productivity, and the disparity between the Canadian and US dollars makes Canadian labour relatively cheap. Both Alberta's unemployment rate and the position of the Canadian dollar against the US dollar have seen fluctuations in the past and will undoubtedly see them again in the future.

Building off of plant gate costs, identifying destination markets and comparing netbacks between jurisdictions will allow a project proponent to compare between jurisdictions. Sample netback calculations for Alberta and the USGC to a Chinese market incorporated estimated transportation costs and showed the USGC to have higher netbacks than Alberta (see Figure 4.5).

Figure 4.5: Sample Netback Calculations



Source: CERI

Consistent with calculated netbacks, the USGC seems to be the more favourable location for investing when looking at recent and current investment plans. Texas is expected to see US$50 billion in investment over ten years,[2] while Alberta hopes to see between $3 and $5 billion invested as a result of the Petrochemicals Diversification Program.[3] Factors other than project economics must be taken into consideration when these investment decisions are made, such as the integration of the petrochemical industry, the access to market, the burden or risk associated with the regulatory environment and the government's willingness to offer project-specific incentives. Table 4.1 highlights the results of CERI's analysis, including interviews with industry and government, in order to show the most favourable jurisdictions in terms of various factors. The scale used is Least/Medium/Most, with least being least favourable, and most – most favourable.

[2] Houston Chronicle, Houston prepares for its plastics and chemicals export boom, August 25, 2016, http://www.houstonchronicle.com/business/energy/article/Houston-prepares-for-its-plastics-and-chemicals-9185520.php

[3] Government of Alberta, Petrochemicals Diversification Program, August 2016, http://www.energy.alberta.ca/EnergyProcessing/4130.asp

Table 4.1: Comparing Jurisdictions

	Alberta Industrial Heartland	**Sarnia, ON**	**USGC**	**Saudi Arabia**
Plant Gate Costs	Least**	Least	Medium**	Most
Regulatory Environment	Medium	Medium	Most	Least/Most*
Access to Market	Least	Medium	Most	Medium
Sector Integration	Medium	Medium	Most	Most

*Depends on the company ownership.
**The USGC also ranks higher than Alberta when looking at sample netback calculations

Source: CERI

It should be noted that the most comprehensive comparisons were made between Canadian and US jurisdictions; information on government and industry practices in Saudi Arabia is not as readily available. In terms of the regulatory environment, it would be expected that operating in Saudi Arabia as a Saudi Arabian-owned company would be the most favourable situation, however foreign-owned corporations are regulated under a different, more prohibitive, set of guidelines.

It should also be noted that while neither of the two Canadian jurisdictions appear to be the most favourable in terms of any of the variables listed in Table 4.1, companies may, and do, still see Canada as an attractive location to invest in petrochemicals.

Appendix A: Petrochemical Feedstock Production: Methodology

In order to model the availability of methane and natural gas liquids (ethane and propane), gas forecasts were developed for the provinces of Alberta and British Columbia.

Historical well data was used to calculate the 2015 production inputs. Information was collected from the Alberta Energy Regulator (AER) and the British Columbia Oil and Gas Commission (BCOGC) that details the historic production of hydrocarbon fluids as well as general well characteristics, such as completion date, initial production rate, total depth, true vertical depth and location.

CERI analyzed data for all of Alberta and British Columbia's natural gas processing facilities for the past decade including their capacities, their outputs, and their liquids yield. This analysis was then aggregated on an area by area basis and was further broken down to separate components such as specification products from natural gas field plants versus NGL mixes, as well as to separate field plants from straddle plants (or reprocessing plants) and NGL fractionators.

It is important to clarify that the capacity of the plants (both for gas processing and liquids extraction) was calculated by CERI as the stated capacity or the maximum processed capacity at one point in time during the surveyed period.

From this, what the liquids yield allows us to determine is the likely composition of the gas being processed by each plant in each area. Theoretically, if a field plant had an extraction efficiency of 100 percent, the amount of liquids being produced by the plants should be equally reflective of the composition of the gas being produced and processed in the area. Thus, the liquids yield as a function of the composition of the gas in the area represents the extraction efficiency of the liquids at the field level.

With NGL mixes produced at the field level the story is somewhat different because it is difficult to determine what the composition of that NGL mix is. However, there are ways to estimate their composition with reasonable accuracy. One way is by looking at the product being produced by the fractionators. The output coming out of the fractionators is directly related to the product coming into the fractionator because the fractionator function is to break down the liquids into its individual components, and therefore, theoretically, no volume losses or gains occur in the process.

It can be determined that fractionators in the Fort Saskatchewan area (major fractionation center) receive the majority of their product via pipeline and some propane plus NGL volumes (from the closest areas) via trucks or rail. Knowing which pipeline systems are connected to the fractionators (Pembina pipelines NGLs system primarily but also Co-Ed system) and knowing which fields and plants are connected to those pipelines allow us to understand the makeup of the NGL mixes being produced in those plants.

The composition of the NGL mix for each area connected to each pipeline system is then determined and, similar to the estimation of the extraction efficiency for the spec product, the extraction efficiency for each liquid in the NGL mix is modeled. This in turn will determine the amount and the type of liquids available to the fractionators going forward. This approach works well in determining the amount of a given liquid in the NGL mix stream.

One of the last pieces of the analysis involves the straddle plants. The straddle plants act as re-processors and thus extract the liquids remaining in the gas stream after the liquids have been partially recovered at the field level either in form of spec product or an NGL mix. Finally, knowing the composition of the gas flowing through the NGTL system (liquids in gas stream minus liquids extracted as spec products and NGL mixes at the field level), we know in theory the volume of barrels of each liquid that is flowing in the gas stream through the pipeline system.

Using historical data from the AER and comparing the barrels flowing through the straddle plant versus the number of barrels extracted we can calculate the extraction efficiency of each straddle plant, which is used for the forecast years. This allows CERI to estimate the liquids of volumes being produced at the straddle plants over the forecast period.

Appendix B: Plant Gate Cost Calculation Methodology

Plant gate costs were calculated for new liquid and solid petrochemical facilities in the Alberta Industrial Heartland, Sarnia, the US Gulf Coast and Saudi Arabia. The costs to design, construct and run the plant for a period of 18 years were calculated. Capital costs included equipment, systems and working capital. Hans Lang's 1947 factors for estimating costs of installed equipment were used for the capital cost calculations, with a factor of 4.74 for a fluids plant and 3.10 for a solids plant used. The factors are used in the equation TOC = EF, where TOC is the total installed cost, E is the cost of equipment and F is the Lang factor. Operating costs included inputs (feedstock, chemicals, power and water), labour, maintenance, insurance, and financial considerations (taxation, interest rates, capital renewal).

The liquids plant was assumed to be a natural gas to methanol process while the solids plant was assumed to be a propane to polypropylene process. The assumed methanol plant produces 300 Mgal/year and requires 0.0929 MMBTU of natural gas for every gallon of methanol produced. The methanol is sold at a price of $0.83/gallon (250 Euro/MT in Saudi Arabia).[1]

The assumed polypropylene plant produces 500,000 mtonnes/year and requires 137.74 gallons of propane for every tonne of polypropylene produced. The polypropylene is sold at a price of $1,105/tonne.[2]

The price of natural gas used was US$4.54/MMBTU in the USGC,[3] US$3.63/MMBTU in Alberta,[4] US$5.1/MMBTU in Sarnia[5] and US$1.75/MMBTU in Saudi Arabia.[6]

The plants were assumed to use 14 MW of power over a year, and power rates were calculated using the data assembled in Table B.1.

[1] Methanex Website, Current Posted Prices, accessed September 2016, https://www.methanex.com/our-business/pricing, Saudi Arabia was assumed to sell at the European rate
[2] Platts, Platts Global Petrochemical Index, December 17, 2015, http://www.platts.com/news-feature/2015/petrochemicals/pgpi/index
[3] Average of EIA's Annual Energy Outlook 2016 reference case outlook
[4] Using the Henry Hub/AECO-C differential from PSAC, CAD1.17/mcf, http://www.psac.ca/business/GMPFirstEnergy/
[5] Using the Henry Hub/Dawn differential from PSAC, http://www.psac.ca/business/GMPFirstEnergy/
[6] Platts, Saudi Arabia hikes price of gas for power production, ethane, gasoline in 2016 budget, December 29, 2015, http://www.platts.com/latest-news/natural-gas/dubai/saudi-arabia-hikes-price-of-gas-for-power-production-26323825

Table B.1: Power Rates Across Jurisdictions

AIH (CAD)[7]	Sarnia (CAD)[8]	USGC (USD)[9]	Saudi Arabia[10]
• $212.42/day • $0.34/kWh • $0.3465/kW/day	• Monthly Service Charge: $25,543.24 • $7.6653/kW • $0.013/kWh	• $21,994.08 for the first 2,000 kW • $10.9/kW for additional kW • $0.00784/kWh	• 0.18SAR/kWh • 30SAR/month

Source: EPCOR, Bluewater Power Distribution Corporation, Entergy Louisiana and Saudi Electricity Company

Table B.2, below, shows the sources of information used for the various jurisdictions considered in this study.

Table B.2: Public Sources of information

AIH	Sarnia	USGC	Saudi Arabia
• Government of Alberta Wages and Salaries Survey • CRA Corporation Tax Rates • Government of Alberta, Competitive Corporate Taxes • Compass International Global Construction Costs Yearbook	• Statistics Canada Wage Survey • CRA Corporation Tax Rates • Compass International Global Construction Costs Yearbook	• US Department of Labor Occupational Employment Statistics • Louisiana Department of Revenue • IRS Revenue Manual • Compass International Global Construction Costs Yearbook • Texas/Louisiana Bureaus of Labor Statistics	• Compass International Global Construction Costs Yearbook • Hays Oil and Gas Global Salary Guide • National Industrial Clusters Development Program

[7] EPCOR, Commercial Rates & Fees, accessed July 2016, http://www.epcor.com/power-natural-gas/regulated-rate-option/commercial-customers/Pages/commercial-rates.aspx

[8] Bluewater Power Distribution Corporation website, Commercial Rates, accessed July 2016, http://www.bluewaterpower.com/index.php/business-top/commercial/commercial-rates

[9] Entergy Louisiana, LLC, Large Industrial Service Rate Schedule, accessed July 2016, http://www.entergy-louisiana.com/content/price/tariffs/ELL/ell_lis.pdf

[10] Saudi Electricity Company, Consumption Tariff, accessed July 2016, https://www.se.com.sa/en-us/customers/Pages/TariffRates.aspx

The calculated values for the components listed above were verified through interviews with government and industry. The majority of knowledge centered around the Alberta and USGC clusters, with little additional information known about Saudi Arabia.

The net cost for each component is discounted back over the lifetime of the project (assumed to be 18 years) to the first time period using discount rates specified in Table B.3, depending on location. All costs were converted to 2016 USD.

Table B.3: Financial Variables for Project Economics Calculations

Factor	AIH	Sarnia	USGC	Saudi Arabia
Inflation	1%	1%	1%	2.7%
Nominal Cost of Capital	10%	10%	10%	10%
Discount Rate	8.9%	8.9%	8.9%	7.1%
Conversion Rate	1USD = 1.294CAD	1USD = 1.294CAD	--	1USD = 3.75SAR

Source: CERI, Bank of Canada, US Federal Reserve, Saudi Arabian Monetary Agency

Appendix C: Transportation Infrastructure

Figure C.1 illustrates CN's North American rail network, one of the longest railway systems in North America and the longest in Canada. CN's network in Canada reaches from the Pacific coast in British Columbia to the Atlantic coast in Nova Scotia; it is Canada's only transcontinental railway. CN's extensive network, however, also reaches to the US Gulf Coast. CN operates in 8 provinces and 16 US States, with a total of slightly more than 20,000 route miles, or approximately 32,160 route kilometers.[1,2] By province, CN's largest first main track rail networks are in Ontario (4,688 km), followed by Alberta (4,421 km) and British Columbia (4,362 km).[3]

Figure C.1: Map of CN's Rail Network

Source: CN[4]

CN serves most of Canada and the Midwestern and Southern US, including approximately 75 percent of the US population and all major Canadian markets.[5] Figure C.1 illustrates CN

[1] CN Rail, Transportation Solutions for Oil Sands Production Phase, Randy Meyer Presentation, The Van Horne Institute, May 13, 2009, http://www.vanhorne.info/files/vanhorne/2%20CN.pdf (pp. 3)
[2] CN website, Investor Financial 2nd Quarterly 2014, http://www.cn.ca/-/media/Files/Investors/Investor-Financial-Quarterly/Investor-Financial-Quarterly-2014/Q2/Q2-2014-US-GAAP-MDA-en.pdf (pp. 23)
[3] Statistics Canada, Table 5 Rail transportation, Length of track operated, by area, at December 31, all carriers http://www.statcan.gc.ca/pub/52-216-x/2009000/t002-eng.htm
[4] Canadian National website, Who we are: facts and figures, http://www.cn.ca/en/about-cn/who-we-are/facts-and-figures
[5] ibid

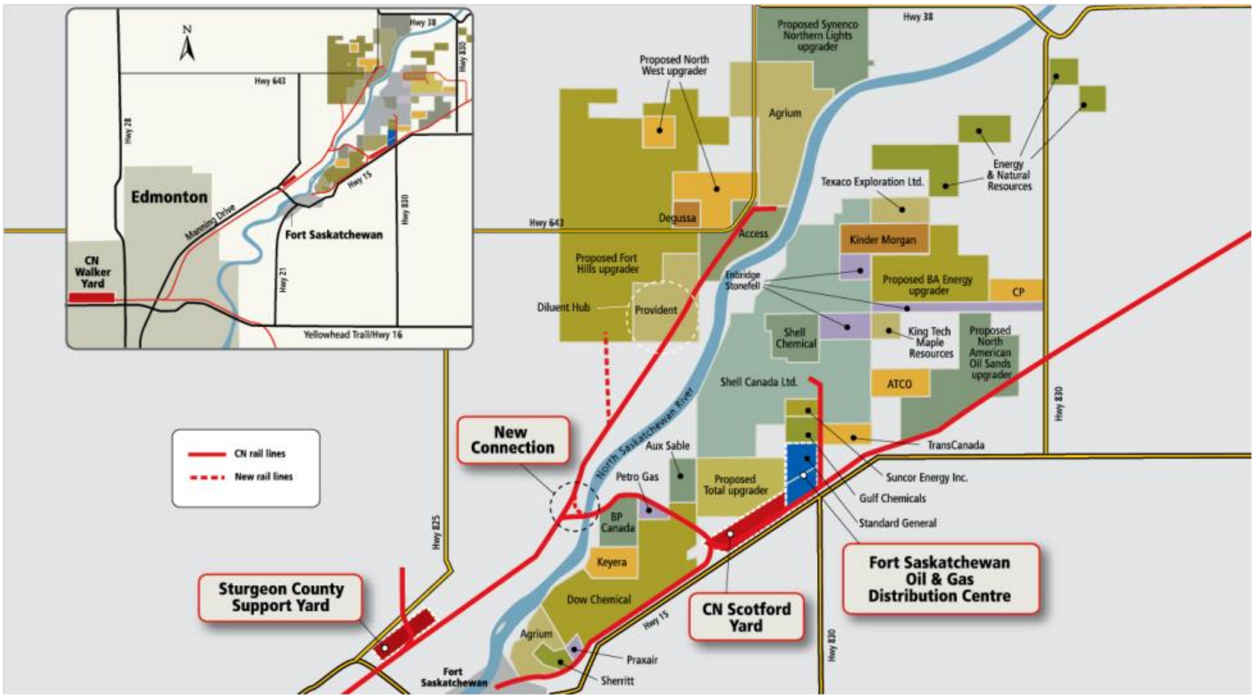
Intermodal terminals in red, CN-served ports in blue and CN-served destinations in green. Intermodal terminal locations in Canada include Brampton, Calgary Logistics Park, Edmonton, Halifax, Mississauga, Moncton, Montreal, Prince George, Prince Rupert, Saskatoon, Vancouver and Winnipeg. Intermodal terminals in the US include Auburn, Chicago, Chippewa Falls, Detroit, Indianapolis, Jackson, Joliet, Memphis, Minneapolis, New Orleans and Worchester.

CN is well connected to marine terminals in Vancouver, Kitimat and Prince Rupert on the west coast or to ports on Canada's east coast, as well as to refineries in the southern US and US Gulf Coast. CN-served ports include Port of Halifax, Port Montreal, Prince Rupert Port Authority, Port Metro Vancouver (PMV) and Port of New Orleans. CN also has ties to other ports including Port of Mobile, the Port de Québec, Port Saint John and Port de Belledunes. CN has a supply chain agreement with the Prince Rupert Port Authority and terminal operator Maher Terminals. The Ridley Terminal at Prince Rupert, on the other hand, currently handles metallurgical and thermal coal and petroleum coke.[6,7] CN also has supply chain agreements and access to three terminals at the Port Metro Vancouver and the terminal operators TWI Terminal Services, DP World and Squamish Terminals.[8,9] It is important to note that CN can access other ports on the west coast, including the Port of Tacoma and the Port of Longview; both are accessible via BNSF at Vancouver/New Westminster.

Figure C.2 illustrates CN's access to Alberta's Industrial Heartland, Fort Saskatchewan, northeast of Edmonton. The area is crucial to upgrading and is an important hub of transportation of crude oil and NGLs. CN runs north and south of the North Saskatchewan River towards Fort McMurray, and operate rail corridors and spurs in the Industrial Heartland and the Sturgeon Industrial Park. In the fall of 2007, CN opened its new state of the art multi-commodity Fort Saskatchewan Oil & Gas Distribution Centre.[10] It is situated next to CN's Scotford Yard.

[6] CN website, Supply Chain Agreements, http://www.cn.ca/en/our-business/our-network/ports/supply-chain-agreements
[7] Ridley Terminals Inc. website, Shipping Commodities, http://www.rti.ca/shipping-commodities
[8] ibid
[9] Bulk terminals handle major commodities, such as coal (Neptune Terminals and Westshore Terminals) and grain (Alliance Grain terminal, Cargill terminal, Cascadia, Pacific elevators and Richardson International). Terminals that handle fertilizers and sulphur include Neptune terminals, Kinder Morgan Vancouver Wharves and Pacific Coast Terminals. Kitimat, on the other hand, offers bulk faculties of import and export liquids and significant potential for expansion.
[10] Alberta's Industrial Heartland website, Transportation, http://www.industrialheartland.com/index.php?option=com_content&view=article&id=50:transportation&catid=23&Itemid=64

Figure C.2: CN's Access to Alberta's Industrial Heartland



Source: CN Rail[11]

With regard to Ontario's petrochemical hub, CN is the principal rail carrier in the Greater Sarnia area, with customers including BP Energy Canada, NOVA Chemicals, Superior Propane, Provident Energy, Suncor Energy Products and Shell Canada.[12] The rail network connects to CSX Transportation's vast US rail network. The latter serves Imperial Oil, Suncor Energy Products, Ethyl, Air Liquide, ARLANXEO Canada and Shell Canada, via the St. Clair tunnel, connecting Sarnia with Port Huron, Michigan.[13]

Traffic density is expressed in terms of gross ton-miles (GTM) per route mile, or rail activity (the number of tons of freight transported by a train as well as the number of tons of locomotives and cars of the train over the distance travelled by the train) per route mile. The section of track between Vancouver and Edmonton is 100.8 million GTMs per route mile in 2014 – the busiest stretch of track on CN's rail network.[14] The stretch of track between Edmonton and Winnipeg is 99.6 million GTMs per route mile in 2014[15] while the stretch of track between Winnipeg to Chicago is 61.7 million GTMs per route mile in 2014.[16] The portion of track between Toronto and

[11] CN Rail, Transportation Solutions for Oil Sands Production Phase, Randy Meyer Presentation, The Van Horne Institute, May 13, 2009, http://www.vanhorne.info/files/vanhorne/2%20CN.pdf (pp.6)
[12] Sarnia Lambton Economic Partnership website, Transportation Infrastructure Information, http://www.sarnialambton.on.ca/infrastructure/transportation/
[13] Sarnia Lambton Economic Partnership website, Petrochemical and Refined Petroleum, http://www.sarnialambton.on.ca/key-sectors/petrochemical-and-refined-petroleum/
[14] CN Investor Fact Book: Building for the Future – 2015 (pp. 16)
[15] ibid
[16] ibid

Montreal measures 61.9 million GTMs per route mile in 2014, the busiest along CN's eastern corridor.[17] Other sections of track with densities above 35 million GTMs per route mile include: Sarnia to Toronto (55.1 million GTMs per route mile), Winnipeg to Toronto (49.0 million GTMs per route mile) and Montreal to Québec (35.7 million GTMs per route mile).[18]

At end-2015, CN's carloads totaled 5,485,000, comprised of Intermodal (2,232,000 carloads), Metals and Minerals (886,000 carloads), Petroleum and Chemicals (640,000 carloads), Grain and Fertilizers (607,000 carloads), Forest Products (441,000 carloads), Coal (438,000 carloads) and Automotive (241,000 carloads).[19] Revenues for CN's business units at end-2015 was Intermodal (C$2.896 billion), Petroleum and Chemicals (C$2.442 billion), Grain and Fertilizers (C$2.071 billion), Forest Products (C$1.728 billion), Metals and Minerals (C$1.437 billion), Automotive (C$719 million) and Coal (C$612 million).[20]

While CP was Canada's first transcontinental railway, it currently does not reach the Atlantic coast. Its rail network stretches from Vancouver to Montreal, and as far north as Edmonton. The CP rail network serves several major US cities, such as Minneapolis, Detroit, Chicago and New York. Key Canadian port cities include Vancouver, Montreal, Thunder Bay and Québec City. Figure C.3 illustrates CP's rail network.

Figure C.3: Map of CP's Rail Network

Source: http://www.cpr.ca/en/choose-rail/transload-trucking

Figure C.3 illustrates CP Intermodal terminals in red and the various transloading facilities. The mainline is shown as a red line while the red-dotted line shows track in which CP has principal haulage or trackage rights.[21] These arrangements give CP access to terminals in Detroit, Buffalo,

[17] ibid
[18] ibid
[19] CN Investor Fact Book: Building for the Future – 2016 Update (pp. 5)
[20] ibid
[21] The latter is an arrangement between 2 railroads where one company owns all the trackage rights but allows another company to operate over sections of its track; the arrangement may be short- or long-term.

New York, Philadelphia and Binghamton. Intermodal terminals located in Canada include Vancouver, Calgary, Edmonton, Regina, Saskatoon, Winnipeg, Montreal, Minneapolis, Milwaukee, Detroit, and two terminals in Toronto and Chicago. CP-served ports include Port Montreal, Port Metro Vancouver and Port of Thunder Bay.

The Western Corridor is the portion connecting Vancouver and Moose Jaw, and includes main rail yards at Calgary, Edmonton and Vancouver. The rail network connects with Union Pacific (UP) at Kingsgate, BC and the Burlington Northern Santa Fe (BNSF) at Coutts, Alberta. BNSF and UP both have access to the west coast ports of Port of Tacoma and the Port of Longview. The Western Corridor also connects with BNSF at Huntingdon, BC. The Southern Corridor connects Moose Jaw and Chicago and Kansas City, running track through main rail yards in Minneapolis and Milwaukee. CP also connects with BNSF, UP, Norfolk Southern Railway, CSX Transportation and CN at Chicago. The Central Corridor connects Moose Jaw and Toronto and has access to the Port of Thunder Bay. A main feeder line connects Edmonton, Saskatoon, Winnipeg and Sudbury. The Eastern Corridor connects the major population centers of Eastern Canada, the US Midwest and US Northeast, including Montreal, Detroit, Chicago, Philadelphia, Buffalo, Newark and Washington, DC.[22] CP connects with NS and CSX at Detroit and Buffalo.

It is important to note that while providing rail freight service to the area through Scotford Yard, located in Alberta's Industrial Heartland, CP is not connected to the Sarnia area.

Figure C.4 illustrates a rail density map along CP's rail network, showing the traffic density expressed in terms of gross ton miles per route mile. In terms of measuring traffic density, the section of track between Vancouver, Calgary and Regina and the portion between Portage la Prairie and Winnipeg are the densest portions of the CP rail network. The average density from Vancouver to Calgary is 73.5 million GTMs per route mile, followed by Glenwood, Minnesota to Chicago (54.4 million GTMs per route mile) and Calgary to Winnipeg (53.0 million GTMs per route mile).[23] The stretch of track between Winnipeg and Toronto is 32.5 million GTMs per route mile.[24]

[22] ibid
[23] Canadian Pacific Investor Fact Book 2014, pp. 20.
[24] ibid

Figure C.4: CP Rail Network Density Map

Source: CP Investor Fact Book[25]

At end-2015, CP's carloads totaled 2,628,000, comprised of International Intermodal (559,000 carloads), Domestic Intermodal (414,000 carloads), Coal (323,000 carloads), Canadian Grain (285,000 carloads), Metals, Mineral, and Consumer Products (217,000 carloads), Chemicals and Plastics (203,000 carloads), US Grain (157,000), Automotive (131,000 carloads), Potash (124,000 carloads), Crude (91,000 carloads), Fertilizers and Sulphur (62,000 carloads) and Forest Products (62,000 carloads).[26] At end-2015, revenue comprised of Canadian Grain (C$1.068 billion), Domestic Intermodal (C$757 million), Chemicals and Plastics (C$709 million), Metals, Mineral, and Consumer Products (C$643 million), Coal (C$639 million), International Intermodal (C$592 million), US Grain (C$522 million), Crude (C$393 million), Potash (C$359 million), Automotive (C$349 million), Fertilizers and Sulphur (C$272 million) and Forest Products (C$249 million).[27]

[25] Canadian Pacific Investor Fact Book 2014, http://www.cpr.ca/en/investors-site/Documents/investor-fact-book-2014.pdf#page=22&zoom=auto,-73,683 , pp. 20-21.
[26] Canadian Pacific website, CP 2016 Fourth Quarter Earnings Release, http://www.cpr.ca/en/investors-site/Documents/cp-2016-investor-fact-book-data-supplement.pdf , pp. 10.
[27] ibid, pp. 7.