Assessment of alternative methods of supplying propane to Michigan in the absence of Line 5

Prepared by London Economics International LLC

July 23, 2018

London Economics International LLC ("LEI") was funded by the Charles Stewart Mott Foundation ("CS Mott") in cooperation with the National Wildlife Federation ("NWF"), to examine alternatives to Enbridge Energy, Limited Partnership ("Enbridge") Line 5 for supply of propane to consumers in the State of Michigan. Enbridge Line 5 provides natural gas liquids ("NGLs") from which propane is extracted, directly to a facility in Michigan's Upper Peninsula, and to facilities in Ontario that then supply propane to Michigan's Lower Peninsula. LEI's assessment assumes that Line 5 would not be in use for the transport of oil and NGLs across the Straits of Mackinac.

LEI finds that, with strong recent and projected growth in supply of NGLs from the United States, and with flat to declining demand for propane in Michigan, the prospect of persistent propane supply shortages in Michigan is unlikely, even if Enbridge Line 5 ceased to operate. Event-driven supply interruptions or weather-driven shortages such as experienced in 2014 during the Polar Vortex winter, will likely occur on occasion, as they have in the past. But with the prospect of plentiful supplies relative to demand, the main concern with the potential absence of Enbridge Line 5 is the delivered cost of alternative sources of propane.

With this focus on the cost of alternatives, LEI's key findings are that the lowest-cost alternative options to Enbridge Line 5 would be truck or rail from Superior, Wisconsin ("WI"). LEI estimates the price increase to consumers in the Upper Peninsula would likely be about $0.05 per gallon. This small price increase would be lost in the noise of typical propane price volatility.

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1 Introduction and executive summary

1.1 Enbridge Line 5

The State of Michigan is considering options for ongoing operations of the Enbridge Line 5 liquids pipeline, which traverses Michigan's Upper Peninsula and Lower Peninsula. Line 5 begins in Superior, WI and terminates in Sarnia, Ontario ("ON"). The pipeline's capacity is 540,000 barrels per day.[1] It transports light crude oil, light synthetic crude, and NGLs, which include propane.

Enbridge Line 5 was built in 1953. The pipeline runs for 645 miles from Wisconsin, under the Straits of Mackinac, through Michigan to Sarnia. The 30-inch diameter pipeline splits into two 20-inch diameter lines where it crosses the Straits of Mackinac for 4.5 miles (see Figure 1).

Figure 1. Enbridge Line 5

Source: Enbridge[2]

LEI was engaged to assist in understanding the current and potential future role of Enbridge Line 5 from the perspective of Michigan propane consumers. More specifically, the CS Mott Foundation and NWF wished to understand the degree of reliance on Enbridge Line 5 by Upper Peninsula consumers for the supply of propane and if there are alternative viable options; and understand the potential impact on Lower Peninsula consumers.

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[1] Enbridge. "The Straits of Mackinac crossing and Line 5." September 2015. <http://www.enbridge.com/~/media/Enb/Documents/Brochures/Brochure_Line5.pdf>

[2] Enbridge. "About Line 5." Accessed on April 2018. <https://www.enbridge.com/projects-and-infrastructure/public-awareness/line-5-michigan/about-line-5>

In this report, LEI provides an independent view of whether and to what extent Enbridge Line 5 is needed for Michigan propane consumers; and what would be the cost impact on consumers if Enbridge Line 5 into Michigan did not exist.

A report by Dynamic Risk Assessments, Inc ("Dynamic Risk")—funded by Enbridge Energy and overseen by the State of Michigan—also estimated the potential impact on Michigan propane consumers.[3] LEI did not perform a comprehensive critique of the Dynamic Risk report, which covers a wide variety of issues in addition to the impact on propane consumers. However, Dynamic Risk provided specific assumptions about the elements of pipeline, rail, and trucking costs for propane, which LEI compared to publicly-available data and then used to evaluate the impact on the cost per gallon of propane. Dynamic Risk's assumptions and their resulting estimates for the cost of alternatives to Enbridge Line 5 provide useful comparisons to LEI's, and we refer to Dynamic Risk's assumptions and results in this report.

1.2 LEI's approach

To provide a foundation for understanding the cost of alternatives to Enbridge Line 5, LEI began by laying out the facts that describe the Michigan propane market (supply, demand, storage, transportation, and prices) in the context of the relevant broader US propane market (see Section 2). This provides a deeper understanding of the most important issues for propane supply in the Upper Peninsula and the rest of Michigan.

Then LEI analyzed the cost of propane supply, particularly to the Upper Peninsula, with and without Enbridge Line 5 (see Section 3). LEI took a three-step approach to this. First, LEI examined publicly-available data sources for reported prices at propane trading hubs, published pipeline tariffs, and public reports of rail and truck shipment costs. Second, LEI re-produced the cost calculations provided by Dynamic Risk[4] to understand to what degree Dynamic Risk's cost results (in dollars per gallon of propane) depended on their assumptions about key elements of cost. Third, LEI substituted publicly-available data for key cost elements, and applied the Dynamic Risk methodology, to arrive at new estimates of the additional cost per gallon to propane consumers if Enbridge Line 5 did not exist. LEI also examined several alternatives not considered by Dynamic Risk.

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[3] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." October 26, 2017. Prepared for the State of Michigan. October 26, 2017.

[4] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." October 26, 2017. Prepared for the State of Michigan. October 26, 2017. Appendix J.

1.3 Key findings and conclusions

LEI's key findings were:

1. There is no shortage of propane in the United States; supply is growing faster than demand;
2. The least expensive alternative supply options are pipeline transportation to Superior, WI combined with either trucking from Superior to Rapid River or rail from Superior to Rapid River. The cost of these two options could be nearly identical. They could add an estimated $0.11 per gallon to the cost of propane supply in the Upper Peninsula (see Figure 2). An econometric analysis of propane demand in Michigan shows that this cost increase would translate into a $0.05 per gallon increase in consumer propane prices in the Upper Peninsula;
3. Although more expensive options are available, as shown in Figure 2, it would not make sense to assume that these would be chosen instead of the least expensive option, except under emergency conditions. Even if rail or trucking from Kincheloe to Rapid River was free, the total cost of using the Kincheloe route would be higher than the route from Edmonton through Superior;
4. In the Lower Peninsula, the impact on the cost of propane may be negligible.
5. A price increases of $0.05 per gallon is small compared with the usual volatility of weekly propane prices. Michigan prices swung from $0.86 per gallon to $3.50 per gallon over the past few years. The small price increase from using alternatives to Enbridge Line 5 would be lost in the noise of typical price volatility.

Figure 2. Estimated weighted average annual cost of propane supply to Rapid River (all costs in $ per gallon)

Market hub	Edmonton, Alberta				Conway, KS
Hub price, 2017	$0.53	$0.53	$0.53	$0.53	$0.72
Mode of transportation	Pipeline	Pipeline	Pipeline	Rail	Rail
Cost of transportation	$0.078	$0.064	$0.064	$0.27	$0.15
Terminal		Superior, WI	Superior, WI	Kincheloe, MI	Owen, WI
Mode of transportation		Rail	Truck	Truck	Truck
Cost of transportation		$0.126	$0.124	$0.08	$0.11
	Rapid River Terminal (total cost, $/gallon)				
Total cost	$0.61	$0.720	$0.718	$0.88	$0.99
Difference		$0.11	$0.11	$0.27	$0.38

1.4 Roadmap to this report

This report begins by describing the propane market in Michigan, neighboring states, and the United States, trends in propane consumption, sources of supply, use of storage, transportation modes, and wholesale and retail prices; these are presented in Section 2 of this report. In Section 3, LEI examines the cost of propane supply and delivery to the Upper Peninsula, and Lower Peninsula, of different supply sources and transportation routes. In Section 4, LEI uses econometric analysis to estimate the impact of higher supply costs on residential consumer prices. LEI's conclusions and implications are in Section 5. Details of LEI's econometric analysis can be found in Appendix A (Section 6).

2 Understanding the Michigan propane market

2.1 What is propane?

Propane is a hydrocarbon classified as a liquefied petroleum gas ("LPG"); LPGs in turn are a subset of natural gas liquids ("NGLs"). Propane is one of the NGLs that come to the surface during field production of natural gas. The produced natural gas (methane and NGLs) is sent to a gas processing plant near the point of field production, which separates the NGLs from the methane to produce pipeline-quality natural gas (mostly methane, sometimes with a small amount of ethane) in a gaseous state. The leftover NGLs can then be transported or stored in their liquid state. For propane, a second stage of processing, called fractionation, separates the propane from the other NGLs. Unlike natural gas processing, which occurs near the point of field production, fractionation often occurs closer to markets, after the NGL stream has been shipped to market hubs.

Propane produced from natural gas drilling therefore requires two stages of processing: 1) natural gas plant processing, to separate NGLs from methane, and 2) fractionation, to separate the propane from the other NGLs. Companies involved in this process often combine fractionation and transportation into a single service for wholesale buyers of propane. Such companies also usually also operate natural gas processing plants in the field. Propane can also be extracted from refinery gas streams during the crude oil refining process.

Propane is used for space and water heating, cooking, crop drying, as fuel for vehicle engines, and for refinery operations.

2.2 Propane demand in Michigan

The Michigan residential sector has the highest consumption of propane of any residential sector in the United States, according to the Energy Information Administration ("EIA") (see Figure 3).[5] EIA reports that Michigan residential propane demand ranged from 0.83 million gallons per day to 1.02 million gallons per day (303 million gallons per year to 372 million gallons per year) for 2013-2017.[6]

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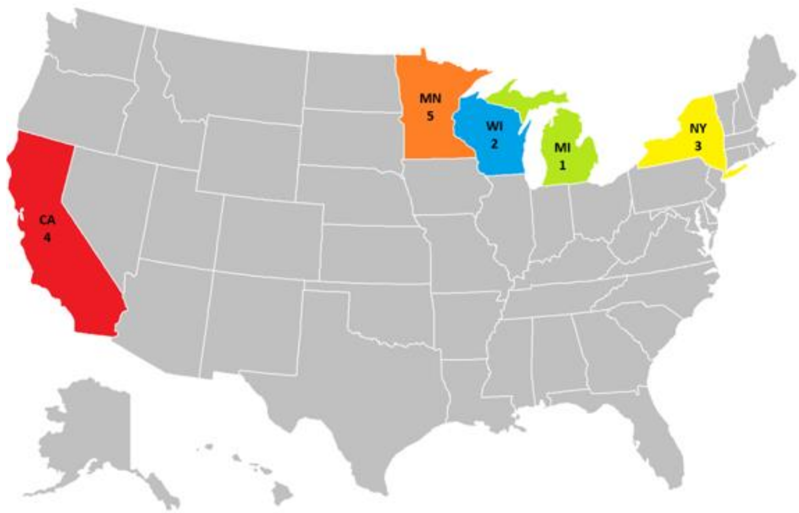
[5] US-wide, five percent of households use propane for heating, while in Michigan it is estimated to be around eight percent. Sources: Michigan Agency for Energy. "Michigan Energy Appraisal. Winter Outlook 2017/18." November 2017. <http://www.michigan.gov/documents/energy/ea-winter17_606208_7.pdf>¿ EIA. Michigan State Energy Profile. May 18, 2017. <https://www.eia.gov/state/print.php?sid=MI#42>

[6] EIA. "Prime Supplier Sales Volumes of Propane (Consumer Grade)." April 2, 2018.

Figure 3. Top five states for residential sector propane consumption, 2015



Source: EIA[7]

The State of Michigan estimates propane is used as a primary heating fuel in about 320,000 households in the state.[8] This translates into annual average consumption per household of 1,037 gallons per year if residential consumption of 0.91 million gallons per day (the 2013-2017 state-wide average, per EIA) is divided by the 320,000 households. Other sources of information are consistent with this; one source notes that a typical Michigan household using propane consumes 500-1,200 gallons per year.[9]

2.2.1 Propane demand in Michigan has been falling

Consumption of propane in Michigan has generally been falling since the 1980s (see Figure 4). Propane use for heating in Michigan is being displaced by electricity, which is estimated to have increased by almost 30 percent from 2009 to 2016.[10] Gas used for heating remained stable during this time.

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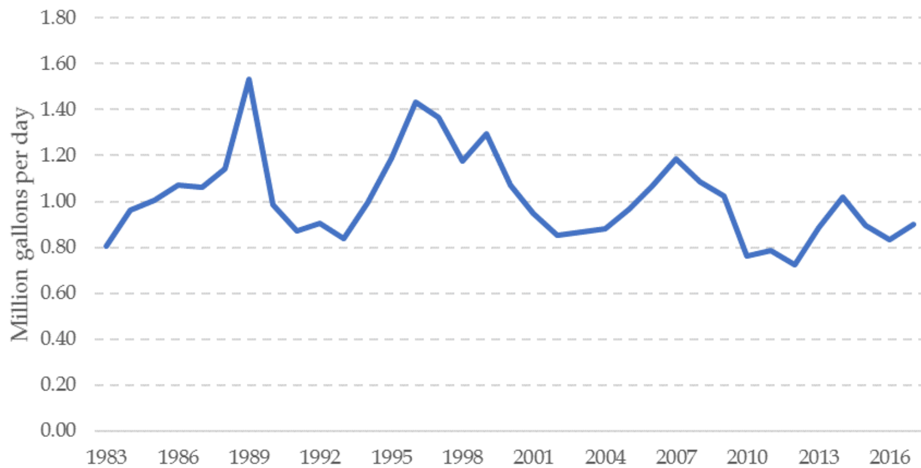
[7] EIA. "Top five residential sector propane consuming states." 2015. <https://www.eia.gov/energyexplained/images/charts/propane_consuming_states_map-large.gif>

[8] Michigan Agency for Energy. "Propane in MI." Accessed on April 9, 2018. <http://www.michigan.gov/energy/0,4580,7-230-73789_83112_83114---,00.html>

[9] Crumm, Charles. "Lower utility prices and a milder winter in the forecast." Macomb Daily. November 27, 2015. <http://www.macombdaily.com/article/MD/20151127/NEWS/151129620>

[10] US Census Bureau. "2011-2015 American Community Survey 5-Year Estimates." Accessed on April 18, 2018.

Figure 4. Annual propane consumption in Michigan



Source: EIA Propane Prime Supplier Sales Volumes[11]

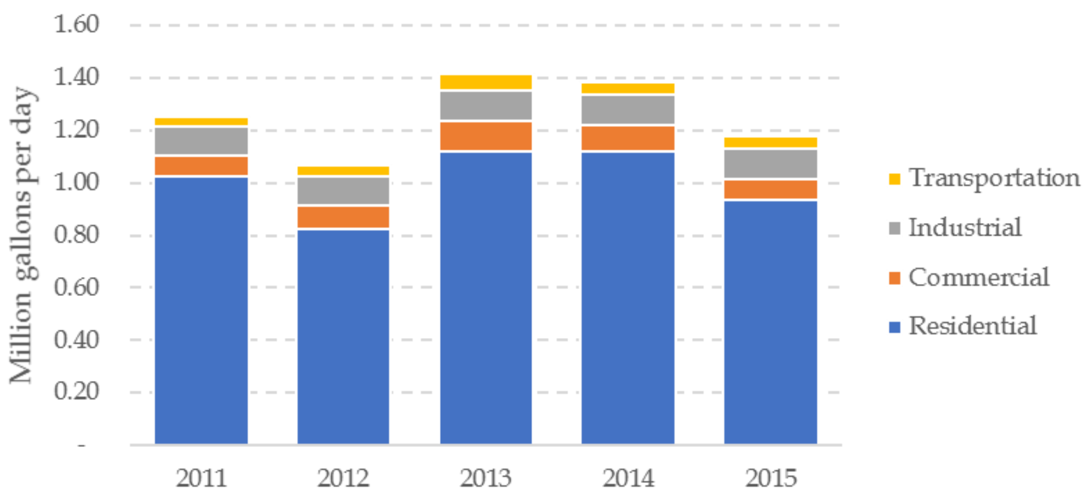
2.2.2 The residential sector consumes much of the propane used in Michigan

The EIA reports that in Michigan, the residential sector consumes about 80 percent of all the LPGs (propane, ethane, and olefins) used in the state (see Figure 5). EIA does not provide a sectoral breakout for propane specifically; but, as mentioned above, EIA reports state-wide average 2013-2017 propane consumption to be 0.91 million gallons per day. Comparing to the 1.2 million gallons per day for LPGs in 2015 in Figure 5 implies that propane makes up about 75 percent of LPGs used in Michigan. The residential sector does not have much direct use for ethane or olefins, so it is safe to assume that the residential consumption shown in Figure 5 is all propane.[12]

[11] EIA. "Michigan Propane All Sales/Deliveries by Prime Supplier." Accessed on April 2018. <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=C900020261&f=M>

[12] EIA. "Hydrocarbon gas liquids explained." <https://www.eia.gov/energyexplained/index.php?page=hgls_uses>

Figure 5. Total LPG consumption by sector in Michigan



Source: EIA State Energy Data System (SEDS). June 30, 2017

2.2.3 Upper Peninsula propane consumption

Unlike Michigan state-level consumption data which is provided by the EIA, there are no official figures for annual consumption of propane in the Upper Peninsula versus Lower Peninsula.

- The Michigan Propane Gas Association reported that 460 million gallons of propane was consumed in Michigan in 2015, of which 430 million gallons was in the Lower Peninsula.[13] This leaves 30 million gallons (about 6.5 percent of the Michigan total) consumed in the Upper Peninsula.[14] These estimates include all sectors, not just the residential sector.

- The US Census Bureau estimates that in the 15 counties in the Upper Peninsula, 22,050 households used bottled, tank, or LP gas ("LPG") as the primary source of heating fuel in 2016.[15] If the typical Michigan household consumes 500-1,200 gallons per year, as

[13] Note that the Michigan Propane Gas Association's estimate of propane consumption in Michigan in 2015 is higher than EIA's estimate.

[14] MPGA. "Comments on the Alternatives Analysis for the Straits Pipeline." August 4, 2017.

[15] https://www.census.gov/hhes/www/housing/census/historic/fuels.html

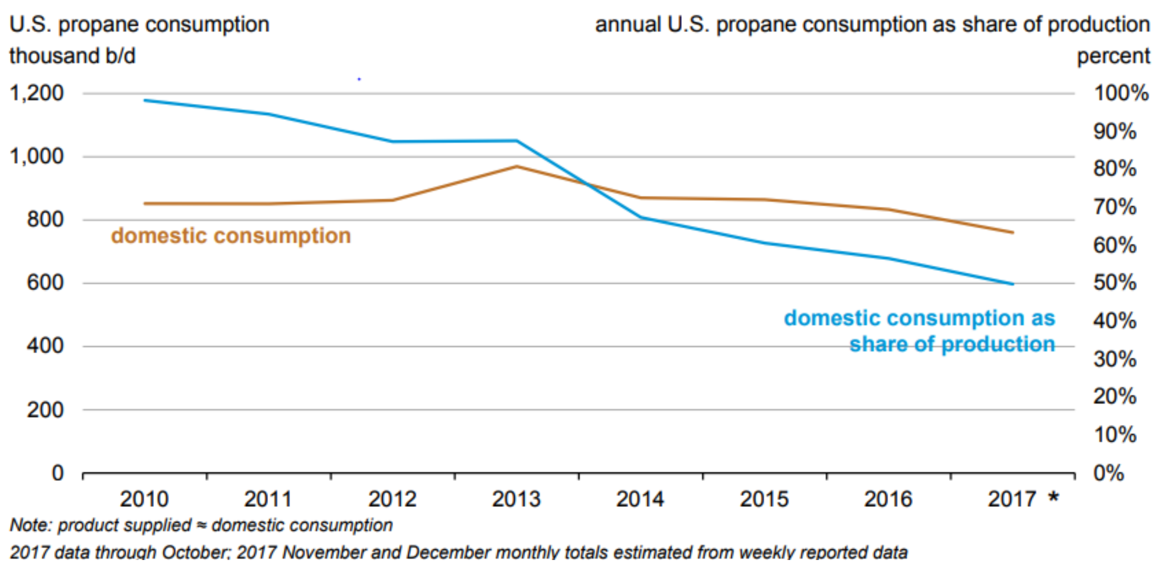
noted above[16] then the 22,050-household residential sector consumes 11 million to 26.5 million gallons per year.

The estimates all indicate that Upper Peninsula propane consumption is small compared with Michigan over all.

2.2.4 Propane demand in the United States is flat to declining

Falling propane consumption is not unique to Michigan. Consumption of propane in the United States was lower in 2017 than in 2010 (see Figure 6). At the same time, US production (to be discussed in more detail in Section 2.3) has been on the rise, resulting in US domestic demand accounting for a smaller share of US production.

Figure 6. EIA's US propane consumption, and consumption as share of production



Source: EIA[17]

2.2.5 US propane demand is seasonal

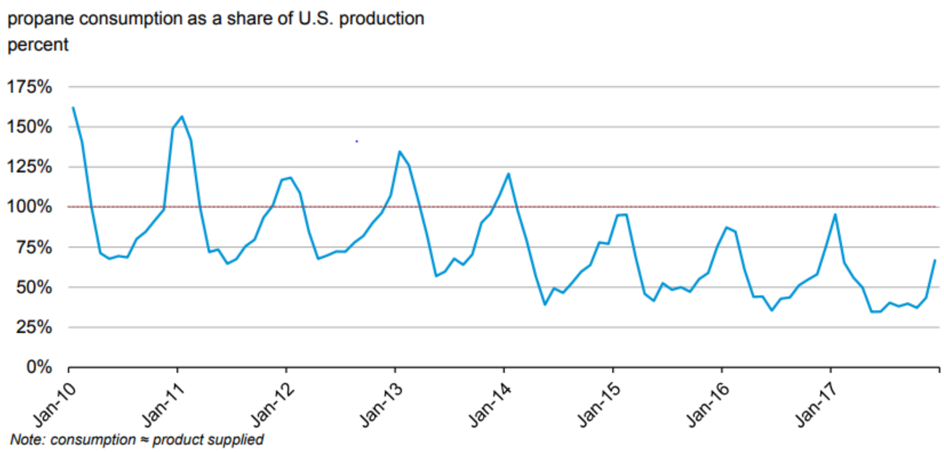
Propane is consumed seasonally, because much of it is used for home heating. Propane is produced year-round as that is the most efficient way to produce it, therefore seasonal storage has played an important role in meeting wintertime demand. US wintertime demand of 61

[16] Crumm, Charles. "Lower utility prices and a milder winter in the forecast." Macomb Daily. November 27, 2015. <http://www.macombdaily.com/article/MD/20151127/NEWS/151129620>

[17] EIA. "EIA's propane market indicators and measures of supply adequacy." January 10, 2018. <https://www.eia.gov/pressroom/events/pdf/Propane_01102018.pdf> Note: EIA uses "product supplied" as a proxy for propane consumption. Product supplied = production + imports – stock change – exports.

million gallons per day (the weekly average during the months of December 2016, and January and February 2017) was somewhat lower than total US production of 75 million gallons per day on average in 2017.[18]

Figure 7. United States seasonal propane demand as share of US production



Source: EIA[19]

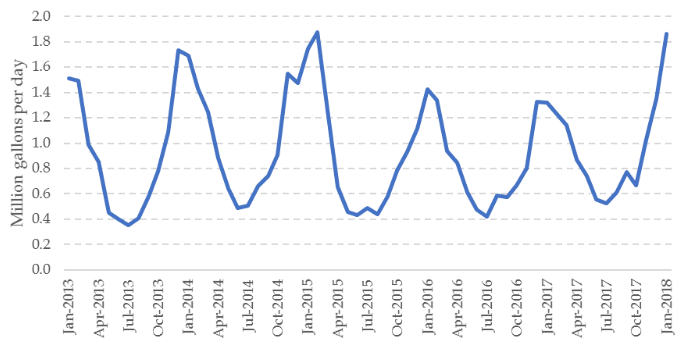
2.2.6 Michigan propane demand is also seasonal

In Michigan as in the United States more broadly, propane demand is much higher in the winter than in the summer (see Figure 8). The colder-than-normal winters of 2013/14 and 2014/15 are evident in the spikes in demand during those winters, compared winter 2015/16 and 2016/17.

[18] EIA. "Weekly U.S. Refiner Blender and Gas Plant Net Production of Propane and Propylene." Accessed on April 2018. <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WPRTP_NUS_2&f=W>; and EIA. "Weekly U.S. Product Supplied of Propane and Propylene." Accessed on April 2018. <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WPRUP_NUS_2&f=W>

[19] EIA. "EIA's propane market indicators and measures of supply adequacy." January 10, 2018. <https://www.eia.gov/pressroom/events/pdf/Propane_01102018.pdf> Note: EIA uses "product supplied" as a proxy for propane consumption. Product supplied = production + imports – stock change – exports.

Figure 8. Michigan seasonal propane demand

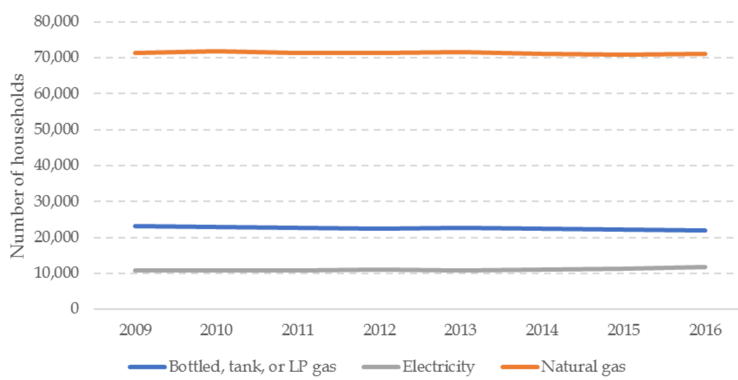


Source: EIA Propane Prime Supplier Sales Volumes[20]

2.2.7 Number of Upper Peninsula households using propane is unlikely to increase

The number of Upper Peninsula households using LP gas (including propane) has not changed in many years (see Figure 9). The total number of households in the Upper Peninsula (whether or not they are users of propane) decreased by one percent from 2010 to 2016, according to the US Census Bureau.[21] LEI believes the number of households in the Upper Peninsula which use propane is unlikely to rise in the future.

Figure 9. Number of Upper Peninsula homes heated with propane and other fuels



Source: US Census Bureau "2012-2016 American Community Survey 5-Year Estimates - House Heating Fuel."

[20] EIA. "Michigan Propane All Sales/Deliveries by Prime Supplier." Accessed on April 2018. <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=C900020261&f=M>

[21] US Census Bureau. U.S. Census Bureau. "2012-2016 American Community Survey 5-Year Estimates - House Heating Fuel."

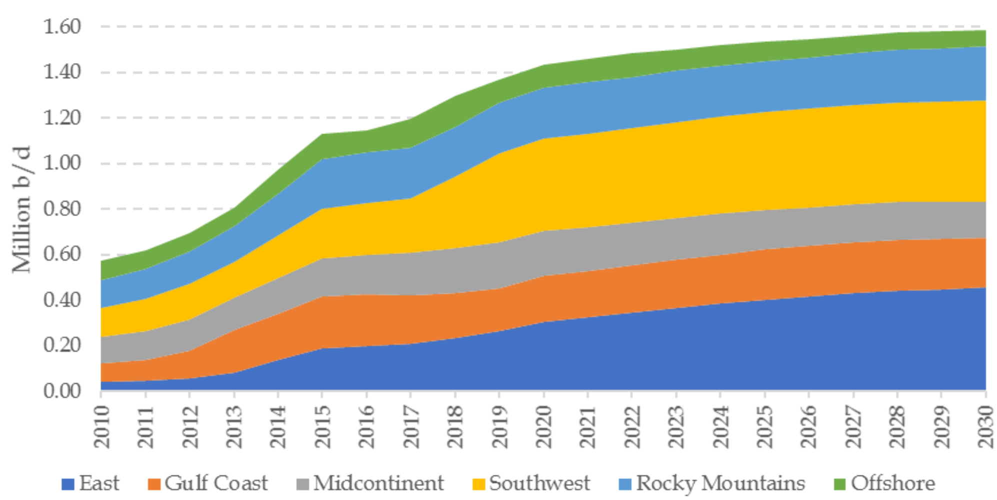
2.3 Sources of propane supply

The United States and Canada have both seen substantial growth in oil and gas production, driven by prolific and cost-effective shale oil and gas plays (and, in Canada, the oil sands). This is boosting production of NGLs, including propane.

2.3.1 United States propane production is rising

Annual propane production in the United States is increasing and reached a record 1.2 million barrels per day in 2017 (see Figure 10). EIA forecasts a 9 percent increase in propane production in 2018, and projects long-term growth at a slower pace, with production rising to 1.6 million barrels per day in 2030.[22]

Figure 10. Outlook for US propane production from natural gas processing



Source: EIA NGPL production[23]
Note: Michigan is included in the East region

2.3.2 Propane supply from states near Michigan is set to increase

Michigan is part of the US refined product Petroleum Administration for Defense District ("PADD") 2 (see Figure 11). PADDs are an administrative concept, developed by the federal government during World War II to help manage fuel rationing. Thus, PADDs do not represent physical boundaries between markets. However, PADDs are useful to help keep track of supply, demand and transportation issues and trends for refined products and other petroleum liquids, including propane.

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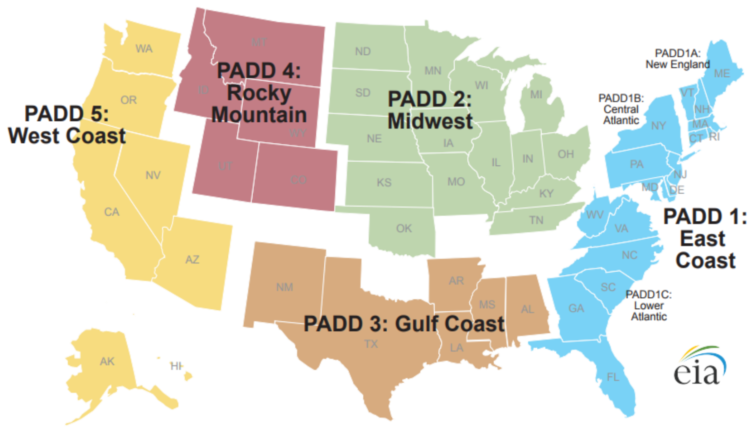
[22] EIA. "Natural Gas Weekly Update for week ending February 28, 2018." March 1, 2018. <https://www.eia.gov/naturalgas/weekly/archivenew_ngwu/2018/03_01/>

[23] Ibid.

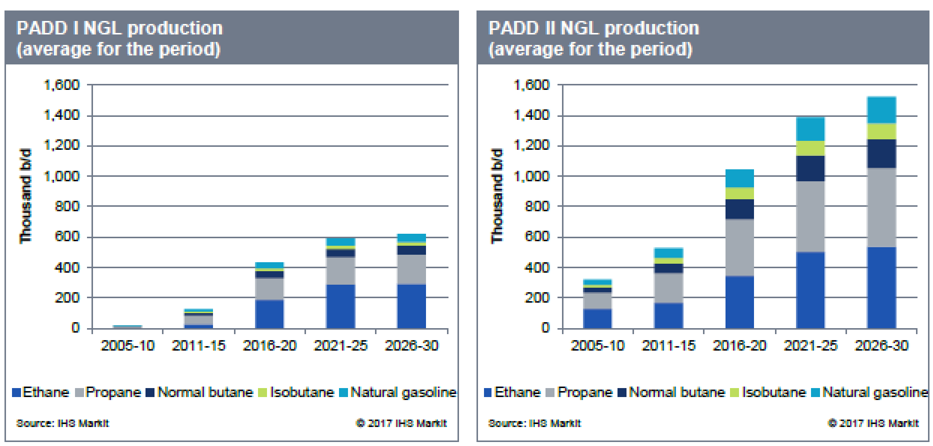
Figure 11. United States Petroleum Administration for Defense Districts (PADD)



Source: EIA

NGL production in PADD 1 and PADD 2 has been increasing strongly and EIA expects it to keep rising (see Figure 12).[24] PADD 1 includes Pennsylvania, with huge growth in NGLs associated with shale gas production. PADD 2 includes Ohio, also with strong growth in shale gas; Kansas, which is the location of an important storage and trading hub for propane; and North Dakota, which has seen strong growth in tight oil production.

Figure 12. Projections for PADD I and PADD II NGL production from natural gas



Source: IHS Markit[25]

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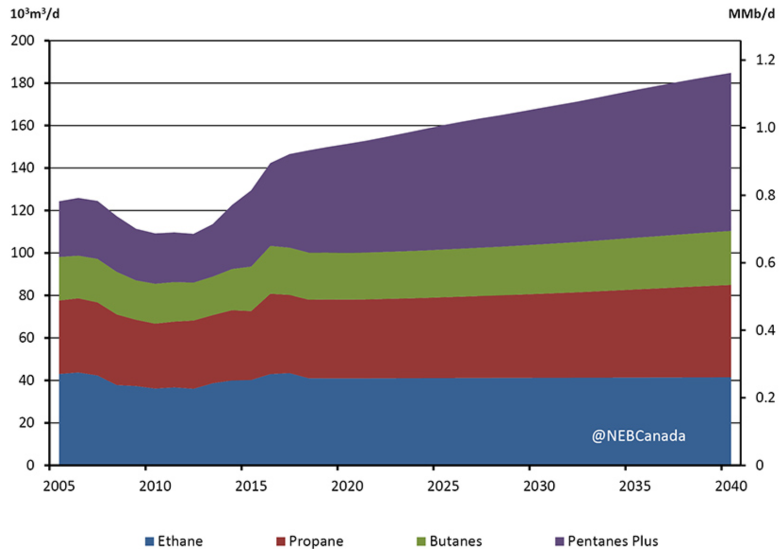
[24] IHS Markit. "Prospects to Enhance Pennsylvania's Opportunities in Petrochemical Manufacturing." March 2017. <https://teampa.com/wp-content/uploads/2017/03/Prospects_to_Enhance_PAs_Opportunities_in_Petrochemical_Mfng_Report_21March2017.pdf>

[25] Ibid.

Canada's National Energy Board's ("NEB") expects NGL production to increase, though not at the fast rate of supplies expected from the United States. Propane production in Alberta increased in 2017 by 11 percent.[26] The NEB 2017 outlook projects Canadian propane production to increase somewhat in the long term (see Figure 13).

Figure 13. NEB outlook for Canadian NGL production



Source: National Energy Board https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2017/chptr3-eng.html

2.4 Propane transportation

Propane can be transported by various means including pipelines, rail, and trucking. In pipelines, propane sometimes travels with other NGLs, and is separated at a fractionation plant near final end-users. Sometimes it is shipped in dedicated propane pipelines. Propane can also be transported in water-borne vessels, which facilitate exports from the United States to markets overseas.

2.4.1 Pipelines are the option traditionally favored for transporting large volumes

Pipelines are usually the lowest-cost form of transportation for propane and NGLs.[27] For this reason, pipelines are the most widely-used transportation for propane between PADDs within the United States.[28]

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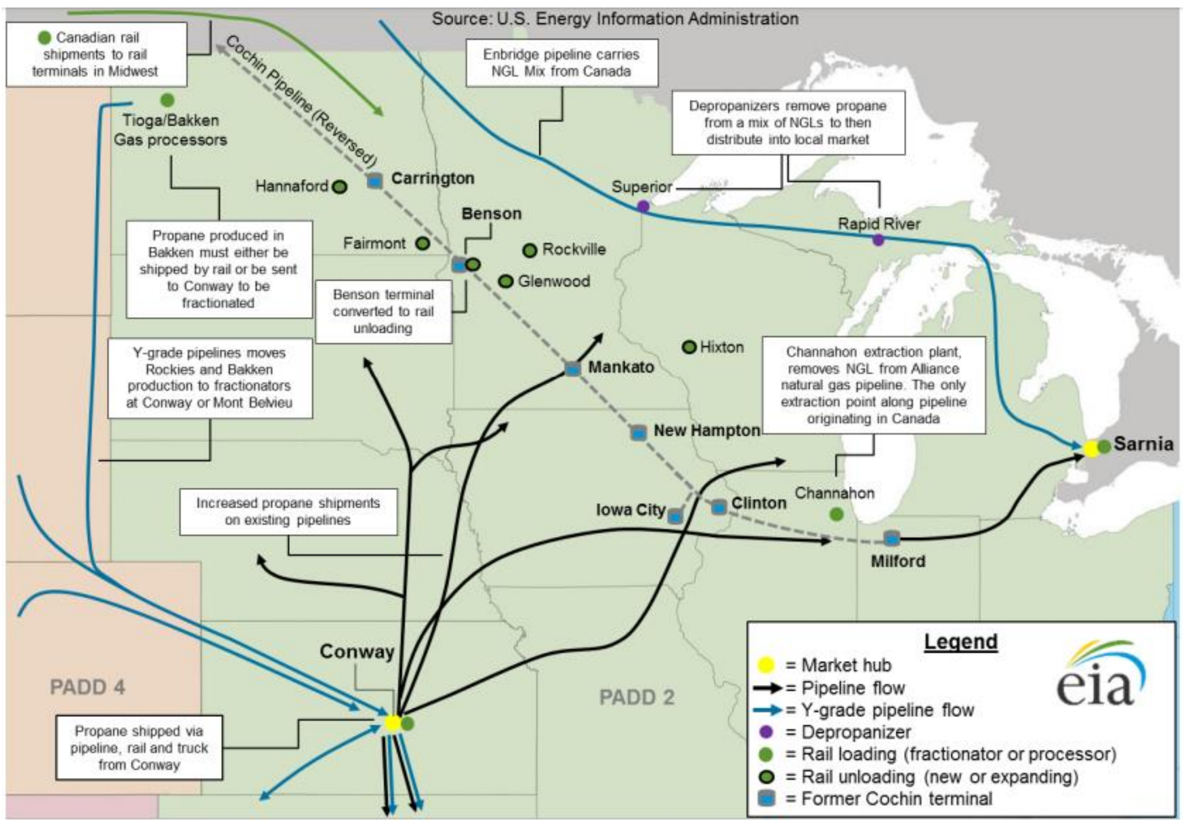
[26] AER. "Propane Supply/Demand." Accessed on April 2018. <https://www.aer.ca/data-and-publications/statistical-reports/propane-supply-demand>

[27] EIA. "Hydrocarbon Gas Liquids (HGL): Recent Market Trends and Issues." November 2014. <https://www.eia.gov/analysis/hgl/pdf/hgl.pdf>

2.4.2 Cochin pipeline taken out of propane service

In April 2014, the 95,000 barrels per day Cochin pipeline, which shipped propane from Alberta to the US Midwest was taken out of service for southbound propane shipments (see Figure 14).[29] That stretch of the pipeline was re-configured to ship light condensate petroleum liquids northbound from Milford, Illinois to Alberta. After the conversion, rail imports of propane from Canada to the Midwest increased from 5,700 barrels per day in 2013 to 28,400 barrels per day in 2017.[30]

Figure 14. Cochin pipeline and related propane transportation infrastructure in 2014



Source: www.eia.gov/petroleum/heatingoilpropane/workshop/2014/pdf/propanesupply.pdf

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[28] EIA Propane Movements by Pipeline, Tanker, Barge and Rail between PAD Districts, and Propane Movements by Pipeline between PAD Districts.

[29] Kinder Morgan. "Cochin Pipeline System." Accessed on April 12, 2018. <https://www.kindermorgan.com/business/products_pipelines/cochin.aspx>

[30] EIA. "Winter 2014-15: Propane Supply & Infrastructure for State Heating Oil and Propane Program (SHOPP) Workshop." October 8, 2014, Washington, DC. <https://www.eia.gov/petroleum/heatingoilpropane/workshop/2014/pdf/propanesupply.pdf

2.4.3 Utopia pipeline could supply additional propane to Michigan

In January 2018, the Utopia project, which could support expanded propane deliveries into Michigan, entered service (see Figure 15). The Utopia project converted the eastern portion of the Cochin pipeline to transport up to 50,000 barrels per day (expandable to 75,000 barrels per day) of ethane and ethane/propane ("E/P") mix from gas processing plants in Ohio to Windsor, ON. It is reported to be flowing ethane only at the current time, with a capacity of 50,000 barrels per day.[31] If it were expanded to 75,000 barrels per day, it could in theory supply additional propane to Michigan. This could expand propane supplies to the Lower Peninsula.

Figure 15. The Utopia pipeline project

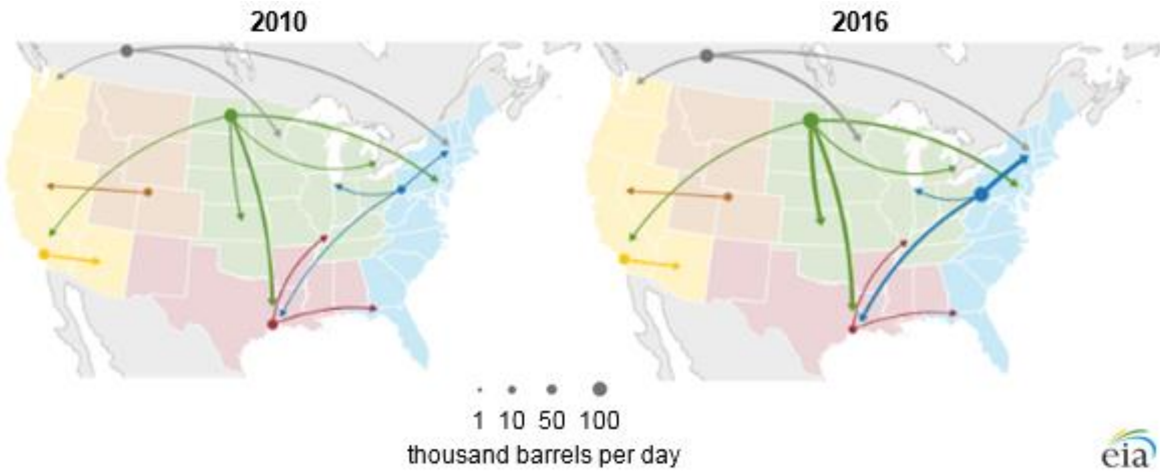
Source: Kinder Morgan. "Utopia Pipeline." https://www.kindermorgan.com/business/products_pipelines/utopia/

2.4.4 Propane by rail to US Gulf Coast for export has increased

Shipments of propane by rail have increased dramatically from the Marcellus area (Pennsylvania and Ohio) and the Bakken region (North Dakota) (see Figure 16). Oil and gas production from these regions has run ahead of the pipeline capacity needed to ship NGLs to market hubs such as Mont Belvieu, Texas and Conway, Kansas. As can be seen in Figure 16, these two hubs are important destinations for propane from the Marcellus and Bakken regions.

[31] Kinder Morgan. "Utopia Pipeline." https://www.kindermorgan.com/business/products_pipelines/utopia/

Figure 16. US and Canadian propane shipments by rail

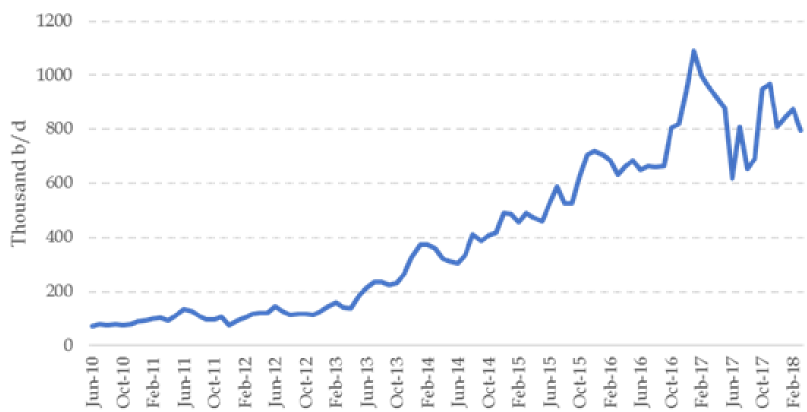


Source: EIA[32]

2.4.5 US exports of propane surged beginning in 2013

With strong growth in supplies and flat-to-declining demand, exports of propane from the United States began growing rapidly in 2013 (see Figure 17). Most of these exports originated from the US Gulf Coast.

Figure 17. US propane exports



Source: EIA[33]

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[32] EIA. "New EIA data series track shipments of hydrocarbon gas liquids by rail." February 2, 2017. <https://www.eia.gov/todayinenergy/detail.php?id=29792>

[33] EIA. "4-Week Avg U.S. Exports of Propane and Propylene (Thousand Barrels per Day)." <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=w_epllpz_eex_nus-z00_mbbld&f=4>

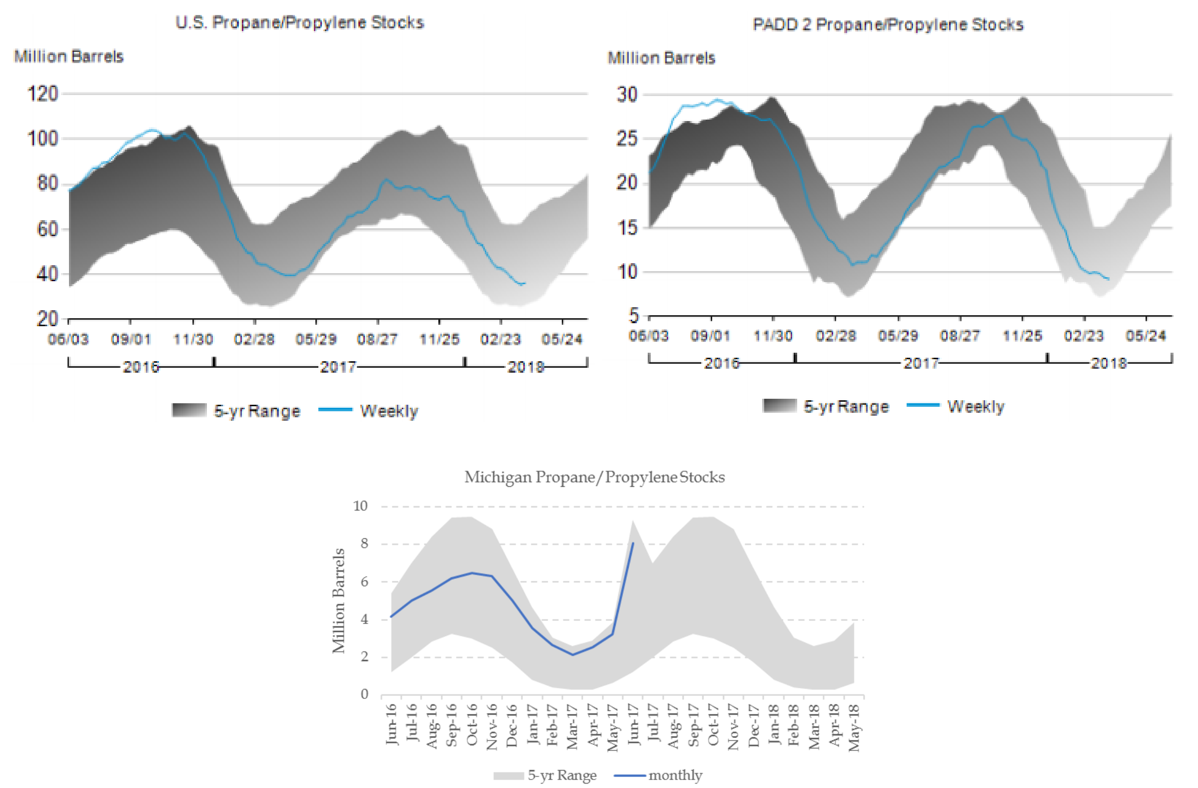
2.5 Propane seasonal storage

As noted previously in Section 2.2.5, propane demand in the United States varies greatly by season. Propane storage facilities are used to match seasonal demand with year-round production.

2.5.1 Michigan propane storage capacity

Michigan has above-ground propane and propylene storage capacity of about 9 million barrels (378 million gallons).[34] Michigan also has large volumes of propane storage capacity in underground rock formations and caverns.[35]

Figure 18. Stocks of propane and propylene in the US, PADD 2, and Michigan



Source: EIA[36] Note: Vertical axes are different scales

[34] EIA Stocks of Propane/Propylene dataset (maximum recorded stock volume)

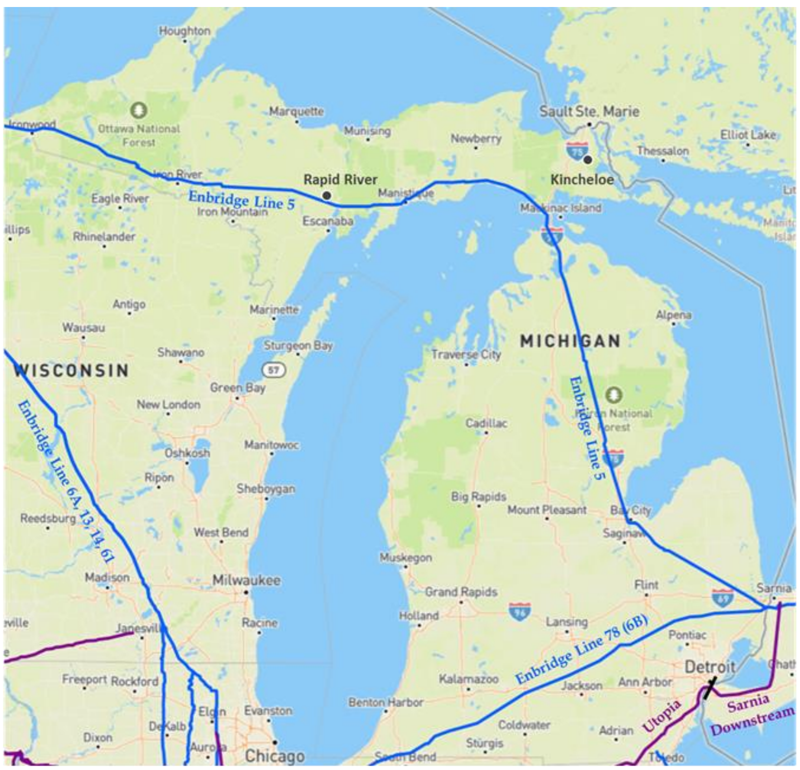
[35] Michigan Agency for Energy. "Propane in MI." Accessed on April 11, 2018. <http://www.michigan.gov/energy/0,4580,7-230-73789_83112_83114-333394--,00.html>

Michigan's capacity accounts for about one-quarter of PADD 2's 32 million barrels (1,344 million gallons) of propane and propylene capacity, which in turn is about 20 percent of total propane and propylene working and net available shell storage capacity in the United States (see Figure 18). Storage capacity at Rapid River is reported by Dynamic Risk to be 1.26 million gallons of NGLs; Michigan Public Service Commission data reports one million gallons.[37]

2.6 Propane transportation into Michigan

Propane is imported into Michigan from outside the state through two pipeline systems: Enbridge Line 5, and the Sarnia Downstream System ("SDS") operated by Plains Midstream Canada (see Figure 19). SDS carries propane from Sarnia, Ontario to the Michigan border near Detroit.

Figure 19. Liquids pipelines in Michigan



Source: Bloomberg

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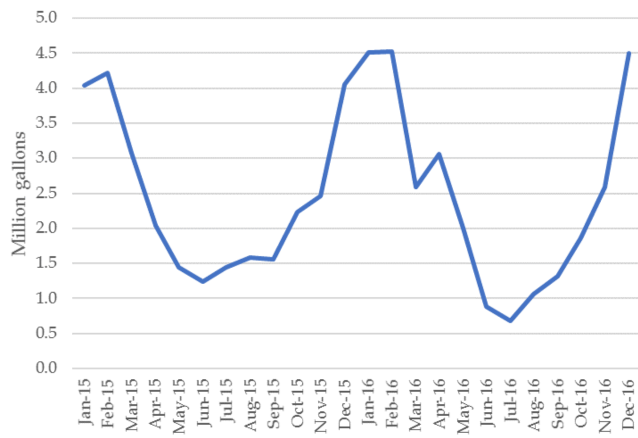
[36] EIA. "Stocks of Propane/Propylene by PAD District, June 2016 to Present." <https://www.eia.gov/petroleum/supply/weekly/pdf/figure6.pdf>

[37] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Prepared for the State of Michigan. October 26, 2017. P. 4-7; and Michigan Public Service Commission "Michigan SHOPP: Energy Data and Security Section." 10-2-2014. LEI converted to gallons at 42 gallons per barrel. https://www.eia.gov/petroleum/heatingoilpropane/workshop/2014/pdf/michigan.pdf

2.6.1 Enbridge Line 5 propane deliveries

Enbridge Line 5 transports about 3.4 million gallons per day of NGLs out of Superior, WI and into Michigan. At Rapid River, MI, about 0.081 million gallons per day (about 29 million gallons per year) are extracted. Much more propane is delivered in the winter than in the summer (see Figure 20).

Figure 20. Propane deliveries to Rapid River, Enbridge Line 5, 2015 and 2016



Source: Dynamic Risk, Appendix C[38]

2.6.2 Propane deliveries from Sarnia nearly match Lower Peninsula demand

After Rapid River, there are no further propane or other NGL withdrawals from Line 5 in Michigan. All the remaining NGLs are transported across the Lower Peninsula and delivered to Sarnia, Ontario for fractionation.[39] According to Enbridge, these deliveries amounted to an average of 3.321 million gallons per day of NGLs in 2015/16.[40] Sarnia also has rail links with

[38] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix C, P. C-3. Prepared for the State of Michigan. October 26, 2017. Dynamic Risk notes on page PR-7 of its Final Report that "Enbridge obtained permission from shippers to release publicly the historical and gross throughput of Line 5 on a monthly an annual basis showing deliveries and withdrawals of oil and NGLs at various points on Line 5.… Portions of the volume data were cleared for release in June 2017 and are provided in Table C-1 of Appendix C."

[39] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." P. PR-7. Prepared for the State of Michigan. October 26, 2017.

[40] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix C. Prepared for the State of Michigan. October 26, 2017. Pp. C-3, C-3.

western Canada which supply NGLs;[41] and the Sarnia region is connected by rail to the US Marcellus natural gas region.

Sarnia's fractionation capacity is reportedly 4.79 million gallons per day with an 84 percent capacity utilization rate, which amounts to throughput of 4.02 million gallons per day.[42] Based on this, the NGL shipments on Enbridge Line 5 in 2015/16 accounted for about 83 percent of the throughput of the fractionation plant at Sarnia.

An average of 1.08 million gallons per day of propane from Sarnia was shipped to the US border at Detroit through the SDS system from 2015-2017.[43] The 1.08 million gallons per day is about 90 percent of the 1.2 million gallons per day average annual consumption of the Lower Peninsula (based on Michigan Propane Gas Association consumption estimates for 2015). If consumption is lower than 1 million gallons per day, as EIA data shows, then SDS provides more than the equivalent of all the propane used in the Lower Peninsula.

2.7 Drivers of wholesale and retail propane prices in Michigan

2.7.1 US propane prices are connected to North American natural gas prices and global oil prices

Propane prices in the Unites States reflect the global price of crude oil, as represented by the price of Brent crude, a widely-used global benchmark price (see Figure 21). As one source explains "depending on market conditions, produced propane may be sold, consumed as fuel (in the refinery) or transformed to other refined products within the refinery."[44] This is one reason that propane's price can rise and fall with the price of crude oil. The price of crude oil in turn is determined by continental as well as global supply and demand events.

Another reason for the connection to Brent crude oil prices is that, with propane supplies growing faster than demand, the United States is exporting increasing volumes of propane. Most exported propane originates from the US Gulf Coast, but the US Northeast has begun exporting NGLs, to provide an outlet for growing Marcellus-area supplies. This expanding connection to the global market means that propane prices in North America can be influenced by global propane prices, which in turn are influenced by global oil prices.

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[41] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix G. Prepared for the State of Michigan. October 26, 2017. P G-10.

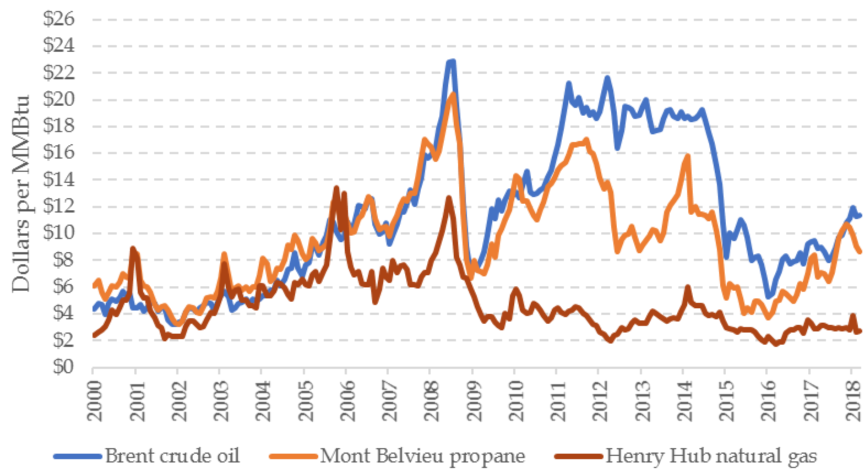
[42] Canadian Energy Research Institute. "Natural Gas Liquids (NGLs) in North America: An Update Part II – Midstream and Downstream Infrastructure." May 2014. P. 12.

[43] Plains Midstream Canada. "Filing of Plains Midstream Canada ULC – Sarnia Downstream System (SDS) Tariff Filing NEB No. 112 – International Join Rate Tariff Land Matters Consultation Initiative (LMCI) Collection Mechanism. May 12, 2017. https://docs2.neb-one.gc.ca/ll-eng/llisapi.dll/fetch/2000/90465/92837/813094/813186/3266454/A83570-1_PMC-_SDS_NEB_No._112_%E2%80%93_Tariff_Submission_Letter_-_A5L7G0.pdf?nodeid=3268764&vernum=1

[44] Gas Processing Management Inc. "Canadian Propane Supply and Demand through 2055." January 2018. P. 14.

The cost and supply of natural gas plays an important role in propane prices. The price of natural gas in the United States is determined mostly by supply and demand in the North American continent, rather than global gas supply and demand. With strong growth in natural gas supplies in the United States, continental gas prices declined dramatically after 2008, and the availability of NGLs increased. This reduced the price of NGLs such as propane. Before 2010, propane prices were nearly identical to crude oil prices; but starting in about 2011, a gap has appeared between Brent crude oil prices and United States propane prices, with US propane usually selling at a discount to Brent crude.

Figure 21. Prices of Brent crude oil, Henry Hub gas, and Mont Belvieu propane

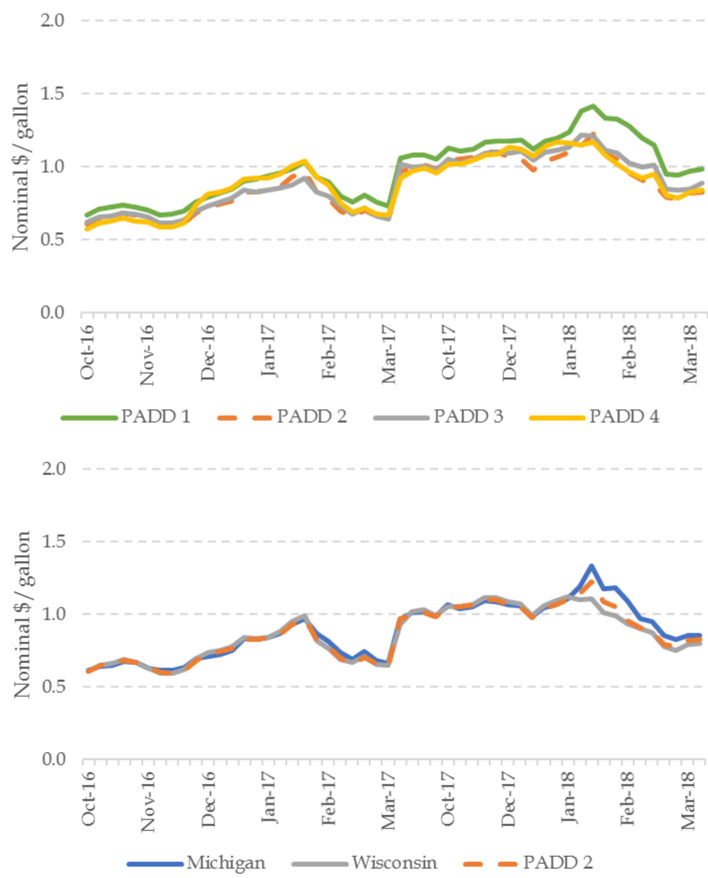


Source: EIA Europe Brent Spot Price FOB, EIA Propane Wholesale/Resale Price, EIA Henry Hub natural gas price

2.7.2 Wholesale prices in Michigan usually track PADD 2 prices closely

The average wholesale price of propane in Michigan usually tracks the PADD 2 price closely (see Figure 22). The average wholesale price of propane in Michigan was about $0.76 per gallon for winter (November-March) 2016/17, and $1.04 per gallon for winter 2017/18.

Figure 22. Wholesale winter propane prices



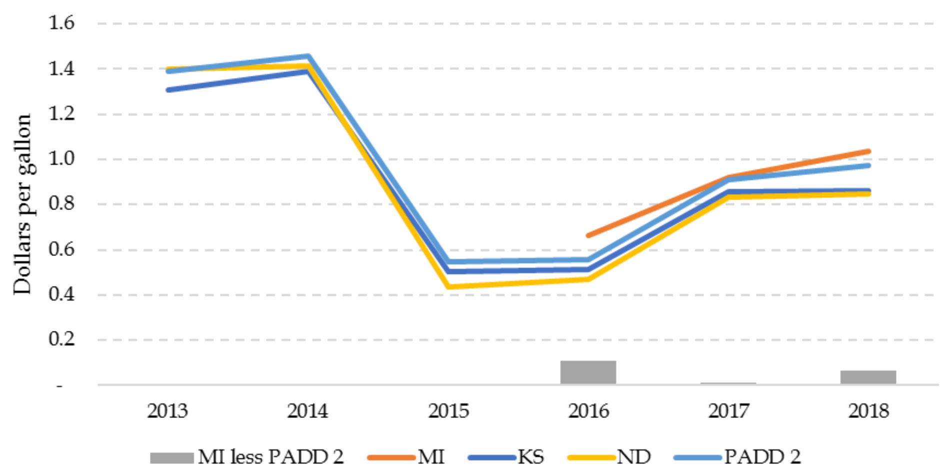
Source: EIA. Wholesale propane excluding taxes, from Weekly Heating Oil and Propane Prices (October - March)

Michigan wholesale prices averaged one percent higher than in Wisconsin in 2017. However, in 2018 Michigan prices were seven percent higher than the PADD 2 average. This may have been related to an unusual January and February 2018 price increase at Sarnia, Ontario.[45]

EIA data, which begins in 2016 for Michigan wholesale prices, shows the wholesale price of propane in Michigan was an average of $0.06 per gallon higher than the PADD 2 average in 2016/18 (see Figure 23). Other PADD 2 locations include Kansas, the location of the Conway propane supply hub; Ohio, home of the prolific Marcellus supply region; and North Dakota, home of the Bakken supply region. These low-wholesale cost areas contribute to slightly lower PADD 2 average wholesale prices compared with Michigan.

[45] Based on the higher spot FOB propane prices from Bloomberg at Sarnia, Ontario, observed in early 2018.

Figure 23. Wholesale propane prices, PADD 2 and selected PADD 2 states



Source: EIA. Wholesale propane excluding taxes, from Weekly Heating Oil and Propane Prices (October - March)

2.7.3 Recent residential propane prices in Michigan were about $2 per gallon

Propane prices to residential consumers in Michigan were about $2 per gallon for the winter of 2017/18, about $1 more than wholesale price (see Figure 24). Part of the total residential price of propane in Michigan is a four-percent sales tax on propane (classified by the State as an "unregulated fuel") used in the residential sector.[46] Propane sales for any other use are charged a six-percent sales tax, with some exemptions.

[46] Michigan Department of Treasury. https://www.michigan.gov/treasury/0,4679,7-121-44402_44415_44416-7217--,00.html

Figure 24. Wholesale and residential winter 2017/18 propane prices

Source: EIA Weekly Heating Oil and Propane Prices (October - March)

3 Cost of propane supply with and without Enbridge Line 5

With strong growth in supply of NGLs in the United States, and with flat to declining demand for propane in Michigan, indeed, in the United States overall, the prospect of persistent propane supply shortages in Michigan is unlikely. Weather-driven or event-driven supply interruptions, such as experienced in 2014 during the Polar Vortex winter, will likely occur on occasion, as they have in the past. But with the prospect of plentiful supplies relative to demand, the main concern with the potential absence of Enbridge Line 5 is the delivered cost of alternative sources of propane.

LEI took a three-step approach to examining the cost of alternative supply sources and transportation routes to the Upper Peninsula.

1. **LEI examined public supply and transportation cost data.** To the extent public data were available, LEI compared them to the cost assumptions that underpinned the analysis conducted by Dynamic Risk. Section 3.1 provides a review of those costs. LEI found that some of Dynamic Risk's assumptions were consistent with publicly-available data, and others were not.

2. **LEI replicated Dynamic Risk's computations.** Using Dynamic Risk's own assumptions and their cost model, LEI replicated Dynamic Risk's calculations of the cost of alternatives to Line 5. This step ensured that we understood Dynamic Risk's methodology and used their model correctly (but does not imply we agree with their assumptions). This is presented in Section 3.2.

3. **LEI tested the reasonableness of Dynamic Risk's results**. LEI used the publicly-available data from Step 1 in the Dynamic Risk model (see Section 3.3) and calculated the results. LEI concluded that Dynamic Risk's pipeline and trucking cost estimates were consistent with public sources of data, but the rail cost estimates were higher than supported by public sources. LEI calculated alternative rail transport costs.

LEI did not perform precisely the same analysis for the impact on Lower Peninsula costs, as the region is less reliant on Enbridge Line 5. However, we provided a qualitative view on the impacts on propane costs in the Lower Peninsula, in Section 3.3.5.

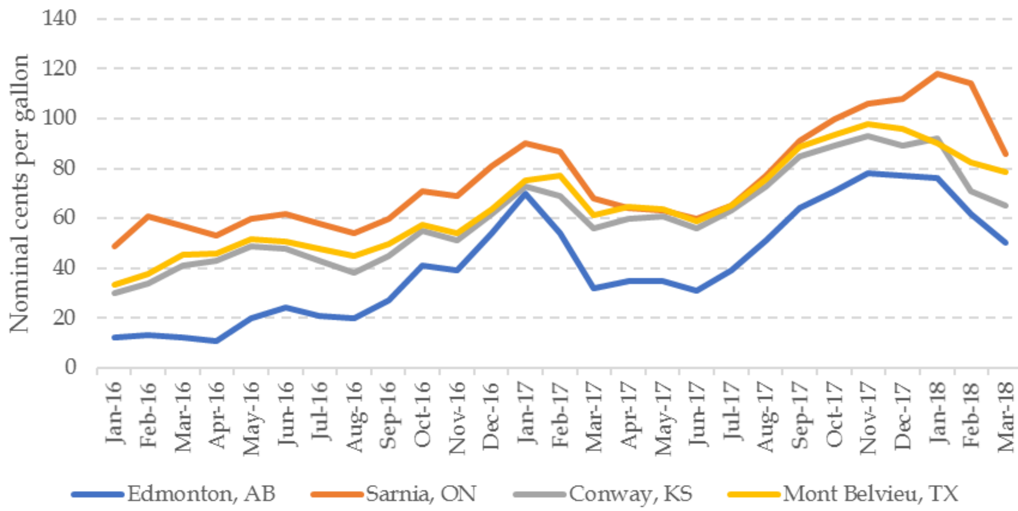
3.1 Step One: LEI examined data from publicly-available sources

LEI examined a broad array of public data sources to collect information on the key determinants of the cost of propane supply in Michigan.

3.1.1 Propane prices at supply hubs

Propane prices are published for hubs where large volumes are traded: at Mont Belvieu in Texas, Conway in Kansas, Sarnia in Ontario, and Edmonton in Alberta. Prices tend to be higher during winter and lower during summer (see Figure 25). Prices at Edmonton are lower than at the other hubs because supplies in Alberta are abundant, demand is much less than supply, the distance to markets is long, and transport capacity to the rest of North American is tight.

Figure 25. North American wholesale propane prices by market hub



Source: Bloomberg (spot FOB prices for Edmonton, Sarnia, and Conway) and EIA (Mont Belvieu, propane spot price FOB)

3.1.2 Transportation cost data

Pipeline tariffs for transportation of propane or NGLs are publicly available. Rail and truck costs have many elements which are not publicly available and are not simple to estimate, but some cost information is available in the public domain. This section covers key elements of pipeline, rail, and trucking costs for propane.

3.1.2.1 Costs by pipeline

Propane contracted for delivery via a pipeline usually pays for transportation costs at a published tariff for a specific route, with a receipt point near where the propane or NGLs are produced, to a delivery point where they are fractionated if needed and stored for distribution.

For transportation to Michigan, the transportation tariff for NGLs (including propane) on Enbridge's system from Edmonton, Alberta to Rapid River, MI, is $20.5562 per cubic meter, or $0.078 per gallon.[47] This is based on Enbridge's 2011 Competitive Tolling Settlement ("CTS") that came into effect in 2011 and expires in June 2021.[48]

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[47] International joint rate tariff. "NEB No. 402 FERC No. 45.12.0." Issued July 22, 2016.

[48] NEB. "Canada's Pipeline Transportation System 2016 - Enbridge Pipelines Inc.'s Enbridge Mainline." Accessed on April 12, 2018. <https://www.neb-one.gc.ca/nrg/ntgrtd/trnsprttn/2016/grp1cmpns/lndlqds/nbrdg-ppln-nc-nbrdg-mnln-eng.html?=undefined&wbdisable=true>

From Sarnia to the US border in Michigan (the end of the SDS line) the propane transportation pipeline tariff effective in 2016 was $0.008 per gallon.[49]

3.1.2.2 Elements of rail costs

Railroads offer tariffs in the form of "walk-up" rates which apply to the equivalent of a last-minute transaction. Most shippers do not pay walk-up rates. Instead, they pay discounted rates by providing their own equipment such as tanker cars, and/or committing to shipping large or fixed volumes.

Pressurized tanker cars are an important piece of the kit required to transport propane or other NGLs. The cost to lease such tankers is reported to range from about $100 per car per month to about $500 per car per month in 2017, down from a range of $100-$750 per car per month in 2016 (see Figure 26).

Rail cars may also be used to store propane. A distributor may find it cost-effective to buy propane in the summer when it is cheap and store it in a railcar until the winter. The cost to store a loaded rail car is reported to range from $10-$15 per rail car per day (about $300-$450 per month), while the cost to store an empty car is reported at about $3 per car per day (about $90 per month).[50]

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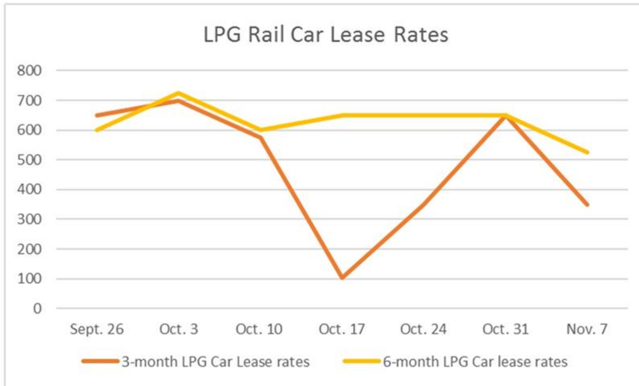
[49] NEB. "Plains Midstream Canada ULC Tariff (via the Sarnia Downstream Pipeline System)." Issued March 01, 2016.

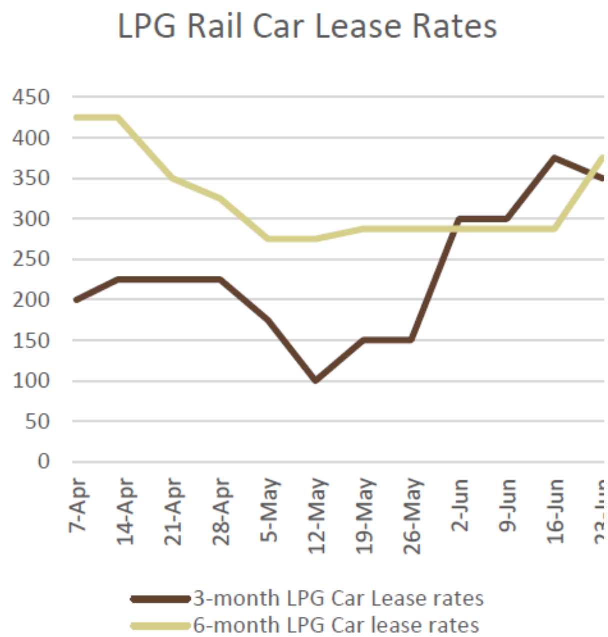
[50] Energy Transport Insider. "Longer-Term LPG Tank Car Lease Rates Up as Urge to Avoid Storage Continues." June 23, 2017. Vol. 2, Issue 25. <https://www.tradepointrail.com/wp-content/uploads/2017/07/Energy_Transport_Insider_June_23_2017.pdf>

Figure 26. LPG railcar lease rates, 2016 and 2017

Lease rates, 2016



Lease rates, 2017



Source: Energy Transport Insider[51]

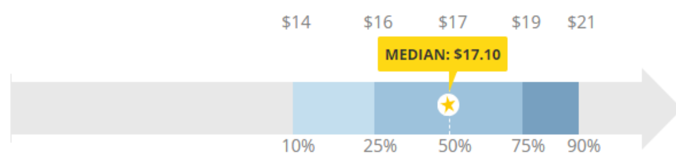
[51] Energy Transport Insider. "LPG Rail Car Lease Rates Fall as Demand Softens; Firms Try to Keep Cars Out of Storage." November 11, 2016. <http://energytransportinsider.com/blog/2016/11/11/lpg-rail-car-lease-rates-fall-as-demand-softens-firms-try-to-keep-cars-out-of-storage/>; and Energy Transport Insider, June 23, 2017. Vol. 2, Issue 25. <https://www.tradepointrail.com/wp-content/uploads/2017/07/Energy_Transport_Insider_June_23_2017.pdf>

3.1.2.3 Elements of propane trucking costs

Two important components of the cost of trucking propane are the driver's salary and the cost of diesel fuel.

Public data for the hourly pay for a propane truck driver is reported to range from about $14 per hour to about $21 per hour not including benefits, bonuses, or commissions (see Figure 27).[52] In comparison, Dynamic Risk assumed an hourly wage rate of $35 per hour, but might have included benefits, bonuses and commissions (they did not specify).

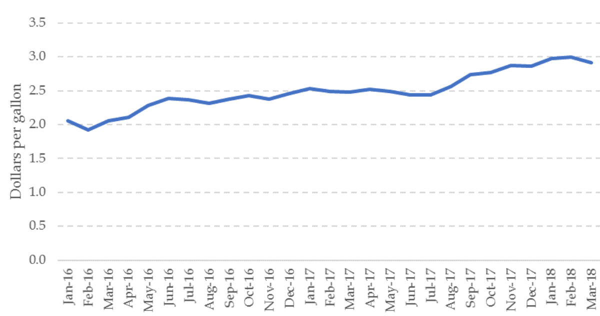
Figure 27. Hourly wage for propane delivery truck driver, not including benefits, bonuses, or commissions



Source: PayScale[53]

Public data for the retail price of diesel fuel in PADD 2 including taxes was $2.00 to just under $3.00 per gallon in 2016/17 (see Figure 28). This compares to the $3.00 per gallon assumed by Dynamic Risk.

Figure 28. PADD 2 retail price of No. 2 diesel, ultra-low sulfur (0-15 ppm), including taxes



Source: EIA[54]

[52] PayScale. "Propane Delivery Driver Salary." Accessed on April 2018. <https://www.payscale.com/research/US/Job=Propane_Delivery_Driver/Hourly_Rate>

[53] PayScale. "Propane Delivery Driver Salary." Accessed on April 2018. <https://www.payscale.com/research/US/Job=Propane_Delivery_Driver/Hourly_Rate>

[54] EIA. "Midwest No 2 Diesel Ultra Low Sulfur (0-15 ppm) Retail Prices Dollars per Gallon." Accessed on April 2018. <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMD_EPD2DXL0_PTE_R20_DPG&f=M>

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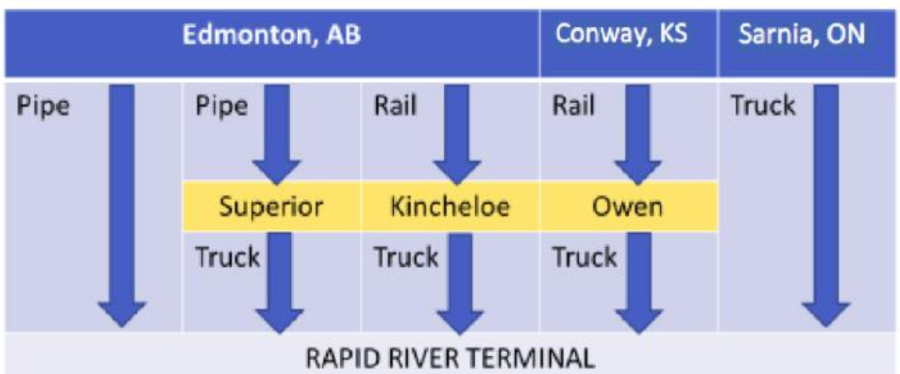
As discussed in more detail in Section 3.3, LEI used this public information to test the reasonableness of Dynamic Risk's cost estimates.

3.2 Step two: LEI replicated Dynamic Risk's propane supply cost results

Dynamic Risk calculated the impact on the cost of propane of several alternatives to Enbridge Line 5. Dynamic Risk concluded that the Upper Peninsula could face cost increases in the range of \$0.10-\$0.35 per gallon (based on winter months only).[55] LEI replicated this analysis and arrived at a similar low end of the range. However, as LEI discusses in Section 3.3, high-cost options would not be adopted if low-cost options are available, and therefore should not be used to assess impacts on consumers.

To perform their analysis, Dynamic Risk examined several transportation and supply alternatives from three different hubs (see Figure 29).

Figure 29. Dynamic Risk's alternatives to Enbridge Line 5 for Upper Peninsula propane supplies



Source: Dynamic Risk Appendix J[56]

Dynamic Risk relied on extensive and detailed cost assumptions and analysis, which they supplied in Appendix J of their Final Report.[57] LEI will be referring to these assumptions, so we reproduced them for the reader's convenience (see Figure 30 for rail cost assumptions and Figure 31 for trucking cost assumptions).

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[55] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines" Prepared for the State of Michigan. October 26, 2017. P 4-13.

[56] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix J, P. J-1. Prepared for the State of Michigan. October 26, 2017.

[57] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix J. Prepared for the State of Michigan. October 26, 2017.

Figure 30. Dynamic Risk assumptions for alternative supply of propane – rail cost analysis

General			
Volume of Propane per Railcar	31,500		gal
Terminal Load/Unload Time	24		h
Operating Hours Per Day	24		h/d
Railcar Lease Cost	$3,000		Monthly
Railcar Storage Cost	$1,000		Monthly
Freight Charge	$10.00		$/bbl
Transload Cost	$700		$/Railcar
Incremental Overhead	0.30		Man Years
Incremental Storage	270,000		gal
Capital Cost Storage Tanks (90,000 gal)	$350,000		$/Unit
Capital Cost Transload Equipment	$100,000		$/Unit
Useful Life (Storage Tank/Transloader)	20		Years
Amortization Rate	15%		Per Annum
Cost of Overhead	$80,000		$/Annum
Terminal Specific	**Transit Time (h)**	**Cycle Time (h)**	**Fleet (#)**
Kincheloe, MI	72	192	39
Owen, WI	36	120	25

Source: Dynamic Risk Appendix J[58]

[58] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix J, P. J-2. Prepared for the State of Michigan. October 26, 2017.

Figure 31. Dynamic Risk assumptions for alternative supply of propane - trucking cost analysis

General				
Volume of Propane per Tractor Trailer	10,400		gal	
Terminal Load/Unload Time	1		h	
Operating Hours Per Day	24		h/d	
Truck Fuel Mileage	7.9		mpg	
Driver Wage	$35		$/h	
Diesel Fuel Costs	$3.00		$/gal	
Capital Costs of Tractor Truck	$120,000		$/Unit	
Capital Cost of Propane Trailer	$145,000		$/Unit	
Insurance/License Fees/Permits	$0.09		$/Mile	
Truck/Trailer Repairs	$0.16		$/Mile	
Truck/Trailer Tires	$0.04		$/Mile	
Truck Tractor Life	7		Years	
Propane Trailer Life	15		Years	
Incremental Overhead	0.45		Man Years	
Incremental Storage	270,000		gal	
Incremental Transload Equipment	2		Units	
Capital Cost Storage Tanks (90,000 gal)	$350,000		$/Unit	
Capital Cost Transload Equipment	$100,000		$/Unit	
Useful Life (Storage Tank/Transloader)	20		Years	
Amortization Rate	15%		Per Annum	
Cost of Overhead	$80,000		$/Annum	
Terminal Specific	**Distance mi. (km)**	**Transit Time (h)**	**Cycle Time (h)**	**Fleet (#)**
Kincheloe, MI	150 (241)	3	8	5
Owen, WI	240 (386)	5	12	8
Superior, WI	290 (467)	6	14	9
Sarnia, ON	427 (688)	8	18	12
Lewiston, MI	221 (356)	4	10	21

Source: Dynamic Risk Appendix J[59]

3.2.1 Replicating Dynamic Risk's methodology and assumptions

As mentioned above, the purpose of Step 2 was to ensure LEI performed the cost calculations in the same way that Dynamic Risk did. Once that was established, LEI could then change key assumptions and examine the impact on the bottom line.

3.2.1.1 Replicating pipeline shipping costs

LEI compared the pipeline costs used by Dynamic Risk to the published tariffs for Enbridge Line 5 and SDS. Dynamic Risk's assumptions were consistent with the published tariffs ($0.078

[59] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix J, P. J-4. Prepared for the State of Michigan. October 26, 2017.

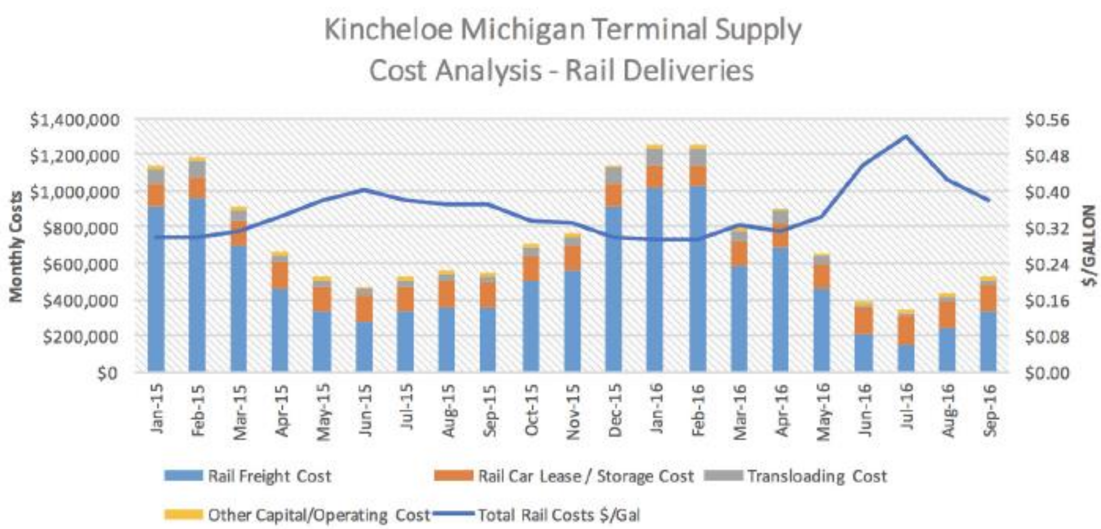
per gallon for Enbridge Line 5 and $0.008 per gallon for SDS). There was therefore no need for LEI to perform further calculations to replicate pipeline shipping costs.

3.2.1.2 Replicating rail shipping costs

For the cost to ship by rail, LEI first examined Dynamic Risk's results for the cost to ship by rail from Edmonton to Kincheloe; these costs include monthly railcar lease and storage costs, monthly freight costs, monthly transloading costs, and other costs. Dynamic Risk did not provide the numerical data for these results, but they did provide a visual representation in the Final Report, as Figure 4-4, page 4-10 and in Appendix J, as Figure J.2.1 (reproduced as Figure 32 below, for the reader's convenience).

Dynamic Risk noted that their estimated transport costs by rail from Edmonton to Kincheloe were in the range of $0.12 to $0.50 per gallon (Final report, Section 4: Alternative 6, page 4-10). However, it is clear from the figure that accompanied the discussion that the range is more like $0.28 to $0.50 per gallon. If their Figure (reproduced as Figure 32 below) is correct, the Dynamic Risk text appears to contain an error.

Figure 32. Dynamic Risk's Edmonton to Kincheloe rail cost estimates



Source: Dynamic Risk Appendix J, Figure J.2.1.[60]

LEI used this visual representation (and the $0.28 to $0.50 range) as a "target" for our replication of the Dynamic Risk analysis.

[60] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Appendix J, P. J-2. Prepared for the State of Michigan. October 26, 2017

LEI replicated these costs by using monthly propane deliveries to Rapid River (from Appendix C, pages C-2 and C-3). LEI cannot confirm the exact level of monthly propane deliveries Dynamic Risk used in its analysis, but we think it is reasonable to assume that their monthly estimate would be close to actual deliveries reported by Enbridge. Dynamic Risk said it reduced these deliveries by five percent to derive propane production volumes from the NGL flow data provided by Enbridge. To match Dynamic Risk's methodology, LEI did the same. LEI then calculated the monthly freight charge by using the $10 per barrel charge used by Dynamic Risk (see Figure 30 above), converting it to dollars per gallon, and multiplying it by the number of gallons of propane delivered.

LEI replicated the railcar lease cost by multiplying Dynamic Risk's monthly costs per car ($3,000, see Figure 30 above) by the number of railcars assumed by Dynamic Risk (39 cars, see Figure 30 above).

To replicate monthly storage costs, LEI first estimated the number of cars that would be in storage each month (Dynamic Risk did not provide this number). In December, January, and February we assumed no cars would be in storage, i.e., we assumed all 39 railcars would be needed for deliveries. For the other months, we scaled down the 39 cars based on the quantity of propane delivered in the month relative to the quantity delivered in December, January, and February. For example, if propane deliveries in April were only half the level of monthly deliveries in December, we assumed that half the railcars would be in storage in April. We then multiplied the number of cars in storage by the $1,000 per car storage cost assumed by Dynamic Risk (see Figure 30).

To replicate monthly transloading costs,[61] LEI multiplied the monthly transloading fee of $700 per car by the number of cars in the fleet which were assumed to be operating in a given month (i.e., 39 less the number of cars assumed to be in storage) and by the number of trips the cars needed to make.

To replicate "Other operating costs," LEI calculated monthly overhead and incremental overhead costs; for incremental overhead costs we assumed a 2,000-hour work year and a labor cost of $30 per hour.

To replicate "Other capital costs," LEI assumed a 20-year asset life for storage tanks and transloading equipment (the same as Dynamic Risk); used the same capital costs as Dynamic Risk; assumed two units of transloading equipment (one for each end of the journey) would be needed, and three storage tanks (to accommodate the assumed 270,000 gallons of storage), and the same 15 percent discount rate that it appears Dynamic Risk used, to arrive at net present value of the capital. LEI assumed deliveries of 30 million gallons per year for 20 years, to arrive at an average annual fixed cost recovery charge of $0.0055 per gallon.

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[61] Transloading refers to transferring cargo from one mode of transportation to another (such as railcar to truck) or transferring cargo from one vehicle to another. Source: UPDS. "How Transloading Works." <https://web.archive.org/web/20160603200116/http://www.upds.com/customers/attachments/transload/transload_works.pdf>

LEI added all the monthly costs and divided by the monthly deliveries to Rapid River. We arrived at an average of $0.32 per gallon to ship by rail from Kincheloe to Rapid River for the time period covered by the Dynamic Risk analysis (see Figure 33 and Figure 34, which is a visual representation of the data in Figure 33). This is very close to Dynamic Risk's $0.31 per gallon estimate of the incremental rail cost for the same route.[62]

Figure 33. LEI's replication of Dynamic Risk's costs for rail shipping from Edmonton to Kincheloe (numerical data)

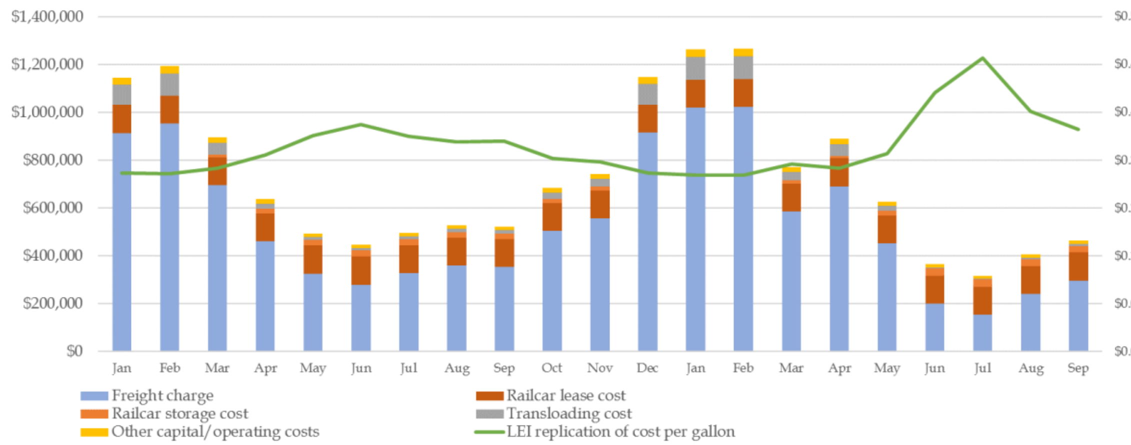
Year	Month	Propane deliveries to Rapid River (gallons)*	Freight charge	Number of rail cars in fleet	Railcar lease cost	Railcar storage cost	Transloading cost	Overhead plus incremental overhead cost	Fixed capital recovery	LEI replication of cost per gallon
2015	Jan	3,843,224	$915,053	39.0	$ 117,000	$0	$ 85,405	$ 8,167	$ 21,138	$0.30
2015	Feb	4,005,346	$953,654	39.0	$ 117,000	$0	$ 92,762	$ 8,167	$ 22,029	$0.30
2015	Mar	2,925,207	$696,478	39.0	$ 117,000	$9,316	$ 49,477	$ 8,167	$ 16,089	$0.31
2015	Apr	1,934,913	$460,694	39.0	$ 117,000	$19,365	$ 21,648	$ 8,167	$ 10,642	$0.33
2015	May	1,369,246	$326,011	39.0	$ 117,000	$25,105	$ 10,841	$ 8,167	$ 7,531	$0.36
2015	Jun	1,174,500	$279,643	39.0	$ 117,000	$27,081	$ 7,976	$ 8,167	$ 6,460	$0.38
2015	Jul	1,377,026	$327,863	39.0	$ 117,000	$25,026	$ 10,964	$ 8,167	$ 7,574	$0.36
2015	Aug	1,509,282	$359,353	39.0	$ 117,000	$23,684	$ 13,171	$ 8,167	$ 8,301	$0.35
2015	Sep	1,483,182	$353,139	39.0	$ 117,000	$23,949	$ 12,720	$ 8,167	$ 8,158	$0.35
2015	Oct	2,116,107	$503,835	39.0	$ 117,000	$17,526	$ 25,892	$ 8,167	$ 11,639	$0.32
2015	Nov	2,341,471	$557,493	39.0	$ 117,000	$15,239	$ 31,701	$ 8,167	$ 12,878	$0.32
2015	Dec	3,851,004	$916,906	39.0	$ 117,000	$0	$ 85,751	$ 8,167	$ 21,181	$0.30
2016	Jan	4,286,673	$1,020,637	39.0	$ 117,000	$0	$ 95,259	$ 8,167	$ 23,577	$0.30
2016	Feb	4,300,476	$1,023,923	39.0	$ 117,000	$0	$ 95,566	$ 8,167	$ 23,653	$0.29
2016	Mar	2,458,419	$585,338	39.0	$ 117,000	$14,053	$ 34,946	$ 8,167	$ 13,521	$0.31
2016	Apr	2,906,134	$691,937	39.0	$ 117,000	$9,509	$ 48,834	$ 8,167	$ 15,984	$0.31
2016	May	1,898,273	$451,970	39.0	$ 117,000	$19,737	$ 20,836	$ 8,167	$ 10,441	$0.33
2016	Jun	843,231	$200,769	39.0	$ 117,000	$30,443	$ 4,111	$ 8,167	$ 4,638	$0.43
2016	Jul	645,724	$153,744	39.0	$ 117,000	$32,447	$ 2,411	$ 8,167	$ 3,551	$0.49
2016	Aug	1,011,375	$240,804	39.0	$ 117,000	$28,737	$ 5,914	$ 8,167	$ 5,563	$0.40
2016	Sep	1,249,788	$297,569	39.0	$ 117,000	$26,317	$ 9,032	$ 8,167	$ 6,874	$0.37
Weighted average										**$0.32**

*Deliveries reduced by 5 percent per month to be consistent with Dynamic Risk's calculations.

As can be seen in Figure 34 in comparison to Figure 32, LEI's total monthly freight charges were nearly identical to Dynamic Risk's, which indicates LEI replicated Dynamic Risk's approach for that cost component almost perfectly. LEI's estimates of monthly storage and transloading costs appear to be slightly different from Dynamic Risk's, which probably reflects slightly different assumptions for the number of cars in service versus in storage in a given month.

[62]Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." Prepared for the State of Michigan. October 26, 2017. P. 4-13.

Figure 34. LEI's replication of Dynamic Risk's cost for rail shipping from Edmonton to Kincheloe



LEI's replication of Dynamic Risk's results does not imply that LEI agrees with Dynamic Risk's assumptions. It simply confirmed that LEI understood Dynamic Risk's approach and used Dynamic Risk's assumptions correctly.

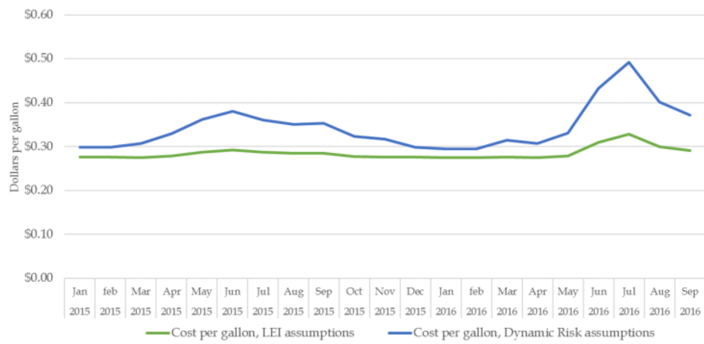
3.3 Step three: LEI calculated propane transportation costs using public data

For the final step, LEI substituted public data into the Dynamic Risk models, and calculated the results.

For the rail analysis, LEI's research of public sources discussed in Section 3.1 above indicated that LPG tanker car lease costs were considerably less than $3,000 per car per month assumed by Dynamic Risk. Costs for 2016-2017 ranged from $100-$750 per car per month, depending on supply and demand conditions and length of lease (see Figure 26 previously). Railcar storage costs (for empty cars) was reported at $90 per car per month; storage of loaded cars was reported at $300-$450 per car per month.

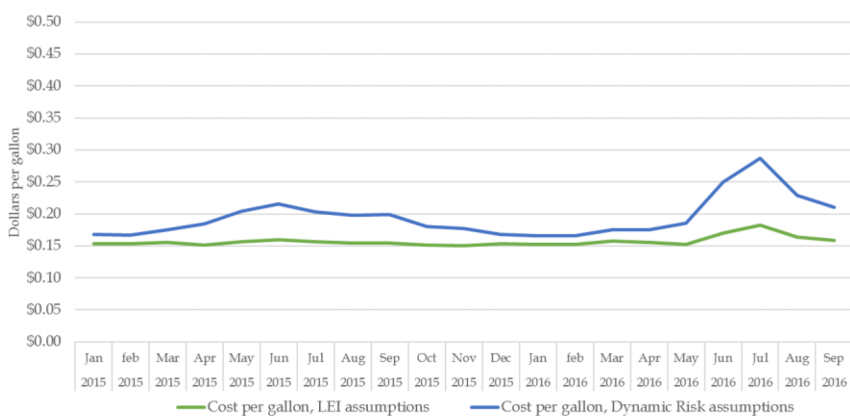
LEI performed the same analysis as described above but substituted $750 per car per month for the railcar lease cost (Dynamic Risk assumed $3,000) and $450 per car per month storage cost—assuming cars are stored loaded (Dynamic Risk assumed $1,000 per car per month). This resulted in an average cost of $0.27 per gallon (see Figure 35), which was $0.05 per gallon lower than the $0.32 per gallon estimated by LEI using Dynamic Risk's assumptions. The lower lease cost per rail car shifted the cost per month downward, while the lower storage cost flattened the summer peak in cost per gallon.

Figure 35. Edmonton to Kincheloe rail cost per gallon, comparison of impact of lease and storage cost assumptions



LEI performed the same calculations for the rail cost from Conway, KS to Owen, WI. We calculated the cost per gallon assuming lease costs were $750 per car per month and storage costs were $450 per car per month. LEI's assumptions based on the public data resulted in costs of $0.15 per gallon, a reduction of $0.03 per gallon compared to LEI's replication of Dynamic Risk's results.

Figure 36. Conway to Owen rail cost per gallon, comparison of impact of lease and storage cost assumptions



3.3.1 Trucking costs

For the cost of trucking propane to Rapid River, Dynamic Risk reported a winter average cost of $0.06 per gallon (Kincheloe to Rapid River), $0.09 per gallon (Owen to Rapid River), and $0.11 per gallon (Superior to Rapid River) (see Figure 37).[63] LEI replicated Dynamic Risk's trucking

[63] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." P. 4-13. Prepared for the State of Michigan. October 26, 2017.

analysis in the same manner as we did for their rail analysis. On an annual average basis, LEI calculated that trucking costs were $0.09 per gallon from Kincheloe to Rapid River, $0.12 per gallon from Owen to Rapid River, and $0.14 per gallon for Superior to Rapid River. LEI's annual averages are somewhat higher than Dynamic Risk's wintertime averages, because fixed costs are spread over fewer volumes in the non-winter months.

Figure 37. Comparison of trucking cost estimates

Route	Dynamic Risk estimate (November-March average)	LEI replication of Dynamic Risk's results using Dynamic Risk's assumptions (annual average)	LEI trucking cost using public data (annual average)
Kincheloe to Rapid River	$0.06	$0.09	$0.08
Owen to Rapid River	$0.09	$0.12	$0.11
Superior to Rapid River	$0.11	$0.14	$0.12

LEI's replication of Dynamic Risk's results does not imply that LEI agrees with Dynamic Risk's assumptions. It simply confirmed that LEI understood Dynamic Risk's approach and used Dynamic Risk's assumptions correctly.

LEI's analysis of publicly available data showed different values to those used by Dynamic Risk: 11,000-gallon truck volume (Dynamic Risk assumed 10,400 gallons); and recent (winter 2017/18) diesel fuel prices somewhat below Dynamic Risk's $3.00 per gallon). Public data for driver wages was lower than the $35 per hour used by Dynamic Risk, but did not include benefits, bonuses, or commissions. LEI assumed an average pay of $17 per hour (from Figure 27), a 2,000-hour working year, $18,000 per driver per year for health insurance,[64] and $8,000 for bonuses and commissions,[65] for a total cost of $30 per hour. Substituting public data (11,000-gallon truck, $2.90 per gallon diesel price, and a wage cost of $30 per hour) into the Dynamic Risk model reduced the cost per gallon for each of the routes by about $0.01 per gallon (see Figure 37 above).

3.3.2 The cost of rail from Superior to Rapid River

LEI also estimated the cost of transportation on a hypothetical new rail connection and transloading facilities at Rapid River. We used the same analytical framework and cost assumptions we used for the analysis of the other rail options and adjusted for the distance between Superior and Rapid River (which impacts transit time and therefore the number of railcars needed). We included the cost of storage and offloading equipment using the same

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[64] National Conference of State Legislatures. *2016 Employer Health Benefits Survey*. http://www.ncsl.org/research/health/health-insurance-premiums.aspx.

[65] https://www.indeed.com/q-Propane-Delivery-Driver-Class-B-CDL-Tanker-Hazmat-jobs.html

assumptions as Dynamic Risk. The one important element of cost which is not publicly available is the freight rail charge. Canadian National Railway Company ("CN") currently serves this route but does not have a published tariff for LPGs. LEI calculated that, assuming a freight rate of up to $4.00 per barrel ($0.095 per gallon), rail from Superior to Rapid River would be within a fraction of a cent of trucking. This $4.00 per barrel would likely be the highest price a railroad could charge—it if were any higher, it would lose the propane business to truckers.

3.3.3 Upper Peninsula propane costs could increase $0.11 per gallon on an annual average basis

LEI combined the transport costs we estimated based on public data with cost of supply at alternative sources, to arrive at the total cost of propane at Rapid River.[66] On a weighted average annual basis, the cost of propane at Rapid River was lowest, at $0.61 per gallon, if delivered by Enbridge Line 5 from Edmonton (see Figure 38). The next lowest-cost options are the combination of pipeline to Superior, and thence by rail or truck to Rapid River, with an incremental cost of $0.11 per gallon (including variable costs, overhead, and capital costs). A rail carrier may choose to charge a freight rate lower than $4.00 per barrel, in which case the incremental cost could be lower than $0.11 per gallon.[67]

Figure 38. Estimated weighted average annual cost of propane supply to Rapid River (all costs in $ per gallon)

Market hub	Edmonton, Alberta				Conway, KS
Hub price, 2017	$0.53	$0.53	$0.53	$0.53	$0.72
Mode of transportation	Pipeline	Pipeline	Pipeline	Rail	Rail
Cost of transportation	$0.078	$0.064	$0.064	$0.27	$0.15
Terminal		Superior, WI	Superior, WI	Kincheloe, MI	Owen, WI
Mode of transportation		Rail	Truck	Truck	Truck
Cost of transportation		$0.126	$0.124	$0.08	$0.11
	Rapid River Terminal (total cost, $/gallon)				
Total cost	$0.61	$0.720	$0.718	$0.88	$0.99
Difference		$0.11	$0.11	$0.27	$0.38

[66] By using the propane price at Edmonton rather than a value for NGLs at Edmonton, LEI implicitly assumed fractionation costs are included in the supply hub price, though the fractionation does not occur until the NGLs arrive at Rapid River.

[67] LEI also analyzed the cost of trucking from Sarnia to Rapid River, using the same assumptions used for the other trucking options. This route requires crossing the Straits, which is not favored by NWF. In any case, the cost of that option was $1.00 per gallon ($0.82 per gallon supply cost plus a $0.18 per gallon trucking cost) which made it clearly out-of-the money.

3.3.4 Other alternatives cost more

In theory, there are a wide variety of options for supply sources and routes to the Upper Peninsula. In practice, any viable alternative would have to be cheaper than the Edmonton-Superior alternatives, otherwise suppliers would not invest in it—they would not be able to beat the cost of the Edmonton-Superior route. For example:

- **Expanding storage at Kincheloe:** Dynamic Risk noted that propane storage exists at Kincheloe, which receives propane by rail from Alberta.[68] LEI's analysis summarized in Figure 38 shows that that even if rail or trucking from Kincheloe to Rapid River was free, the total cost of using the Kincheloe route would be $0.80 per gallon, which is more expensive than the Edmonton-Superior route. Therefore, LEI did not examine the option of expanding storage at Kincheloe--it cannot compete economically with the Edmonton-Superior route.

- **A new 4-inch diameter pipeline from Superior:** LEI was asked to examine whether a new, smaller pipeline dedicated to transport of propane to the Upper Peninsula would be economically viable. LEI modeled a 4-inch (internal diameter) pipeline running 290 miles from Superior Wisconsin, to Rapid River. Even if the cost of abandoning Line 5 in the Upper Peninsula is excluded, and even if operating and maintenance costs are excluded, the cost of this option was very expensive. At an assumed capital cost of about $2 million per mile,[69] a length of 290 miles from Superior to Rapid River, a 40-year period to cover return of capital, and a four percent discount rate, the cost would be $0.86 per gallon. This is expensive because the volume of propane needed in the Upper Peninsula is too small to support the capital cost of dedicated pipeline.

- **Using existing Line 5 far below capacity:** Apart from any engineering and operational problems, this would involve a large increase in transportation costs per gallon. Pipeline tariffs are designed to recoup investment and are agreed under a regulatory process. Propane demand in Rapid River is less than 4,000 barrels per day even in high-demand months, less than one percent of the 540,000 barrels which is the basis of the current tariff. Continued operations would require a very large increase in the tariff, given the small volume of propane and large pipeline capacity.

LEI concluded that the Edmonton-Superior route which relies on pipeline service to Superior and trucking or rail transport to Rapid River, is the lowest-cost alternative and therefore the most likely market response if Enbridge Line 5 did not exist.

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[68] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." P. 4-9. Prepared for the State of Michigan. October 26, 2017.

[69] ICF. "North America Midstream Infrastructure through 2035: Capitalizing on Our Energy Abundance." INGAA Foundation Final Report No. 2014.01. March 18, 2014. Pp. 14, 17.

3.3.5 Lower Peninsula may have negligible cost impact

For the Lower Peninsula, the loss of the delivery of NGLs to Sarnia may have a negligible cost impact. Enbridge Line 5 is the main source of NGLs to Sarnia as noted in Section 2.6, but it is not the only source. Sarnia is located close to cheap sources of NGLs from the Marcellus shale. Dynamic Risk noted that "(w)ith the potential availability of low cost ethane and additional propane from Marcellus and Utica, the Sarnia area petrochemical industry is able to source alternate feedstock supplies for their respective plants given the well-developed infrastructure and logistics available in the region as well as proposed new pipelines."[70]

Dynamic Risk estimated the cost impact at $0.06 per gallon (on Sarnia supply costs), and also noted that the producers would probably absorb some of this cost increase.[71] LEI examined Dynamic Risk's assumptions and calculations and found that, assuming Dynamic Risk's assumption of a stand-alone rail rate of $6.49 per barrel from Superior to Sarnia (which we could not verify) and the other assumptions (which we could verify), that the $0.06 per gallon could be accurate, assuming the NGLs had to come from Edmonton through Superior.

However, there is no obvious reason why the 4 million gallons per day of NGLs processed at the Sarnia fractionation plant would have to be sourced from Edmonton via Superior. Sarnia is closer to the Marcellus supply region than it is to Superior. If Sarnia needed additional supplies of NGLs, rail transport from Ohio through Michigan might be cheaper because the distance is shorter, and pipeline transport costs might be lower still. So, if Line 5 were not in service, Sarnia could still receive NGLs, and still provide propane via SDS to Michigan.

Also, in terms of propane rather than NGLs, the potential future expansion of the Utopia pipeline could increase the quantity of propane shipped into the Lower Peninsula. This could potentially add 25,000 barrels per day, which coincidentally is the equivalent of the 25,000 barrels per day currently shipped from Sarnia on SDS. The tariff for this has not been established (as the expansion is not under way, it is only proposed) so costs are not known. LEI examined several recent tariff filings and found a range of $0.064 per gallon to $0.089 per gallon for propane transportation by pipeline, which gives a general indication of the potential cost.[72] The supply cost of propane in the Marcellus region is not widely available or publicly reported, so LEI could not estimate the total cost of propane supply plus transportation, to compare it to the $0.828 per gallon total from Sarnia.[73]

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[70] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines (Appendices)." October 26, 2017. Prepared for the State of Michigan. October 26, 2017. Appendix G, P. G-9.

[71] Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." October 26, 2017. Prepared for the State of Michigan. October 26, 2017. Appendix J. P. J-12.

[72] Blue Racer NGL Pipelines, Inc. "Local pipeline tariff. FERC oil tariff." December 2015; Tri-Sates NGL Pipeline, LLC. "FERC oil tariff." January 2016; and Mid-America Pipeline Company.

[73] Adding the $0.008 per gallon rate on SDS to the average propane cost at Sarnia of $0.82 (from January 2016-December 2017) totals $0.828 from Sarnia to Detroit.

4 Impact of a cost increase on consumer prices

The cost increases will not be borne entirely by consumers in the Upper Peninsula of Michigan. LEI found that $0.05 per gallon of the $0.11 per gallon cost increase would be borne by consumers in the form of a price increase. The remaining $0.06 per gallon would be borne by producers and suppliers in the form of lower margins.

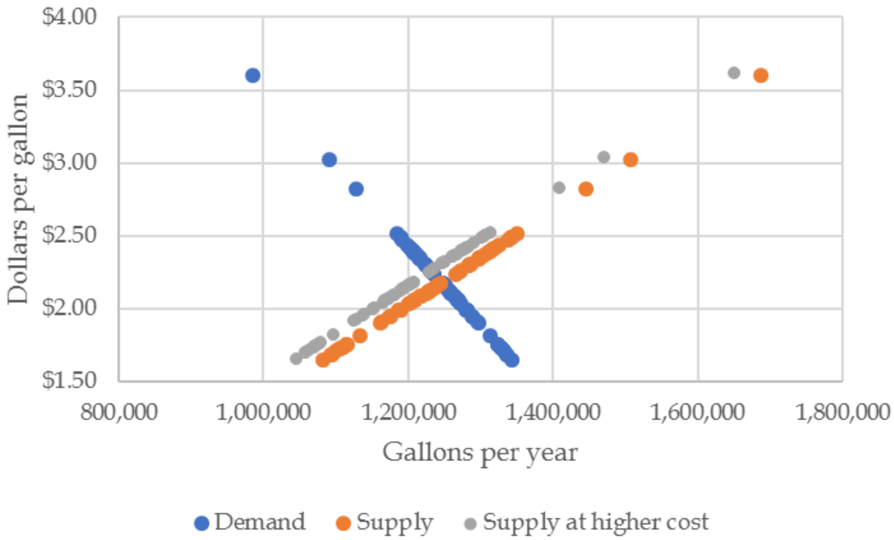
4.1 Cost increase is shared by suppliers and consumers

To estimate the shares of the cost borne by suppliers versus consumers, LEI used econometric analysis of propane supply and demand in Michigan. LEI focused on the impact of prices on supply and demand; there are drivers other than price that can affect supply and demand, and econometric analysis isolates these, so that we can examine the impact of prices alone. Detailed information about the econometric methodology, the drivers tested, data LEI used, and the results are available in Section 6 (Appendix A).

LEI used the econometric analysis to create supply and demand curves for propane in Michigan (see Figure 39). The orange dots represent Michigan propane supply as it relates to the price of propane; as prices rise suppliers are willing and able to supply more propane, so the orange trend has an upward slope. The blue dots are Michigan demand for propane as it relates to price. It has a downward slope in relation to propane prices, because as prices rise consumers are less able or willing to buy propane. The market-clearing residential price, where (orange) supply and (blue) demand meet, is $2.284 per gallon (see Appendix A for calculations).

The grey line shows the supply of propane if the cost goes up $0.11 per gallon. This added cost shifts the supply curve upward: at any given quantity, the cost is $0.11 per gallon more. However, the new market-clearing price is not $2.394 (i.e., $2.284 + $0.11) per gallon. It is lower than that. This is because the demand curve is not perfectly vertical—it has a downward slope, because, as mentioned above, people want less propane when it costs more. The new market-clearing price, where supply and demand meet, is $2.337 per gallon, which is $0.053 per gallon higher (see Appendix A for calculations).

Figure 39. Supply and demand for propane in Michigan, 2008-2018



Based on data for January-March and October-December

5 Conclusions and implications

Without access to propane from Enbridge Line 5, consumers would seek the next-least-expensive alternative; and suppliers would not attempt to serve the market using a supply route that costs more than the cheapest option. The cheapest option is rail or trucking from Superior, WI. LEI estimates this would add about $0.11 per gallon to the weighted average annual cost of propane.

It would not make sense for consumers to choose the other alternatives unless there were some interruption in pipeline service to Superior, or road or rail access from Superior to Rapid River was closed off. Thus, it does not make sense to assume that the impact of the loss of Line 5 would be a $0.35 per gallon "upper bound," as Dynamic Risk argued.[74] The upper bound would only be relevant if the lower-cost alternatives did not exist. The upper bound cost impact under normal operating conditions would be $0.11 per gallon, the cost at which the two lowest-cost alternatives would compete to supply the market.

5.1 Consumers would pay for part of the cost increase, but not all of it

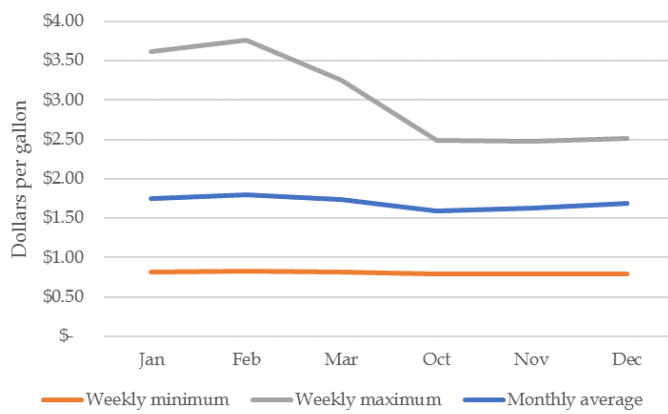
The demand for propane in Michigan, like demand for most goods and services in most places, is "downward-sloping." This means that consumers will buy less of something when its price goes up. LEI's econometric analysis shows that, of an $0.11 per gallon cost increase, the residential price of propane would increase $0.05 per gallon.

5.2 The price increase would be lost in the noise of typical price volatility

Each week, the price of propane varies widely compared with its monthly average. For Michigan, weekly prices of propane have been as low as $0.86 per gallon even in the winter, and as high as over $3.50 per gallon (see Figure 40). This wide variation is often referred to as price volatility and is typically measured as the standard deviation of prices. For Michigan residential propane prices, the standard deviation of weekly prices for 2008-2018 was about $0.58 per gallon. This is much larger than the $0.05 per gallon price increase estimated for the Upper Peninsula from using an alternative to Enbridge Line 5.

[74] Dynamic Risk. Analysis of Alternatives Dynamic Risk. "Final Report: Alternatives Analysis for the Straits Pipelines." October 26, 2017. Prepared for the State of Michigan. October 26, 2017. P. 4-13.

Figure 40. Weekly maximum and minimum prices, and monthly average prices for residential propane in Michigan (2008-Jan 2018)



Source: EIA, Weekly Michigan residential propane price

5.3 New supplies, but no surprises

LEI's economic analysis of supply options assumes that the need to transition to a new supply option, and the timing of this need, would be known in advance. This gives the industry time to plan. The Polar Vortex and surprises such as pipeline outages drive up prices precisely because they are unexpected. But if Enbridge Line 5 were not operating, ideally regulators and stakeholders would establish a timeline so that the industry can create new supply and transportation routes.

If Enbridge Line 5 did not exist, consumers should not expect shortages of supply under normal conditions (i.e., assuming the railroads are running, and highways are open). Consumers should continue to expect the price of propane to reflect supply and demand, weather conditions, and volatility, as it has for many years.

6 Appendix A: Details of econometric analysis of propane supply and demand

Econometric estimation is a technique based on statistical analysis of historical data. If enough data is available, econometric analysis allows isolation of the individual impacts of prices and of other drivers (known as regressors, or explanatory variables) on demand for a good; or similarly, on supply of a good.

6.1 Econometric model specification

LEI used a standard formulation of a system of demand and supply equations, which includes the price of the good as an explanatory variable for both demand and supply.

6.1.1 Demand model

The price of a good is a driver of demand, in that a higher price would probably reduce demand and a lower price would increase demand, so economists include price an explanatory variable in any demand model. Propane is used for heating, so the weather (measured as number of heating degree days ("HDD")) is likely to be an important driver.[75] Propane is also used for drying crops, a seasonal activity which typically happens in October. Finally, demand for propane could increase over time, or it could fall over time, depending on other factors such as adoption of other heating fuels, or a rising population. We do not necessarily know what these time-dependent factors might be, but we can include an explanatory variable which tracks an underlying trend over time and discover whether it tends to increase or decrease demand. If there is no impact over time, the econometric results would indicate that, too. This model is shown in Figure 41.

Figure 41. Demand and supply models estimated

Dependent variable	Regressors
Quantity demanded	Price, HDD, October, time
Quantity supplied	Price, time

6.1.2 Supply model

The price of propane is an incentive to supply it. A rising price would, all else equal, encourage more supply, while a lower price would induce less supply. Availability of propane could increase over time, or it could fall over time, depending on a variety of factors such as NGL

[75] A heating degree day is defined as the difference in the average temperature on a given day from 65 degrees Fahrenheit. For example, a day in which the temperature averaged 30 degrees would account for 35 heating degree days.

production and demand from refineries. Just as for propane demand, we do not necessarily know what these time-dependent factors might be, but we can track the trend over time and discover whether it tends to increase supply, decrease supply, or has no impact on supply. The supply model is also shown in Figure 41.

6.2 Data used in the econometric analysis

LEI used data from the EIA and the US National Oceanographic and Atmospheric Administration ("NOAA") (see Figure 42). The EIA price and consumption data are available for Michigan as a whole, but not for the Upper Peninsula separately; LEI used Michigan-wide data for the econometric analysis.

Figure 42. Data sources for econometric analysis

Variable	Source	Notes
Residential propane prices	EIA, Weekly Michigan Propane Residential Price (Dollars per Gallon)	converted to monthly prices to match consumption
Michigan propane consumption	EIA, Michigan Propane All Sales/Deliveries by Prime Supplier (Thousand Gallons per Day)	monthly data
Michigan heating degree days	NOAA, heating degree days, ftp://ftp.cpc.ncep.noaa.gov/htdocs/degree_days/weighted/legacy_files/heating/statesCONUS/	monthly data

LEI created the variable for October by using a "1" if the observation was in October, and "0" if not. This standard formulation is known as a "dummy variable." The time trend regressor equals "1" in 2008, and subsequent years are "2", "3", "4", etc. All the data values are shown in Figure 43. All data was for 2008-2018, for the months of January-March and October-December (except for 2018, for which only January data was available). This provided a sample size of 61 observations, which is enough observations to support statistically significant results.[76]

LEI computed the logarithms of consumption, price, and HDD and used those values in the econometric model. This widely-used formulation provides a straightforward way of interpreting the estimated coefficients: they are the elasticities of demand, as in "a one-percent change in the price of propane is associated with an x-percent change in demand."

[76] The more observations in a sample of data, the more likely it is that the sample represents reality. Statistical significance refers to whether the results of the econometric analysis are likely to closely match reality.

Figure 43. Data used in econometric analysis

Year	Month	MI residential price (2016 $ per gallon)	MI heating degree days	Time trend	October dummy	Consumption (gallons per day)
2008	1	2.71	1205	1.00	0	1,778,000
2008	2	2.71	1257	1.00	0	2,047,300
2008	3	2.72	1066	1.00	0	1,329,100
2008	10	2.73	511	1.00	1	1,087,000
2008	11	2.67	824	1.00	0	1,074,800
2008	12	2.65	1239	1.00	0	1,680,900
2009	1	2.59	1521	2.00	0	1,945,900
2009	2	2.58	1085	2.00	0	1,525,300
2009	3	2.54	911	2.00	0	1,055,000
2009	10	1.97	556	2.00	1	972,100
2009	11	2.14	669	2.00	0	1,111,600
2009	12	2.31	1176	2.00	0	1,654,000
2010	1	2.56	1296	3.00	0	1,554,700
2010	2	2.55	1116	3.00	0	1,481,600
2010	3	2.48	799	3.00	0	911,800
2010	10	2.31	395	3.00	1	633,900
2010	11	2.41	758	3.00	0	878,400
2010	12	2.50	1246	3.00	0	1,516,000
2011	1	2.55	1397	4.00	0	1,528,400
2011	2	2.59	1156	4.00	0	1,335,300
2011	3	2.59	1023	4.00	0	1,061,500
2011	10	2.61	420	4.00	1	656,000
2011	11	2.65	654	4.00	0	972,600
2011	12	2.69	980	4.00	0	1,138,100
2012	1	2.65	1116	5.00	0	1,164,700
2012	2	2.66	995	5.00	0	1,132,200
2012	3	2.68	534	5.00	0	704,700
2012	10	2.08	473	5.00	1	830,000
2012	11	2.12	800	5.00	0	1,085,800
2012	12	2.12	962	5.00	0	1,246,800
2013	1	2.16	1198	6.00	0	1,513,400
2013	2	2.21	1141	6.00	0	1,494,100
2013	3	2.23	1052	6.00	0	989,800
2013	10	2.17	423	6.00	1	777,300
2013	11	2.27	849	6.00	0	1,087,100
2013	12	2.46	1249	6.00	0	1,732,400
2014	1	2.91	1520	7.00	0	1,689,400
2014	2	3.71	1364	7.00	0	1,434,500
2014	3	3.11	1234	7.00	0	1,247,000
2014	10	2.15	459	7.00	1	909,600
2014	11	2.18	920	7.00	0	1,546,000
2014	12	2.19	1031	7.00	0	1,472,500
2015	1	2.19	1391	8.00	0	1,743,400
2015	2	2.20	1491	8.00	0	1,877,200
2015	3	2.20	1039	8.00	0	1,256,400
2015	10	1.68	414	8.00	1	784,100
2015	11	1.75	626	8.00	0	930,500
2015	12	1.77	811	8.00	0	1,115,200
2016	1	1.76	1215	9.00	0	1,422,800
2016	2	1.78	1047	9.00	0	1,341,600
2016	3	1.74	783	9.00	0	936,400
2016	10	1.70	300	9.00	1	664,800
2016	11	1.70	612	9.00	0	803,700
2016	12	1.83	1167	9.00	0	1,326,400
2017	1	1.93	1123	10.00	0	1,318,400
2017	2	2.01	853	10.00	0	1,234,500
2017	3	1.98	956	10.00	0	1,143,500
2017	10	1.90	310	10.00	1	668,600
2017	11	2.02	800	10.00	0	1,033,500
2017	12	2.11	1256	10.00	0	1,353,000
2018	1	2.12	1286	11.00	0	1,865,100

6.3 Econometric analysis

LEI estimated the demand and supply equations separately. We then used the results of the econometric analysis to calculate the impact of a $0.11 per gallon cost increase on the market-clearing price.

6.3.1 Econometric results, demand

LEI's econometric results showed that, for the demand model, the impact of a one-percent increase in price was to reduce quantity demanded by 0.29 percent (see Figure 44). This relationship defines the downward slope of the demand curve. For every one percent increase in HDD in a given month, demand increased by 0.88 percent. The impact of the time trend was negative: each year, Michigan demand declined by 0.01 percent. The impact of October was positive: 0.26 percent more propane would be used in October than in the other months, independently of price, time, or HDD.

Figure 44. Econometric results, demand

Demand model	Estimated coefficient	Standard Error	t-Statistic	P value
Intercept	8.27	0.45	18.53	0.00
ln real price	-0.29	0.13	-2.24	0.03
ln HDD	0.88	0.07	13.02	0.00
Time trend	-0.01	0.01	-2.00	0.05
October	0.26	0.07	3.73	0.00

Note that "ln" refers to the natural logarithm of the regressor

The results are statistically significant. The measures of statistical significance LEI used in this analysis are the well-known t-statistic and P value. The t-statistic is the difference between the estimated coefficient and zero (i.e., its value under the null hypothesis "H_0"),[77] divided by its standard error (see Figure 44). A t-statistic with an absolute value which is 2 or greater (given our 61 observations) indicates that we can be 95 percent confident that the estimated coefficient is accurate.

The P value is the probability of erroneously rejecting H_0 when it is true. For example, the P value of 0.03 in Figure 44 for the estimated coefficient on price indicates that there would be

[77] For our study, zero is the hypothesized value—i.e., we test the estimated coefficient against zero, which would be its value if the driver (for example, price) had no impact on demand. This is referred to as the "null hypothesis" or "H_0."

only a 3 percent chance of making that mistake. This means that we can be 97 percent sure that the estimated coefficient for price is accurate.

6.3.2 Econometric results, supply

LEI's econometric results showed that, for the supply model, a one percent increase in price increased quantity supplied by 0.54 percent (see Figure 45). This relationship defines the positive slope of the supply curve. The P value indicates that the estimated coefficient for price is significant at 98 percent.

The impact of the time trend was not statistically significant in a model that LEI tested which included the time trend, so we left time out of the final supply model.

Figure 45. Econometric results, supply

Supply model	Estimated coefficient	Standard Error	t-Statistic	P value
Intercept	13.54	0.19	72.76	0.00
ln real price	0.54	0.22	2.45	0.02
Intercept after cost increase:				
	13.52			

6.3.3 Impact of cost increase

When supply is equal to demand, the market is said to "clear." LEI solved for the market-clearing price (where the supply and demand curves intersect):

> ln(quantity demanded) = 8.27 – (0.29 x (ln(price)) + (0.88 x ln(HDD average value)) - (0.01 x time average value) + (0.26 x October average value)
>
> ln(quantity supplied) = 13.54 + (0.54 x ln(price))

Setting supply equal to demand and solving for the market-clearing price results in a price of $2.284 dollars per gallon.

If the cost to supply propane goes up $0.11 per gallon, the supply curve shifts upward by $0.11 per gallon, resulting in a new intercept of 13.52. The set of equations now has a new intercept for the supply curve:

> ln(quantity demanded) = 8.27 – (0.29 x (ln(price)) + (0.88 x ln(HDD average value)) - (0.01 x time average value) + (0.26 x October average value)
>
> ln(quantity supplied) = 13.52 + (0.54 x ln(price))

Again, we set supply equal to demand and solve for the market-clearing price. The new price is $2.337 per gallon, $0.053 per gallon more than the old price.

7 Appendix B: Consultant CV

Marie N. Fagan, PhD

Managing Consultant and Lead Economist, London Economics International, LLC

KEY QUALIFICATIONS:

Marie Fagan is Managing Consultant and Lead Economist at London Economics International, LLC, based in Boston, Massachusetts. With over 25 years of experience in research and consulting for the energy sector, Marie's career has spanned international upstream and downstream oil and gas, global coal, North American gas markets, and North American power markets. She has advised C-suite industry clients, buy-side and sell-side financial clients, as well as legislators and regulators; she has served as an expert witness. At LEI, Marie's expertise across electricity markets and fuels provides integrated perspectives and supports sound strategic advice for clients.

Marie leads LEI's engagements related to oil and natural gas market analysis. She directs gas pipeline modeling efforts based on a sophisticated network model, supporting outlooks for natural gas prices and basis, and analysis of flows on North American interstate pipelines. She provides in-depth expert testimony on issues such as basis differentials, pipeline capacity and utilization in key regions, and LNG import and export supply and demand. Recent projects for LEI have included serving as independent market expert for the Maine Public Utilities Commission, in the evaluation of the costs and benefits of new natural gas pipelines into New England, and as independent market expert assisting the Minnesota Department of Commerce in evaluating the application of an oil pipeline expansion project.

Marie directs LEI's research of the Electric Reliability Council of Texas ("ERCOT") electric power market. Recent projects have included examination of the political, legislative, and economic drivers the led to creation of ERCOT's Competitive Renewable Energy Zones ("CREZ"), and assessment of the potential for state-level support for further expansion of CREZ transmission lines.

Marie draws on her long-time experience across fuels and regions to ensure clients benefit from an integrated understanding of market rules and practices. Recent projects have included providing expertise related to the design of capacity markets in the electric power sector. Marie is experienced in the use of scenario analysis, an approach which helps clients identify potential turning points and arrive at decisions that are robust given the uncertainties inherent in any future set of market conditions.

From 1996-2014, she was with Cambridge Energy Research Associates ("CERA," now part of IHS, Inc.). She served as an Associate, then Associate Director for CERA's Global Oil research practice, as Director for the North American Gas research practice; she founded the CERAView Institutional Investor Service and co-founded CERA's Global Steam Coal service; she served as Senior Director for CERA's North American Electric Power service and of IHS CERA's Upstream Strategy service. Before joining CERA, Marie served as an economist with the United States Energy Information Administration ("EIA"), conducting analysis and modeling supporting the Annual Energy Outlook ("AEO"), and conducting analysis of energy company financial performance.

Marie is the author of original research with publications in academic and industry journals. She holds a PhD in Economics from the American University in Washington, DC.

EDUCATION:

Institution	American University, Washington DC
Date:	1995
Degree(s) or Diploma(s) obtained:	PhD in Economics. Dissertation: "Measuring Cost and Efficiency in US Crude Oil Resource Development, 1977-1990: A Frontier Translog Cost Function Approach"

Institution	University of Connecticut
Date:	1984
Degree(s) or Diploma(s) obtained:	Bachelor of Science, Business Administration (Finance)

EMPLOYMENT RECORD:

Date:	2014-present
Location:	Boston, MA
Company:	**London Economics International LLC ("LEI")**
Position:	Managing Consultant and Lead Economist

Date:	2003-2014
Location:	Cambridge, MA
Company:	**IHS (formerly Cambridge Energy Research Associates ("CERA"))**

Position:	Senior director, Upstream Strategy Advisory service (2012-2014). • Responsible for the re-vamp of research services and development of new research services focused on the needs of oil and gas exploration and production companies. Defined product architecture, defined deliverables, and generated research, as well as managed the delivery of research. Responsible for marketing plans and focus, conducting presentations to Board of Directors meetings and other C-suite client groups. Keynote speaker at IHS CERA events such as CERAWeek and other industry events and conferences Senior director, North American Gas, Power, and Renewables group (2007-2011). • Responsible for thought leadership, development, and delivery of research for IHS CERA's North American Electric Power Advisory Service and North American Gas and Power Scenarios Service. Led client engagements, as well as wrote and published research. Provided oversight and direction of the launch of a new research service, the IHS CERA Global Steam Coal Advisory Service Director/Senior director, CERAView Institutional Investor Service (2004-2007) • Created, launched and directed IHS CERA's first research service encompassing the oil, gas, and power sectors to serve a targeted client community. Developed a new IHS CERA research publication, *Investors' Energy Monthly*, and served as publication's executive editor. In this role, won the IHS Circle of Excellence Award in 2005 Director, North American Gas Advisory service (2003-2004) • Responsible for rapid re-construction and turnaround of one of CERA's largest research advisory services. Contributed to and helped define the research agenda and was responsible for the editorial content and publication of major research and analytical reports related to gas infrastructure and markets in North America. Advised senior executive clients, including leading discussions of sensitive client-related issues.

Date:	2001-2002
Location:	Boston, MA
Company:	**International Human Resources Development Corporation ("IHRDC")**
Position:	Director, International Gas Program • Developed and implemented management training programs for middle and senior energy company managers, designed interactive presentations and teaching materials, and served as instructor. Taught principles of project development and financial analysis of energy company operations.

Date:	1996-2001
Location:	Cambridge, MA
Company:	**CERA**

Position:	Associate director, Global Oil advisory service (1999-2001) • Authored original research reports, responsible for client presentations and the management, execution, and delivery of consulting projects. Associate, Global Oil advisory service (1996-1998) • Developed and maintained IHS CERA's expertise in exploration and production costs, technology, and financial factors affecting the upstream oil and gas industry.

Date:	1994-1996
Location:	Washington, DC
Company:	**US Department of Energy, Energy Information Administration**
Position:	Economist • Conducted financial analysis of upstream and integrated oil and gas companies; evaluated and implemented conceptual approaches to analysis of energy markets and market incentives and wrote and published original research reports.

Date:	1989-1994
Location:	Vienna, Virginia
Company:	Decision Analysis Corporation of Virginia (DAC)
Position:	Research associate/Associate • Performed economic and econometric analysis, modeling, and forecasting to support the Energy Information Administration energy end-use models. Designed the National Energy Modeling System's Commercial Energy Demand Model; conducted financial analysis of energy companies.

Date:	1988
Location:	Washington DC
Company:	US Department of Energy, Office of Policy, Planning and Analysis
Position:	Intern • Researched waste-to-energy potential in the United States; constructed a database, developed econometric models, analyzed results and produced written reports.

RECENT PROJECT EXPERIENCE:

Date:	July-June 2018
Location:	United States, MISO
Company:	Minnesota Department of Commerce (as subcontractor to Ecology & Environment)
Description:	Marie served as independent market expert assisting the Minnesota Department of Commerce in evaluating the application of Enbridge Energy for a Certificate of Need for its Line 3 oil pipeline expansion project (Docket No. PL-9/CN-14-916, OAH Docket No. 65-2500-32764). Marie's analysis covered global and local trends in refined product demand and crude oil supply, refinery utilization rates and utilization of high-conversion refinery capacity in Petroleum Administration for Defense District ("PADD") 2 and in the local Minnesota region. It involved examination of issues around electric vehicle adoption. Her analysis also required detailed examination of the assumptions and methodology of an oil pipeline linear programming-based model, in order to assess another witness's testimony which relied on the model. Marie provided written testimony; responded to interrogatory requests, provided written surrebuttal, and oral testimony.

Date:	June-December 2017
Location:	United States, MISO
Company:	Mississippi Public Service Commission
Description:	Marie led a management audit of the fuel (gas, coal, and nuclear) and energy procurement activities of a major vertically-integrated utility in MISO. Marie's team assessed fuel and energy contract terms and reviewed the prudency of coal and nuclear fuel procurement and inventory practices. Marie's team also assessed management, organization, controls, strategies, and outcomes for the company's hourly MISO offers. The team investigated the operations of a nuclear power plant, and the financial implications of the utility's power purchase agreement for nuclear power.

Date:	April 2017
Location:	United States and Canada
Company:	Private client
Description:	For a private equity client, Marie led an extensive project reviewing all investable energy sectors in the United States and Canada (except oil and gas exploration and production). The sectors included: electricity generation (natural gas, wind, solar, hydro), AMI, distributed resources, demand response, retail energy, gas LDCs, gas storage, gas pipeline transportation, LNG-related infrastructure, vertically-integrated utilities, electric distribution utilities, and water utilities. LEI assessed the investment potential of each sector for the next five years and proposed a methodology to screen and identify investment opportunities and execute on these opportunities.

Date:	March 2017
Location:	Alberta, Canada

Company:	Private client
Description:	LEI was engaged to provide global perspectives on the detailed mechanisms that make up capacity markets, so that eventual capacity market design in Alberta will be workable and efficient, with minimal unintended consequences. Marie led research and delivered a detailed report on market power mitigation mechanisms and their potential impacts on capacity market performance.

Date:	February 2017
Location:	North America
Company:	Provider of services to vehicle fleet industry
Description:	Developed scenario outlook for electric vehicle ("EV") market penetration in the United States; examined the role of electric utilities (and their emerging EV-related business models) as potential partners versus competitors to the downstream transportation industry; identified activities and strategic positioning of upstream and downstream industry participants; led discussion of implications of "electrification of transportation" for fleet service companies, convenience stores, and other downstream industry participants. Presented material to company's partner advisory board.

Date:	December 2016
Location:	Alberta, Canada
Company:	Private client
Description:	To support Board-level understanding of the implications of potential capacity market designs in Alberta, Marie prepared a detailed review and comparison of capacity markets across international and North American jurisdictions. Report concluded "the devil is in the details" of capacity market design. Market design details with potentially large impacts on the client were resource eligibility definitions, price setting mechanism, demand curve design, performance requirements, and market power mitigation rules.

Date:	September 2016
Location:	Northeast United States
Company:	Private client
Description:	For a client performing due diligence related to a potential investment in business-to-business behind-the-meter solar in the Northeast United States, Marie led a project examining US federal and state incentives for solar adoption, and assessing business models used for targeting commercial, institutional, and industrial sectors. For each business model, LEI assessed the competitive environment—who is operating in the sector, what is their go-to-market strategy, and in general how these models have been performing. Marie's team also provided a 10-year outlook for solar renewable energy credits ("SRECs") for certain jurisdictions. Finally, LEI developed key questions the client should ask as part of its evaluation of potential transactions in the behind-the-meter solar sector.

Date:	October/November 2016
Location:	California, Kansas
Company:	Law firm

Description:	Marie prepared an expert report in support of litigation in Case 15CV-04225 in the District Court of Johnson County, Kansas. LEI was retained by counsel to examine the value of the green attributes of landfill gas ("LFG") produced by a project in Kansas City and sold under long-term contract to the Sacramento Municipal Utility District ("SMUD"). Marie's report demonstrated several flaws in the opposing counsel's expert's methodology. Marie proposed an alternative, more appropriate methodology for valuing the green attributes of LFG, based on market fundamentals driven by the California RPS requirements.

Date:	August-October 2016
Location:	Maine
Company:	Maine Public Utilities Commission
Description:	Marie led an engagement to estimate the macroeconomic impact of biomass generation within the state of Maine (Maine PUC Docket No. 2016-00084). This included direct, indirect, and induced impacts on: permanent direct jobs, payments to municipalities, payments for fuel harvested in the State, payments for in-state resource access, in-state purchases of goods and services, and construction-related jobs and purchases. Marie used the macroeconomic model known as IMPLAN to capture the economic impacts on industries including logging, sawmills, and other forestry-related industries and well as on state and local taxes.

Date:	May 2016
Location:	ERCOT, Texas
Company:	Private client
Description:	Marie conducted a case study assessing the current ancillary services ("CAS") market in ERCOT, outlining the structure of ERCOT's proposed Future Ancillary Services Nodal Protocol Revision Request ("FAS-NPRR"), and examining the implications of ERCOT's experience so far for the Alberta electricity market. This involved examining the drivers of ancillary services supply and demand in ERCOT, the price-setting mechanisms and procurement processes, and the technical requirements of the various ancillary services in ERCOT. Findings included the following: While it was widely expected that the addition of large amounts of wind (and other non-synchronous generation) on the ERCOT system would significantly increase the need for ancillary services, by 2015, ERCOT's procurement of CAS products had not increased compared with 2011. However, the need for synchronous inertial response ("SIR") which is not part of CAS did increase somewhat over the time period, though ERCOT did not include SIR in its FAS-NPRR.

Date:	April/May 2016
Location:	ERCOT/Texas
Company:	Renewable power investor
Description:	LEI was hired to perform due diligence for an investor interested in wind assets in ERCOT. Marie examined the political, legislative, and economic drivers of ERCOT's Competitive Renewable Energy Zones ("CREZ") and provided an assessment of state-level support for further expansion of CREZ transmission lines. She also provided assessment of and outlook for ERCOT's and the Public Utility Commission of Texas's views of the "system cost" of wind (the potential increased need for ancillary services and firm capacity on the system).

Date:	June 2014-April 2016
Location:	Maine
Company:	Maine Public Utilities Commission
Description:	Marie served as project manager, independent market expert, and expert witness for the Maine Public Utilities Commission, in the evaluation of the costs and benefits of alternatives for expansion of natural gas supply into Maine pursuant to the Maine Energy Cost Reduction Act (MPUC Docket #2015-00071). Marie reviewed and evaluated proposals for firm natural gas transportation service by pipeline developers. These evaluations included LEI's review of commercial terms include in the pipeline Precedent Agreements that underpin capacity expansion projects; review of contract provisions for Firm Transportation Agreements and Negotiated Rate Agreements; and evaluation of the status of the FERC and state-level permitting process for each pipeline proposal. Marie provided expertise in upstream natural gas (exploration and production), midstream natural gas (interstate pipelines) and global energy markets including oil and LNG markets, to provide a solid grounding for LEI's long-term outlook for New England natural gas prices. Marie directed the natural gas network modeling (using GPCM, an industry-standard network model of the North American natural gas system) and power simulation modeling (using LEI's proprietary POOLMod model) to arrive at a quantitative cost-benefit analysis of proposals. She authored reports provided to the Commission; responded to discovery from other parties; prepared discovery questions and cross-examined witnesses; reviewed testimony by other parties and provided assessments of the issues presented; and she served as an expert witness in the proceedings.

Date:	November-December 2015
Location:	US Northeast
Company:	Renewable power developer
Description:	LEI was hired by a wind developer to provide a quantitative assessment, based on an economic dispatch model, of congestion/curtailment risk for a wind asset in Maine. LEI used its proprietary dispatch model, PoolMod, to provide an outlook from 2016 through 2020 of hourly LMPs, as well as the components of LMP (energy, losses, and congestion). We incorporated information from the interconnection impact study to examine system limits for the plants in question. LEI also provided an assessment of risk of outages based on NERC outage data for NPCC. Marie led the project

Date:	October-November 2015
Location:	ERCOT, Texas
Company:	Private equity company
Description:	LEI was hired to forecast the potential energy revenues of two wind farms in Texas, using its proprietary dispatch model, PoolMod. Marie led the project, and also examined the implications of the PPA related to the two wind farms.

Date:	July 2015
Location:	North America/United Kingdom
Company:	UK Department of Energy and Climate Change
Description:	Marie participated in a review of auction design for the UK DECC. The UK market

	regulator was interested in whether US power markets evaluate generation bids based on criteria other than the price bid, specifically, if the length of contract had a role in the auctions. LEI reviewed capacity market rules for PJM, ISO-New England and the New York ISO. Marie examined whether and for how long a "lock-in" option for the first year capacity price is offered to new generation assets bidding into the auctions. She also reviewed international spectrum auctions, North American gas transmission open season rules, and international auctions for toll roads to examine whether and how duration or length of contract is incorporated into bidding.

Date:	May 2015
Location:	Connecticut; Virgina
Company:	Private equity company
Description:	Marie evaluated contracts for firm gas transportation capacity for gas-fired plants in Virginia and Connecticut.

Date:	April 2015
Location:	Connecticut; New Jersey
Company:	Private equity company
Description:	LEI was retained to forecast delivered gas prices in New England (Connecticut) and PJM (New Jersey) and locational marginal prices as well as retail electricity prices in Connecticut. Marie led the gas market analysis.

Date:	August 2014 - January 2015
Location:	North America
Company:	Private client
Description:	LEI was engaged to support an energy company's Regulatory Group in its administering of the company's compliance program. The purpose of the engagement was to ensure that client's transactional and business groups were made aware of market rules and regulatory risks. This involved creating and delivering a monthly report covering developments by regional market and traded products which included: energy, capacity, long-term transmission service, FTR auctions, ancillary services, diesel oil, PRB coal, natural gas commodity, transmission, and storage, RECS, and CO_2. Marie served as project manager and executive editor of the monthly report and monthly conference call, and provided the research and insight on US gas, oil, and coal markets, and FERC activities.

Date:	October 2014
Location:	New England
Company:	Private equity company
Description:	To support potential acquisition of hydropower assets, Marie provided analysis of ISO-New England's Locational Forward Reserves Market ("LFRM").

Date:	April-June 2014
Location:	US Midwest
Company:	Private equity company
Description:	LEI was engaged by an investment firm in association with due diligence related to a

	district cooling system in the Midwest. Marie reviewed contracts and developed a model for projecting revenues and gross margins for the asset. Marie provided insight by identifying the potential for lower customer contract prices at renewal (in contrast to the seller's assumptions) and other areas of revenue risk.

Date:	June 2014
Location:	North America
Company:	Law firm
Description:	LEI was engaged by a law firm on behalf of a Canadian energy company to provide market advisory for an investigation related to the timing of outage scheduling under PPAs. Marie provided research and expertise covering FERC practices related to monitoring, enforcement, and definition and prosecution of alleged market manipulation.

Date:	April-May 2014
Location:	Nova Scotia
Company:	Government of Nova Scotia
Description:	LEI was retained by the Nova Scotia Department of Energy to perform analysis of the organization and governance of electricity systems both cross-jurisdictionally and within the province of Nova Scotia. Marie provided a detailed overview of the Nova Scotia gas and power sectors, including governing institutions, the legal and regulatory framework, recent developments and challenges, and SWOT analysis.

PUBLICATIONS:

Technical/Academic

"New England Oil, Gas, and Power Markets" guest lecture, University of Massachusetts, Boston, MA, October 2005, with Lawrence Makovich.

"The Disappearing Middle Class: Economies of Scale in Exploration and Development," presented at the International Association for Energy Economics, 26th annual conference, Aberdeen, June 2002.

"The Key Role of Technology in Reducing Offshore Finding and Development Costs," *Fundamentals of the Global Offshore Industry,* The Petroleum Economist Ltd., London, September 2001.

"The US Oil and Gas Supply Situation: How Did We Get Here?" guest lecture, Clark University, Worcester, MA, October 2000.

"The Technology Revolution and Upstream Costs," *The Leading Edge* (Journal of the Society of Exploration Geophysicists), June 2000.

Review of *Exploration, Development, and Production—Texas Oil and Gas 1970-1995,* for the *Journal of Economic Literature,* 1999.

"Resource Depletion and Technical Change: Effects on US Crude Oil Finding Costs from 1977 to 1994," *The Energy Journal,* 1997.

"Inter-jurisdictional Competition, Resource Rents, Tax Exporting, and Oil and Gas Severance Taxes," *The Journal of Energy Finance and Development,* 1997, with Kevin Forbes.

"Fiscal Illusion and Fiscal Sclerosis: The Case of Oil and Gas Severance Taxes," presented at the US Association for Energy Economics/International Association for Energy Economics conference, Boston, MA October 1996.

"Prices, Depletion, and Technical Change 1977-1990: The Declining Cost of Crude Oil," presented at the Allied Social Science Association Annual Meeting, American Economic Association/International Association for Energy Economics session, San Francisco, CA, January 1996.

"Technical Change and Scale Economies in US Onshore Oil and Gas Exploration 1977-1990," presented at the Southern Economic Association meeting, New Orleans, LA, November 1993.

US Department of Energy

State Energy Severance Taxes, DOE/EIA-TR/0599, Washington, DC, 1995.

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SPEAKING ENGAGEMENTS:

News Media

"Upstream oil costs on the rise" (excerpts from *Another Decade of Rising Upstream Costs?* IHS CERA Decision Brief 2006), *The Wall Street Journal Morning Brief,* June 28, 2006.

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Chairman, Strategy Session *Financing the Power Future*, March 10, 2011
Chairman, Expert Dialog *North American Gas and Power Scenarios Wildcards*, March 9, 2011
Chairman, Strategy Session *Financing a North American Power Sector in Transition*, March 12, 2010
Panelist, CERA Insights *Global Power Outlook*, March 12, 2010
Chairman, Strategy Session *US Electric Power Transmission: The Battle of the Jurisdictions*, March 11, 2010
Chairman, Critical Issue Forum, *Financing the Power Sector in a Turbulent Economy*, February 12, 2009
Chairman, Critical Issue Forum *Power Sector Investment: Global Capital, Local Strategies* February 15, 2008
Panelist, Leadership Circle *Global Power Outlook* February 14, 2008
Chairman, Critical Issue Forum *Rising Costs and the Outlook for North American Gas*, February 14, 2007
Host and Commentator, *Reception for Institutional Investors* February 13, 2007
Panelist, Critical Issue Forum *Oil Sector Finance: The Cliff behind the Clouds?* February 13, 2007
Host and Commentator, *Reception for Institutional Investors* February 7, 2006
Chairman, Critical Issue Forum *Financing the Oil Future: A Three-Trillion Dollar Dilemma* February 7, 2006
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