

THE EVOLUTION AND FUTURE OF HYDRAULIC FRACTURING POLICY IN ONTARIO

by

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ABSTRACT

As of 2015 hydraulic fracturing for unconventional shale gas in Ontario is not currently being used. In this paper, qualitative in person interviews of government officials and a province wide survey of municipal leaders were conducted to determine the level of support for the potential use of unconventional fracking in Ontario. Potential reasons for the current absence of unconventional fracking in Ontario are geology and lack of investment. Although fracking is a topic of discussion in most municipal governments, support is low. The likely future of unconventional fracking in Ontario is slim, but it cannot be completely ruled out. There is a general consensus that municipal support is important if horizontal fracking was to be used in Ontario.

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DEDICATION

I would like to dedicate this project to my father and mother, Michael and Carolyn McKinley.

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1.0 Introduction

Hydraulic fracturing is a technique used by oil and gas companies to extract natural gas from the earth. Its colloquial term is “fracking,” which represents the fractures that are created in the shale rock, as part of the extraction process, and the term is interchangeable with fracturing. Although it has been around since the mid 1900s, it is more extensively used today as it is combined with horizontal well drilling, known as multistage horizontal fracking (Yergin, 2011). Natural gas can be extracted conventionally or unconventionally. When natural gas is located near the surface of the earth in porous and high permeable zones, conventional extraction is used with a single staged vertical well and a lower volume of fracking fluid. However, when natural gas is trapped far beneath the ground in low permeability areas, unconventional fracking is used. Meaning that a higher volume of fracking fluid is used in conjunction with multistage horizontal drilling (Ontario Petroleum Institute, n.d.).

Oil and gas companies argue that fracking is a cost effective method of extracting natural gas from the ground as hundreds of conventional wells would be needed to match the contact provided from one fractured well (Fitzgerald, 2013). Fracking projects on average account for 10% of Canada’s GDP and contributed 36 billion dollars to the United States’ economy in 2011 (American Enterprise Institute, 2013; Natural Resources Canada, 2014). Increased extraction of shale gas has been projected to make USA a net exporter of liquefied natural gas by 2016 (Boersma & Johnson, 2012). Opponents of fracking argue that there are too many environmental concerns to justify the practice. From groundwater contamination, extensive water

use, and the release of methane, fracking has been shown to cause environmental hazards (Sumi, 2010).

This research project has two central goals: 1) to evaluate the evolution of policies, and regulations for horizontal fracking in Ontario; and, 2) to examine the attitudes, opinions, and knowledge of municipal leaders towards horizontal fracking in Ontario. To date, there has been very little research on the policy and regulatory framework for fracking in Ontario, and no research on municipal leader attitudes. This latter omission is surprising given that fracking would be a contentious local land use issue in Ontario. Since there is very little research on fracking in Ontario, this project has the potential to provide important knowledge for future policies and regulations in Ontario. The reason multistage horizontal hydraulic fracturing is worth studying is because it has the potential to produce many benefits, such as allowing countries to become their own supplier of natural gas, however, at the same time many environmental concerns are at the forefront of doubts about pursuing hydraulic fracturing. More specifically, Ontario is in such a unique situation because it is one of the few provinces to have had conventional fracking operations with not a single well drilled using unconventional methods. Why this is will be answered in this research project.

1.1 Methods

The information gathered for this research project came from three dominant sources: secondary literature for preliminary research; in-person interviews, and a province-wide survey of municipal leaders. The secondary

literature including government reports, novels, and journal articles sparked the eventual goals and research question of this project. By examining what had already been researched and what was missing, it was clear that a municipal perspective on fracking was needed. The secondary sources were used to theorize and help structure the interview questions, based on what was missing.

The in-person interviews were qualitative in nature, semi-structured, and used a snowball method. They were qualitative, as the aim of the interviews was to acquire individual perspectives of government officials on questions about hydraulic fracturing in Ontario. The format was semi-structured, as the interviews operated using a standard set of interview questions; however, if other questions arose in the interview or if the interviewee was not comfortable answering certain questions, changes were made. A snowball method was used, meaning at the end of each interview, the interviewee was asked to identify potential people that would also be a sufficient candidate for an interview. These interviews took place from mid December 2014 to the end of January 2015. A total of four interviews were conducted, at locations chosen by the interviewees. The interviewees were all government officials related to hydraulic fracturing, with most of them being senior level officials. The organizations they work for are: the Environmental Commissioners office, the Council of Canadians, and the Ministry of Natural Resources and Forestry. However, to keep their identities anonymous, they are simply addressed as “Interviewees A, B, C, and D” without other specifications. Each interview lasted 30-60 minutes. The Ryerson Research Ethics Board approved the interview protocol. Refer to appendix A for the interview question guide. The

main limitation of the in-person interviews would be the interviewees not giving honest answers due to fear of their identity being exposed. Although the proper steps were taken to prevent this, some of the interviewees might have been worried, which prevented them from giving full and honest answers.

The survey was sent out to 350 municipal leaders of Ontario in October 2014. Using a list of the 444 municipalities of Ontario, emails of municipal leaders were obtained. However, some emails were not working, or some places were counties and therefore had duplicate emails in the list. For this reason, the sample size was 350 and not 444. The term “municipal leader” refers to either the mayor or the reeve of the jurisdiction. Some jurisdictions are large enough to have a mayor, while others have reeves. Using an online survey, 50 responses were returned, which is a response rate of 14%. The responses were from a variety of small, medium, and large municipalities with a geographical spread throughout Ontario. Although a survey of provincial or federal leaders would have been beneficial, this project was interested in municipal officials’ opinion regarding hydraulic fracturing, therefore was sent at the municipal level. As fracking is a local land use issue, it was important to look at how municipalities view the issue. The questions were closed ended, and the survey covered the following topics: hydraulic fracturing, the Great Lakes, wind energy, renewables, and land use issues. The section regarding hydraulic fracturing had nine questions, ranging from the municipal leaders’ personal opinion of fracking to whether the municipality is aware or not aware of any potential shale plays in their area. Refer to appendix B for the survey questions.

One of the main reasons an online survey was used is for the sample size and geographical location of the subjects. We had a fairly large sample size and our participants were distributed in a broad geographical area. According to Sue and Ritter (2007), online surveys have higher start-up costs than other methods but become cost-effective, as the number of surveys are completed, with telephone and face-to-face interviews feasible only when the participants are in a narrow geographic area with a smaller sample size. Since our respondents are spread out all over Ontario, an online survey was the best option. The limitation with doing an online survey would be not having open-ended questions. Although the responses had many options to choose from the exact answer that the respondent wanted to give might have not been on the list, concealing their true response to the question. Another limitation is the fact that although the survey was sent out the municipal officials' email, the officials themselves might have not been the ones answering the survey. The main limit to the survey is the sample size. Due to the low response rate of 14%, the sample size for the survey was 50. Therefore the discussion of the results and the conclusions that were drawn were from the 50 responses, which might not be a full representation of all the municipalities of Ontario.

This paper is organized by first briefly explaining what natural gas and hydraulic fracturing is while examining the benefits and concerns. It will then summarize fracking operations around the globe, while narrowing the focus onto Canada and then Ontario. Next, the results from the interviews and survey will be discussed, being separated into different categories. It will then explain the likely future of unconventional fracking in Ontario, while also providing recommendations

if fracking was to be used in Ontario. Although the future of unconventional fracking seems unlikely, it cannot be ruled out. Municipal leaders believe that most of the authority should reside with the local jurisdictions. Given that fracking is a local land issue, if it was to be used in Ontario, local government support is important to obtain.

2.0 Hydraulic Fracturing: Opportunities and Concerns

This section will explore what natural gas is and a brief history of hydraulic fracturing. The environmental concerns will be discussed along with the opportunities and benefits of fracking.

2.1 Natural Gas and Fracturing: History

Natural gas is a naturally occurring hydrocarbon consisting primarily of methane, which is formed over millions of years as heat and pressure transform decaying plant and animal matter buried in sedimentary rock layers (Canadian Association of Petroleum Producers, 2012). Natural gas has been a part of Canada's energy mix since its discovery in 1859, and today accounts for 30% of Canada's energy needs and 11% of Ontario's energy needs (CAPP, 2012; OEB, 2015).

In North America, hydraulic fracturing was first used at the end of the 1940s (Yergin, 2011). However, modern day fracking is now being combined with multistage horizontal well drilling where wells are drilled vertically, kilometres below the surface, and after reaching the shale rock, are drilled horizontally (United States Environmental Protection Agency, 2014). Fractures are then created by pumping the hydraulic fracturing fluid consisting of water, proppant (sand which keeps the fractures open), and chemicals that wedge and enlarge fractures in the rock (USEPA, 2014). The gas then flows through these fractures to the horizontal well, and eventually pumped to the surface through the vertical well (USEPA, 2014). Hydraulic fracturing has actually been used in conventional natural gas extraction, but recent innovations have opened up unconventional fields (CAPP, 2012). There

has been natural gas production from shale in the Appalachian Mountains since the 1800s; however, it is only been recently that shale formations started to be a major source of North American gas supplies (IFC International, 2010). Recent attention has been directed to the controversies with hydraulic fracturing, more specifically the environmental concerns.

2.2 Environmental Concerns with Fracking

Fracking is highly debated by governments, energy companies, and environmental groups mainly because of its real and potential environmental effects. One of the main issues with hydraulic fracturing is the amount of water required per well.

Modern day fracking uses a technique called “slickwater” fracturing, which uses a much higher volume of water than previous fracking sites (Sumi, 2010).

Unconventional hydraulic fracturing requires 1 to 10 million gallons of water per well, compared with 50,000 gallons for conventional wells (Sumi, 2010). In order to transport a million gallons of water, an estimated 200 trucks are required (Sumi, 2010). With this comes concern for local air quality (Sumi, 2010). Operators generally try to extract water close to the fracking site, which can cause aquifer depletion, stream flow depletion, and disruption of natural flow regimes (Sumi, 2010). However, when comparing the water used to produce a unit of energy from other resources such as coal and nuclear power, hydraulic fracturing requires far less water (Lave and Lutz, 2014). Still, due to the high demand of water use, some areas might not be able to use hydraulic fracturing (Lave and Lutz, 2014). Although fracking uses a small amount of water intensity (water use per unit energy), the

total amount is still large. Because of this, there needs to be strict regulations in place.

The volume and type of chemicals used in fracking fluids is also an environmental concern. The typical fracking fluid contains over 200 different chemicals (Sumi, 2010). The fracking fluids could cause groundwater contamination from underground injection or accidents above the ground (Gordalla et al., 2013). The purpose of the fracking fluid is to transport the proppant into the well and stabilize the pressure of the fracture (Gordalla et al., 2013). The design of the fluid is unique to each drilling site as it must suit the different properties of the formation (permeability, water saturation, capillary effects) and the conditions of the fracking operation (ground pressure and temperature) (Gordalla et al., 2013). Health workers and operators could be exposed to the fracking fluids if a fluid spill was to occur (Sumi, 2010). Although most of the fracking fluid is composed of water and a small percentage is chemicals, the large quantity of fracking fluid still leads to a lot of chemicals being used. Chemical disclosure of these chemicals is becoming more common in jurisdictions.

In addition to the fracking fluid, methane (the main component of natural gas) in some places has been found in drinking water wells of homes closer to active wells compared to homes further away (Lave and Lutz, 2014). However, because there was no baseline data pre-fracking, it was impossible to tell if this methane was a result of the fracking operation or from natural seepage of methane to the groundwater (Lave and Lutz, 2014). Due to a lack of preexisting data, it is difficult to determine if fracking operations do in fact cause groundwater contamination. When

baseline data was obtained and compared with data after fracking, some operations in Pennsylvania had no change in methane levels, where as in northern Texas there was an observed increase (Lave and Lutz, 2014). As there is a potential for groundwater contamination, it is clear that baseline data is needed, and is addressed in the recommendations section.

There has also been debate whether fracking causes seismic activity, which can lead to earthquakes. According to CAPP (2012), hydraulic fracturing can cause seismic activity; however, the level is microseismic. The process of injecting pressurized fluids into the shale rock releases energy and can cause sub-surface microseismic events (CAPP, 2012). Oil and gas companies argue that the seismic events are contained in the area where gas is extracted (deep underground) and pose no risk to people, the environment, or structures on the surface (CAPP, 2012). According to Skoumal, Brudzinski, and Currie (2015) hydraulic fracturing fluids could raise fluid pressures in a pre-existing fault or fracture zone, which could reduce the normal stress of the fault and cause a fault slip. Seismic events associated with fracking can occur near or up to 100 metres from a well (Skoumal et al., 2015). In recent years, America has had over 100,000 wells hydraulically fracked with the largest induced earthquake only being a magnitude 3.6 on the Richter scale (Ellsworth, 2013).

2.3 Cost Effectiveness and Economic Benefits

Although fracking is believed to degrade the environment, many energy companies use it because it is a cost effective way to extract natural gas. According to Fitzgerald (2013), hydraulic fracturing is one process that has transformed the energy industry over the past 15 years. There have been four innovations that have changed fracking over its lifetime: 1) larger volumes of fluid and proppant are used; 2) slickwater fracturing has been created, which enhances permeability by adding additional lubrication and provides cleaner fractures; 3) the improvement of multistage jobs which gives additional fracks per well, allowing for more gas flow; and 4) changing the chemicals that are used in the injection fluid which allow for a greater yield of natural gas (Fitzgerald, 2013). Oil companies argue that fracking is a cost effective extraction technique as operators would have to drill hundreds or thousands of wellbores in order to match the contact provided by one fracked well (Fitzgerald, 2013). This is because fracking generally involves horizontal drilling (as opposed to vertical drilling in the conventional use), which can extract more gas using only one well (Fitzgerald, 2013).

Along with cost effectiveness, hydraulic fracturing does contribute to countries' economies. The oil and gas industry in Texas employs over 200,000 people, with over half coming from the shale gas industry, and contributes over \$200 billion (USD) to the state's economy (Davis, 2012). More specifically, shale gas extraction in the United States using hydraulic fracturing, contributed \$36 billion to the country's economy in 2011 and caused a drop in natural gas imports by 25 percent from 2007 to 2011 (American Enterprise Institute, 2013). The oil and gas

industry currently contributes 500,000 jobs across Canada and is expected to contribute \$3.5 trillion to the Canadian economy in the next 25 years (Natural Resources Canada, 2012). Shale gas development in Canada contributes over 300,000 direct jobs and 10% of Canada's total GDP (Natural Resources Canada, 2014). Given the economic benefits and the environmental consequences of hydraulic fracturing, nations and jurisdictions have decided to regulate fracking differently, some being supporters while others applying moratoriums or outright bans. In the next section, the paper reviews the scope of fracking regulation in places outside North America, and also in the United States and Canada.

3.0 Fracking Outside North America

European shale gas development is still very new, and unlike North America, there are very few wells being explored using unconventional methods, including fracking (Boersma & Johnson, 2012). France and Bulgaria are the only two countries in the world to have completely banned hydraulic fracturing (Boersma & Johnson, 2012). A vested interest in nuclear energy keeps France from likely using fracking for its energy needs. Poland and the UK have seen some interest in fracking and both have potential shale plays along with government support (Sergie & McBride, 2015; Kavanagh, 2014). Hydraulic fracturing has been used in the UK, mostly for conventional purposes; however, recent attention has turned to the use of fracking for unconventional shale gas (The Royal Society, 2012). A UK energy company is planning on testing two different wells in the Bowland Basin, with hopes of showing the commercial potential (Kavanagh, 2014). The UK shale gas and oil industry has welcomed community engagement in the planning process as well as creating an economic package to those areas where fracking would take place. During the exploration process, the community will receive £100,000 per well-site as well as 1% of revenues at the production stage (Cronin, n.d.).

In Poland, where government enthusiasm is high and public opposition is low, as of 2012 there were only six wells drilled for natural gas extraction (Boersma & Johnson, 2012). In 2014 a London based company withdrew their investment in a well drilled in Poland's Baltic Basin. Although gas and oil were extracted, the flow rates were not profitable. However, government support for fracking in Poland is

still high, as Poland wants to minimize their dependence on Russian-supplied gas (Kavanagh, 2014).

3.1 United States

Projections are that the increased extraction of shale gas using hydraulic fracturing will make the United States a net exporter of liquefied natural gas (LNG) in 2016 (Boersma & Johnson, 2012). In 2010 the US production of natural gas was 5 tcf and is likely to triple by 2035 (Boersma & Johnson, 2012). Many states have taken different regulations towards fracking. Early adopters of shale gas, including Texas, Oklahoma, and Pennsylvania, are extensively using fracking methods to extract natural gas to promote job creation, state income, and economic development (Boersma & Johnson, 2012). However, other states such as New York, Delaware, Vermont, and New Jersey all are very reluctant to use unconventional gas extraction methods (Boersma & Johnson, 2012). New York currently has a moratorium on hydraulic fracturing and even if it was lifted, fracking is unlikely to take place because of strict regulations on shale gas drilling in the upstate area that supplies most of New York's drinking water (Sumi, 2010). As companies are required to conduct an environmental impact review for every proposed well in New York, this is one reason why there is difficulty in using hydraulic fracturing (Sumi, 2010).

4.0 Fracking in Canada

Canada has been producing natural gas since the middle of the 19th century; however, production has increased in the second half of the 20th century due to the use of hydraulic fracturing in large reserves in Alberta and BC (Council for Canadian Academics, 2014). Canada's conventional reserves have been declining since 2001 and private companies have been using unconventional methods such as hydraulic fracturing to fill the gap (Council for Canadian Academics, 2014). There is an estimated 700-1000 tcf of shale gas in Canada, with the majority of the shale being "sweet" (containing no sulfur content) (Council for Canadian Academics, 2014).

In Canada, the federal government has very little control over hydraulic fracturing (Schroeck & Karisny, 2013). Most of the power to regulate natural gas extraction is delegated to the provinces by the Canadian Constitution (Schroeck & Karisny, 2013). The federal government has jurisdiction over interprovincial and international natural gas projects and when the drilling is on federally owned lands (Schroeck & Karisny, 2013). The *Canadian Fisheries Act* does give federal jurisdiction over natural gas extraction to protect against impacts to fish populations (Schroeck & Karisny, 2013). Canadian production of shale gas is substantial in BC with potential in Quebec, New Brunswick, and Nova Scotia (Council of Canadian Academics, 2014). Western Canadian provinces such as BC and Alberta have had ongoing oil and gas development with public acceptance, with most of the land that fracking takes place on, crown lands, being owned by the provincial government (Council of Canadian Academics, 2014). In Eastern Canada, no significant shale gas development has occurred in the past half century, with

much of the land with potential shale gas reserves being privately owned (Council of Canadian Academics, 2014).

4.1 British Columbia

The majority of shale gas development in Canada takes place in the Horn River and Montney Basins in BC, known as the biggest frack in the world (Council for Canadian Academics, 2014; The Council of Canadians, 2014). The regulatory board responsible for regulating hydraulic fracturing in BC is the BC Oil and Gas Commission (Council for Canadian Academics, 2014). The BC Oil and Gas Commission is responsible for the entire life cycle of the well (exploration, production, to reclamation) (BC Oil & Gas Commission, 2014). Hydraulic fracturing has been used in BC since 1960 but more intensively since 2004 for unconventional formations (BC Oil & Gas Commission, 2014). In 2013, 86% of new wells in BC were hydraulically fractured (BC Oil & Gas Commission, 2014). Since 2005, 7300 wells have been fracked with almost 1000 wells being permitted annually. The estimated resources of BC's shale are 1000 tcf of natural gas (The Council of Canadians, 2013). There are current proposals for Liquefied Natural Gas plants in northern BC, and an already approved fracking pipeline that would transport natural gas from eastern BC to the coast (The Council of Canadians, 2013). There has been controversy with hydraulic fracturing in BC as well. In 2013, Sierra Club BC and the Wilderness Committee sued the BC oil and Gas Commission and an energy company, Encana, over their short-term water approvals, which violates BC's Water Act (The Council of Canadians, 2013).

4.2 Alberta

Alberta has the most mature oil and gas industry in Canada with 400,000 conventional wells drilled at the end of 2012 (Council for Canadian Academics, 2014). Since the 1950s, 171,000 wells have been fractured in Alberta and there are fifteen prospective shale gas formations in the province (The Council of Canadians, 2013). The agency responsible for regulation of oil and gas development is The Alberta Energy Regulator. Amongst other things, this agency is responsible for providing guidelines on environmental issues, deep-well water disposal, and water management associated with the oil and gas industry in Alberta (Council for Canadian Academics, 2014). Although Alberta is known as a major oil and gas producing province in Canada, hydraulic fracturing is relatively new to Alberta (The Council of Canadians, 2013). Conventional fracking has been used in Alberta for 50 years, but multistage horizontal fracking has been introduced recently, contributing to an increase in Alberta's oil production by 14 percent from 2011 to 2012 by giving more access to Alberta's shale (The Council of Canadians, 2013). Much like BC, there is controversy over the use of fracking in Alberta. A private landowner sued Encana, Alberta Environment, and the Energy Resources Conservation Board over contamination of the owner's water well; however, the land-owner ended up losing the lawsuit (The Council of Canadians, 2013).

4.3 Quebec

Most of the primary shale gas in Quebec is the Utica Shale, which underlies the south shore of the St. Lawrence River (Council of Canadian Academics, 2014). Exploration

is still in its early stage, and local opposition to shale gas development using hydraulic fracturing in Quebec has been substantial (Council of Canadian Academics, 2014). As a result, the government of Quebec has taken a precautionary approach in evaluating the environmental risks and developing a regulatory framework before deciding if hydraulic fracturing can proceed (Council of Canadian Academics, 2014). In 2011, the provincial government extended a moratorium on hydraulic fracturing and shale gas development in the province until further research is conducted on the environmental concerns (Council of Canadian Academics, 2014).

Although fracking is controversial in provinces like British Columbia, Alberta, and Quebec, there is literature and knowledge on the subject in these provinces. Ontario can be seen as somewhat of an anomaly in this respect, as there is not much research on fracking, specifically multistage horizontal fracking in the province. The rest of this paper will discuss hydraulic fracturing in Ontario.

5.0 Fracking in Ontario

Ontario's history of oil and gas production dates back to the 1800s as the first commercial natural gas well in Ontario was drilled in 1889 in the Essex County area (Environmental Commissioner of Ontario, 2011). According to one interviewee, conventional fracking has taken place for many years in Ontario; however, unconventional multistage horizontal fracking has not (Interviewee D, January 28th, 2015). The multistage horizontal fracking is what is being discussed in this paper. To date there has been only one exploratory well drilled in Ontario, located near Chatham in 2011. However, it was plugged without completing the fracking processes due to inadequate natural gas volumes (Environmental Commissioner of Ontario, 2011). Despite this low level of activity, some media reports indicate that some companies are engaging in the early stages of fracking as they are obtaining the mineral rights for natural gas in southern Ontario (Environmental Commissioner of Ontario, 2013). According to the Environmental Commissioner of Ontario (2011), an increase in local production of natural gas could help lessen the strain on the existing supply since Ontario's natural gas demands are equal to 30% of Canadian gas consumption.

5.1 Ontario's Shale Potential

There are three major locations for hydraulic fracturing potential in Ontario: 1) Blue Mountain Formation and Collingwood Shale; 2) Marcellus Shale; and 3) Kettle Point Formation (Carter, Fortner, & Beland-Otis, n.d). The Collingwood Shale covers an area of 25,000 km² and the Blue Mountain Formation covers an area of 75,000 km²

(Carter et al., n.d). The Marcellus Shale covers an area of 4700 km², which is mostly beneath Lake Erie, while the Kettle Point Formation covers an area of 9500 km², which is located 50% beneath Lake Erie (Carter et al., n.d). This information is further supported in Beland Otis' article on the potential Ordovician shale gas units in Southern Ontario (Beland Otis, 2012). Figure 1 shows where these formations are in the province of Ontario.

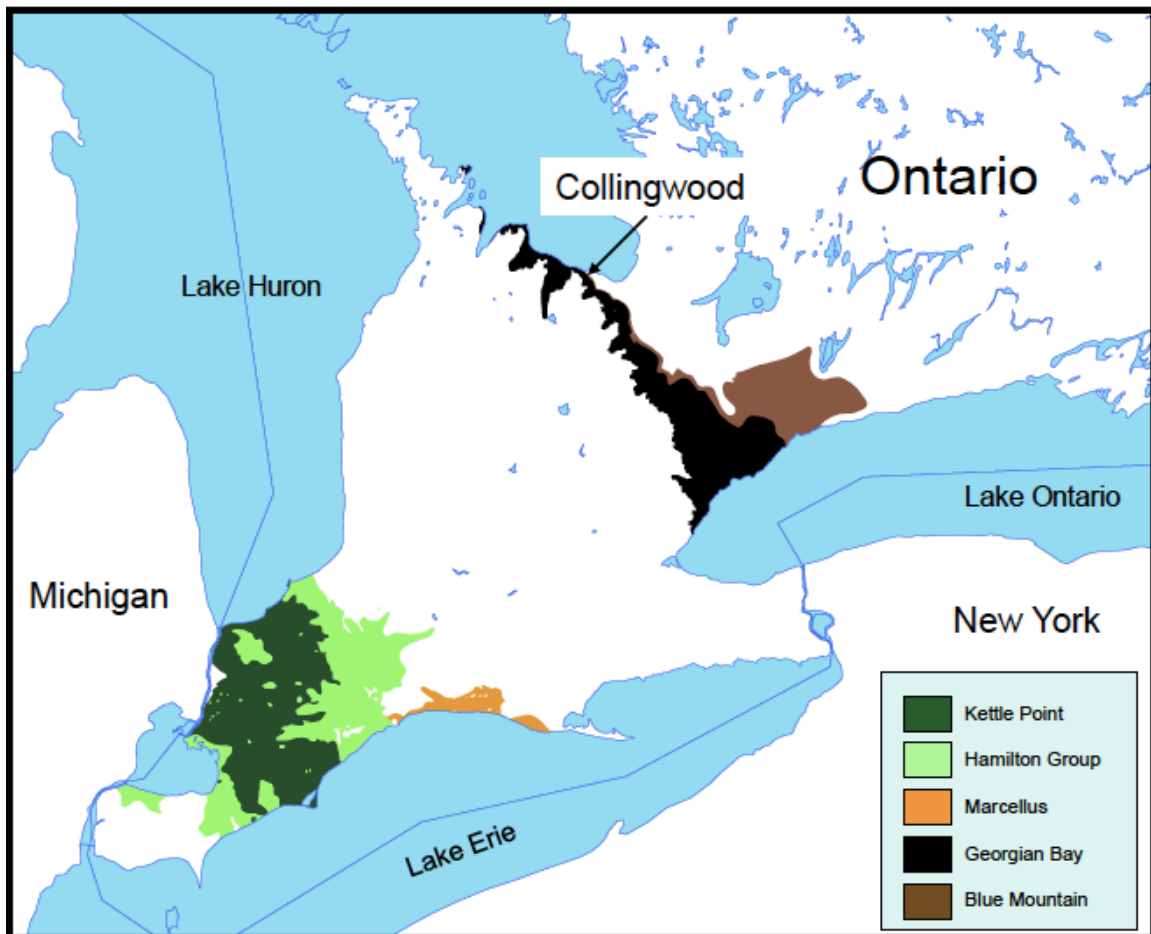


Figure 1. Potential shale gas plays in Ontario. From *Shale Gas Opportunities in Southern Ontario – and Update*, by T. Carter, L. Fortner, and C. Beland-Otis, n.d, retrieved from http://www.ogsrlibrary.com/downloads/Ontario_Shale_Gas_OPI_2009_Nov11.pdf

5.2 Current Regulatory Framework for Hydraulic Fracturing in Ontario

In Ontario, all oil and gas activities are regulated by the Ministry of Natural Resources and Forestry (MNRF) and the Ontario Energy Board (OEB) (Schroek &

Karisny, 2013). The MNR regulates the permitting, construction, and inspection of natural gas wells while the Ontario Energy Board controls natural gas production and price setting (Schroeck & Karisny, 2013). In order to drill a natural gas well in Ontario, a well owner must apply for a well license with the MNR under the *Oil, Gas, and Salt Resources Act*. After the well is constructed, gas production may begin and the producing well comes under the jurisdiction of the OEB (Schroeck & Karisny, 2013). The well owner, if selling gas to low volume consumers (residential or small commercial consumers), must apply for a gas marketer license to prevent utility price gouging and interruptions in service (Schroeck & Karisny, 2013). Ontario currently permits oil and gas drilling under the Great Lakes and has 500 conventional (onshore and offshore) wells producing natural gas from under the bed of Lake Erie, without the use of hydraulic fracturing (Schroeck & Karisny, 2013). To date, Ontario has not implemented a comprehensive fracking regulatory system since there are no current horizontal fracking operations in the province; however, if Ontario was to permit fracking in the future, a separate regulatory program would need to be in place to address this issue (Schroeck & Karisny, 2013). The following sections provide an overview of the state of regulatory development in Ontario based on interviews with government experts responsible for, or knowledge about, fracking potential in the province.

6.0 Survey and Interview Results

The following sections will discuss the results from the interviews of government officials as well as the province wide survey of municipal leaders. The sections are framed into different themes regarding hydraulic fracturing in Ontario.

6.1 Current State of Horizontal Fracking in Ontario

It is important to discuss the current state of fracking in Ontario given the uncertainty surrounding its use. Ontario's gas industry is based on conventional extraction methods. Therefore, overtime there have been changes to policies governing conventional extraction, but not related to unconventional fracking (Interviewee C, January 13th, 2015). "We haven't really done anything on fracking here...There is no fracking and there aren't any proposals"(Interviewee C, January 13th, 2015). According to Interviewee C, given that there is no activity, it can be considered a non-event. This does not mean there has not been progress on potential policies. According to Interviewee C, the province is looking at Ontario's current laws and potential policy frameworks before any decisions are to be made about the potential use of high volume fracking in the province. If the government was to make any proposals in terms of changing laws and policies there would be consultation with First Nations, stakeholders, and the public as this is a requirement under the Environmental Bill of Rights (Interviewee C, January 13th, 2015). Some municipal planners have been in contact with the provincial government, curious about what exactly hydraulic fracturing is. However this is more of a "reactive

engagement, not proactive” (Interviewee C, January 13th, 2015). Currently, exploration is not occurring and there are no wells being drilled for hydraulic fracturing of natural gas (Interviewee C, January 13th 2015). The government of Ontario has no stated position on multistage horizontal fracking; however, it would be allowed since vertical fracking has occurred in Ontario (Interviewee D, January 28th, 2015). As of now there is lots of discussion within government ministries but “no applications for test wells that we know of” (Interviewee D, January 28th 2015).

Interviewee A, another government employee familiar with the issue, explained that there is not a moratorium on fracking in Ontario, there is just nothing currently happening. There are two companies that have holdings and own land property containing natural gas but have yet to develop it (Interviewee A, December 4th, 2014). The Ontario government is committed to a review of the environmental consequences before fracking can take place (Interviewee A, December 4th, 2014). The Ontario government is looking into what types of policies are needed if fracking was to take place, but at this stage, no information on potential policy frameworks were expressed: “because there is a review on the way, I can’t comment” (Interviewee C, January 13th, 2015). The interviews revealed that there are no current applications for wells to be used for unconventional fracking in Ontario, however the provincial government is looking into laws and frameworks for the potential use.

6.2 Ontario Municipalities and Fracking

Fracking operations produce challenging interactions between local and sub-national governments. To set a context for the local-subnational challenges that Ontario could face, a brief case study of Pennsylvania's fracking industry is discussed. Although a significant contributor to the local governments of Pennsylvania, horizontal fracking has led to many environmental consequences such as water contamination, strained community relations, and degraded air quality (Rabe & Borick, 2013). The agency responsible for governing fracking in Pennsylvania is the Bureau of Oil and Gas Management in the Pennsylvania Department of Environmental Protection (Rabe & Borick, 2013). However, much like Ontario, the regulations outlining permit and inspection for conventional drilling were created before hydraulic fracturing was ever used, and the agenda of the Bureau has been challenged as it has roles in both promoting fossil fuels while also protecting the environment (Rabe & Borick, 2013).

The Unconventional Gas Well Impact Fee Act (*Act 13*) was created in 2012, which is seen to maximize short-term development of the shale in Pennsylvania and unfairly constraining local governments' authority (Rabe & Borick, 2013). This is also known as the "impact fee," which put the burden of implementation onto local governments, with the state of Pennsylvania itself avoiding responsibility (Rabe & Borick, 2013). This act also is a deterrent to local governments from creating other environmental protection plans that are not defined in the act, as the local governments could lose revenues if there is noncompliance (Rabe & Borick, 2013). With this act, the state of Pennsylvania also has the power to withhold impact fee

revenue from local governments if the state finds local governments are being inconsistent with the provisions in the Act. In 2012, the state withheld revenues from seven local municipalities (Rabe & Borick, 2013). A survey was conducted in 2011 and 2012, which found strong public opposition to many of the legislations of Act 13 (Rabe & Borick, 2013). This example highlights the complex and important relationship between local and subnational authorities in fracking operations. In other jurisdictions around the world, it is often local governments and residents that are most concerned and outspoken about concerns from fracking. For these reasons, this project presents original results from a survey of Ontario municipal elected leaders' perspectives on horizontal fracking of unconventional shale gas. Ontario is in a unique situation because it is one of the few provinces, other than New Brunswick, to have had conventional fracking operations, however not one well has been drilled using unconventional methods. Even more surprising given the fact that there are potential shale gas plays in Ontario.

To start, it is important to discuss how familiar municipal leaders are with fracking in general. The survey asked, "How familiar would you say you are with hydraulic fracturing?" Looking at Figure 2, out of the 50 people who answered the survey, 62% answered they are "somewhat familiar" with fracking; this meant they had heard of it, understood it, but did not know many details. Twenty-two percent of respondents answered they are "mostly unfamiliar" with fracking; and only 16% considered themselves "very familiar" with fracking meaning they knew a great deal about it.

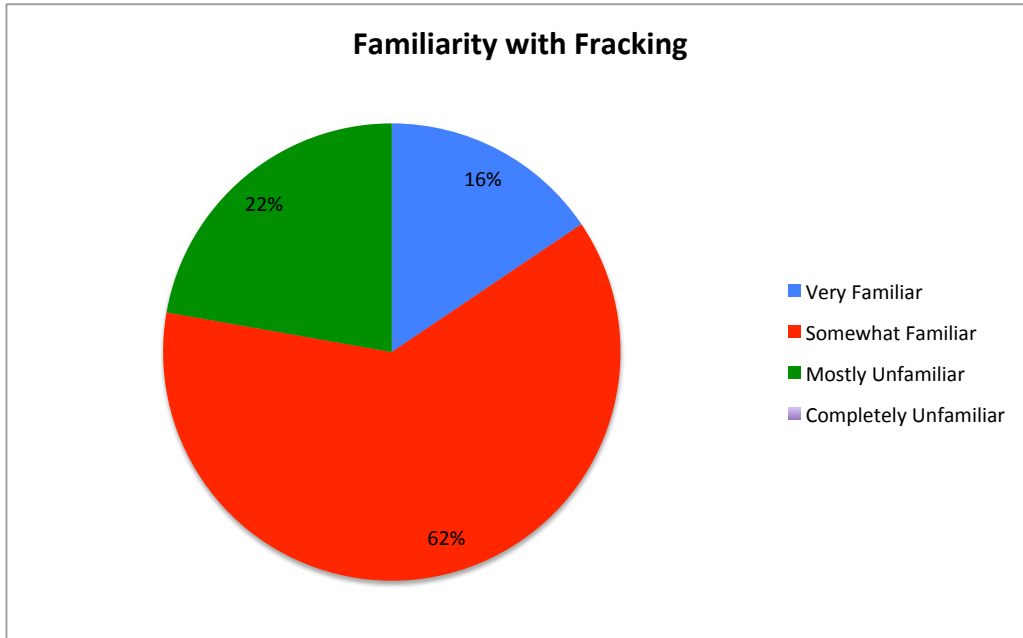


Figure 2. Local governments' familiarity with hydraulic fracturing.

How prominent is fracking in Ontario municipalities? The survey asked, "To what extent, if at all, would you say current or potential fracking within your jurisdiction is a topic of discussion, either in the community at large or within your jurisdiction's government?" Looking at Figure 3, 82% answered that fracking was "not an issue" meaning that there has not been any discussion of fracking within the municipality now or in the past. Eleven percent answered that fracking is a "minor issue," meaning that fracking has been discussed, but not extensively, and 7% (3 out of 45) answered that fracking is a "major issue," meaning that fracking has been discussed extensively within the jurisdiction.

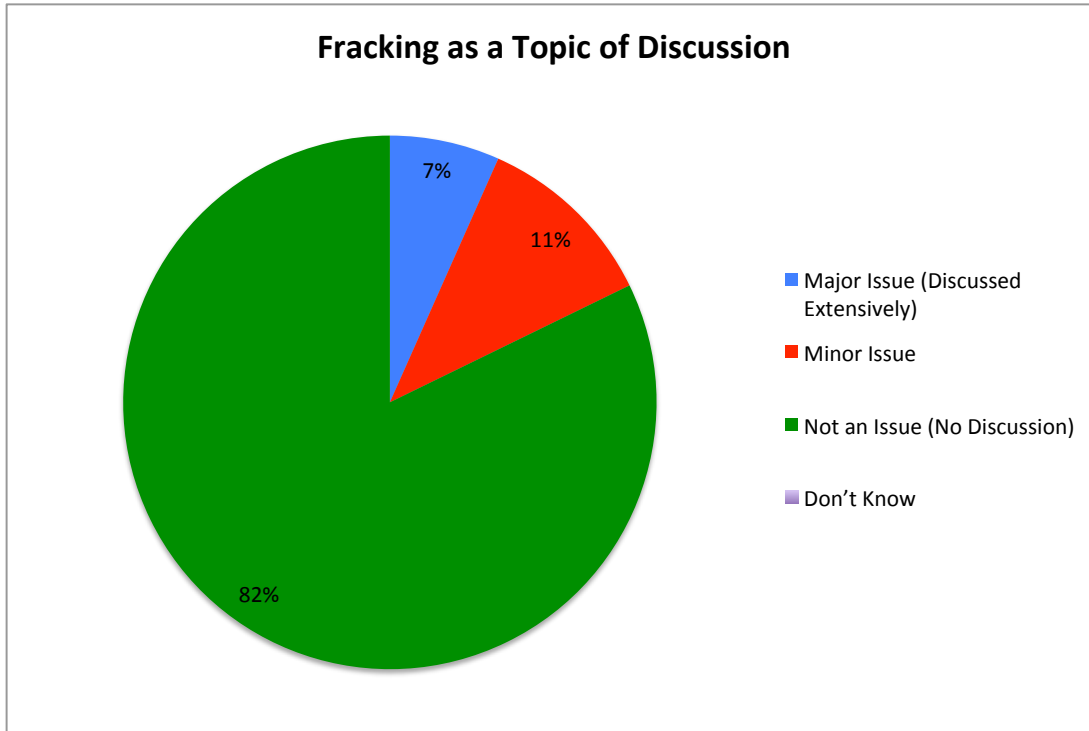


Figure 3. How often hydraulic fracturing is discussed in local governments.

These results indicate that although a high percentage of municipal leaders answered they are somewhat familiar with fracking, an overwhelming number answered that fracking is not a topic of discussion. It is clear that fracking is currently not a topic of discussion in the jurisdictions that responded to the survey, but does remain an important issue in a small number of responding municipalities. When looking at the 3 municipalities that make up the 7% who responded fracking is a “major issue” it is interesting to note that their jurisdiction is not in the vicinity of the potential shale gas play locations discussed earlier. Only 2 of the municipalities are only near a potential shale gas play and not actually in it.

6.3 Municipal Support for Fracking

To better understand how fracking resonates with municipal leaders, the survey asked about the degree of support and opposition to horizontal fracking. Figure 4 shows the results. Leaders were asked, “We are interested in sources of support or opposition to the potential use of hydraulic fracturing in your community. In your opinion, do the following people or groups either support or oppose the use of fracking in your jurisdiction?” 14% responded that their jurisdiction’s council strongly opposed the potential use of fracking in their community. 25% responded that their jurisdiction’s council neither supported nor opposed the potential use of fracking in their jurisdiction. Less than 5% responded that their jurisdiction’s council strongly supports the potential use of fracking in their jurisdiction. The conclusion that can be drawn from these results is that from the perspective of local governments, there is not a high level of support for horizontal fracking in Ontario. This can be seen in the fact that there is currently an absence of unconventional natural gas fracking in Ontario.

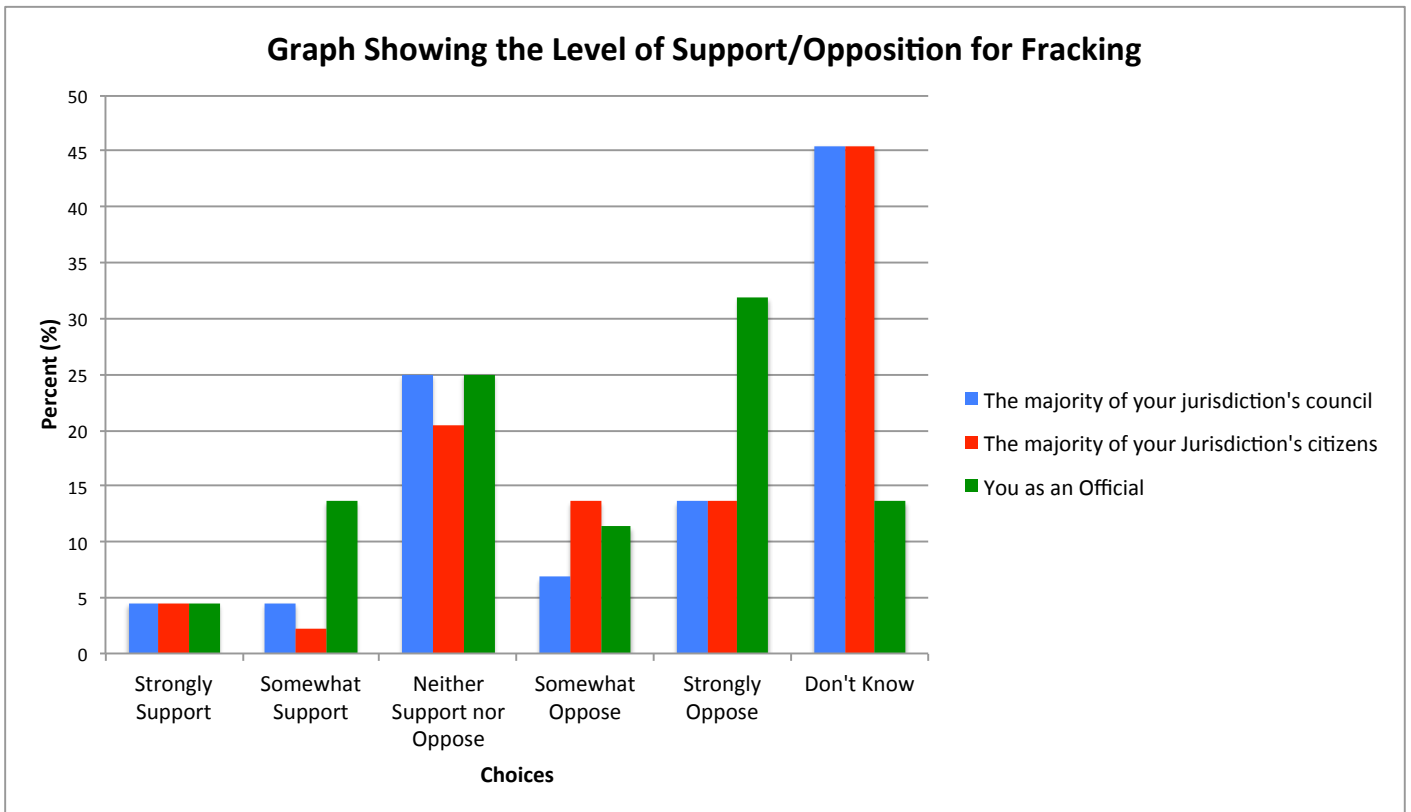


Figure 4. Local governments' level of support or opposition for horizontal fracking.

So far the survey has indicated that although municipal leaders see themselves familiar with fracking, it is not an issue in their jurisdiction, with a low level of support. The following section will explain what role municipal governments should play if unconventional fracking was to occur in Ontario.

6.4 Municipal Governments' Engagement

If hydraulic fracturing was to take place in Ontario, how might municipalities be engaged in the process? It is important to consider what view municipal governments of Ontario have on fracking and how they should be engaged. If Ontario was to use hydraulic fracturing to extract natural gas, municipalities would be affected, as fracking is a local land issue. To what extent should municipalities

play a role or desire to play a role in influencing decisions about fracking in Ontario and in the development of a provincial policy framework around fracking? In interviews with provincial officials one of the central issues discussed was what role municipalities should play in the regulation and oversight over the processes.

One interviewee believes that when looking at other jurisdictions that have hydraulic fracturing, municipalities have played a significant role and if multistage, horizontal fracking was to occur in Ontario, it would be “important to engage them in the process” (Interviewee C, January 13th, 2015). In general, however, because municipal officials in Ontario do not have experience with oil and gas industries, it would be important to work with them to determine what role they could play, which would be the social and planning side. The municipalities themselves have an interest in participating as well. This is because there are many ways that fracking may produce costs and benefits to municipalities and different ways that authority over fracking operations can be shared. In Pennsylvania there is an Impact Fee, which calculates the dollars coming into the state and is distributed to the municipalities (Interviewee C, January 13th, 2015).

To investigate how municipal governments in Ontario feel about authority for fracking, the survey asked municipal leaders to give their opinion on what level of government (federal, provincial, or municipal) should have authority over hydraulic fracturing. The survey asked, “For each of the following entities, please indicate whether you think they should have a great deal of authority, some authority, or no authority for such decisions regarding fracking.” Figure 5 shows that 55% of respondents believe that the municipal government should have “a

great deal of authority,” 52% believe the provincial government should have “a great deal of authority,” and 38% believe the federal government should have “a great deal of authority.” This latter response is interesting given that the federal government has no jurisdiction over fracking in provinces.

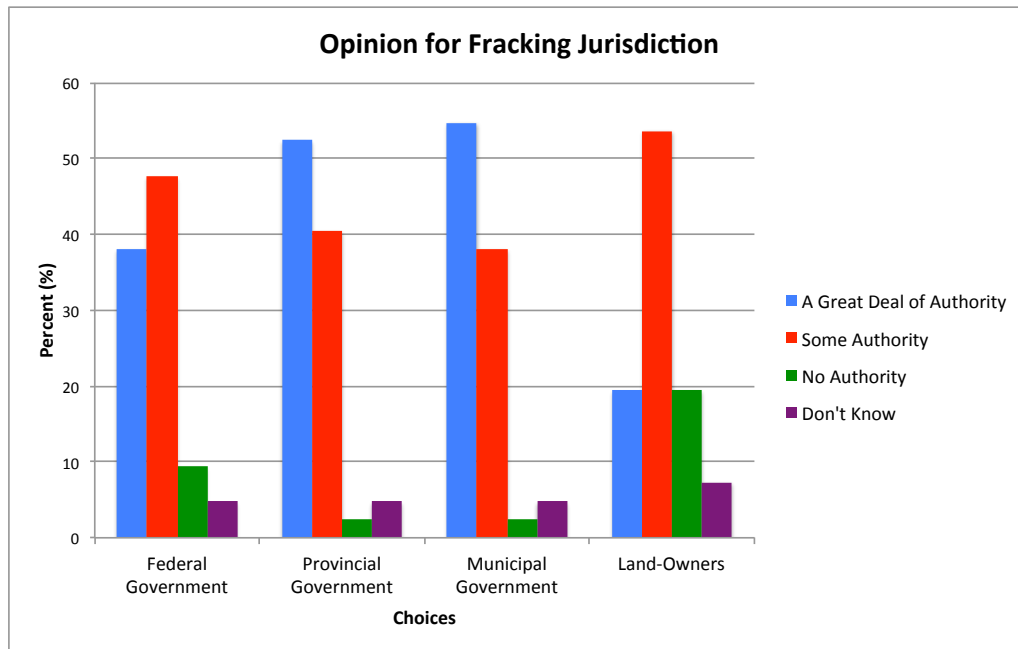


Figure 5. Municipal leaders’ opinion for jurisdiction over hydraulic fracturing

Out of the three possible level of governments, over half of the respondents of the survey believe that if fracking was to occur in Ontario, municipal governments should have a great deal of authority. In the comment section of the survey, one municipal leader commented, “municipal input before fracturing occurs.” Next to the municipal government, municipal leaders believed that the provincial government should have the second most amount of authority as it received the second highest responses for “a great deal of authority” (52%). In short, the survey reveals that municipal leaders believe they and the province should have a role. It is interesting to note that 54% of respondents believe that land-owners should also have “some authority” if fracking was to take place in Ontario. According to this,

municipal leaders believe land-owners are also entitled to a say over fracking operations.

In another interview, a government official said that municipal governments should “definitely” play a role in the policy framework if hydraulic fracturing for unconventional natural gas was to take place in Ontario (Interviewee A, December 4th, 2014). The interviewee referred to the conflict that has emerged around renewable energy projects not supported by the community and the value of having communities on side if fracking proceeded: it would “be scary if [the provincial government] would do that [what it did with renewable energy project siting] with fracking” (Interviewee A, December 4th, 2014).

Interviewee B believes that it is beneficial to have municipal support and engagement if fracking for unconventional shale gas was to occur. When a certain municipality does not want fracking to take place, there is a lot of tension between locals and government. “Municipalities bear the brunt of the complaints... A lot of citizens could complain to the local councillor” especially with the issues fracking causes: local air quality, noise, land degradation (Interviewee B, January 9th, 2015). There would be benefits to have the discussion with a potential municipality before, to prevent such occurrences (Interviewee B, January 9th, 2015). Municipal governments are not currently involved in the permitting of natural gas extraction, and it is unlikely that this will change, as it is regulated by the provincial government. However, because horizontal fracking is much more intrusive than conventional extraction techniques, it will be wise if the province includes consultation at the municipal level, which does not exist now (Interviewee D,

January 28th, 2015). The following section will explain potential reasons for the absence of unconventional fracking in Ontario.

7.0 Explanation of Absence of Fracking in Ontario

Given that there are areas in Ontario where natural gas could be extracted using hydraulic fracturing, what explains the absence of extraction in Ontario? This paper finds the main reasons for such an absence are: 1) the geological factors of Ontario's shale; 2) lack of investment due to other jurisdictions already having a solidified conventional/unconventional fracking industry; and 3) low local and provincial support to conduct fracking.

Geology is an important factor in determining whether a fracked well will be economically feasible or not. As fracking a well can account for twenty-five percent of the total drilling cost, it is important that the geological features of the shale be favorable for a productive well (Fitzgerald, 2013). If, however, the geological conditions do not favour a productive well, it would not be beneficial to use horizontal hydraulic fracturing. In Ontario the "geology is not as promising" as the western provinces of Canada (Interviewee B, January 9th, 2015). Based on the one exploratory well that was drilled, the geological formation of Ontario's shale are "B list," meaning that the gas content of the formations is expected to be low (Interviewee D, January 28th, 2015). The shale gas plays (shale rock containing natural gas) that are found in Ontario are such that most of the shale is too shallow and not as thick as they are in other places (Interviewee C, January 13th, 2015). The shallow nature of Ontario's shale makes the probability of seismic activity and flowback of the fracking fluid greater (Interviewee B, January 9th, 2015). This means that oil and gas companies would not be able to use as high a pressure when fracking, making it less economically feasible (Interviewee B, January 9th, 2015). In

the areas identified as potential shale gas plays in Ontario, only the Blue Mountain play has a distance from the surface to the top of the shale greater than 250 metres. The Collingwood Shale, Marcellus Shale, and Kettle Point Shales in Ontario all have a depth that ranges from 175 metres to 225 metres below the earth's surface to the top of the shale play (Carter et al., n.d).

Along with geological issues, the fact that British Columbia, more recently Alberta, and many American states have a respected fracking industry makes the incentives to experiment in Ontario low. "If people are going to invest money, they want a sure return" (Interviewee C, January 13th, 2015). British Columbia and Alberta, for example, already have proven resources for hydraulic fracturing and along with a low price of natural gas, this discourages companies from exploring in Ontario for unconventional shale (Interviewee C, January 13th, 2015). If companies know they can go to other places for natural gas, they will be less inclined to produce in an area with potentially poor geology (Interviewee C, January 13th, 2015).

Another reason for slow investment in Ontario is the lack of clear encouragement or support for exploration by the Ontario and municipal governments. Compared to British Columbia and Alberta, Ontario does not have a skilled labour force for hydraulic fracturing to "kick-start the industry" (Interviewee B, January 9th, 2015). Looking at Figure 6, 87% of the respondents answered that their municipality has no history regarding conventional natural gas extraction, with 7% having inactive traditional wells, and only 4% of the respondents with having current active conventional wells.

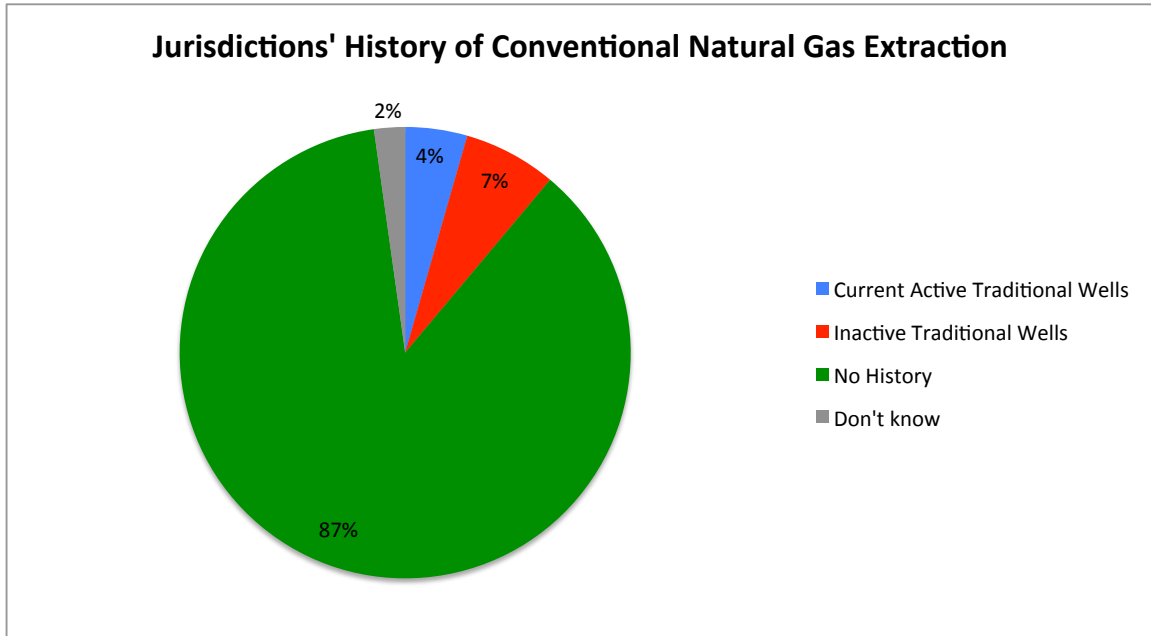


Figure 6. History of conventional natural gas extraction in local governments of Ontario.

Seeing that 87% of the respondents' municipalities have no history of conventional natural gas extraction could make the labour force needed and equipment required for unconventional natural gas extraction an issue.

The interviews and the survey reveal that there is no provincial policy currently on hydraulic fracturing for unconventional shale gas; however, the provincial government is conducting a review. In addition, if fracking of shale gas was to occur, municipal governments seem to want to have an active role in the planning process. The following section will discuss the likely future of unconventional fracking in Ontario.

8.0 The Future of Fracking in Ontario

Given the current absence and uncertainty of unconventional shale gas fracking in Ontario it is difficult to determine what the future of it will be in Ontario. Based on my interviews, government officials had mixed views; most interestingly, they didn't seem to agree if the province might consider fracking in future. According to one interviewee, "the answer is probably yes," that the province will consider allowing fracking. However, the interviewee was unsure how quickly it would develop or grow (Interviewee C, January 13th, 2015). Interviewee C said that Ontario is in an interesting situation. It is learning from other jurisdictions and can learn from their policies, more specifically what has worked and what hasn't. As Ontario doesn't have "anyone knocking on the door, we don't need to rush" (Interviewee C, January 13th, 2015). One of the biggest obstacles that would have to be overcome if fracking was to be used would be social acceptance. Much like nuclear power, where people always associate it with a catastrophic meltdown, there is a cloud of fear around hydraulic fracturing. "There is an emotional element that will contribute to the challenges" (Interviewee C, January 13th, 2015).

In contrast, according to a different interviewee, fracking in Ontario is unlikely: "I personally don't see fracking happening in Ontario, as the way Ontario's energy sector is structured, people don't want it" (Interviewee A, December 4th, 2015). This view is explained by the fact that Ontario does not need to start exploring their own shale plays as it is less costly to import natural gas from eastern United States. Because of this, Ontario has gone from a major exporter to a major importer of natural gas since the start of the century (Canadian Gas Association,

2015). “There is precedent in Ontario that public opposition will stop fracking” (Interviewee A, December 4th, 2014). However, because Ontario does not have a policy framework for hydraulic fracturing, one would need to be created. “Ontario would have to update regulations so they address unconventional extraction of natural gas using hydraulic fracturing” (Interviewee B, January 9th, 2015). Another interviewee, said that it is unlikely that multistage fracking will occur in Ontario’s future unless someone does more exploration and finds that the geology is in fact favourable, which is thought to be unlikely (Interviewee D, January 28th, 2015). The two biggest reasons for interviewees’ view that fracking is unlikely relates to the unfavourable geology and the lack of financing, dropping horizontal fracking from a high level of concern to a low level of concern (Interviewee D, January 28th, 2015).

How does natural gas fit into Ontario’s energy supply, and what is the future of natural gas in this mix? In Ontario, natural gas is used to mainly heat homes and businesses. The current mix of electricity sources in Ontario are nuclear, hydro, natural gas, coal, and wind/alternative sources, with nuclear accounting for 57% and natural gas accounting for 15% of the total (OEB, 2015). Ontario is currently relying on gas from western Canadian provinces and northeastern American states. It is hard to say exactly how natural gas will change in the future of Ontario’s energy supply and ultimately if this would encourage or discourage the use of unconventional fracking. Ontario is committed to increasing renewable energy as well as the continual use of nuclear power in the future (Ministry of Energy, 2015). Because of this, natural gas use would only increase conservatively, and therefore the likelihood of unconventional fracking being used very slim.

8.1 Municipal Policy on Fracking

The survey of municipal leaders asked them if they had adopted or implemented any policies or regulations in support or opposition to fracking. Figure 7 shows the results and reveals that municipalities themselves do not see horizontal fracking as part of their future. When asked if they are “likely to adopt any tax or other incentives, moratoria, or zoning changes that attempt to promote, restrict, or simply regulate hydraulic fracturing,” 87% of the respondents answered they have neither adopted nor likely to adopt any tax incentives; 78% answered they have neither adopted nor likely to adopt a local moratorium/ban on horizontal fracking; 82% answered they have neither adopted nor are likely to adopt local regulation/zoning conditions; and, 84% answered they have neither adopted nor likely to adopt an intergovernmental agreement with neighbouring jurisdictions. Only 2% answered their jurisdiction has adopted a local moratorium/ban on fracking and 2% answered their jurisdiction has adopted local regulations/zoning conditions for fracking. These results suggest that fracking is not a central area of concern and not taking up time on municipal agendas.

Looking at what jurisdictions have already adopted some hydraulic fracturing policy is interesting. The two jurisdictions that have adopted some fracking policy also responded to fracking being a “major issue” in their jurisdiction. Interestingly enough, the jurisdiction that has implemented a local moratorium/ban on fracking is not located near a prospective shale play. The jurisdiction that has implemented local regulations/zoning conditions is located near a shale gas play. This jurisdiction seems to be taking a proactive approach by implementing their

own regulations towards hydraulic fracturing. This explains both jurisdictions' reasoning for answering that fracking is a major issue, which is discussed extensively in their jurisdiction.

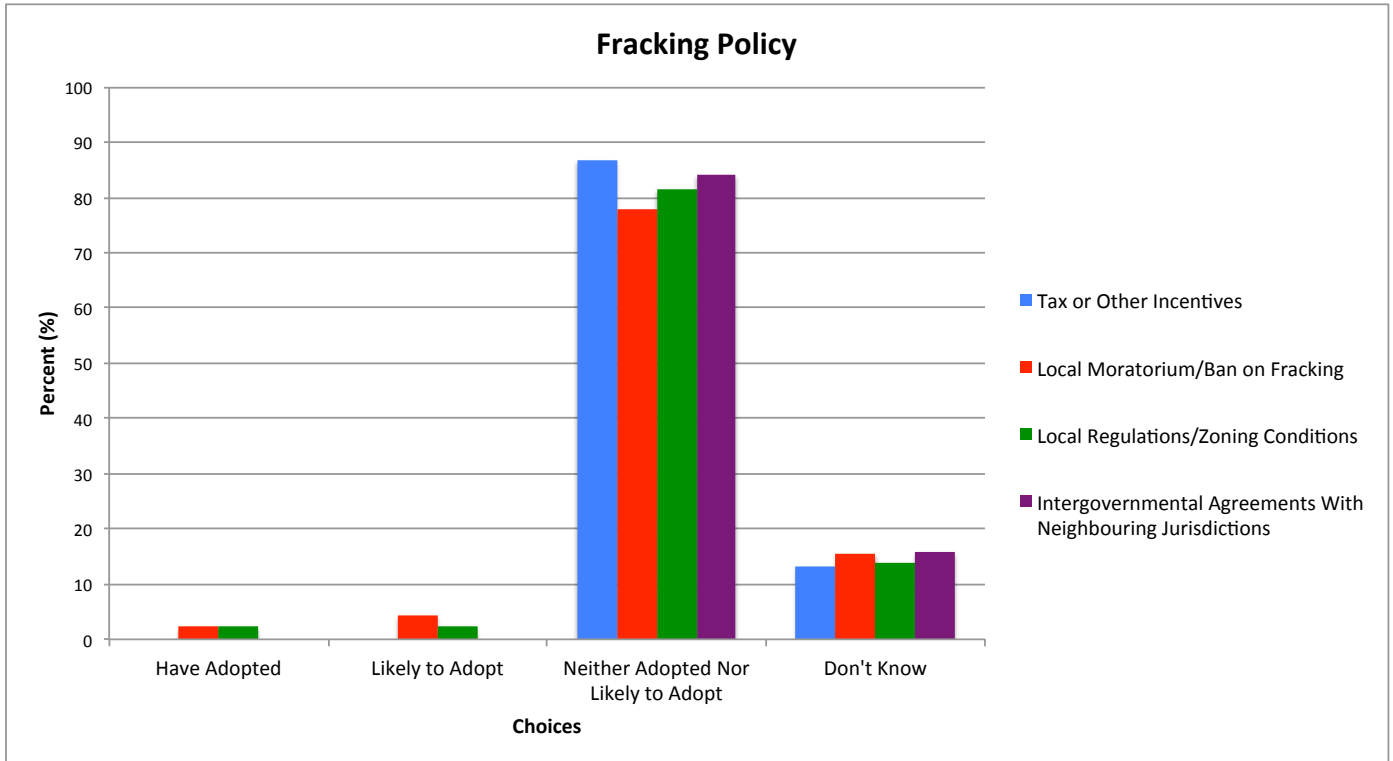


Figure 7. Different fracking policies municipalities of Ontario have adopted or are likely to adopt.

8.2 Factors Encouraging/Discouraging Potential Use of Unconventional Fracking

The survey also asked the municipal leaders to note what factors encouraged or discouraged consideration of fracking. Leaders were presented with a series of potential risks and benefits from fracking and then asked, “Even though your community does not have any current fracking operations, to what degree would you say the following items may encourage or discourage the use of fracking within your jurisdiction in the future?” Figure 8 shows the results from this question. The top factors that municipal officials believe significantly *discourages* the use of

horizontal fracking are: risk to water (48%), environmental damages from fracking (40%), risk to citizens' health (38%), and impact on property values (33%). The factors that municipal officials believe significantly *encourages* the use of horizontal fracking are: potential lower energy prices (from relying on own resources) (18%), job creation/economic development (13%), property tax revenue (13%), and environmental benefits from cleaner burning natural gas (10%).

It is clear that there is a far greater emphasis on factors that municipal leaders believe discourage the use of fracking as opposed to encourage. Written responses for the comment section had differing opinions. One respondent believed environmental protection is the top priority as their jurisdiction has a strong aboriginal presence and threatened and endangered species. Another respondent felt that it is hard to find an unbiased view on fracking and that there should be a way to get scientific information on fracking that is believable by the majority of the jurisdiction. When looking at what municipal leaders responded to what factors encourage or discourage the use of fracking, location of the municipalities did not significantly affect the choices. For factors that encourage the use of fracking, there was a mix of municipal leaders representing small and large jurisdictions both near and far from a shale play. The same trend was found for factors that discourage the use.

The results from the survey show that most municipalities are not taking a proactive approach to adopting policies and the factors that discourage the potential use outweigh the factors that encourage the use.

Graph Showing Factors that are Discouraging/Encouraging Use of Fracking in Jurisdictions

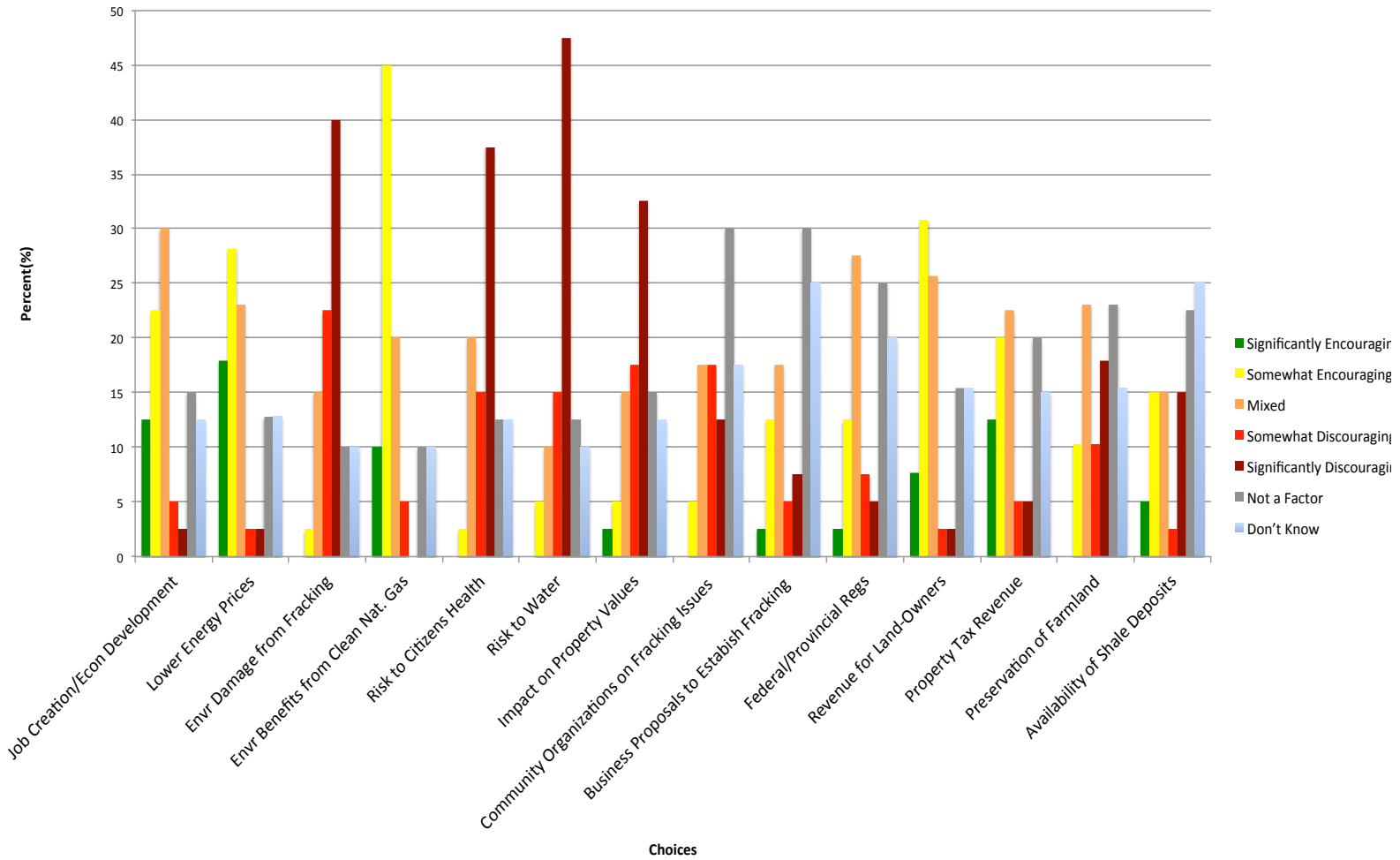


Figure 8. Factors municipal leaders believe that are encouraging/discouraging the potential use of fracking for shale gas in Ontario

8.3 Municipal Perspectives Compared with Public Opinion

The above results show an overall low level of support and concern for unconventional hydraulic fracturing amongst municipal leaders. Does this, however, match the opinions of the general public? In 2014, Brown et al. surveyed US and Canadian citizens living in the Great Lakes Basin. This survey also asked about who should have authority over hydraulic fracking. The survey revealed that 47% of the Basin residents believed the provincial/state governments should have a great deal of authority, 36% believe the federal government should have a great deal of authority, 35% believe local governments should have a great deal of authority, and 49% of the Basin residents believe land-owners should have a great deal of authority. Thus, in contrast to Ontario municipal leaders, residents in the Great Lakes Basin believe that subnational governments should have much more authority than municipal governments (Brown et al., 2014).

Level of Government	Great Deal of Authority		Some Authority		No Authority		Not Sure	
	Public Opinion	Municipal Leaders	Public Opinion	Municipal Leaders	Public Opinion	Municipal Leaders	Public Opinion	Municipal Leaders
Federal	36%	38%	37%	48%	18%	10%	9%	5%
Provincial/State	47%	52%	40%	40%	6%	2%	7%	5%
Local (Municipal)	35%	55%	47%	38%	11%	2%	8%	5%
Land-owners	49%	20%	38%	54%	6%	20%	7%	7%

Table 1. Comparing Great Lake's Basin and Ontario's municipal leader opinion for fracking authority. Adapted from *Shale Gas and Hydraulic Fracturing in the Great Lakes Region: Current Issues and Public Opinion*, by Brown et al., (2014), retrieved from: <http://closup.umich.edu/issues-in-energy-and-environmental-policy/9/shale-gas-and-hydraulic-fracturing-in-the-great-lakes-region-current-issues-and-public-opinion/>

Table 1 shows that the greatest variation between municipal leaders and citizens surrounds the degree of authority each should have over fracking. Only 35% of Great Lakes Basin citizen respondents said that local governments should have a great deal of authority for fracking, while 55% of the municipal leaders answered the local governments should have a great deal of authority. More than double (49% to 20%) of the public surveyed believe land-owners should have a great deal of authority over fracking.

When the same question was asked to just Ontarians living near the Great Lakes Basin, oddly, Ontarians believed the federal government should have most of the authority (43%), with only 11% answering the federal government should have no authority (Brown et al. 2014). This is surprising given that the constitution provides little to no authority for municipal and federal governments. Referring to Table 2, it seems that the public of Ontario is slightly more trusting of the federal government to have jurisdiction over fracking than the municipal leaders (43% compared to 38% for “a great deal of authority”). These are interesting results and contrast with the basin-wide results quite significantly.

A Great Deal of Authority		Some Authority		No Authority		Not Sure	
Public Opinion	Municipal Leaders	Public Opinion	Municipal Leaders	Public Opinion	Municipal Leaders	Public Opinion	Municipal Leaders
43%	38%	33%	48%	11%	10%	13%	5%

Table 2. Comparing Ontario’s public and municipal leader opinion for federal government authority over fracking. Adapted from *Shale Gas and Hydraulic Fracturing in the Great Lakes Region: Current Issues and Public Opinion*, by Brown et al., (2014), retrieved from: <http://closup.umich.edu/issues-in-energy-and-environmental-policy/9/shale-gas-and-hydraulic-fracturing-in-the-great-lakes-region-current-issues-and-public-opinion/>

The surveys show a discrepancy between who the public and municipal leaders believe should have authority over the potential use of unconventional fracking in Ontario. The public of Ontario believes that jurisdiction should be with the federal government; while the municipal leaders believe that jurisdiction should be with the local governments. Given that the province is the one with authority over fracking, there is a discrepancy between reality and desires. No matter what the opinion of municipal or public opinion, it remains that Ontario will have to consider a new policy and regulatory framework if fracking is considered in future. The following section outlines some recommendations for such a framework.

9.0 Recommendations

While the likelihood seems slim, it is still possible that Ontario could use fracking to extract natural gas in future. Given this, a comprehensive policy framework would need to be created to protect the environment and human health, and seeing that there is not a current policy framework, it is a contentious issue. This section will outline some recommendations that could be useful when considering a regulatory system for unconventional fracking.

9.1 Flowback Water

One of the most important issues that would need to be addressed is flowback water management. According to one interviewee, if there were a horizontal fracking operation in the shale rock, flowback water would be the biggest issue. This is because there is no proper pathway for managing this wastewater as it cannot be put in sewage plants, even if it was diluted, due to its toxic nature (Interviewee D, January 28th, 2015). Up to 30 percent of the water that is used in hydraulic fracturing is returned to the surface (Grottenthaler, 2011). The flowback contains dissolved solids, hydrocarbons, and heavy metals, which makes discharging into streams impossible due to dangers to the environmental and human health.

Untreated flowback water cannot be used again, and in order for the fluid to be reused, the flowback must be treated to remove harmful chemicals (Grottenthaler, 2011). The high concentration of organic and inorganic matter such as diluted acids, biocides, viscosity modifiers, has caused public concern about effective management of the flowback water (He, Wang, Liu, Barbot, & Vidic, 2014). However, due to high

concentrations of total dissolved solids, the best option for Ontario would be to reuse the flowback water for subsequent fracking (He et al., 2014). This would be done through regulations for proper disposal, which are needed in advance of any horizontal fracking operation (Interviewee D, January 28th, 2015). Different shale plays have different means of water treatment. States around the Marcellus shale use injection wells (injecting the flowback water into wells in the earth), recycle the water, and have municipal wastewater treatment facilities while places around the Barnett Shale have injection wells and recycle the water. The geological factors of the shale play and jurisdictional laws decide what type of option is necessary (GWPC, 2009).

If Ontario was to use fracking for the unconventional extraction of natural gas, a separate treatment facility should be set up to treat the flowback of unwanted chemicals for reuse. An investigation would need to be completed in order to see what municipality would allow such a treatment facility, as massive amounts of water will be transported to and from the treatment plant. In order for this to happen, a facility siting and risk assessment investigation would have to take place to determine what municipalities are actually capable of taking this treatment plant and what municipalities actually want it.

9.2 Water Extraction

The second issue that would need to be resolved in order for Ontario to use hydraulic fracturing would be stringent regulations on water extraction. As hydraulic fracturing uses a substantial amount of water per well, a water policy

would need to be created to protect the local lakes and aquifers that would be used. Although Ontario signed the *Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement* in 2005, which aims at maintaining sustainable extraction of the Great Lakes, the integrity of the Great Lakes is being diminished due to slickwater fracking (Schroeck & Karisny, 2013). This is because the use of water for fracking is more common now than it was when the agreement was signed, making it out of date. Ontario currently allows oil and gas drilling under the Great Lakes and has over 500 onshore and offshore wells producing natural gas (from conventional methods) under Lake Erie (Schroeck & Karisny, 2013). The reason why Ontario would need a better regulatory system on water extraction from the Great Lakes is because other watersheds that are connected to the Great Lakes could be affected as well if contamination or low water levels were to occur (Schroeck & Karisny, 2013).

9.3 Chemical Disclosure

Another important issue that would need to be included in an Ontario policy framework is chemical disclosure of the fracking fluid. The fracking fluid contains a cocktail mixture of chemicals, which should be disclosed to the local jurisdictions that have fracking operations. In Canada and the United States, as fracking is regulated by the individual provinces and states respectively, there exists different regulations regarding chemical disclosure. According to Maule, Makey, Benson, Burrows, and Scammell (2013) insufficient disclosure laws will leave regulators, public safety officers, and the public uninformed and under prepared to mitigate environmental and human health hazards associated with hydraulic fracturing

fluids. A chemical disclosure website for American companies is fracfocus.org and fracfocus.ca for Canadian companies. Under provincial law, British Columbia was the first Canadian province to enforce the public disclosure of chemicals used in fracking fluids (FracFocus, 2014). As of January 1, 2012 public disclosure for hydraulic fracturing fluid is mandatory in British Columbia. On December 19, 2012 Alberta also joined in on the disclosure of chemicals used in fracking fluid; however, no information on whether the disclosure in Alberta is voluntary or mandatory is provided (FracFocus, 2014). In the United States, most of the states that disclose their chemicals to fracfocus.org do so voluntarily (Maule et al., 2013). This makes the accuracy and completeness of the reported chemicals unknown as well as the exact chemical identity unknown as most companies report classes of chemicals and not specific names (Maule et al., 2013).

If Ontario was to use fracking, mandatory chemical disclosure of all chemicals used in the fracking fluid should be implemented. However, given the fact that companies would want to keep their competitive advantage with regards to their own fracking fluid, there should be enough secrecy that would allow the company to keep their own recipe, but at the same time disclosing enough information needed. Regardless of whether or not Ontario uses fracking, Canada should implement a nationwide disclosure law for all provinces. According to Maule et al., (2013) oversight at the federal level will ensure a standard set of regulations, which could streamline the regulatory process.

9.4 Baseline Data

Proponents of hydraulic fracturing claim that there is insufficient data to determine if fracking causes environmental degradation. This is because they claim there is not enough baseline data (methane concentrations, total dissolved solids, biodiversity) taken before fracking takes place in a well. Therefore, an important regulation that would be needed if fracking was to take place in Ontario is mandatory baseline data of every well that is going to be fracked. This could be done in an environmental impact assessment. Before a well would be drilled, an impact assessment can be used to collect the necessary data. According to Yergin (2011), it is difficult to tell if methane migrates from fracking sites into wells because there is a lack of baseline data. The Council of Canadians (2014) also states that shale gas extraction has proceeded without sufficient environmental baseline data being collected. One example of a type of chemical that could be monitored is methane. Methane levels before fracking, during fracking, and after fracking should be collected. However, because methane is believed to migrate, both temporal and spatial analysis should be collected (Lave and Lutz, 2014). If methane concentrations around the well and aquifers surrounding the well increase after fracking takes place, this would suggest that fracking is responsible, and not due to natural events. Another component of the baseline data should be general groundwater quality levels. A general measurement such as total dissolved solids (TDS) is a good indicator of groundwater quality. The higher the amount of TDS, the more polluted the water is (Wilson et al., 2014). If baseline data was taken similar to the methane concentrations over time and space, a correlation would exist that could show an

increase of TDS with fracking. A last indicator that could be taken is wildlife habitat. Indicators such as land degradation, land fragmentation, and animal biodiversity are all variables that could change due to fracking, and should be documented throughout the process to show if fracking does affect these variables. These are important baseline data measurements that should be included in a regulatory framework if fracking was to take place in Ontario.

10.0 Conclusion

The goals of this research project were: 1) to evaluate the evolution of policies, and regulations for horizontal fracking in Ontario; and, 2) to examine the attitudes, opinions, and knowledge of municipal leaders towards horizontal fracking in Ontario. Currently, there are no wells being drilled in Ontario that will be used for multistage horizontal fracking, and there is no specific regulation for fracking in Ontario. Although municipal leaders surveyed generally know what fracking is, in most municipalities it is not a topic of discussion, and most municipal leaders responding to a survey said they neither support nor oppose fracking. From the survey and interviews, it is generally agreed that municipalities should play some role in future decisions over fracking, yet there is a variation of this perceived role between municipal leaders themselves and public opinion.

This paper argued that there is an absence of fracking in Ontario due to two prominent reasons: Ontario's physical geology and economic viability, which were confirmed by interviews. Ontario's shale is such that it is potentially too shallow and of a lower class/quality to support productive fracking, leading to a lack of investment. The future of horizontal fracking in Ontario is uncertain, as there is mixed opinion, with municipalities not likely to adopt any taxes, incentives, or moratoriums. From the in-person interviews with key informants at the provincial level, and the survey, the possibility of unconventional fracking being used in Ontario seems slim, but that is not to say it will never be used. Given the current trend of Ontario importing gas from the US, fracking for unconventional gas does not seem like it is needed in Ontario

What is significant about this paper is that it is the first time municipal views on fracking in Ontario were researched and expressed. It revealed that fracking is not a major concern to most municipalities in Ontario. Further research can build on what this paper uncovered. Over the next few years there will hopefully be more clarity on the issue, future research could look at what municipalities would be facing pressures for fracking operations (if they have shale plays). If this was investigated, municipal engagement and support is needed, along with early communication about how authority will be shared or divided, what risks and costs may be incurred and mediated, and how benefits, if any, would be shared. Future research could also look at provincial attitudes towards fracking, in the same way this paper did with municipal attitudes. The onus is on the current government authority – the province – to initiate these next steps.

Appendix A

Interview Question Guide

- 1) Please explain your position.
- 2) What is the government of Ontario's current position on the role of fracking in energy development in Ontario?
- 3) How and why have fracking policies evolved in Ontario the way they have?
- 4) How is Ontario different to other provinces regarding land rights for drilling and oil rights?
- 5) Are municipal governments being engaged if there is any province wide process of potential fracking policies?
- 6) Do you think municipal governments should play a role in regards to policies if unconventional fracking was to be used?
- 7) Are there any current applications for exploration wells?
- 8) What explains the absence of unconventional fracking currently in Ontario?
- 9) Do you think unconventional fracking will play a role in the energy sector of Ontario in the future?
- 10) What types of policies are necessary if unconventional fracking was to occur in Ontario?
- 11) Are there any other comments that you can share?

Appendix B

Survey Questions

- 1) Recent attention has focused on the extraction of natural gas through hydraulic fracturing and horizontal drilling of underground shale deposits, using high volumes of fluid to break the rock. This is sometimes called "fracking," and we use these terms interchangeably throughout this section to refer to high-volume hydraulic fracturing. How familiar would you say you are with hydraulic fracturing?
- 2) As far as you know, is there any natural gas in your jurisdiction or neighbouring jurisdictions that could be extracted using hydraulic fracturing?
- 3) To what extent, if at all, would you say current or potential fracking within your jurisdiction is a topic of discussion, either in the community at large or within your jurisdiction's government?
- 4) We are interested in sources of support or opposition to the potential use of hydraulic fracturing in your community. In your opinion, do the following people or groups either support or oppose the use of fracking in your jurisdiction?
- 5) Has your jurisdiction adopted, or is it likely to adopt, any tax or other incentives, moratoria, or zoning changes, that attempt to promote, restrict, or simply regulate hydraulic fracturing in your jurisdiction?
- 6) We're interested in factors that may be encouraging or discouraging the use of hydraulic fracturing in jurisdictions across Ontario now or in the last few years. Even though your community does not have any current fracking operations, to what degree would you say the following items may encourage or discourage the use of fracking within your jurisdiction in the future?
- 7) Hydraulic fracturing operations are sometimes regulated in terms of their location, setbacks, waste disposal, chemical disclosure, and so on. For each of the following entities, please indicate whether you think they should have a great deal of authority, some authority, or no authority for such decisions regarding fracking.

References

- American Enterprise Institute. (2013). *Benefits of Hydraulic Fracturing*. Retrieved from: <https://www.aei.org/publication/benefits-of-hydraulic-fracking/>
- BC Oil & Gas Commission. (2014). *Defining Hydraulic Fracturing*. Retrieved from: <http://www.bcogc.ca/defining-hydraulic-fracturing>
- Beland Otis, C. (2012). Preliminary results: Potential Ordovician shale gas units in Southern Ontario. *Earth Resources and Geoscience Mapping Section, Ontario Geological Survey, 6280*, 29-1 - 29-12. Retrieved from: http://canadians.org/sites/default/files/0721_001.pdf
- Boersma, T & Johnson, C. (2012). The shale gas revolution: U.S. and EU policy and research agendas. *Review of Policy Research, 29(4)*, 570-576. <http://onlinelibrary.wiley.com/doi/10.1111/j.1541-1338.2012.00575.x/full>
- Brown, C., Borick, C., Gore, C., Banas-Mills, S., & Rabe, B.G. (2014). Shale gas and hydraulic fracturing in the Great Lakes region: Current issues and public opinion. *Issues in Energy and Environmental Policy, (9)*, 1-20. Retrieved from: <http://closup.umich.edu/issues-in-energy-and-environmental-policy/9/shale-gas-and-hydraulic-fracturing-in-the-great-lakes-region-current-issues-and-public-opinion/>
- Canadian Association of Petroleum Producers. (2012). *Hydraulic Fracturing and Seismic Activity*. <http://www.capp.ca/aboutUs/mediaCentre/CAPPCommentary/Pages/hydraulic-fracturing-and-seismic-activity.aspx>
- Canadian Association of Petroleum Producers. (2012). *The Facts on: Natural Gas*. Retrieved from: <http://www.capp.ca/getdoc.aspx?DocId=217568&DT=NTV>
- Canadian Gas Association. (2015). *The Changing Pattern of Canada's Natural Gas Trade*. Retrieved from: http://www.cga.ca/wp-content/uploads/2015/01/Natural-gas-trade_January-2015_EN.pdf
- Carter, T., Fortner, L., & Beland-Otis, C. (n.d) *Shale Gas Opportunities in Southern Ontario – an Update*. Retrieved from http://www.ogsrlibrary.com/downloads/Ontario_Shale_Gas_OPI_2009_Nov11.pdf
- Council of Canadian Academics. (2014). *Environmental Impacts of Shale Gas Extraction in Canada: The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction*. http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/shale%20gas/shalegas_fullreporten.pdf

- Cronin, K. (n.d.). *Community Engagement Charter Oil and Gas from Unconventional Reservoirs*. Retrieved from:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/256360/Publication_UKOOG_communityengagementcharterversion6.pdf
- Davis, Charles. (2012). The politics of “fracking”: Regulating natural gas drilling practices in Colorado and Texas. *Review of Policy Research*, 29(2), 177-191. Retrieved from: <http://onlinelibrary.wiley.com/doi/10.1111/j.1541-1338.2011.00547.x/full>
- Ellsworth, W.L. (2013). Injection-induced earthquakes. *Science*, 341(6142). doi: 10.1126/science.1225942
- Environmental Commissioner of Ontario. (2011). *Engaging Solutions: Annual Report 2010/2011*. Retrieved from: http://www.eco.on.ca/uploads/Reports-Annual/2010_11/Final-English-Bookmarked-2010-AR.pdf
- Environmental Commissioner of Ontario. (2013). *Serving the Public: Annual Report 2012/2013*. Retrieved from: http://www.eco.on.ca/uploads/Reports-Annual/2012_13/13ar.pdf
- FracFocus. (2014). *Canada's First Hydraulic Fracturing Registry Now Online*. Retrieved from: <http://fracfocus.ca/node/358>
- FracFocus. (2015). *Fracturing Fluid Management*. Retrieved from: <https://fracfocus.org/hydraulic-fracturing-how-it-works/drilling-risks-safeguards>
- Fitzgerald, T. (2013). Frackonomics: Some economics of hydraulic fracturing. *Case Western Reserve University School of Law*, 63(4), 1337. Retrieved from: http://go.galegroup.com.ezproxy.lib.ryerson.ca/ps/i.do?action=interpret&id=GALE%7CA334277577&v=2.1&u=rpu_main&it=r&p=AONE&sw=w&authCount=1
- Gordalla, B.C., Ewers, U., & Frimmel, F.H. (2013). Hydraulic fracturing: a toxicological threat for groundwater and drinking-water? *Environmental Earth Sciences*, 70(8), 3875-3893. doi: 10.1007/s12665-013-2672-9
- Gov.UK. (2015). *Developing Shale Gas and Oil in the UK*. Retrieved from: <https://www.gov.uk/government/policies/providing-regulation-and-licensing-of-energy-industries-and-infrastructure/supporting-pages/developing-shale-gas-and-oil-in-the-uk>
- Grottenthaler, D. (2011). Recycling water for hydraulic fracturing. *Mechanical Engineering*, 133(12), 21. Retrieved from:

<http://search.proquest.com.ezproxy.lib.ryerson.ca/docview/910125324?pq-origsite=summon>

Ground Water Protection Council. (2009). *Modern Shale Gas – Development in the United States: A Primer*. Retrieved from:
http://fracfocus.org/sites/default/files/publications/shale_gas_primer_2009.pdf

He, C., Wang, X., Liu, W., Barbot, E., Vidic, R.D. (2014). Microfiltration in recycling of Marcellus Shale flowback water removal and potential fouling of polymeric microfiltration membranes. *Journal of Membrane Science*, 462, 88-95. doi: 10.1016/j.memsci.2014.03.035

ICF International. (2010). *2010 Natural Gas Market Review*. Retrieved from:
http://www.ontarioenergyboard.ca/oeb/_documents/eb-2010-0199/icf_market_report_20100820.pdf

Interviewee A. (2014, December 4).

Interviewee B. (2015, January 9).

Interviewee C. (2015, January 13).

Interviewee D. (2015, January 28).

Kavanagh, Michael. (2014). *Hostility limits growth of fracking in Europe*. Retrieved from: <http://www.ft.com/intl/cms/s/0/03752734-4966-11e4-8d68-00144feab7de.html#axzz3Ukj7GBEb>

Lave, R. & Lutz, B. (2014). Hydraulic fracturing: A critical physical geography review. *Geography Compass* 8(10), 739-754. doi: 10.1111/gec3.12162

Maule, A.L., Makey, C.M., Benson, E.B., Burrows, I.J., & Scammell, M.K. (2013). Disclosure of hydraulic fracturing fluid chemical additives: Analysis of regulations. *New Solutions: A Journal of Environmental and Occupational Health Policy*, 23(1), 167-187. doi: 10.2190/NS.23.1.j

Ontario Energy Board. (2015). *Ontario's Energy Sector*. Retrieved from:
<http://www.ontarioenergyboard.ca/OEB/Consumers/OEB+and+You/Ontario+Energy+Sector>

Ontario Energy Board. (2015). *Natural Gas Rate Updates*. Retrieved from:
<http://www.ontarioenergyboard.ca/OEB/Consumers/Natural+Gas/Natural+Gas+Rates>

- Ministry of Energy. (2015). *Ontario's Long-Term Energy Plan*. Retrieved from: <http://www.energy.gov.on.ca/en/ltep/>
- Natural Resources Canada. (2012). *Shale Gas*. Retrieved from: <http://www.nrcan.gc.ca/energy/natural-gas/5687>
- Natural Resources Canada. (2014). *Shale Gas Development in Canada – An NRCAN Perspective*. Retrieved from: <http://www.nrcan.gc.ca/energy/natural-gas/14186>
- Ontario Petroleum Institute. (n.d.) *Safely Harvesting Energy: An Overview of Hydraulic Fracturing in Ontario*. Retrieved from: http://www.dundeedrilling.ca/docs/ONTARIO_SAFELY_HARVESTING_ENERGY.pdf
- Palliser, J. (2012). Fracking fury. *Science Scope*, 35(7), 20-24. Retrieved from: <http://search.proquest.com/docview/927534588?pq-origsite=summon>
- Rabe, B.G. & Borick, C. (2013). Conventional politics for unconventional drilling? Lessons from Pennsylvania's early move into fracking policy development. *Review of Policy Research*, 30(3), 321-340. doi: 10.1111/ropr.12018
- Schroeck, N. & Karisny, S. (2013). Hydraulic fracturing and water management in the Great Lakes. *Case Western Reserve Law Review*, 63(4), 1167-1185. Retrieved from: http://go.galegroup.com.ezproxy.lib.ryerson.ca/ps/i.do?id=GALE%7CA334277571&v=2.1&u=rpu_main&it=r&p=AONE&sw=w&authCount=1
- Sergie, M.A. & McBride, J. (2015). *Hydraulic fracturing (fracking)*. Retrieved from: <http://www.cfr.org/energy-and-environment/hydraulic-fracturing-fracking/p31559>
- Skoumal, R.J., Brudzinski, M.R., & Currie, B.S. (2015). Earthquakes induced by hydraulic fracturing in Poland Township, Ohio. *Bulletin of the Seismological Society of America*, 105(1), 189-197. doi: 10.1785/0120140168
- Sue, V.M. & Ritter, L.A. (2007). *Conducting online surveys*. Thousand Oaks, CA: SAGE Publications, Inc. doi: <http://dx.doi.org/10.4135/9781412983754.nl>
- Sumi, L. (2010). *Environmental Concerns and Regulatory Initiatives Related to Hydraulic Fracturing in Shale Gas Formations: Potential Implications for North American Gas Supply*. http://www.ontarioenergyboard.ca/oeb/_Documents/EB-2010-0199/Report_Sumi_CoC.pdf

- The Council of Canadians. (2013). *A Fractivist's Toolkit*. Retrieved from:
<http://www.canadians.org/sites/default/files/publications/fracking-toolkit.pdf>
- The Royal Society and The Royal Academy of Engineering. (2012). *Shale Gas Extraction in the UK: A Review of Hydraulic Fracturing*. Retrieved from:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/256359/Publication_RoyalSociety_2012-06-28-Shale-gas.pdf
- United States Environmental Protection Agency. (2014). *The process of hydraulic fracturing*. Retrieved from:
<http://www2.epa.gov/hydraulicfracturing/process-hydraulic-fracturing>
- Wilson, J., Wang, Y., & VanBriesen, J. (2014). Sources of high total dissolved solids to drinking water supply in southwestern Pennsylvania. *Journal of Environmental Engineering*, 140(5), B4014003-1 – B4014003-10. doi:
<http://ascelibrary.org.ezproxy.lib.ryerson.ca/doi/pdf/10.1061/%28ASCE%29EE.1943-7870.0000733>
- Yergin, D. (2011). *The quest: Energy, security, and the remaking of the modern world*. New York, NY: Penguin Group.