THE ECONOMIC IMPACT OF CRUDE OIL TRANSPORTATION IN THE GREAT LAKES-ST. LAWRENCE REGION: A PRELIMINARY STUDY

Prepared for the Great Lakes Commission

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Authors' Bios

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Peter Gunther is Senior Research Fellow in the Connecticut Center for Economic Analysis (CCEA), School of Business, at the University of Connecticut and President of Smith Gunther Associates Ltd. At CCEA he and its Director Fred Carstensen have carried out about 70 REMI and other model simulated impacts of major projects in Connecticut. From 2004 to the signing of the Peace Agreement, he was also the Resource Person for the International Government Authority on Development's Wealth Sharing Table on Sudanese Peace Negotiations. Energy projects on which he has estimated impacts range from those in Sudan to the Dome's work on oil in the high Arctic, various pipeline ventures, and electricity exports from Canada to the United States.

Eva Lema is as a Postdoctoral Research Fellow in the Department of Geography at Central Michigan University. Her research area is transportation and environmental economics, and the regional development of coastal areas. While overseas, Eva served as General Secretariat advisor at the Greek Ministry of Shipping and as a research associate at the University of Piraeus. She holds a Bachelor in Maritime Studies and a M.Sc. in Shipping Economics from the University of Piraeus, Greece and a Ph.D. from the Department of Economics and Regional Development at the Panteion University, Greece.

Executive Summary

- ✓ A series of datasets was created, collecting regional-level socioeconomic, industrial, demand, ecological, and fiscal data.
- ✓ Major differences exist in the data collection process between Canada and the United States, including differences in defining crude oil movements, NAICS precision level, and Census designated areas.
- ✓ Using Freight Analysis Framework areas, the GLR has mobilized 1.176bn barrels of crude oil in 2015, valued at about $64.7bn at $55/barrel.
- ✓ Crude oil transportation in the GLR occurs primarily via pipeline and rail, in line with nation-wide patterns of both Canada and the USA.
- ✓ Rail-based transportation has consistently increased, almost tripling between 2012 and 2015. In Canada, rail-based transportation is expected to expand further by 2024.
- ✓ In 2016, GLR watershed hosts 676 establishments operating within crude-oil transportation related industries, employing 26,944 workers, and generating $12.6bn in sales based on firm-sourced data (direct sales).
- ✓ Considering direct, induced, and indirect jobs, selected NAICS industries (within which crude oil transportation occurs) account for 370,093 jobs and $2.6bn in taxes within the GLR-USA (counties), mainly through refining processes.
- ✓ In the GLR-Canada (divisions), crude oil transportation industries account for CND $14.1bn in wages and 311,278 jobs in Canada (NAICS 4 level), mainly in trucking, rail, and refining processes.
- ✓ The U.S. side and the Canadian side of the GLR watershed differ significantly in the level of specialization, with the latter favouring employment in the railroad sector.
- ✓ From an employment perspective, the GLR states (U.S.) do not specialize in pipeline-related activities, favouring other modes. However, the region's supply chain spends slightly more on in-region products than on imports.
- ✓ Canadian divisions within the GLR tend to spend more on in-region purchases for pipeline transportation, mainly through the local provision of advanced services and electricity consumption for operating the pipelines.
- ✓ From our counterfactual experiment, transferring most of crude oil transportation from pipelines to rail would have a minor negative direct economic impact within the GLR-USA (counties), and a larger, positive impact on the Canadian divisions.
- ✓ In the United States, these 'transfers' would result in a loss of 10 jobs, $13.1MM in lost industry earnings, and no overall changes in the tax receipt.
- ✓ In Canada, this simulation generated an additional 6,585 jobs, and an increase of CND $327MM in wages, mainly because of the higher multipliers in the Canadian railway sector.
- ✓ Additional research is needed to model the effects of social and ecological costs once lives lost from additional accidents at level railway crossings, emissions, and the cost of present and future spills are included. These costs can dramatically change the overall economic impact of the entire sector in the region.
- ✓ In terms of emissions, transporting crude oil across the region generates the equivalent of $146MM/year in social costs.
- ✓ In the period 2007-2015, rail-based crude oil transportation in the GLR watershed has provoked about $2.5 billion in environmental and social costs, mainly because of higher injury related and loss-of-lives related costs.
- ✓ Between 2009 and 2015 (2012-2015 for USA), the social and ecological costs of spills from pipelines amounted to $83 million. If the Kalamazoo River accident is included, this amount rises to $1.3bn for the period 2010-2015.
- ✓ Rail-based transportation tends to offer an ecologically safer mode than pipelines, but has higher risks associated with lost lives.

Contents

1. Introduction and Objectives

Since 2007, the production of crude oil (henceforth 'oil') in both Canada and the United States of America has experienced a steady increase, despite macroeconomic shocks (e.g. the 2007-2009 recession, see NBER, 2010). Whether driven by increased demand or changes in the supply structure (Mohaddes and Raissi, 2016), the increase of the regional (i.e. North America) output of oil has been accompanied by an expansion of crude oil trade from Canada to the United States (CANSIM, 2016), which has increased the demand for land- and mixed-based modes of transportation across the continent. Because of its geographic position relative to the US and Canadian oil fields and its large population, the Great Lakes-St. Lawrence Seaway Region (GLR) represents both an important end-market, and a strategic location for Canadian exports to the Southern-East and Eastern USA (DAG and DEQ, 2015). In terms of employment and earnings, the sectors considered in this analysis as relevant to the transportation of crude oil have grown by 15.3% in the period 2001-2016, almost three times more than the national average in the US-side of the GLR (GLR-USA). Furthermore, the region has 13% more jobs in these sectors (in the USA) than the rest of the nation. On the Canadian side of the GLR (GLR-Canada), the sectors of interest for crude oil employ on average 7% fewer people than the rest of the country, mainly due to the lower incidence of the oil industry on the area's economy compared to the resource-rich Western provinces. However, since 2001 GLR-Canada employment in these sectors has grown by 1.9%, versus a national decline of about 7.7%.

This report presents an introductory analysis to the economic contribution of crude oil transportation (oil) across the GLR, while presenting currently available data. The analysis relies partly on publicly available sources, and partly on proprietary datasets. The aim of these datasets is to create a harmonized data source between US states and Canadian provinces, for performing a region-wide, dynamic economic impact analysis of the oil transportation across the region, with the inclusion of amenity costs/benefits. The term 'economic impact' is multi-faceted, focusing on employment impacts to contributions to Real Gross Domestic Product (GDP, where 'domestic' refer to the region/scale of analysis), to linkages between social and ecological input-outputs. Being envisioned as a seminal research background for further analysis, this report categorizes the data and orders them following the comprehensive broad categories of the impacts in the widely used Regional Economic Modelling Inc. (REMI) model, and listed above. This structure and broad inclusion of multi-faceted impact metrics allows future users of the data to select narrower sections, or/and to undertake comprehensive regional analyses of the impacts of crude oil transport across the GLR.

As discussed below in depth, the report delineates the GLR watershed boundaries as the extent of its area, a choice dictated by the necessity of linking environmental, logistics, and economic impacts to the area of major concern for the GLR. However, due to data limitation, certain sections of the report will consider data for the entire extent of the GLR based on political boundaries of its states/provinces, or for sub-regions of the GLR.

This report is organized as follows: In ***section 2*** we review previous works quantifying the economic impacts of sectors relevant to crude oil transportation; in ***section 3*** we present the study area and the sectors considered in this study; in ***section 4*** we present the sources for preparing the dataset components, along with the results for initial analyses on the economic impacts; in ***section 5*** we present the results of a counterfactual analysis of two specific sectors, pipeline and rail-based crude transportation from readily available data; finally, in ***section 6*** we present the next steps to be undertaken.

1.1 Transportation of crude oil and the economy: what we know so far.

The contribution that oil transportation provides to the economies of Canada and the USA has been studied recently by several institutions, mainly using expenditure data both capital expenses, CAPEX, and operational and maintenance expenses, OPEX, at times as inputs to simple Input-Output (I/O) models. This has been particularly true for two sets of modes of transportation: railroads, whose studies have mainly focused on the safety issues and environmental benefits, and pipelines, mainly focusing on their safety and contribution to regional and national economies. Table 1 offers an overview of the most recent studies focusing on either Canada and/or the United States, indicating the mode and topic focus. Few of these studies have been peer-reviewed, and thus they should be taken with a certain caution.

Table 1: Summary of selected works on crude oil transportation economic impact

Work	Area	Mode	Year	Modelling Strategy
Angevine	Canada	Pipeline	2013	I/O model
Carlson et al.	Ontario	Rail	2015	I/O and trade flows
Deloitte	Canada	Pipeline	2013	I/O model
Frittelli et al.	USA	Rail	2014	Technical and Policy analysis
I.H.S.	USA	All	2013	I/O and Questor
Kleinhenz	Ohio	All	2011	REMI model
O'Neill et al.	USA	Pipeline	2016	I/O model
Skinner and Sweeney	Canada	Pipeline	2012	Technical and Policy analysis
Wade et al.	USA/Canada	Pipeline	2012	REMI model

Most of these studies used Input-Output (I/O) models to quantify economic impacts of various kinds. However, these models may incur issues and shortcomings, which we define later in the report (see Carlson et al., 2015). Despite these limitations, the models may still offer comprehensive overviews of selected impacts, especially when focusing on benefits, rather than costs (e.g. environmental costs, loss of lives, etc.). Exceptions include dynamic REMI-based models, which, at the state level, overreach GLR boundaries, and therefore are of only partial interest to the GLR and the crude oil transportation industry.

One of the most comprehensive, US-wide studies recently completed by O'Neil et al (2016) offers a quantification of the economic impacts[1] of new and existing oil pipelines, mainly using CAPEX/OPEX data from IHS Questor® software database. In their analysis, the overall contribution to the US economy is substantial, with 4,410 jobs created in 2015 through OPEX on existing crude oil pipelines, and 55,136 jobs from CAPEX in new pipelines, mainly in construction and manufacturing jobs. Although only performed with an I/O model, the analysis provides the estimates in Table 2.

[1] Employment, income, output and GDP.

Table 2: *Estimate of economic outputs per mile of new and existing CAPEX/OPEX in crude oil pipelines in the US (O'Neill et al., 2016)*[2]

	New pipelines[1]		Existing pipelines	
	Total	Direct	Total	Direct
Jobs/mile (CAPEX)	24.1	8.1	N/A	N/A
Contribution to GDP MM$/mile (CAPEX)	2.288	0.682	N/A	N/A
Jobs/mile (OPEX)	1.9	0.3	0.43	0.07
Contribution to GDP MM$/mile (OPEX)	0.3	0.1	0.06	0.03
[1] **Note:** *OPEX for new pipelines is for first year only.*				

Assuming that the GLR possesses an ability to provide for both labor and capital similar to the rest of the US economy (i.e. assuming that the region has the skills for maintaining the pipelines), Table 2 suggests a potential direct contribution of 165 jobs for OPEX of existing pipelines in the USA-Canadian GLR watershed, a direct additional contribution to the GDP of the watershed region of $71 million/year for pipelines older than one year.[3] These numbers are somewhat similar to those found in Canada by AEC (2013), whose simple input-output (I/O) model estimated a direct impact of 33 and 46 jobs sustained every year in Ontario and Quebec respectively from operating crude oil pipelines. The authors did not estimate the net contribution to GDP, but the GDP output from these operations is in line with those found in the USA, once adjusted per mile, although Quebec displays higher numbers per-mile, possibly because of lower economies of scale. Because the analysis was conducted at a national level, we do not focus as much on induced and indirect effects at this juncture.

Broader reports and analyses have focused on either the transportation of crude oil through different modes, or focusing on the social and environmental risks associated with transporting crude oil. Within the first group of studies, we find the comprehensive analysis developed by IHS (2013) on the economic impacts of investing in hydrocarbon infrastructures, including crude oil. The analysis is particularly relevant as it offers an overview of the economic impact differentials across multiple modes of transportation for crude oil (and other hydrocarbons). Overall, impacts from rail transportation and other modes generate lower economic benefits in terms of contribution to GDP and employment (IHS,

[2] In Table 2 we show only the aggregate total and the direct impacts: this is because indirect (i.e. occurring in related sectors), and induced impacts (i.e. generated throughout the economy) are more problematic to interpret, especially because the model used by O'Neill et al. is not dynamic.
[3] Assuming 2,351 miles of pipeline in the watershed, as per EIA classification.

2013). For marine transportation (which is excluded for most of the Midwestern region), the effects are larger on a per-dollar basis when considering output and employment, although the fiscal impacts are more limited (due to the nature of the mode).

Pipelines seem to have the lowest fiscal contribution per-dollar spent, possibly due to economies of scale, whilst both rail and pipelines share similar per-dollar contributions when it comes to employment and output. Transporting crude oil is not a risk-free activity, and several studies have highlighted both the short- and the long-term economic effects on regions affected by accidents/spills. Major attention has been given to oceanic marine accidents such as the Exxon Valdez accident of 1989 in Alaska which has had severe ecological, social and economic costs for the affected region (Palinkas et al., 1993; Cohen, 1995). This focus is partly justified by the high sensitivity of coastal regions, as in most of the GLR, to pollutants such as crude oil which can severely disrupt the delivery of ecosystem services upon which other sectors rely heavily (Gundlach and Hayes, 1978). For instance, Skinner and Sweeney (2012) have recently argued that the oil spills can severely reduce employment in unrelated, yet affected sectors, such as high-productive agriculture and tourism, as in the case of the Kalamazoo River spill of 2010 (Skinner and Sweeney, 2012). Minor accidents, such as tiny leaks, or major rail-related disasters have also occurred in both Canada and the USA, and, as later reported, within the GLR. The 'cost-side' of transporting crude oil should be included in order to provide a comprehensive understanding of the economic impacts of this activity on the regional economies. Finally, at a regional level, the GLC has recently published an analysis of issues and trends related to the transport of crude oil in the region (GLC, 2015). The major findings in the report were related to the need for further investigation into how to accommodate the changing supply landscape (e.g. because of the aging of pipelines and the increase in capacity demand), the overall need in infrastructure investments, and the need for improved regulatory and policy measures to reduce uncertainty and increase the efficiency of the overall transportation system for crude oil in the region (Skinner and Sweeney, 2012; IHS, 2013; GLC, 2015).

The existing differences in estimation at national, and macro-regional levels, the lack of regional analyses, as well as the need to account for costs that are usually borne by society in the form of ecological and long-standing damages, provide a need to gather sufficient data and to draw a strategy for delivering a comprehensive analysis of the economic impacts of crude oil transportation across the GLR.

Area Geography and Relevant Sectors: the 'where' of the analysis.

The area covered by this report differs from the political boundaries of the GLR. In agreement with the GLC, and to reflect the issues/impacts related to the movement of crude oil across the Great Lakes and St. Lawrence River, the study has been selected as the overall watershed of the GLR (figure 1), plus the statistical metropolitan area (MSA) of Chicago. The latter will include counties technically not within the watershed. However, because of the *megacities effect* (von Goslow et al., 2013),[4] and its role as both a refinery-hub and a major market for crude oil, a comprehensive data-gathering (or analytical) effort demands its inclusion.

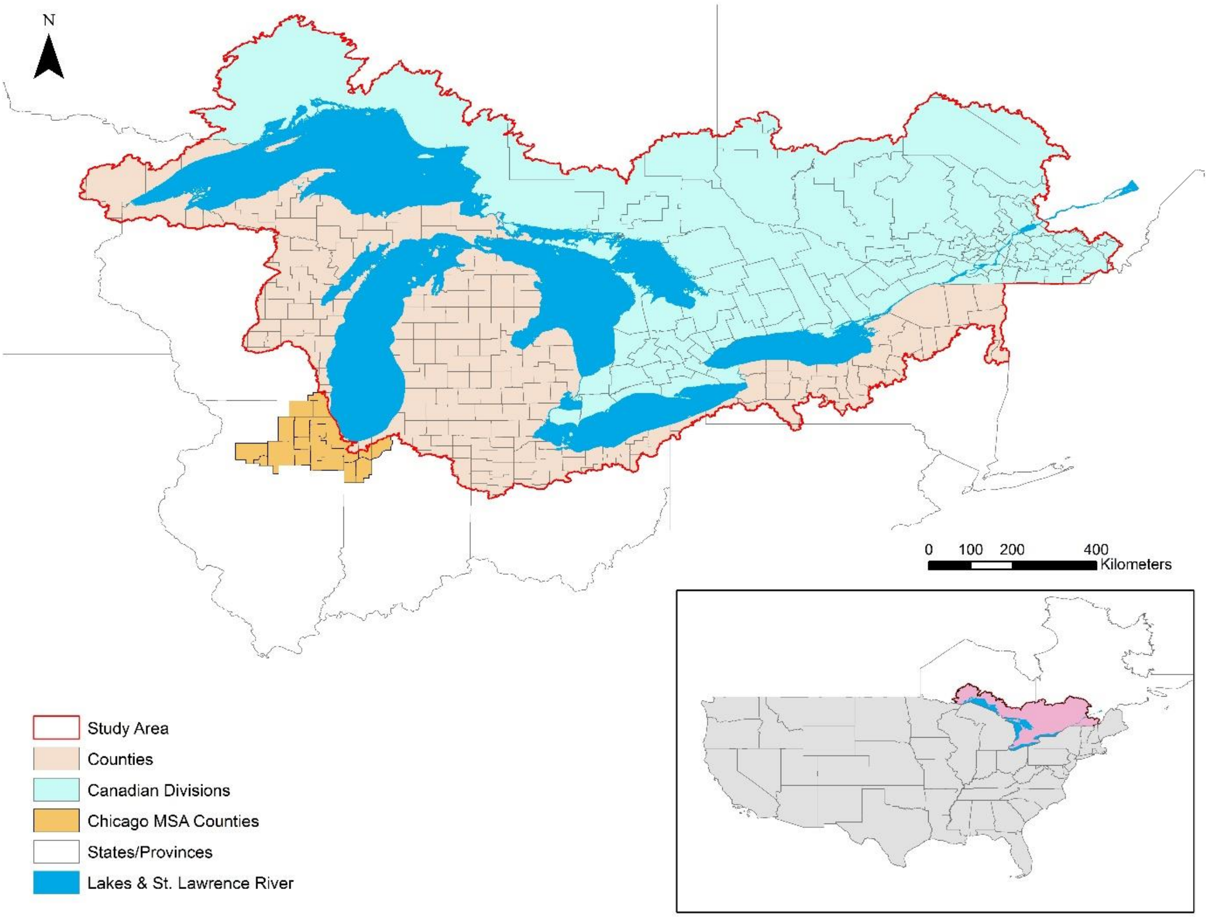

Figure 1. Study Area: Great Lakes-St. Lawrence Seaway basin(s).

Overall, the study covers 223 U.S. counties (plus 17 separate counties for Chicago), and 111 Canadian (Census) Divisions, and 3,491 U.S. towns. The advantage of this definition

[4] Megacities are seen as great socio-economic drivers, which, however, influence the ecology of an area larger than their own, due to demand for natural resources in various forms (e.g. food), and their impacts in terms of pollutants (e.g. emissions).

is that it links the transportation of crude oil directly to the underlying ecosystem, weighing the impacts across the states/provinces per their reliance on GLR-related crude oil delivery, rather than over-weighing their impact based on the overall transport/demand of crude oil, for instance from Atlantic-based deliveries. For the purpose of this report, data are collected at the U.S. Census town level (county subdivision) when possible. Point and county-level data are also introduced when appropriate.

2. Data Sources and Results per RED-component

The overall structure of the datasets collected and built follows five categories, as shown in Figure 2. An overview of the datasets compiled is provided in Appendix A.[5]

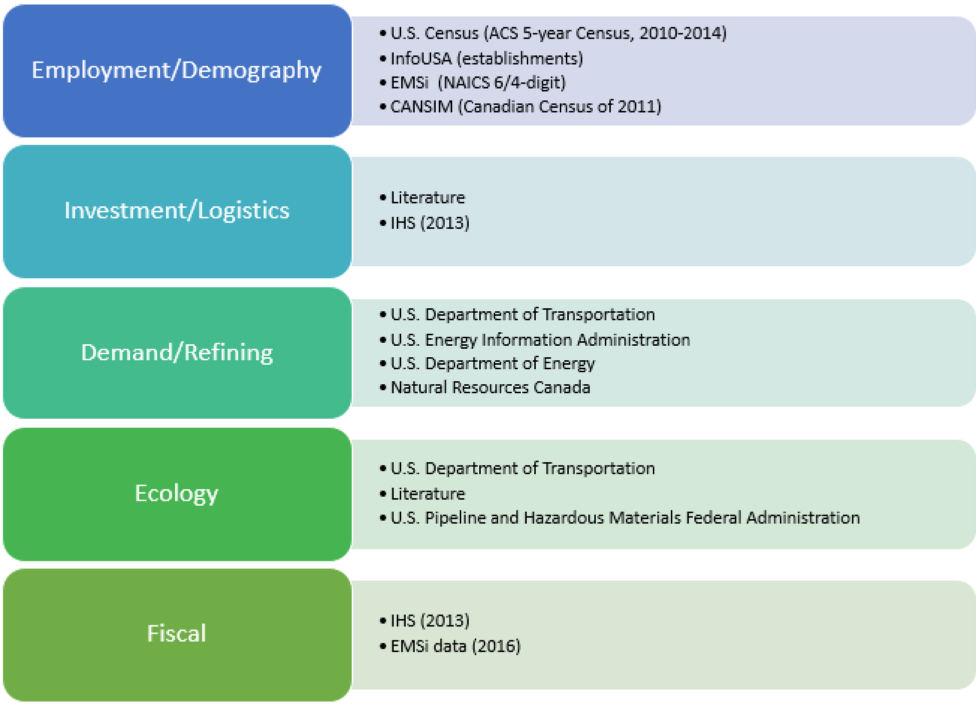

Figure 2. Dataset components and major sources.

Some of the components, or parts of them, rely on data from other components (e.g. the ecological impact relies on calculations based on data from the *Demand* component). Nevertheless, the structure implemented here provides an outline for users interested in analyzing different *foci* of the economic impacts of crude oil transportation. Additionally, and considering future work to be performed with widely employed economic impacts models

[5] Attached as a separate document for the purposes of clarity.

(e.g. REMI and/or IMPLAN), the structure eases the extrapolation of useful information to model the inputs for the analysis.

2.1 Employment/Demography

Employment/Demography data have been collected from three sources - Table 3.

Table3. Socio-demographic and economic data sources.

Data Name	Source	Developer	Level	Coverage
ACS	The U.S. Census American Community Survey 2011-2015 5-year average (ACS, 2014)	U.S. Census	Town[6]	USA
CANSIM	The Canadian 2011 Census Data (CANSIM, 2011)	Statistics Canada	Census Division and Subdivision	Canada
InfoUSA	Establishment-level data from InfoUSA (2016)	InfoUSA/BLS	Establishment	Canada/USA

The data from the ACS and CANSIM datasets constitute the core of the database presented here. Their structure is used throughout the database to connect towns and statistical divisions to other types of data such as numbers of establishments. Because of differences in conceptualizing statistical areas between the United States and Canada, we will present findings in parallel when this improves clarity. The InfoUSA data are more consistent, as these are collected at establishment-level; however, differences still are present in terms of information recorded, such as the level of technical specialization of an establishment or its size characterization (e.g. 'small-sized business'), with the US dataset being richer. In terms of establishments analyzed, we focused on firms belonging to the following North American Industry Classification System (NAICS) codes:

- 486110: Pipeline Transportation of Crude Oil
- 424710: Petroleum Bulk Stations and Terminals
- 324110: Petroleum Refineries
- 482111: Long-Haul Railroads
- 482112: Short Line Railroads
- 483113: Coastal and Great Lakes Freight Transportation
- 484121: General Freight Trucking, Long-Distance, Truckload.

[6] The U.S. Census label for this extent is 'County Subdivision' to reflect differences in terminology and jurisdictional powers across U.S. states. For clarity's sake, we will refer to them as 'towns' in the present report.

The use of 6-digit NAICS codes gives us a higher level of detail compared to previous studies, allowing us to focus on the direct impacts of crude oil transportation. This cautious approach is the most appropriate given the lack of a regional partial or general equilibrium model capability. The choice of the above codes has followed previous literature, particularly O'Neill et al. (2016), and current sectors operating directly with oil transportation.

2.1.1 Analyzing the data: the 'where' and 'how much' of the crude oil transportation business

The US GLR[7] has a median household income of 2014USD $51,371, slightly below the national value of USD $51,759, while Canadian Divisions within the GLR had a median after-tax household income of 2011CND $56,765, or about 5% above the national average. Figures 3a and 3b show both the location of these firms (establishments) and the income quartile at town/division level for the GLR.[8] Within the region, oil-related activities tend to concentrate either in larger metropolitan areas (e.g. Greater Toronto Area, Chicago, Montreal), or in near border-crossing points (e.g. Niagara Falls/Buffalo, St. Claire River and Sault Ste. Marie - see Figures 3a and 3b), with relatively higher income within the region. In the Chicago area, these establishments are located mainly near the central business district, which, unsurprisingly, also records lower incomes than the remainder of the area, as more-highly paid employees tend to commute from nearby towns.

[7] When not specified, GLR assumes the watershed extent only.

[8] The use of quintiles simplifies the comparison between towns/divisions from the same region, 'ranking' groups of towns/divisions not in absolute terms, but in relation to the median income of the region itself. Quintile values differ between Canada and the USA.

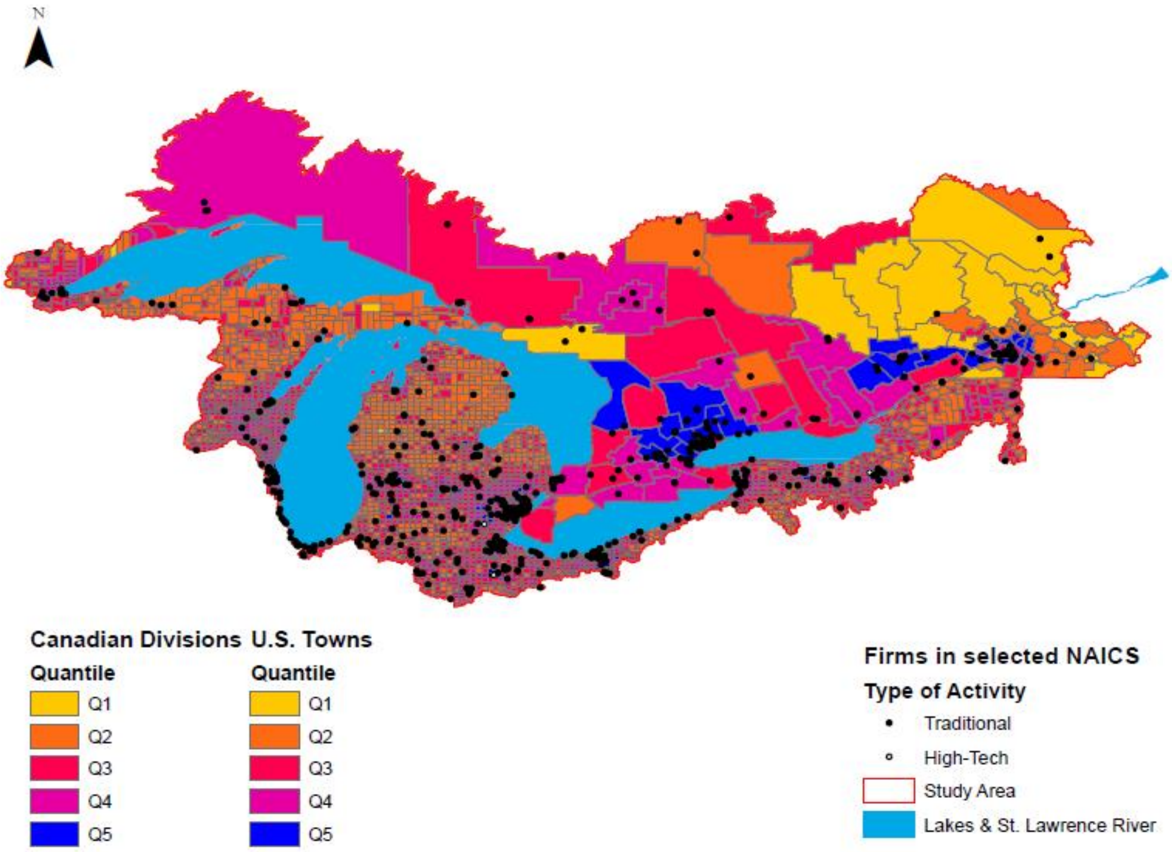

Figure 3a. Median household income and distribution of crude oil transportation-related firms in the GLR.

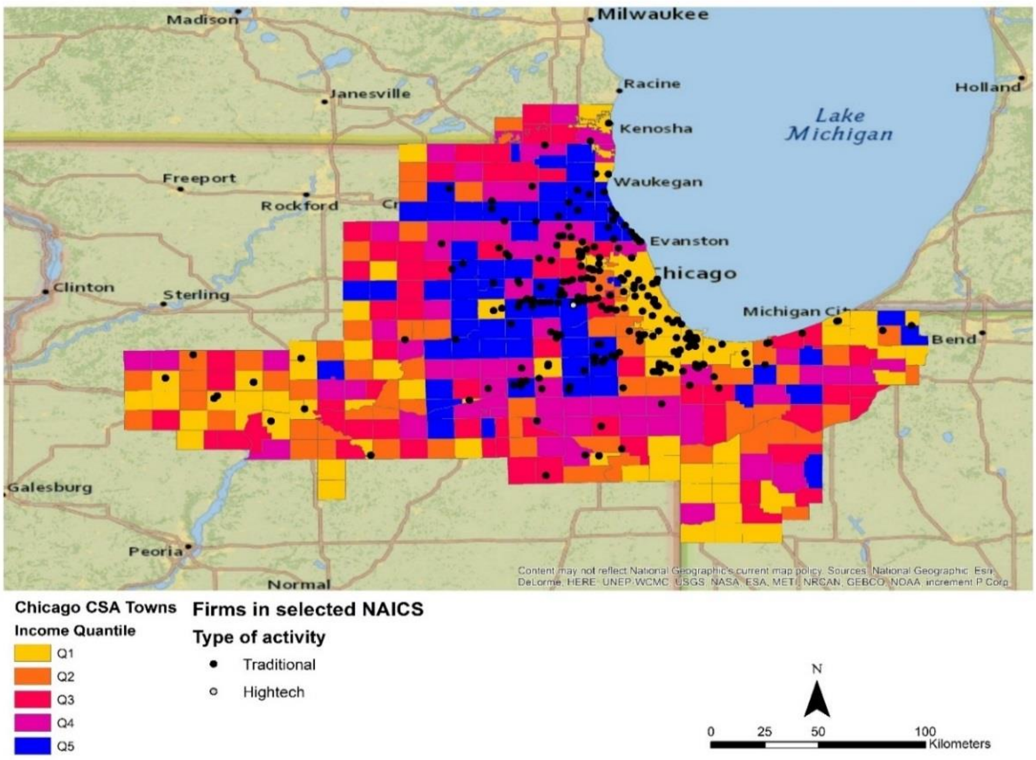

Figure 3b. Median household income and distribution of crude oil transportation-related firms in the Chicago CSA

Overall, the GLR hosts 676 establishments (496 in the USA, 180 in Canada) operating in the eight NAICS sectors identified as directly relevant to crude oil transportation, with a total employment payroll of $26,944 ($15,145 in USA, $11,799 in Canada), and recorded revenues of $19,309,460,920[9] (2015USD $14,463,118,000 in USA, and 2015USD $4,846,342,920in Canada).[10] The Chicago metropolitan area hosts 245 firms, employing 6,616 people, and recorded revenues of USD $14,181,472,000 in 2015. Within the region, only a handful of companies is defined as 'high-tech': this is unsurprising given the traditional nature of crude oil transportation, and should not be taken as necessarily a regional handicap compared to other areas of North America. Furthermore, not all jobs within any of NAICS sectors depend on crude oil transportation: for example, Coastal and Great Lakes Freight Transportation (483113) includes firms moving other goods, such as containers or agricultural products. Further, the establishments recorded by the InfoUSA database only identify those establishments operating at a specific location. For example, if barges in the GLR are recorded to companies in another state outside of the region (perhaps because of more favorable taxation), these will not be considered in the dataset. Table 4 shows the employment results by NAICS and sub-regions (USA, Canada, and Chicago metro). Chicago results, which contain some of the establishments within the USA GLR, demonstrate the 'weight' of this area within the region, mainly as a major destination and refinement market for crude oil. The employment values associated with companies operating within the NAICS associated to crude oil pipelines are quite in line with the value of 165 jobs supported by current OPEX, based on O'Neill et al (2016).

[9] 25 establishments, or 3.7% of the total, did not report their revenues and employment sizes.
[10] Canadian sales total 2016CND $6,376,767,000. Exchange rate to USD assumed to be $1USD = $1.317CND, or $1CND =$0.76USD, based on annual average between February 2016 and January 2017.

Table 4. InfoUSA data on crude oil-related firms in the GLR as of 2016.

	USA GLR	CANADA GLR	CHICAGO METRO
Total Establishments	496	180	245
Total Employment	15,145	11,799	6,616
Total Revenues (USD 2016)	14,463,118,000	4,846,342,920	14,181,472,000
NAICS 324110 (Petroleum Refineries)			
Establishments	148	49	50
Employment	4,237	985	1,285
Revenues	10,463,444,000	2,205,872,640	12,633,639,000
NAICS 424710 (Petroleum bulk stations & terminals)			
Establishments	14	25	1
Employment	137	342	5
Revenues	960,559,000	807,229,440	59,793,000
NAICS 482111 (Line-haul railroad)			
Establishments	188	69	127
Employment	9,435	4,298	4,261
Revenues	2,143,109,000	692,413,960	751,412,000
NAICS 482112 (Short-line railroads)			
Establishments	2	0	2
Employment	60	0	50
Revenues	5,034,000,000	0	24,608,000
NAICS 483113 (Coastal & Great Lakes freight transportation)			
Establishments	0	2	0
Employment	0	11	0
Revenues	0	3,628,240	0
NAICS 484121 (General freight trucking long-distance)			
Establishments	0	2	3
Employment	0	10	32
Revenues	0	706,800	6,687,000
NAICS 486110 (Pipeline transportation of crude oil)			
Establishments	141	33	62
Employment	1,276	6,153	983
Revenues	890,972,000	1,136,491,840	705,333,000

To discern and decompose the effects from connected sectors, an analytical strategy is proposed at the end of this section, and more comprehensively at the end of this report.

Decomposition is particularly important for modes, such as line-haul and short-haul rail roads, where crude oil is only one of the goods transported.

In terms of aggregated sectors, distribution of jobs and job growth differs across the GLR. Employment-wise, the growth that has characterized the NAICS sectors included in this analysis has affected both urban and rural areas, as shown in Figure 4a/b and Figure 5a/b on the US side, with stronger growth occurring in sub-urban counties, especially in the Chicago metro area. In Canada, most jobs and growth have occurred in Ontario and in divisions closer to the US-Canadian border, particularly around and within urban areas, because of the increased role of Ontario as a refining and distribution region for oil from Western Canada (Figure 6a/b).

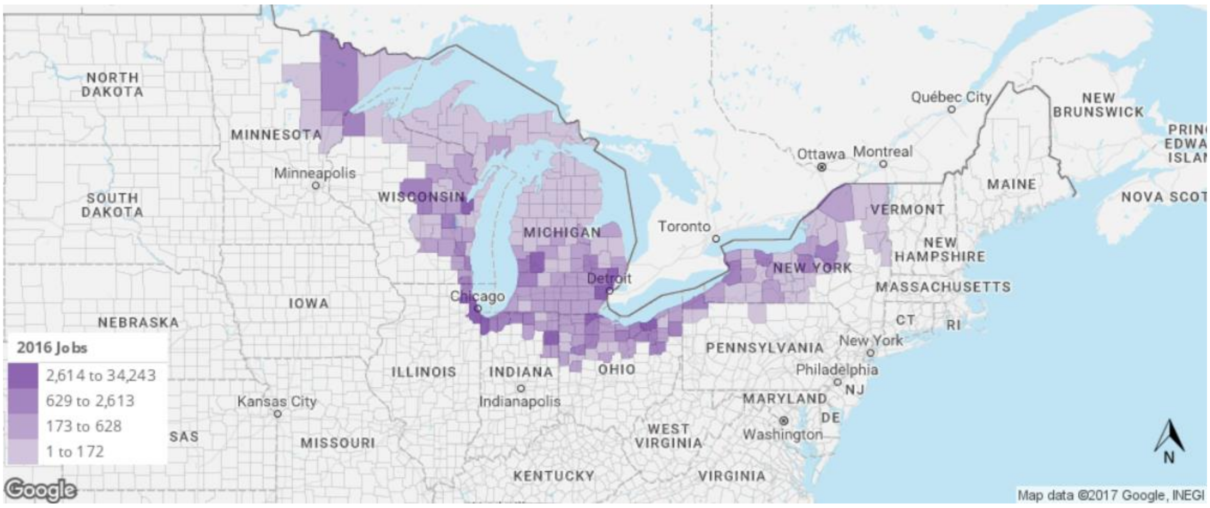

Figure 4a. Location of jobs within US counties of the GLR in 2016, by NAICS 6-digit for selected sectors.

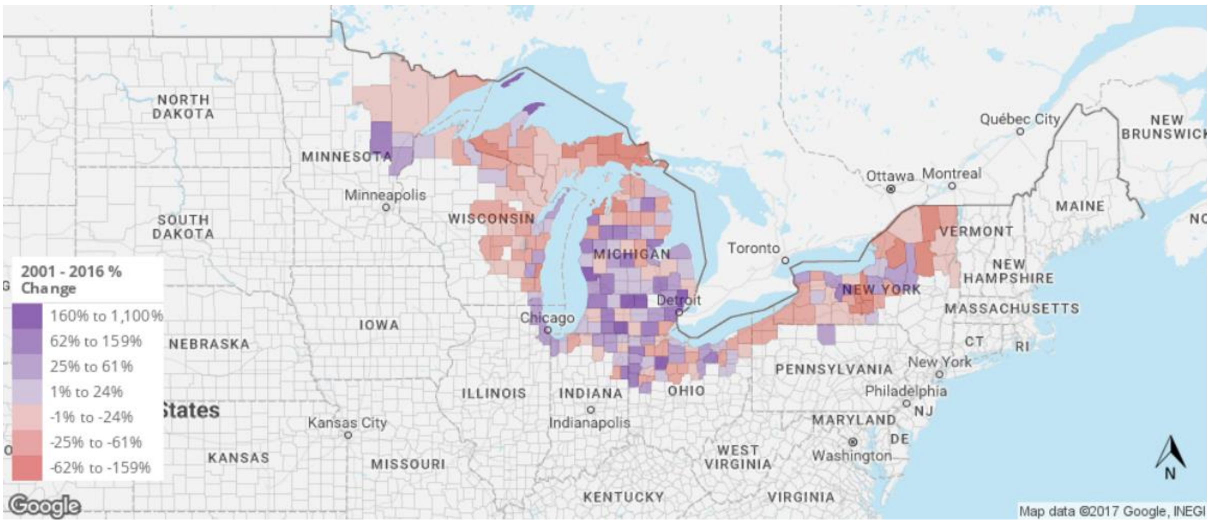

Figure 4b. Location of job change between 2001 and 2016 within US counties of the GLR in 2016, by NAICS 6-digit for selected sectors.

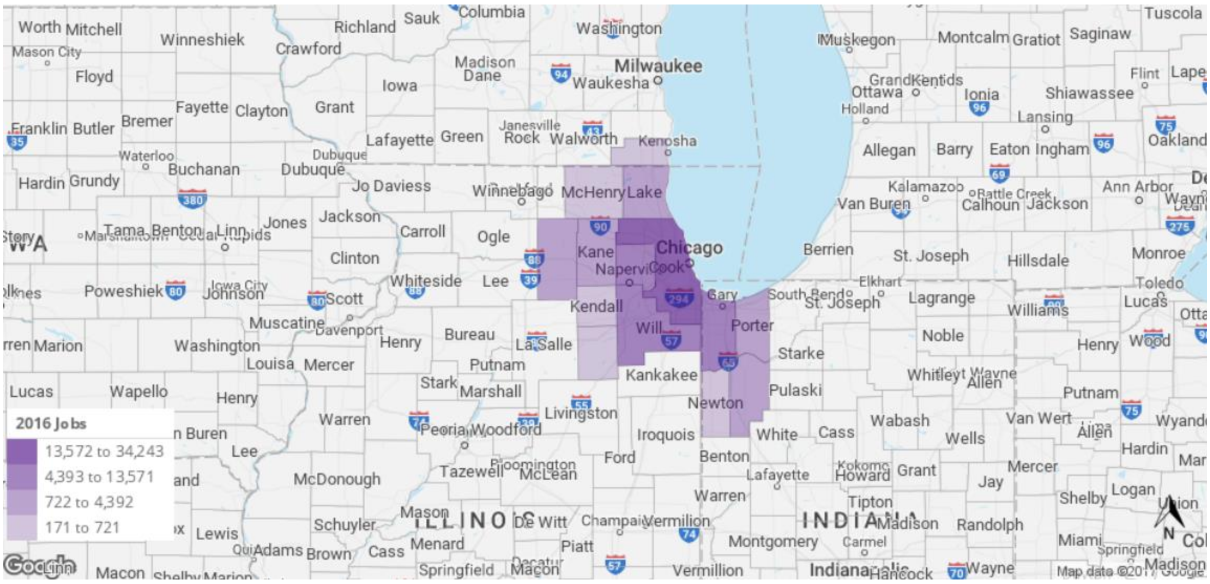

Figure 5a. Location of jobs within the Chicago MSA in 2016, by NAICS 6-digit for selected sectors.

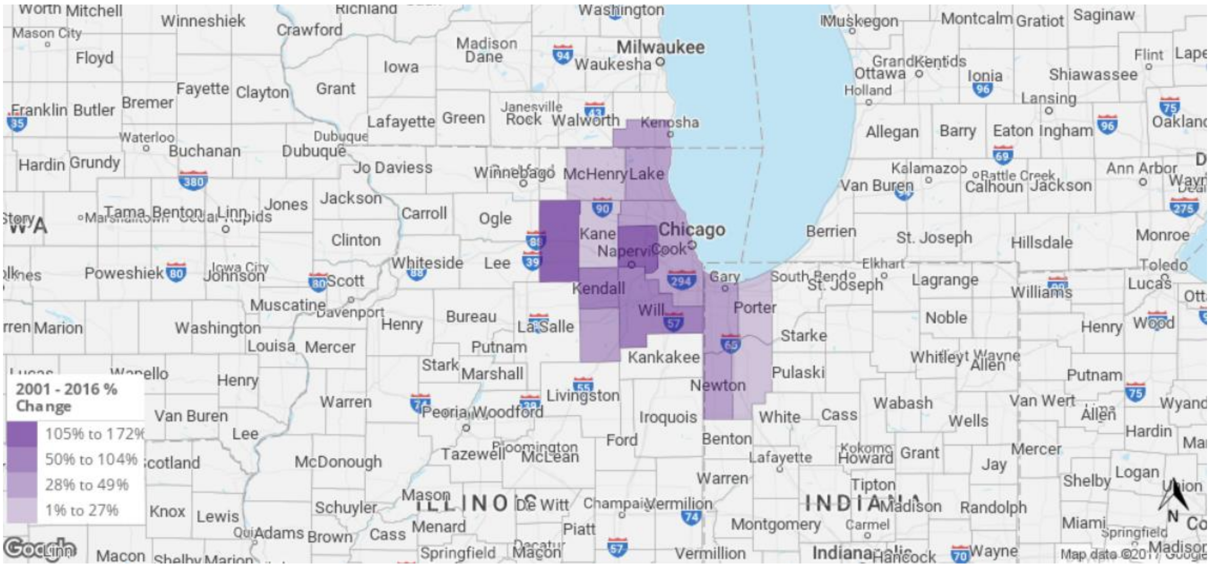

Figure 5b. Location of job change between 2001 and 2016 within the Chicago MSA in 2016, by NAICS 6-digit for selected sectors.

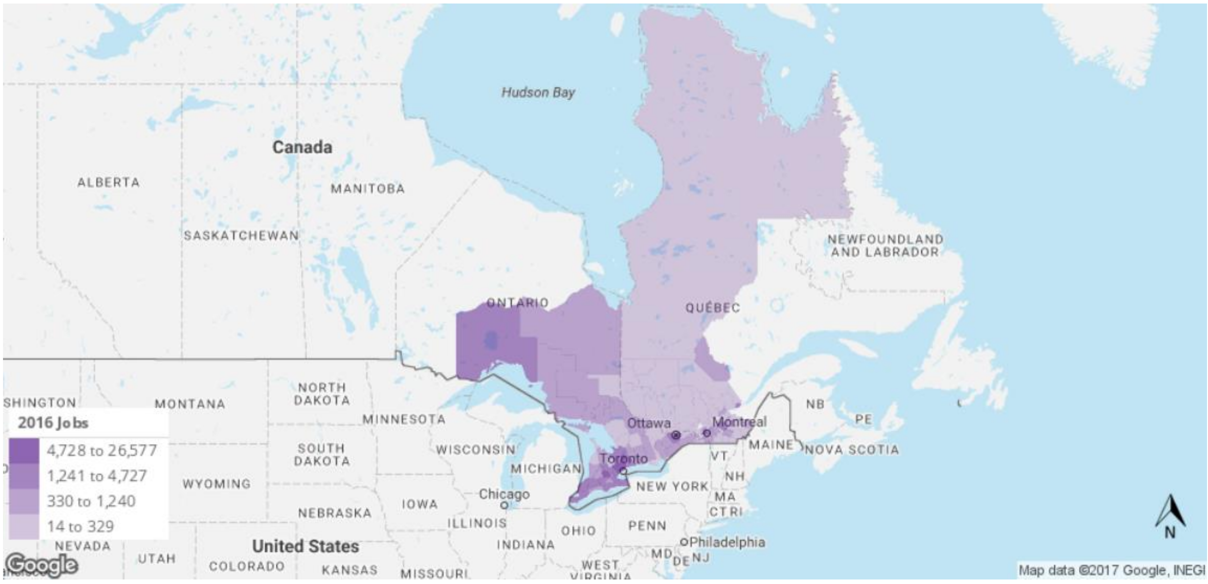

Figure 6a. Location of jobs within Canadian Divisions of the GLR in 2016, by NAICS 4-digit for selected sectors.

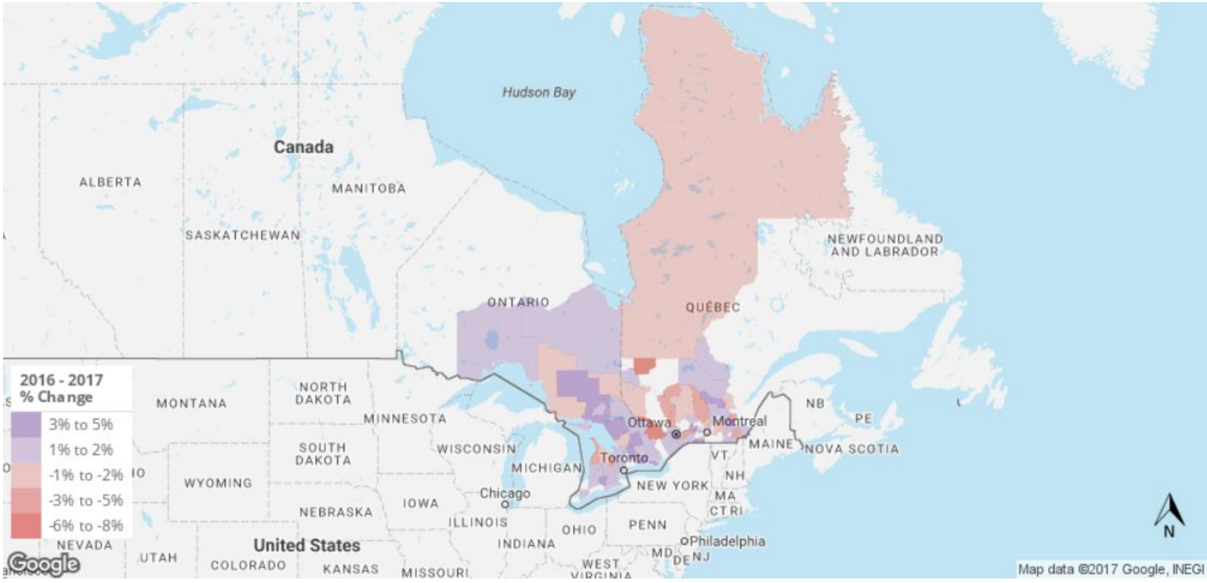

Figure 6b. Location of job change between 2001 and 2016 within Canadian Divisions of the GLR in 2016, by NAICS 4-digit for selected sectors.

2.2 Logistics

Within the GLR, there are three preferred modes for transporting crude oil from, to and within the region: pipelines, railroads, and marine. Trucks represent only a minor portion of the total quantity transported. In this section, we briefly describe the data collected for projecting demand (and value) of the crude oil transported to/through the GLR. Table 5 presents the sources of the datasets. Currently, geographic information system (GIS) data depicting oil infrastructures for Canada are restricted, whilst data for the United States are partially available through the Energy Information Administration.[11] More complete data for the US pipeline system are available through the National Pipeline Mapping System,[12] although the datasets are accessible only to state, local, and federal agencies, including the GLC. For clarity, US states and Canadian provinces are presented separately in this section.

Table 5. List of logistics dataset (spatial/non-spatial).

Data Description	Source	Developer	Level	Coverage	GIS (Y/N)
Quantity and value of imports, exports, and domestic flows of crude oil by mode (2012-2030) (b)	Freight Analysis Framework Data Tabulation Tool (FAF4)	Oak Ridge National Laboratory/ U.S. Bureau of Transportation Statistics	FAF Point and State	USA	N
Pipeline diameters and flows	Enbridge Infrastructural Program	Enbridge	Pipeline	Canada and USA	N
Crude oil transportation infrastructures: crude pipelines, hydrocarbon pipelines, refineries, international crossing points for liquids, oil product terminals, and oil-powered electricity plants.	U.S. Energy Information Administration Mapping System	U.S. Energy Information Administration	Single Feature	USA	Y

Notes: a) all monetary values in USD 2016; b) data have been converted to barrels of oil, 1,000 ton = 7,330 barrels.

In this section data are aggregates at State-level.[13] We relied on other, private, or institutional sources that publish data on specific means of transport. Pipeline is a major means of oil transportation in Canada, with Enbridge being the major operator of crude oil in Ontario and Quebec.[14] For rail transportation data, we used the report "Ribbons of Steel: Linking Canada's Economic Future" by Howard et al. (2015). We used data for transportation of petroleum products in 2012 for province.[15] From an infrastructural point of view, the GLR plays a pivotal role to both internal national markets, and trade between United States and Canada. Of the 3,910M bbl/day produced by Canada in 2015, 3,017M bbl/day were exported to the United States (or 1.374bn bbl, EIA, 2016), of which 2,149.5M bbl/day flowed towards the EIA districts relevant to the GLR.[16] Several areas within the GLR have witnessed increasing flows of crude oil in recent years. For example, Ontario has

[11] https://www.eia.gov/maps/layer_info-m.php
[12] https://www.npms.phmsa.dot.gov/
[13] See the Excel file titled "*modes*" for state-level breakdowns (IL, IN, MI, MN, NY, OH, PA, WI) on four means of transportation: pipelines, rail, water (barge), and truck.
[14] Enbridge has mapped its infrastructure (network) and provides information about the length, diameter and capacity of its pipelines. The capacity for lines 9, 10 and 11 was acquired from the Enbridge website and is presented on the sheet "Canadian pipelines". See Appendix A for a detailed description of the methodology used.
[15] See Appendix A for further information.
[16] Petroleum Administration for Defense Districts, PADD.

increased its role as a refinery hub for oil produced in Western Canada, which accounted for 99.2% of total oil receipt to refineries in 2014, to refineries mainly located within the GLR watershed (NEB, 2015). This intense intra-regional, extra-regional and international trade, including importing and re-exporting into and from the United States, requires an extensive infrastructural network, partly depicted in Table 6.

Table 6. Total count and capacity for crude oil-relevant infrastructures in the GLR, watershed and political boundaries.

Type of Facility	Watershed	Production - Watershed	Political Boundaries (states)	Production (states)	Source
Crude-only Pipelines (km)[17]	2,351	N/A	9,107	N/A	EIA, 2016
All Petroleum product pipelines (km)[15]	9,341	N/A	18,807	N/A	EIA, 2016
Refineries	11	1,937,000[18,19] bbl/day	18	4,170,600 bbl/day	EIA, 2016; NEB, 2016
Oil-powered power plants[15]	49	2,543MW[20]	249	7,390MW[18]	EIA, 2016
Liquid crossing points	7	N/A	9		EIA, 2016
Oil product terminals[15]	109	N/A	N/A		EIA, 2016

The GLR is at the center of the US-Canadian crude oil network, both because it hosts several major final markets, and because of its location in between major westward producing regions (e.g. Alberta, North Dakota), and final markets in Canada and on the Eastern and Southern coasts of the United States of America.

2.3 Ecology

Transporting crude oil across an ecologically sensitive region, whose reliance on water is a key element for its future economic development can generate several socio-ecological and economic costs. Among these costs, we focus on CO_2 emissions for the former, and the monetary costs of spills/accidents for the latter. The results are based mainly on generalized assumptions in relation to actual distances travelled (by mode) for crude oil, since company-level data are restricted. Table 7 summarizes the data sources used for analyzing both the ecological impacts (in terms of spills-accidents), and the current and future demand, by mode, within the region (see next section). Previous studies, such as Skinner and Sweeney (2012) have highlighted the consequences of such costs, focusing on sectors which rely on ecosystem services, such as the agricultural sector and tourism. Further, and besides the costs arising from extreme events such as spills or accidents, the daily transport of crude oil generates CO_2 emissions whose monetary impact can be modelled. In this section, we

[17] U.S. Only.
[18] Based on operating capacity (bbl/stream day).
[19] Chicago CSA: 875,200 bbl/stream day.
[20] From crude only.

present a preliminary analysis of the spills/accidents and emission impacts from transporting crude oil across the GLR.

Table 7. Detailed sources and rationale of spill, accidents, and quantity/demand data

AREA	ITEM	SOURCE	DESCRIPTION
USA	Pipeline accidents	PHMSA	All accidents in watershed counties from 2003 to 2015, with company name, date, spill volume and related costs
	Railroad accidents	Federal Railway Administration Office of Safety	All railroad accidents of the last 4 years in watershed counties with company name, date, spill volume and related costs
	Oil transferred by each mode by state	FAF, 2016	All imports, exports and domestic crude oil transportation by pipeline, truck, rail and water. Each state is presented separately.
	Pipeline spill rate, spill projections and cost	EPA, 2009	Future spill volume and spill clean-up cost for the years 2020, 2025, 2030 and 2035 for each State
	CO_2 and other GHG by mode, expressed as CO_2 Eq.	GREET Model	Emissions of CO_2, N_2O and CH_4 expressed in CO_2 equivalent per mode and state.
	Carbon cost to society	Interagency Working Group on Social Cost of Carbon (2013), Moore and Diaz (2015)	The total cost to society by CO_2 equivalent emissions in 2015 and future projections for 2020, 2025 and 2030 based on three scenarios
Canada	Pipeline capacity	Enbridge	The annual capacity for lines 9, 10 and 11, in ON and QC
	Oil transferred by Railroad	CERI, 2015	Data for transportation of petroleum products (volume and cost) in 2012 and projection for 2024 for province of ON and QC
	Pipeline accidents	Transportation safety board of Canada	All Pipeline accidents in ON and QC with company name, date, spill volume
	Railroad accidents	Transportation safety board of Canada	All railroad accidents in ON and QC with date, spill volume, fatalities and related cost
	Pipeline spill rate, spill projections and cost	Calculated	Pipeline spill rate based on yearly capacity. Projected spill and clean-up cost by Denning 2009 (adjusted)
	Railroad spill rate, spill projections and cost	Calculated	Railroad spill rate, projected spill volume and spill clean-up cost for the year 2024
	CO_2 and other GHG by mode, expressed as CO_2 Eq.	GREET Model	Calculation of CO_2, N_2O and CH_4 emissions for Pipeline and Railroad. Projections for 2024 for railroad
	Carbon cost to society	Interagency Working Group on Social Cost of Carbon report (2013), Moore and Diaz (2015)	The total cost to society by CO_2 equivalent emissions in 2015 based on three scenarios. Projections for 2024 for railway
Both	Cost of life lost	DOT, 2016 Department of Transportation	Cost-estimate for loss of one life.

Table 8 shows the total social costs of emissions of crude oil transportation based on 2015 simulations. These values may be an underestimation, due to the assumptions made in relation to origin/destination points, and further investigation is necessary.

Table 8. Total CO2 equivalent emissions and social cost to society of crude oil transportation in the GLR-political boundaries (38$/ton) in 2015.

GLR Political sub-region	***TOTAL in 2015***
United States- (all modes)	
CO2 EQ KG	3,050,212,056
2016 USD	115,908,058,136
Canada (pipeline and rail only)	
CO2 EQ KG	835,063,367
2016 USD	31,732,407,931

For the US-side of the GLR (defined as political state boundaries), data available allow us to project future annual costs of emissions to increase up to 2016 $48MM/year in 2030, with most of the costs borne by Illinois, Minnesota, and Michigan. The cost of emissions can be easily used as inputs into a dynamic simulation, either as amenity costs or using the CO_{2eq} emissions to calculate region-specific health-related costs, a strategy previously used by McMillen et al (2005). Both these modelling strategies would allow analysts to introduce these costs into the region's economy, although modelling the health costs based on emissions would free the results from social cost assumptions *assumed a priori*.

Spills and accidents are inherent risks to the movement of any good, including crude oil. Currently, spills affecting fresh water coastal areas like the GLR are particularly costly to clean-up, and substantial gaps exist in determining response measures (U.S. Coast Guard, 2013). Although data limitations exist for truck and maritime accidents, we collected a good amount of data on pipeline and rail accidents which occurred within the GLR (basin), inclusive of their clean-up, environmental, and material costs. The summary results are presented in table 9 below, whilst a more detailed cost break-down is presented in the last section of this report, including projects for spill/accident costs based on future demand.

Table 9a. Summary of pipeline spills costs occurred within the GLR watershed area.

	USA, 2012-2015	**CANADA, 2009-2015**
Spill Volume (bbl)	7,227	916
Environmental Cost	$14,950,062	N/A
Product Losses	$269,550	$50,380
Property Losses	$15,319,830	N/A
Cost of lives lost	$9,600,000	Not reported
Total Cost	**$83,002,810**	**N/A**
2025 projected spills in BBL/yr.	1,205	130.74
2025 Cost of spill ($/per year)	**$63,503,261**	**$6,892,909**
Note: all costs in 2016USD, excluding Kalamazoo River oil spill		

Table 9b. Summary of rail accidents which occurred within the GLR watershed area and associated costs.

	USA, 2007-2015	CANADA, 2012-2015
Accidents Volume (bbl)	2,952	39,019
Property Cost (2016 USD/yr.)	$4,064,065	N/A
Environmental Cost (2016 USD/yr.)	$13,749,891	N/A
Cost of lives lost	**$0**	**$451,200,000**
Total Cost (2016 USD/yr.)	**$17,813,956**	**$2,508,202,168**
2025 projection spill from accidents in BBL	609,113	83.78
2025 Cost of accidents (product only, 2016UD/yr.)	**$20,880,608**	**$4,416,673**

The values shown in Tables 9a and 9b are conservative estimates based on reports filed through the PHSA and the EPA, and do not include the largest spill which occurred within the GLR: the Kalamazoo River oil spill. This spill alone had a total discharged volume of at least 1.2 million gallons of oil into the river (EPA, 2016), equivalent to an EPA-based response cost of 2016$1.35bn dollars based on EPA average response cost (EPA, 2009). This spill has been excluded because it occurred before the period taking it into consideration. However, its impact has been so vast, and its costs are still accruing throughout the region, that a deeper analysis is deemed appropriate for the future, especially in relation to the ecological and social monetary costs borne by the affected region, which could potentially exceed the fines and clean-up costs of the pipeline owner (Enbridge). Similarly, Table 9b shows a conservative future estimate of the costs by region from transporting crude oil via rail, in that the loss of human life is not considered in either the US or Canadian projections.

The difference between rail-based and pipeline-based costs is evident when comparing the two tables. Two major factors influence the overall outcome: the time-frame considered which excludes the Kalamazoo River oil spill, and the loss of lives associated with rail-based accidents. Specifically, the second elements are of importance in defining the costs associated between each of these two potentially competing modes of transportation - their infrastructural design, rail-based accidents tend to generate higher immediate social costs associated with injuries and fatalities compared to pipelines (Furchtgott-Roth and Green, 2013; Fritelli et al., 2014). These costs are evident from Table 9b: the single major rail accident involving (in part) crude oil at Lac Megantic, Quebec generated $450 million in terms of lives lost, and infrastructural damages. Pipelines, however, can impose longer-term environmental costs, which often translate into negative effects on human health and economic activity. Both these effects would be better analysed using dynamic models, capable of accounting for amenity and demographic shocks, rather than simple I/O models.

The overall results shown in the two tables, however, should highlight the potential for high costs to be borne by the region, which may reduce the benefits of these sectors, especially when these are imposed on sectors relying on higher environmental quality, such as tourism or agriculture (Skinner and Sweeney, 2012).

2.4 Demand

We grouped data into three categories (flows) – imports, domestic, exports – to determine the distance travelled to delivery, a key component to determine the ecological impact in the following section. Canadian data for oil transportation in the provincial level was not available by a governmental source. There are two major elements that define the overall demand of crude oil transported across the GLR:

1) *A trade element*, which relates to the exchanges between Canada and the United States; this element is influenced by areas outside the GLR, such as Western Canada, and drivers such as exchange rates between the US and the Canadian dollar to determine the overall value of shipments; and
2) *A domestic element*, which defines the volumes of shipments, and is driven by both internal demand and demand in other areas, such as the east coast of the United States and southern areas within the PADD2 EIA region, whose demands for refined oil products are satisfied in part by refineries within the GLR.

Since 2012, the amount of crude oil transported within the states and provinces of the GLR has increased by 112 million barrels (U.S. DOT, 2016), totaling 752 million barrels in 2015, and the Freight Analysis Framework (FAF) projections foresee a further increase to $827 MM by 2025.

Trade wise, Canadian-USA trade of crude oil was worth about 2016 $54bn in 2015 (U.S. Census, 2017), about 87% of which are exports to the United States assuming a uniform price across all export destinations, 2015 $25.85bn directed towards the PADD relevant to the GLR. Transportation wise, and in relation to the second element, the amounts shipped across and within the GLR are hard to identify at watershed level, and therefore are defined in Table 10. Only FAF regions within the GLR watershed, plus Minnesota and Pennsylvania, have been included due to data structure limitations.

Table 10. Volume and value of shipped crude oil by all modes within selected FAF regions of GLR-USA and provinces of the GLR in 2015 and 2025. Sources: FAF, 2017; EIA, 2017,

GLR-USA		
Item	*Total in 2015*	*Total in 2025 (projection)*
Volume transported within region (in bbl)	752,743,475	886,452,923
Volume as share of national receipt to refineries	21.7%	N/A
Share transported via pipeline	94%	93%
Share transported via rail	4%	4%
PRODUCT VALUE (Mil., 55$/bbl)	41,400	48,754
PRODUCT VALUE (Mil. $, FAF)	68,936	81,554
GLR-Canada		
Volume transported within region (in bbl)	423,589,577	537,931,273
Volume as share of national receipt to refineries	32%	N/A
Share transported via pipeline	N/A	N/A
Share transported via rail	N/A	N/A
PRODUCT VALUE (Mil., 55$/bbl)	23,230	29,586
Note: Canadian data are projections based on full use of pipeline capacity.		

The role of the GLR as an intermediate, final, and transition market for crude oil transportation is well exemplified in Table 10: 32% of the Canadian refinery receipts of crude oil was transported through the region, mainly by pipeline, whereas 12.4% of the US receipt was moved within the GLR political boundaries. This lower value for the USA is not surprising given the lack of large extraction areas within the region and smaller shares of its total population in the GLR. The differences in value, particularly for the US side of the GLR, reflect differences in methodology assumed by the FAF data versus average prices per barrel in 2015/2016. Volume wise, and assuming an average export rate of 3.76 MM/bbl/day for 360 days/year (EIA, 2015), the GLR-USA region mobilized 55% of the total volume traded between the USA and Canada in 2015, making this a fundamental strategic region for companies operating on both sides of the border. The overall transportation structure is not expected to change for the US side of the GLR up to 2025, when pipelines will still move most of the crude oil within a scenario of increased demand. This profile reflects a marked difference with the rest of the country, where about a third of all crude oil is delivered through shipping. In the GLR provinces, the current structure, which includes a larger role for rail, is expected to shift further in favor of this mode of transportation unless new planned pipelines are completed in the west of the GLR (EIA, 2016b). However, Canadian projections would be misleading and are not reported because pipeline data rely on the assumption of full capacity use of the pipelines (an overestimate), and rail data are limited. Comparing the

Canadian regional data with the rest of the country, most transportation of crude occurs either via pipeline, while rail has a capacity equivalent to 5% that of pipes, for a combined total of 93.9% of all moved crude oil in 2014 (EIA, 2015b). This overview suggests space for expanding the rail infrastructure within a framework dominated by pipelines over the next ten years, unless major regulatory changes generate abrupt shocks in the investment patterns (IHS, 2013).

2.5 Fiscal

Data about the fiscal contribution of the selected NAICS were collected through the EMSi Analyst Database. The data provided by EMSi do not differentiate between local, state and federal taxes, although they record subsidies paid to specific sectors. The fiscal component is investigated in detail in the next section, along with other economic indicators. Because of the nature of these data, we prefer to integrate the results in the context of the overall

3. Understanding the regional Impacts of crude oil transportation: a preliminary I/O analysis of relevant sectors and a counterfactual analysis

3.1 Understanding the regional Impacts of crude oil transportation: a preliminary I/O analysis of relevant sectors

Given the expected expansion of the crude oil transportation industry across North America, a question arises about whether the GLR has or is developing the necessary supply chain to benefit from this increase in investment. Before answering this question, we need to assess the total impact of some of the relevant NAICS sectors to crude oil transportation in the GLR. All data in this section are derived from queries of the EMSi Analyst dataset, which utilizes U.S. Bureau of Labor Statistics data (EMSi Analyst 2016.1-4 and 2017.1). On the US side of the GLR, the overall contribution to the economy for the selected sectors in 2016 was about $17.1bn, including about $700MM in taxes. Unfortunately, the EMSi model does not compute the fiscal impact for Canada at any scale. In 2016, the industries uniquely linked to crude oil transportation (NAICS 486110, 424710, and 324110), contribute about $7bn, of which $300MM is in taxes. The 2016 value of the supply chain of two very distinct crude oil industries, 48611, is found in Pipeline Transportation of Crude Oil (NAICS 486110) and Petroleum Refineries (324110 or equivalent for Canada), as presented in Table 11.

Table 11. Supply chain aggregate for NAICS 486110, 324110 and 3241 (Canada) in 2016 (USA-GLR) and 2011 (Canada-GLR).

GLR Area – political boundaries	In-region Purchases	% In-region Purchases	Imported Purchases	% Imported Purchases	Total Purchases
USA Refineries	$8,930,456,635	31.61	$19,321,439,519	68.39	$28,251,896,154
Canadian Refineries	$4,745,820,351	18.25	$21,260,066,652	81.75	$26,005,887,003
Total Refineries	$13,676,276,986	24.51	$40,581,506,171	75.49	$54,257,783,157
USA Pipelines	$152,546,120	69.74	$66,184,383	30.26	$218,730,503
Canadian Pipelines	$29,880,154	96.62	$1,046,241	3.38	$30,926,395
Total Pipelines	$182,426,274	73.73	$67,229,624	26.27	$249,655,898
TOTAL ALL SECTORS/REGIONS	**$13,858,703,260**	**24.72**	**$40,648,735,795**	**75.28**	**$54,507,439,055**
Note: Canadian refineries data are at NAICS 4 digits, which partly includes coal-related industries., and data are converted from 2011 levels into 2016 USD					

The current supply chain results show that the region, defined in this case within its political boundaries, shows that these two sectors' supply chain make up 1.6% of the entire states/provinces' GDP, although most of the purchases come from outside the region itself. Looking deeper at each sector, the crude pipelines show a stronger domestic supply chain, with more than 70% of purchases made within the region. Within the USA GLR the highest domestic purchases occur within manufacturing sectors (NAICS 33xxx) for pipelines, centralized offices (NAICS 55xxxx) and transportation (NAICS 48xxx), and oil/gas extraction, which refers to the purchase of the raw material (crude oil), for refineries.

In the Canadian GLR, the pipeline sector mainly influences the domestic electric suppliers (NAICS 2211) financial and support services (NAICS 52xx), whereas crude refineries are mainly supplied by chemical manufacturing (NAICS 32xx) in addition to purchases from the oil sector. Looking at the watershed area from a county perspective, the supply chains for the crude oil pipelines and the crude refineries change slightly, as shown in Table 12 below. Due to the differences in area unit aggregation, year, and NAICS-level, we decided to show this table separating the US data from the Canadian data, without updating the Canadian data to 2016 US dollars.

Table 12. Industry Supply Chain, Great Lakes Region (watershed) at county/division level for selected NAICS (4-digit in Canada, 6-digit in USA).

Area	In-region Purchases	% In-region Purchases	Imported Purchases	% Imported Purchases	Total Purchases
			Pipelines		
GL Canada - Divisions	$35,826,577	96.41	$1,332,399	3.59	$37,158,975
GL USA - Counties	$64,580,393	52.73	$57,892,046	47.27	$122,472,439.97
			Refineries		
GL Canada - Divisions	$5,177,443,785	18.11	$23,404,203,553	81.89	$28,581,647,339
GL USA - Counties	$2,916,038,229	22.75	$9,899,149,975	77.25	$12,815,188,204
TOTAL Canada	**$5,213,270,362**	**18.22**	**$23,405,535,952**	**81.78**	**$28,618,806,314**
TOTAL USA	**$2,980,618,622**	**23.04**	**$9,957,042,021**	**79.96**	**$12,937,660,643**
Note: Canadian data for 2011 and in 2011 CND. US data are for year 2016 and in 2016 USD.					

Tables 11 and 12 provide us with levels of the supply chains for two of the sectors of interest for crude oil transportation within the GLC. The GLR hosts a large refining capacity, as well as final markets for refined oil, thus it is not a surprise that the counties/divisions within the GLR still have a relatively large share of the refinery-related supply chain of crude oil. However, the portion of firms and companies operating within the supply chain for the pipeline sector are reduced, as many may be located outside of the GLR, particularly in other areas of Ohio, Minnesota and Illinois.

It is possible to take a few additional steps in the analysis, mainly understanding the current ability of the GLR to respond to an increased demand for crude oil transportation industries. Further, and to better understand the current contributions to the wider economy of crude oil transportation, it is possible to perform a counter-analysis, that is, to simulate the disappearance of selected sectors from the GLR.

In order to understand the level of specialization of the GLR at county level, this report focuses on the location quotient (LQ) for each of the relevant NAICS as reported in table 13a/b below. LQs are analytical statistics that measure a region's industrial specialization relative to a larger geographic unit (the USA or Canada, in our case, see Appendix B for further details).

Table 13a. Location Quotients (Canada) in 2015/2016, employed and self-employed – selected NAICS.

	LQ					
	Petroleum/coal manufacturing	**Rail Transportation**	**Deep sea, coastal and Great Lakes water transportation**	**General freight trucking**	**Pipeline transportation of crude oil**	**% Job Growth, 2011-2016 – all sectors**
GLR - Divisions	0.83	0.76	0.20	1.06	0.02	1
Ontario	0.87	0.71	0.12	1.12	0.03	2
Quebec	0.86	0.84	0.39	0.39	0.02	1

Table 13b. Location Quotients (USA) 2015/2016, employed and self-employed – selected NAICS, county and state levels.

LQ							
Area	**Petroleum Refineries**	**Petroleum Bulk Stations and Terminals**	**Rail Transportation**	**Coastal and Great Lakes Freight Transportation**	**General Freight Trucking - Long Distance**	**Pipeline Transportation of Crude Oil**	**Total % job Change, 2011-2016**
GLR - Counties	0.75	0.58	**1.12**	0.98	**1.19**	**1.05**	12
GLR - States	0.64	0.67	1.17	0.65	1.04	0.7	7
Illinois	1.07	0.62	1.83	0.33	1.46	1.05	12
Indiana	1.57	1.49	1.68	0.03	2.08	0.29	0
Michigan	0.27	0.51	0.53	0.76	1.01	0.19	17
Minnesota	1.26	0.7	1.11	1.1	1.16	1.6	11
New York	0.01	0.37	1.07	1.28	0.22	N/A	10
Ohio	0.87	0.81	0.92	0.59	1.28	2.15	7
Pennsylvania	0.78	0.88	1.27	0.23	0.91	N/A	3
Wisconsin	0.14	0.52	0.84	0.2	1.55	1.22	2

Note: green color identifies LQ > 1.2; yellow is used for 1<LQ<1.2. These values are usually adopted to identify export-oriented specialized regions.

Table 13 shows that the GLR watershed region specializes slightly in crude oil pipeline transportation, in rail transportation, and in trucking. Further, since 2011, all the sectors combined have seen a 12% growth in overall employment. Marked differences exist within the GLR, which reflect the differences in the economic specializations of each state. For example, Indiana is well specialized in four industries related to crude oil transportation, although not in the more specific pipeline transportation, and, overall, has seen no growth in jobs since 2011 within these industries. Minnesota appears well-endowed in terms of specialization in almost all of these industries, and has seen an overall growth of 10% in employment since 2011. It important to note that, since 2011, the construction of pipelines has contributed greatly to the increase in employment and specialization, with increases in employment up to 219% in the case of Minnesota, mainly determined by local manufacturing and development of new projects (IHS, 2013). This trend could contribute to increase the region's specialization, and may signal the readiness of the region's manufacturing sector to service the expansion of this mode of transportation. Ohio is one of the other two states with a highly specialized profile in pipeline-related industry, mainly because of the presence of several manufacturing firms within the state, but outside of the GLR. Overall, the GLR and the US-GLR do not appear to be highly specialized in crude-oil transportation industries, especially considering that some of these NAICS comprise employment supported by other users (e.g. transportation of food products). Conversely from the US GLR, the Canadian side does not appear to specialize in most of the identified industries, except for trucking, possibly because of the more service-oriented economic structure of the urban areas within the watershed region. Finally, with the westward migration of the pipeline industry, the Canadian side of the GLR and both provinces recorded net job losses in the pipeline sector since 2011.

3.2 A counterfactual analysis of pipelines and rail-based crude oil transportation

At this stage we can provide a first estimate of what would happen to the economy of the GLR counties if certain changes occurred in the transportation structure of crude oil. This initial analysis will not include environmental or amenity costs, mainly because of the model utilized (EMSi I/O). However, we can estimate the current contributions of the pipeline sector to the GLR counties (within the watershed) in comparison to those of rail transportation. To do so, we take an extreme view, and assume that all the refineries within the US and Canadian GLRs are required to stop purchasing their crude via pipeline operations (for example, due to new regulations), shifting their demand to the next largest mode, that is railway. For doing so, we input a loss in the NAICS 486110 (Pipeline transportation of crude oil) equal to the amount of services purchased by the petroleum refineries within the region (2016$ 49.1MM in 2016). We then multiply that amount by 1.4, which represents the average ratio between transporting one barrel of crude via rail and one barrel of crude oil via pipeline (Birn et al., 2014). No infrastructural constraint is envisioned here, which makes the simulation conservative. The results are shown in Table 14.

Table 14. Economic impacts of replacing pipeline delivery of crude oil with rail delivery to GLR refineries in the GLR-USA.

Aggregate Changes	
Earnings (in MM 2016$)	-13.1
Jobs	-10
Taxes	0
Rail transportation	
Earnings (in MM 2016$)	40
Jobs	644
Taxes	5.1
Pipeline transportation of crude oil	
Earnings (in MM 2016$)	-54.3
Jobs	-694
Taxes	-11.7
Note: Specific breakdown of direct, indirect, induced effects is available upon request	

The overall shift would result in a minor change of the GLR-USA economy, with net losses of 10 jobs, and $13.1MM in industry earnings, mainly due to the lower pay of professions associated with rail transportation. In terms of tax receipt, the aggregate effects are not available through the model. However, these results can be highly modified by the inclusion of the cost of lost lives and environmental damages, which may determine larger (smaller) costs throughout the economy for each industry.

Table 15. Economic impacts of replacing pipeline delivery of crude oil with rail delivery to GLR refineries in the GLR-Canada (NAICS 4-digit).)

Aggregate Changes	
Total changes in wages (in MM 2016$)	327.3
Jobs	6,585
Avg. Wage/job	49,708
Rail transportation	
Total changes in wages (in MM 2016$)	371
Jobs	7,474
Avg. Wage/job	49,628
Pipeline transportation of crude oil	
Total changes in wages (in MM 2016$)	-43.5
Jobs	-889
Avg. Wage/job	49.039
Note: Specific breakdown of direct, indirect, induced effects is available upon request	

Total tax receipt in Canada is not available, and the analysis was conducted using NAICS 4-digit level codes, which, in the supply chain, aggregate petroleum and coal manufacturing plants together, disaggregating the demand for crude oil transported via pipeline. The impacts recorded are far bigger than the GLR-USA, both because of higher multipliers for the rail sector, and the larger magnitude of the 'shock' used as an input (2016CND 600MM in additional rail sales). For this side of the border, the shift to a rail-based system, excluding infrastructural investments and ecological costs, appears to generate an increase in employment, providing an overall higher average wage than within the current state. The results of this analysis provide an insight on the relative interests at stake in terms of economic impacts for the two sub-regions of the GLR. Because of its refining capacity and current role within the Canadian crude oil supply chain, the census divisions within the GLR in Canada have a higher-order of magnitude in terms of shifting the supply of crude to rail, whereas in the GLR-USA this decision has far less direct consequences on employment, which may shift the focus onto other considerations, such as environmental safety.

4. Next Steps

The data collected and the introductory analyses in this report are an initial step towards a full assessment of the economic impacts of crude oil transportation in the GLR. To investigate the broader current and future impacts that this macro-sector generates throughout the GLR, we suggest undertaking a dynamic analysis through the following:

1) **Regional Economic Modelling Inc. (REMI) model (or equivalent).** The model allows for estimating two aspects of the crude oil industry:
    a. current contributions to the GLR economy (at county level) through a counterfactual analysis (i.e. 'what if the sector disappeared?');
    b. future contributions to the additional investments in the sector. Both these points were partly investigated by IHS in 2013 for the pipeline sector in the entire USA, although not using a dynamic model, which does not foresee adjustments in the economy, and on behalf of API, and not including social and ecological costs associated with the industry (e.g. spills).

    Both analyses are pivotal to identify the 'how much' and 'where' economic benefits are captured. For example, existing highly-specialized firms in pipeline operations located outside the GLR (e.g. Texas) may benefit more from the expansion of pipelines within the GLR, and, thus, new jobs will be created outside the region. Finally, the REMI model fiscal component can effectively measure the fiscal costs (e.g. from increased demand of services such as schools) and benefits (e.g. increased tax receipts) from new and current crude oil activities over time and across multiple counties.

2) **Use of the collected inputs within the REMI model, to capture the geographical distribution of crude oil transportation operation, future demand, and socio-ecological costs**. The REMI model 'amenity' variable allows for estimating the effects on a region's (e.g. county) attractiveness to agents (households) (Hastorun and Cangeron, 2016), and has been previously used by agencies within the GLR for incorporating the effects of environmental damages to local economies (e.g. MDOT, 2011). The datasets created in the *Demand* and *Ecology* sections can be easily used as inputs to estimate the impacts that past and current crude oil-related accidents had on the GLR economy. Because of its reliance on agriculture and tourism, especially in coastal areas, estimating these longer-term, economy-wide effects is key to gathering a full quantification of the costs/benefits of crude oil transportation across this region.
3) **A more detailed comparison** would also cover expected increases in fatalities from rail-vehicle level crossing accidents with the use of rail. In its assessment of the Keystone Pipeline in the United Sates, Department of State found that an average of six Americans a year would be killed for 50 years in level crossing accidents versus one death over the 50 years from pipeline accidents (U.S. Department of State, 2014).[21] Analysts disregard amenity values (e.g. environmental costs, etc.) at their peril, which is a plea for more sophisticated analysis than covered currently.

[21] Specifically, the report stated that: "*There is also a greater potential for injuries and fatalities associated with rail transport relative to pipelines. Adding 830,000 bpd to the yearly transport mode volume would result in an estimated 49 additional injuries and six additional fatalities for the No Action rail scenarios compared to one additional injury and no fatalities for the proposed Project on an annual basis*."

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Appendices

Appendix A

Enbridge provides a daily maximum capacity for each pipeline, which we multiplied by 360 (days) to get the yearly capacity. According to the company's financial reports, there are some days that the pipelines are not operating, due to maintenance or other emergency reasons. We assume that the pipelines are operated on their maximum capacity and we don't account for any idle time between shipments or tank fills. We considered line 7 being a spin - off from line 9, carrying part of its capacity. We did not include it in our data to avoid double counting. Line 9 is located in Ontario and Quebec and we considered the maximum capacity is transported in both provinces. Since there was an ongoing project aiming to reverse part of its capacity in 2015, data do not accurately reflect the year 2015. Line 10 is exporting oil from Canada to West Seneca, NY. We considered the line to be fully operational despite an ongoing project to replace part of it.

Petroleum products data recorded by the Canadian Energy research Institute (CERI) (2015) include not only crude oil, but also crude bitumen, refined petroleum products, and gaseous hydrocarbons such as propane, butane and pentanes plus. Following CERI (2015), there are 14 rail border crossings with the US in Eastern Canada. Ontario shares five rail crossings with the US: three with Michigan (Sault Ste. Marie/Sault Ste. Marie, Detroit/Windsor and Port Huron/Sarnia), a single crossing with Minnesota (International Falls/Fort Frances) and a single crossing with New York (Buffalo/Niagara Falls). Quebec shares six rail crossings with the US and two of them are in New York (Trout River/Fort River/Elgin and Rouses Point/Cantic). The CERI study presented data measured in metric tonnes and in railcars. We assume 1 rail tank= 30000 gal= 700 bbl= 95 metric tonnes.

Appendix B

As per the U.S. Bureau of Economic Analysis: "*a location quotient (LQ) is an analytical statistic that measures a region's industrial specialization relative to a larger geographic unit (usually the nation). An LQ is computed as an industry's share of a regional total for some economic statistic (earnings, GDP by metropolitan area, employment, etc.) divided by the industry's share of the national total for the same statistic. For example, an LQ of 1.0 in mining means that the region and the nation are equally specialized in mining, while an LQ of 1.8 means that the region has a higher concentration in mining than the* *nation*." (See: https://www.bea.gov/faq/index.cfm?faq_id=478). This report uses EMSi-calculated LQs, based on employment data.