



Responsible Shale Development

Enhancing the Knowledge Base on
Shale Oil and Gas in Canada

Energy and Mines Ministers' Conference
Yellowknife, Northwest Territories
August 2013



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Exploitation responsable du schiste – Accroître la base de connaissances sur le pétrole et le gaz de schiste au Canada

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Executive Summary

Purpose of the Report

At the 2012 Energy and Mines meeting in Charlottetown, Ministers recognized that the North American energy landscape is changing rapidly as technological innovation and increasing affordability of horizontal drilling and multi-stage hydraulic fracturing technologies have unlocked vast unconventional 'shale'¹ oil and gas resources. In both Canada and the U.S., this innovation is supported by world-leading oil and gas infrastructure, technical expertise, and an enabling policy and regulatory environment that have already allowed the shale industry to successfully develop for several years.

Canadian companies are well positioned to expand production and compete globally in bringing shale oil and gas resources to market, as well as competing globally when it comes to ongoing innovation and continuing to develop technologies and expertise that can be applied to issues such as shale resource assessment, environmental impact management, and public awareness.

Governments play a key role in supporting technology innovation and the responsible development of shale resources in Canada, through ongoing efforts to modernize policy and regulatory frameworks, supporting scientific research to better understand the resource potential and the implications of its development for the environment and human health and safety, and engaging in meaningful communications and consultations with the public. Some jurisdictions in Canada, for example British Columbia, Alberta and New Brunswick, have undertaken, or are in the process of undertaking, substantive work that addresses these issues. Other jurisdictions, such as the Northwest Territories (NWT), Nova Scotia, and Ontario are at the earlier stages of determining the potential of their shale resources and how their development might be managed.

Jurisdictions with more experience can offer insight, best practices, and lessons learned to other jurisdictions. This represents an opportunity for knowledge sharing amongst jurisdictions, as they will share many issues in common. Therefore, the purpose of this report to Ministers and its accompanying Compendium is to compile and summarize in a single document all the major efforts and research that federal, provincial, and territorial governments have undertaken (or have underway) on shale resource innovation and development. To this end, this report serves as a 'resource' for all jurisdictions to better understand and benefit from the collective efforts across Canada.

¹ For the purposes of this report the term 'shale' will refer generally to hydrocarbon reservoirs with very low permeability whose viable extraction requires the use of more modern horizontal drilling and/or multi-stage hydraulic fracture stimulation technologies for resource extraction (e.g. also includes 'tight' oil and gas resources). It does not refer to using older, more conventional fracturing techniques for stimulating vertical oil and gas wells.

Another purpose of this report is to highlight how jurisdictions have in fact made important progress in addressing the most critical issues related to shale resource development and on-going efforts in strengthening Canada's overall knowledge base, as well as to help identify any gaps that may exist. Thus, this report also provides recommendations on areas for continued work and collaboration.

Global and Domestic Context

Globally, current estimates of technically recoverable shale gas resources could increase overall global natural gas resources by more than 40 per cent. A significant proportion of shale gas resources exist in countries with limited conventional gas supplies or where they have largely been depleted, such as in China, South Africa and Europe. North America is projected to lead the world in shale gas production over the longer-term. Shale oil currently represents only a small share of total global technically recoverable oil reserves, with around a third located in North America, but it is projected to drive total non-OPEC versus OPEC production growth.

The impact on energy markets is already significant. Shale oil and gas are driving increases in North American supply which in turn is putting downward pressure on prices. Low natural gas prices are already changing consumption and investment patterns, such as a significant switch in U.S. electricity generation from coal to natural gas, and plans for Liquefied Natural Gas (LNG) terminals are changing from import to export facilities.

A major impact for Canada is that exports of oil and gas to the U.S., by far our largest energy customer, are coming under significant pressure with increasing marketable shale resources in the U.S. Demand in the U.S. for both imported oil and natural gas has declined since the mid-2000s.² By 2020, the U.S. could be a net exporter of natural gas, and be producing as much as three million barrels of shale oil a day. This would reverse a steady decline in its total oil production that has been occurring from the 1980s to a few years ago.³ This development, combined with limitations in existing pipeline infrastructure, has led to Canadian production consequently being under pressure to find alternative markets.

Canada's significant shale resources are an opportunity to build on our competitive advantage in global energy markets. Shale gas now accounts for at least half of Canada's marketable natural gas resources. The Canadian Society for Unconventional Resources (CSUR) estimates that Canada has between 733 to 1,304 trillion cubic feet (Tcf) of "marketable" natural gas; of which 357 Tcf are from more conventional resources and between 343 Tcf (low case) and 819 Tcf (high case) are from shale resources.⁴ Marketable resources are a subset of a much larger estimate of around 5000 Tcf

² U.S. Energy Information Administration (EIA) – online data base.

³ EIA, Annual Energy Outlook 2012.

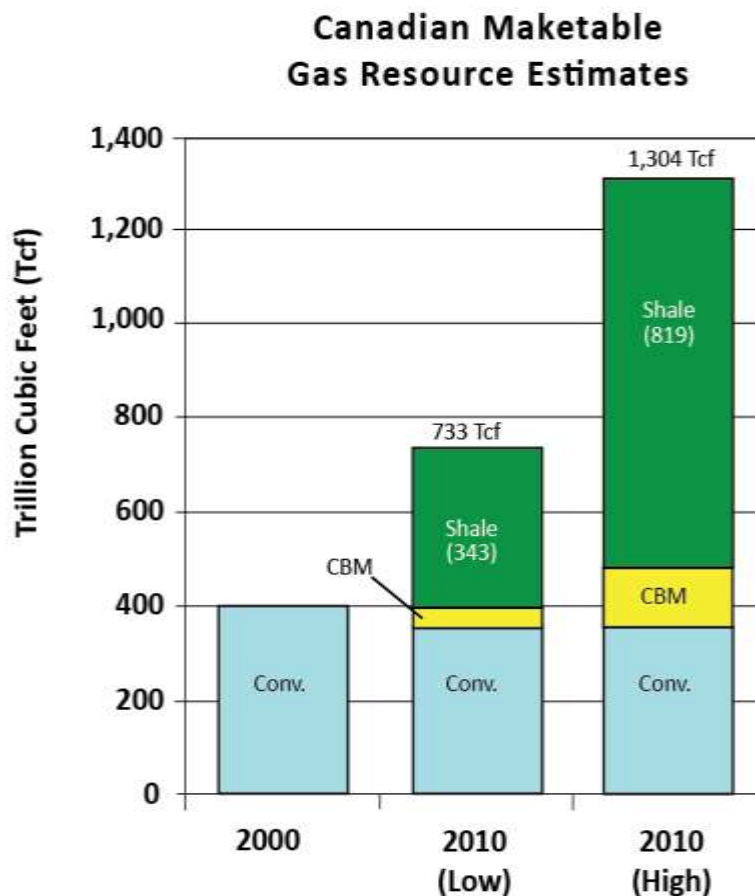
⁴ An Overview of Canada's Natural Gas Resources, CSUR, May 2010; where "marketable" resources are the volume of gas that is deemed recoverable with applicable technology and can be sold in the marketplace, minus losses attributable to processing and fuelling surface production facilities.

of estimated shale gas resources “in place”⁵ in Canada; which includes more recent shale assessments, for example, by Alberta’s Energy Resources Conservation Board.

The current shale estimates for marketable resources alone represent from 65 to over 150 years of supply at Canada’s current rates of production for all natural gas resources.⁶ However, as the CSUR’s 2010 report points out, exploration and evaluation work is ongoing in many individual gas bearing formations that are not yet reflected in an updated assessment for all of Canada. Also, existing estimates that are reflected are often being further refined and updated with better and more detailed information. Therefore, it is expected that a revised aggregate estimate and corresponding years of supply of Canada’s total marketable shale resources will be significantly higher.

Canada is becoming a significant producer of shale gas, with production of about 5 Tcf/year, including from northeastern British Columbia (particularly the Montney formation and Horn River Basin). This is expected to rise over time, including with significant potential resources in Alberta, Quebec, New Brunswick, Nova Scotia, Yukon and NWT, although they are at an earlier stage of exploration and development compared to British Columbia.

For shale oil, preliminary resource estimates to date for the Western Canadian Sedimentary Basin (WCSB) and the Utica formation in Quebec suggest there could be over 600 billion barrels of oil “in



⁵ This figure is based on analysis from the Geological Survey of Canada (2013), using data from Alberta’s Energy Resources Conservation Board, CSUR 2010, and 2013 resource estimates in British Columbia for Horn River, Cordova Embayment, and Montney; where “In Place” is an estimate of the total quantity of the resource to be contained in any given pool or reservoir including both the portion that can be recovered and the portion that will remain in the reservoir after operations, which is generally far greater than the portion of the resource that is considered “recoverable” or “marketable”.

⁶ Based on 2011 production data from the National Energy Board.

place”.⁷ However, of this oil in place, oil and gas companies in the WCSB have to date only identified 500 million barrels that are considered “proven and probable reserves”,⁸ where with reasonable certainty they are deemed recoverable with existing equipment and operating conditions from well-known reservoirs. These estimates are also expected to grow as exploration efforts expand. Overall, shale oil resources are less well developed in Canada than in the U.S. Yet, the Bakken Formation and correlative units in Saskatchewan are already producing commercial quantities of shale oil and liquids, and potential new shale oil plays are being appraised in Quebec, Newfoundland, Alberta and NWT.

In regions where shale resource development has advanced, research and innovation have not only been critical for enabling access and extraction to be cost-effective, but also for enhancing and improving our understanding of the geological setting of the resources, including their assessment for being technically and economically recoverable, ensuring public health and safety, including protecting groundwater resources, evaluating the risk of induced seismicity, mitigating impacts on land and air, and for addressing overall public perceptions and concerns on these issues.

**International Energy Agency’s
Golden Rules for a Golden Age of
Gas, 2012**

“The technology and the know-how already exist for unconventional gas to be produced in an environmentally acceptable way... The industry must win public confidence by demonstrating exemplary performance; governments must ensure that appropriate policies and regulatory regimes are in place.”

Some jurisdictions in Canada, such as British Columbia, Alberta, and Saskatchewan, have been successfully regulating oil and gas projects using hydraulic fracturing technology combined with horizontal drilling for at least a decade. Others have much less experience. Some jurisdictions have undertaken initiatives in recent years, and/or have significant efforts underway, to ensure the overall level of scientific understanding for informing policy and regulatory frameworks is keeping pace with the technology. Social licence to operate is also an important factor, with public concern over hydraulic fracturing being raised in parts of the country, particularly where industrial onshore oil and gas activities did not previously exist to a significant level.

In 2012, the Canadian Association of Petroleum Producers (CAPP) released voluntary Canada-wide *Hydraulic Fracturing Operating Practices* which were developed in concert with gas producers in support of CAPP’s *Guiding Principles for Hydraulic Fracturing* (2011). The operating practices, which put the principles in action, represent a transparent and responsible approach to water management, protection of water resources during sourcing, use and handling and continuous improvement in hydraulic fracturing operations.

⁷ This figure is based on analysis from the Geological Survey of Canada (2013), using in part data from Alberta’s Energy Resources Conservation Board and various industry sources; see footnote 5 for definition of “in place”.

⁸ National Energy Board, Energy Briefing Note, Tight Oil Developments in the Western Canadian Sedimentary Basin, December 2011.

Key Results

In order to better understand the current state of knowledge, information and expertise on shale resource development in Canada, an assessment was done of technology research and development projects, as well as other scientific, technical, policy and regulatory initiatives, that the federal, provincial, and territorial governments have completed or have underway related to shale resource development in Canada.

Pan-Canadian scan of government initiatives and/or studies related to shale resources

- 70 different initiatives were identified across nine jurisdictions, including by the federal government and eight provinces and territories – the majority driven by shale gas development.
- The largest concentration of initiatives (43 per cent) focussed on assessing the related resource base, followed by managing environmental impacts (26 per cent). Overall, around a third of all 70 initiatives include at least a component specific to assessing and managing water resources.
- 17 per cent of initiatives relate specifically to public engagement, awareness, and disclosure; however, around a third of all 70 initiatives contain at least some emphasis on public engagement and communication.
- 14 per cent of initiatives represent a major regulatory development, review or environmental assessment across multiple jurisdictions.

The assessment shows governments are engaged in a broad range of activities in more fully understanding the potential and implications of shale development in Canada. A number of areas of common approach and interest emerge across jurisdictions in Canada. Notably these include:

1- Building on and modernizing existing regulatory frameworks for oil and gas activities:

Provinces and Territories' efforts to develop their energy sector in general, including shale resources, have motivated the review and modernization of oil and gas regulations and policy. Jurisdictions are at various stages of this process. British Columbia has completed the modernization of its regulatory framework, and New Brunswick recently released a new set of rules for the responsible management of oil and gas activities. Four other provinces (Alberta, Ontario, Quebec, and Nova Scotia) are undertaking reviews of shale resource issues and/or modernizing their regulatory frameworks to reflect developments in shale resource technologies. Particular focus by provincial and territorial regulators includes:

- The assessment of hazards and risks at all stages of development;
- Enhanced oversight related to water protection;
- Public and stakeholder engagement; and
- The on-going review of regulations as scientific information is gathered to better understand the risks and how to manage them.

2- Gaining a better understanding of shale and water resources to meet exploration, regulatory and environmental needs:

Significant work is underway to assess and better understand the geological setting that hosts shale resources in order to assess, characterize, and evaluate their potential as a resource ‘play’ on a region, basin, or formation-specific basis. As well, work is being pursued to assess fracturing sand and water availability, with particular efforts to examine potential water resources in more detail for use in resource extraction given the large volumes of water used in drilling and multi-stage hydraulic fracturing. The Geological Survey of Canada and others are undertaking research work to contribute to consistent methodologies for both operators and regulators in order to, amongst other things, assess the resource potential, reduce production risk, prioritise drilling targets, and fill related geological knowledge gaps.

3- Strengthening the knowledge base on environmental impacts of shale development:

Jurisdictions have conducted extensive research work to characterize and monitor the effects of shale oil and gas development on water, air and land. This work has involved baseline water characterization and water consumption, surface and groundwater impacts, potential for induced seismicity of hydraulic fracturing, air quality effects, and land-use impacts.

Water: Evaluating the characteristics of surface and groundwater resources prior to resource development is critical for undertaking a risk-based approach to their management and protection. During development, effective monitoring involves ongoing testing of surface and groundwater to detect changes in water quality that could be attributable to industrial activity.

Seismicity: Induced seismicity is a unique challenge with hydraulic fracturing activities. One study (British Columbia Oil and Gas Commission) found hydraulic fracturing can induce seismicity by activating pre-existing faults, but in the cases studied, the impact was confined to the reservoir. Further work is underway to more fully understand the observed links between shale gas activity and induced seismicity.

Air quality: Baseline information and continued monitoring of regional air quality is important as shale resources are developed to be able to attribute observed trends to industrial activity. Based on current understanding, there is no evidence to conclude emissions from shale development with multi-stage hydraulic fracturing vary significantly as compared to conventional oil and gas developments.

Land-use impacts: Cumulative land use impacts are being monitored in areas of intense oil and gas development activity. It is suggested the land-use impact of shale gas development is not expected to exceed that of conventional operations, despite higher well densities. This is largely because advances in horizontal drilling technology allow for up to 10 or more wells to be drilled and produced from the same well-site.

4- Recognizing the importance of public awareness, engagement and disclosure: Public consultations and engagement have occurred in the development of key policy and regulatory frameworks such as consulting on environmental review processes and recommendations to governments on shale activity. Jurisdictions are making concerted efforts to ensure a range of key stakeholders are included in consultations and, in general, are emphasizing the importance of early and meaningful engagement as part of the regulatory approval process.

A key development has been the increased emphasis on public disclosure of key technical and scientific information, in particular the composition of fracturing fluids to provide the public with information about the chemicals being used to fracture wells. In Canada, the following jurisdictions require such disclosure:

- British Columbia: As of January 1, 2012, the British Columbia Oil and Gas Commission implemented mandatory disclosure of hydraulic fracturing fluids and established a public web-portal, FracFocus.ca, which can be used by other jurisdictions as a single national site for disclosure information.
- Alberta: Alberta also requires the disclosure of hydraulic fracturing fluids which can be accessed via FracFocus.ca.
- New Brunswick: Public disclosure of additives used in hydraulic fracturing have been incorporated in section 11.3 of *Responsible Environmental Management of Oil and Natural Gas Activities in New Brunswick: Rules for Industry*.

Potential Areas for Further Collaboration

Further opportunities to enhance existing knowledge sharing and federal, provincial, territorial collaboration on shale resource development could include:

- Regularly updating the attached Compendium of research projects, technical studies, policy and regulatory developments, and other initiatives that jurisdictions have undertaken or are ongoing related to shale resource development. The Compendium could provide a valuable resource for enhancing knowledge sharing between jurisdictions.
- Establishing a new federal-provincial-territorial Knowledge Sharing Network that focuses on key research questions and technical issues related to shale resources and their development, which could also engage with other key stakeholders, e.g. universities.
- Promoting the use of key tools for sharing information and fostering collaboration (e.g., FracFocus.ca which was built by the British Columbia Oil and Gas Commission based on a U.S. version as well as a British Columbia-led initiative to develop a standardized methodology for measuring surface disturbances) across other jurisdictions in Canada.
- Sharing knowledge between Canada and the U.S. - e.g., under the umbrella of the existing Canada-U.S. Clean Energy Dialogue or other mechanisms - to enhance scientific understanding through discussion of findings from technical studies such as by the U.S. Environmental Protection Agency (EPA) on the impacts of hydraulic fracturing on drinking water and other areas for knowledge sharing between regulatory bodies.

Responsible Shale Development: Enhancing Knowledge Base on Shale Oil and Gas in Canada

Introduction

At the 2012 Energy and Mines meeting in Charlottetown, Ministers identified the sharing of technological expertise and knowledge on shale resources as an important priority. Ministers recognized the increasing attention and importance of unconventional ‘shale’ oil and gas resources within Canada’s energy landscape, and the role of technology and innovation for developing these resources in an economically and environmentally responsible manner. The Federal-Provincial-Territorial (FPT) Energy Technology Working Group was tasked with examining the state of technology and knowledge for shale oil and gas development in Canada.

International and domestic experience to date demonstrates that technology and innovation are critical for addressing several issues related to shale oil and gas, including hydraulic fracturing technologies and the development of new water-based non-toxic fracturing fluids as well as non-water fracturing fluids, exploration and resource assessment, as well as more efficient and cost effective recovery, public health and safety, including ground water protection, and mitigating impacts on land and air. An informed public on how these issues are being addressed by industry and regulators is also important for the sector’s social licence to operate.

Several jurisdictions in Canada have undertaken, or are in the process of undertaking, substantive work that addresses these issues. Some are more advanced than others, for example where shale resources have been under development for several years, such as British Columbia. This circumstance represents an opportunity for knowledge sharing with other jurisdictions facing common issues.

Purpose of Report

The purpose of this report is to undertake a review of technology research and development projects – as well as other scientific, technical, policy and regulatory initiatives – that the federal, provincial, and territorial governments have completed or have underway related to shale resources in Canada. This analytical review and the associated Compendium (Annex B) of projects and initiatives serve as a resource for enhancing knowledge sharing between jurisdictions.

This report is organized according to the following sections: a) global and domestic context for the current heightened interest in shale resources; b) the analytical framework for this report; c) key findings and observations on the projects and initiatives in the Compendium, including the identification of knowledge gaps; and d) considerations for how jurisdictions can continue to share knowledge and deepen collaboration.

Global and Domestic Context

This section will first provide background context on global and North American shale resources more broadly, and then focus more specifically on Canada.

Changing Global and North American Energy Landscape

The energy landscape is changing rapidly as technological innovation and increasing affordability of horizontal drilling and multi-stage hydraulic fracturing technologies have unlocked vast ‘unconventional’ shale gas and oil resources, particularly in North America. Figure 1 below represents a schematic of conventional versus ‘unconventional’ shale gas (which for the purposes of this report also includes ‘tight’ gas). More and more producers are now able to access and develop these resources much more efficiently compared to older extraction technologies, which is being accomplished in various regions in Canada and the U.S. with technological innovation being leveraged by significant overall experience in the oil and gas sector. In the North American context this experience includes: a sophisticated understanding of geological formations; highly developed oil and gas infrastructure from upstream (development) to downstream (market accessibility); world-leading drilling, extraction, processing, and pipeline expertise and services; and a strong enabling policy and regulatory environment, which in some jurisdictions already includes successfully regulating oil and gas resources using hydraulic fracturing technology for at least a decade.

As demonstrated in Figure 2, advances in drilling and fracturing technology have also reduced the number of surface well pads that are needed, which reduces surface impacts in terms of drilling activity, access roads, and pipeline infrastructure. Figure 3 illustrates multiple hydraulic fracturing operations within the same well, far below the depth of ground water resources.

Figure 1: Conventional versus Unconventional Gas Resources⁹

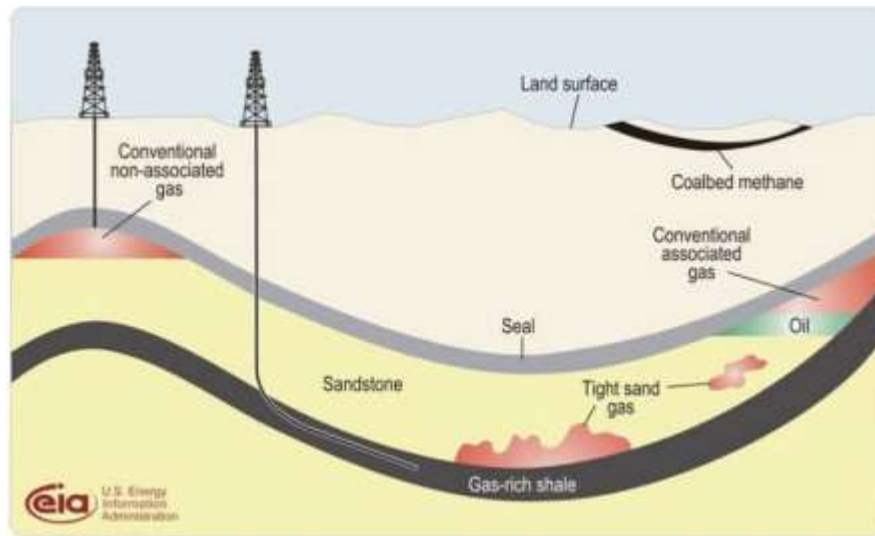
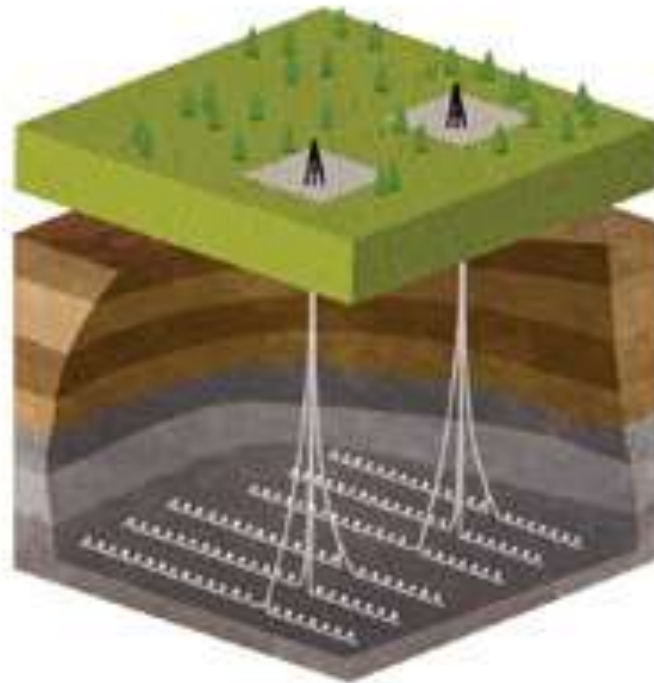


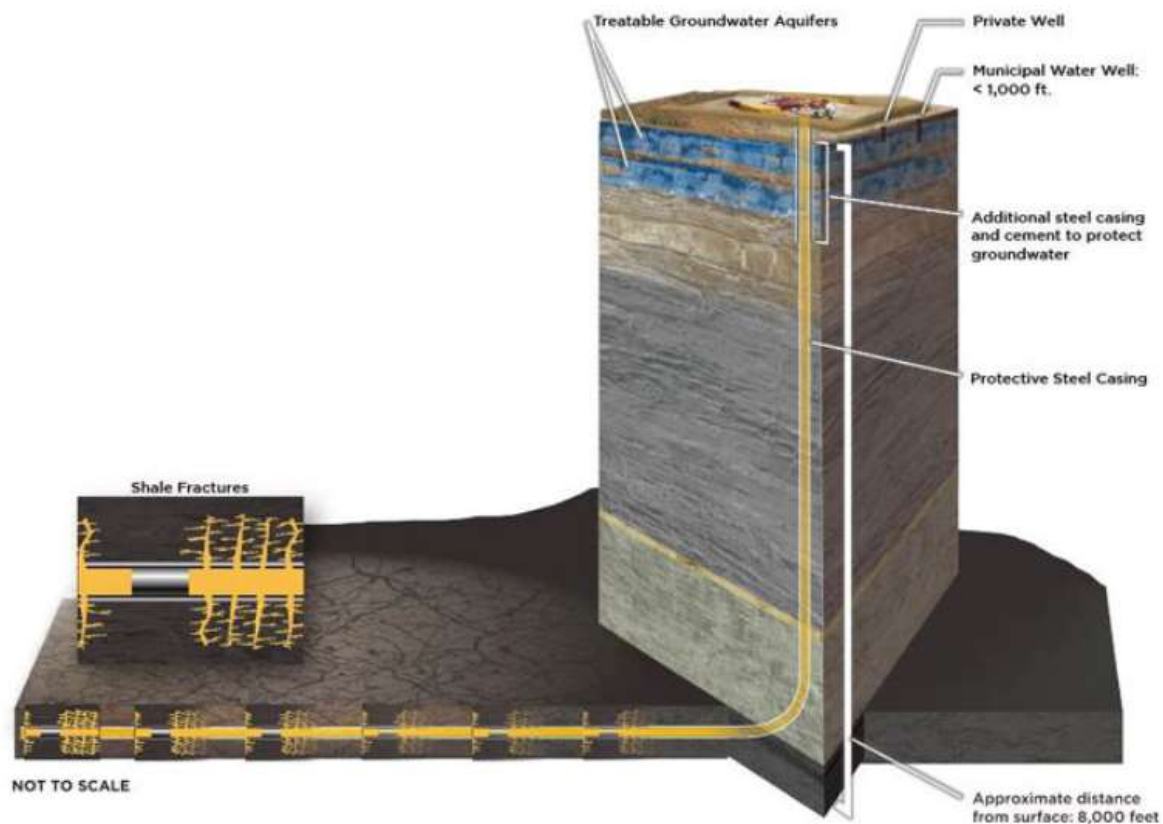
Figure 2: Horizontal Drilling¹⁰



⁹ Source: www.eia.gov/energy_in_brief/article/about_shale_gas.cfm

¹⁰ Source: Nexen website, www.nexeninc.com/en/Colombia/ShaleGas/HowWeDevelop.aspx

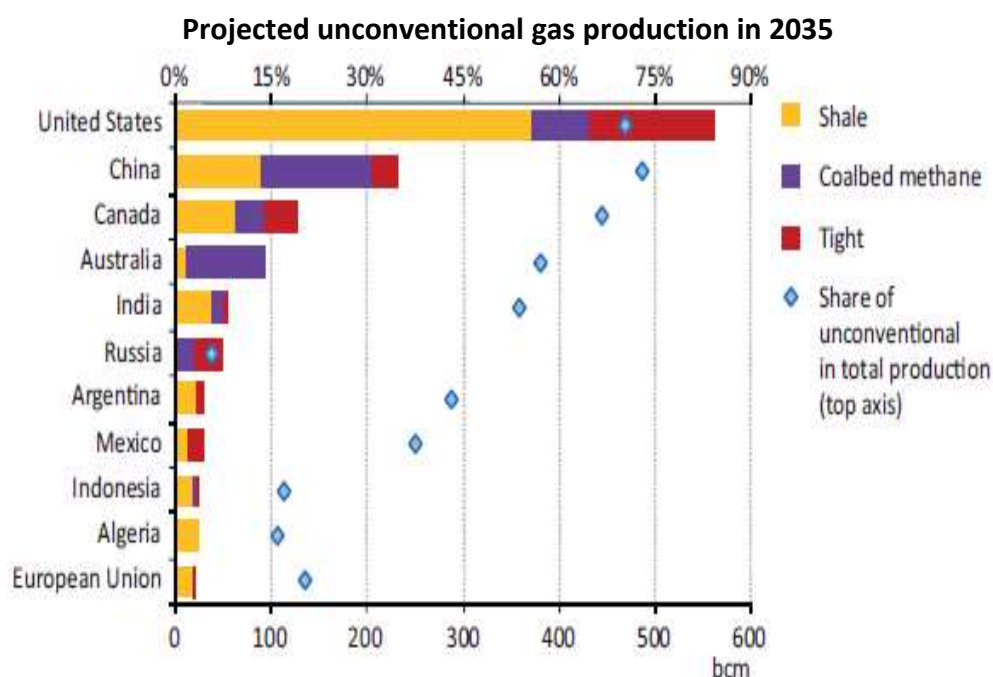
Figure 3: Typical Horizontal Well and Multi-stage Fracturing¹¹



¹¹ Source: CERl's March 2013 report on *Potential Economic Impacts of Developing Quebec's Shale Gas*, [www.ceri.ca/images/stories/2013-03-08 CERl Study 132 - Quebec Shale.pdf](http://www.ceri.ca/images/stories/2013-03-08_CERI_Study_132_-_Quebec_Shale.pdf)

Global Context

Current estimates of technically recoverable shale gas resources around the world would increase overall global natural gas resources by more than 40 percent.¹² These global estimates of shale gas resources are likely to change over time as additional exploration and resource assessment is undertaken. A significant proportion of shale gas resources exist in countries with limited conventional gas supplies or where conventional gas resources have largely been depleted, such as in China, South Africa and Europe. So despite the overall magnitude of global shale gas potential, commercial production in several areas outside of North America is likely five to 10 years away and still subject to precise definition of the shale potential (e.g., recent developments in Poland). Yet, North America, where commercial activity is well underway, is projected to lead the world in shale gas production over the longer-term.



Source: IEA, World Energy Outlook, 2012

Shale oil currently represents only a small share (less than five per cent) of total global technically recoverable oil reserves, with around a third located in North America.¹³ However, these resources are projected to drive over 50 per cent of total growth in non-OPEC oil production by 2017, and contribute to overall growth in non-OPEC oil production outpacing OPEC projected growth.¹⁴ Global production of shale oil, outside North America, is unlikely to make a large contribution to global oil supply until 2020, and even beyond that time-frame production estimates are small. Yet, within North America the emergence of shale oil is already having an impact on oil markets.

¹² U.S. Energy Information Administration, 2011.

¹³ IEA, World Energy Outlook, 2012.

¹⁴ IEA, Oil Medium-Term Market Report, 2012.

North America Context

North America (excluding Mexico) has the most advanced shale gas and oil industry in the world. The development of shale gas plays have become a “game changer” for natural gas markets, led by exploration and production in the U.S. The current estimate of technically recoverable shale gas resources in the U.S. is 862 Tcf, which constitutes 34 per cent of its natural gas resource base.¹⁵ U.S. shale gas production was 7.85 Tcf in 2011 and is projected to increase to approximately 13 Tcf by 2025 and 16.7 Tcf by 2040.¹⁶

The technically recoverable reserves of shale oil in the U.S. are estimated at 24 billion barrels.¹⁷ These estimates could increase as new plays are appraised. Shale oil production, predominantly from the Bakken and Eagle Ford formations and Permian Basin, has grown to more than 1.2 million barrels / day (mmb/d) in 2011. This production is projected to peak at 2.8 mmb/d in 2020 and then decline to about 2.0 mmb/d in 2040, as high-productivity currently known sweet spots are depleted.¹⁸ New tight oil targets in Ohio (Utica Shale), Colorado (Niobrara) and California (Monterey) are currently in the early days of development.

As a result of these developments, the U.S. energy landscape is changing dramatically marked by the fact that natural gas production growth, led by shale gas development, has been outpacing consumption growth and could make the U.S. a net exporter of natural gas by 2020. This scenario could include exports to regions of Canada. Already the increase in natural gas supply is having a major impact on North American energy markets. The New York Mercantile Exchange (NYMEX) natural gas contract price remains well below U.S.\$5/million British Thermal Units (mmBTU), compared to prolonged periods above U.S.\$7/mmBTU five to eight years ago.

Paradigm Shift: The Growth of Shale Resources in North America

The International Energy Agency (IEA) recently highlighted:

- How the shockwaves of rising U.S. shale oil and gas and Canadian oil sands production are reaching virtually all recesses of the global oil market, both in terms of oil and gas supply growth and spreading the benefits of technology breakthroughs globally.
- The transformative impact of shale oil production in the U.S. based on high production volumes, the crude's distinctive light quality, deployment of technologies that unlocked the resource, and the economic and market impact of the new production, with a chain reaction being created in the global transportation, storage and refining infrastructure.

Source IEA, *Medium-Term Oil Market Report*, 2013

¹⁵ U.S. Energy Information Administration, Annual Energy Outlook, 2011.

¹⁶ U.S. Energy Information Administration, Annual Energy Outlook, 2013.

¹⁷ Ibid

¹⁸ Ibid

It is also estimated that the U.S. dependency on imported oil will decrease from about 45 per cent currently to 34 per cent by 2020. Some recent projections even show the U.S. may become a net exporter of oil by 2040.¹⁹

The redrawing of the North American energy map has significant implications for Canada's traditional reliance on the U.S. market for oil and gas exports. For oil, while it is projected the U.S. will remain a net oil importer for the foreseeable future, Canadian oil exports are facing increasing pressure in terms of declining U.S. demand. While growth of Canadian exports to the U.S. have remained steady out to 2012, total U.S. imports of crude oil and petroleum products have declined from a peak in 2005.²⁰ For natural gas, Canadian exports to the U.S. have been falling. In 2012, our natural gas exports to the U.S. were about 19 per cent lower in volumes than in 2007, the value of which was about 70 per cent lower taking into account the lower price.²¹ These conditions put pressure on Canada to access new markets as our unconventional oil and gas production grows, with growing competition in the U.S. market, but also as demand in the Asia-Pacific region increases significantly in the medium to long-term.

Shale Resources in Canada

Canadian companies are well positioned to expand production and compete globally in bringing shale oil and gas resources to market, as well as competing globally when it comes to ongoing innovation and continuing to develop technologies and expertise that can be applied to issues such as shale resource assessment, environmental impact management, and public awareness.

Examples of Canadian Innovation in Shale Resource Technologies

- Exploring capture and supply of CO₂ as fracturing agent to improve well productivity, while reducing need for water and having portion of CO₂ permanently stored.
- Technology training centre at Calgary for developing new technologies such as improved fracturing fluids and cement blends.
- Researching use of saline water as alternative to fresh water for fracturing.
- Leading-edge well completion technologies and processes for multi-stage fracturing.
- GasFrac is a Calgary-based company that has designed and introduced LPG (propane) frac technology. This waterless fracture stimulation technology is now utilized throughout North America.

¹⁹ Ibid

²⁰ EIA – online database.

²¹ Statistics Canada, CANSIM 129-0004.

Shale gas: By some estimates, advances in shale gas extraction technology have contributed to a doubling of Canada's marketable²² natural gas resources since 2000. An estimate in 2010 of between 733 and 1,304 Tcf²³ in total marketable gas resources would provide more than 200 years of available supply at current production rates. Only 357 Tcf are conventional resources, and between 343 Tcf (low case) and 819 Tcf (high case) are shale gas representing from 65 to over 150 years of supply at Canada's current rate of production for all natural gas resources.²⁴ This wide ranging estimate reflects uncertainty over much of Canada's shale resources, which will lessen over time as more information becomes available and as changes in the technology and economic conditions influence what is 'marketable'.

It should also be recognized that this 2010 estimate for Canada's total marketable shale gas resources will be revised as the coverage and effort to better understand the resource base in Canada continues to expand. For example, Alberta published a major shale gas assessment in 2012 that covers additional large formations. As well, existing estimates that are reflected in the 2010 estimate are often being further refined and updated with better and more detailed information. Therefore, it is expected that a revised aggregate estimate and corresponding years of supply of Canada's total marketable shale resources will be significantly higher.

There is no doubt shale resources will continue to drive much of the growth for natural gas in Canada. Beyond the smaller subset of resources deemed "marketable", there is over 5,000 Tcf of currently estimated total natural gas "in place"²⁵ for Canada, of which 85 percent is shale gas. The National Energy Board estimated in 2011 that shale production would increase to over 70 percent of total gas production in Canada by 2035, and starting in the 2016/17 timeframe would result in a reversal of the current downward trend in total gas production.²⁶

Shale gas development in Canada includes northeastern British Columbia (primarily in the Montney and Horn River Basins); where over 1,400 wells are producing over 2 billion cubic feet / day of gas.²⁷ In Alberta, the Duvernay (Woodbend Group), Banff, Exshaw, and Fernie (Nordegg member) formations are receiving most of the attention, as these areas are rich in natural gas liquids and oil as well. Although in the early stages of development of shale gas resources, Alberta produced approximately 2.7 billion cubic feet of shale gas in 2012.

²² See footnote 4 for definition of "marketable".

²³ Refer to footnote 4.

²⁴ Refer to footnote 6.

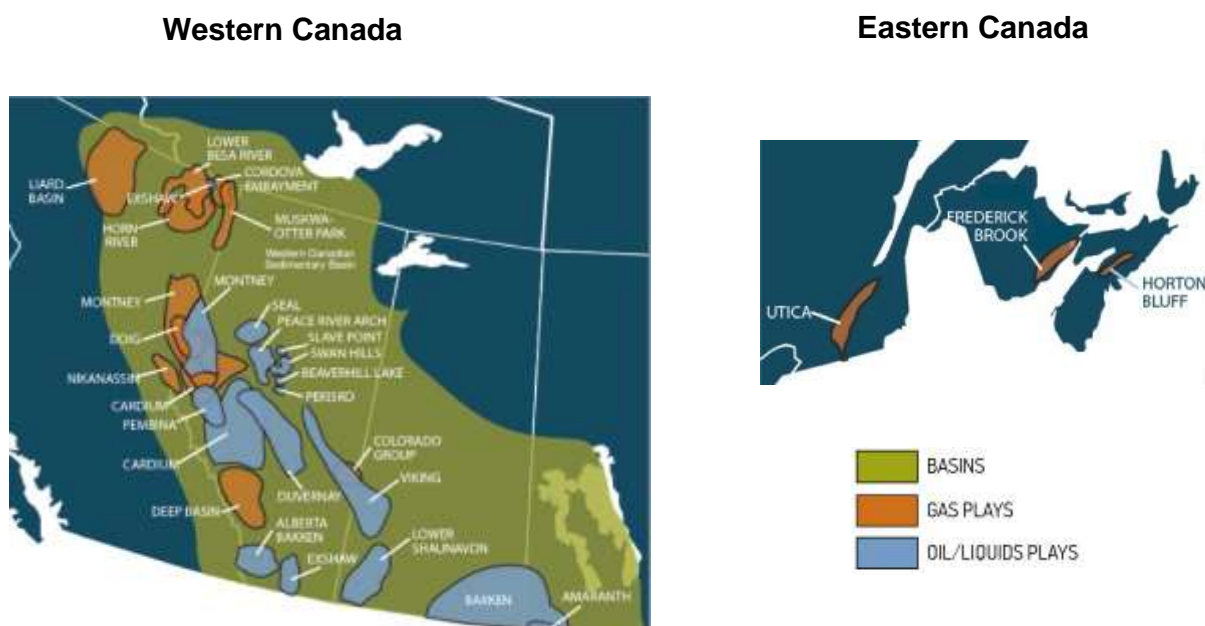
²⁵ Geological Survey of Canada (2013), using in part data from the CSUR. See footnote 5 for definition of "In Place".

²⁶ National Energy Board, *Canada's Energy Future: Energy Supply and Demand Projections to 2035 - Energy Market Assessment*, 2011.

²⁷ As of November 2012, based on data provided by the British Columbia Oil and Gas Commission.

There are other potential shale gas resources in Canada that could add to this total. These include the shales of the Liard Basin in British Columbia – Yukon – NWT, the Muskwa, and Spirit River formations in Alberta, the Utica shale in Quebec, and Frederick Brook shale in New Brunswick. However, potential shale resources have not yet been fully assessed because of their very early stage of development in many jurisdictions, particularly outside of the Western Canadian Sedimentary Basin (WCSB). See Figure 4 for the distribution of Canadian shale resources.

Figure 4: Shale Resources Span Canada²⁸



Shale oil: Resource estimates of the total Canadian shale oil resource are still uncertain, given that shale exploration and production are still at an early stage. Preliminary estimates to date for the WCSB and the Utica formation in Quebec suggest there could be over 600 billion barrels of oil in place.²⁹ However, oil and gas companies working in the WCSB have to date only identified 500 million barrels of “proven and probable reserves”,³⁰ where with reasonable certainty they are deemed recoverable with existing equipment and operating conditions from well-known reservoirs.

While this represents a small share of Canada’s overall oil resources, this estimate of “proven and probable reserves” is expected to grow as exploration efforts expand. This includes other potential shale oil resources in Canada that remain to be assessed, in particular additional shale oil resources being identified in Alberta, (Duvernay, Muskwa, Banff, Exshaw, Fernie, and Spirit River formations),

²⁸ Adapted from www.Shaleresourcecentre.ca.

²⁹ Refer to footnote 7 for reference and definition of “in place”.

³⁰ Refer to footnote 8.

western Newfoundland (Green Point formation), and Quebec (Anticosti Island, Macasty Shale) are expected to add to Canada's total shale oil reserve estimates. As well, the Canol Shale Formation and Hare Indian Formation in the Central Mackenzie Valley of the Northwest Territories are expected to hold significant potential of tight oil and are at the early stage of exploration.

Table 1 – Estimates of Canada's Shale Resource Potential

Shale Gas (TCF)	Shale Oil (billion barrels)
Shale gas in place: 4,995 ³¹ <ul style="list-style-type: none"> compared to an estimate of 837 for "in Place" conventional gas 	Shale oil in place: 623 ³² <ul style="list-style-type: none"> compared to an estimate of 1,800 "in place" for the oil sands resource
Marketable resources: 343–819 ^{33,34} <ul style="list-style-type: none"> equivalent years of supply based on 2011 production rates in Canada for all natural gas resources: 65–154³⁵ 	Proven and probable reserves: 0.5 ³⁶ <ul style="list-style-type: none"> equivalent years of supply based on 2011 production rates in Canada for all crude oil: 0.5

In Alberta alone, a recent study by the Alberta Geological Survey estimated as much as 287.3 billion barrels of in-place oil from shale from the formations mentioned previously. From a production perspective, the long-standing declining trend of the WCSB (not including the oil sands) has been stemmed by the increasing production of shale oil, particularly in the Bakken formation of Saskatchewan. Canada's total shale oil production reached 190 thousand barrels / day in 2011, which represents about six percent of total Canadian oil production. It is estimated Canada's production of shale oil could reach more than 500 thousand barrels /day by 2035.³⁷

³¹ Refer to footnote 5 for reference and definition of "in place".

³² Refer to footnote 7 for reference and definition of "in place".

³³ Refer to footnote 4.

³⁴ This estimate is expected to be significantly higher when an aggregate total assessment for Canada's marketable resources is revised.

³⁵ Refer to footnote 33.

³⁶ Refer to footnote 8.

³⁷ International Energy Agency, World Energy Outlook, 2012.

Current Issues – Developing Shale Resources Responsibly

Jurisdictions have decades of experience in regulating oil and gas exploration and production. Provincial oil and gas regulatory regimes apply to shale resource development such as in the areas of infrastructure development, drilling and production approvals, land management, decommissioning and reclamation. Existing regulation includes a wide range of ‘technical’ requirements that apply to all oil and gas activities, such as for surface casing, cementing, groundwater protection, and pressure testing in order to minimize environmental and health and safety risks, including induced seismicity. These requirements also apply to hydraulic fracturing.

“Golden Rules” for Developing Unconventional Gas

- Measure, disclose, and engage stakeholders prior to development
- Watch where you drill – minimise impact
- Isolate wells and prevent leaks
- Treat water responsibly
- Eliminate venting, flaring, and other emissions
- Be ready to think big – coordinating infrastructure, take into account cumulative impacts
- Consistently high level of environmental performance – with continuous improvement of regulations and operating practices.

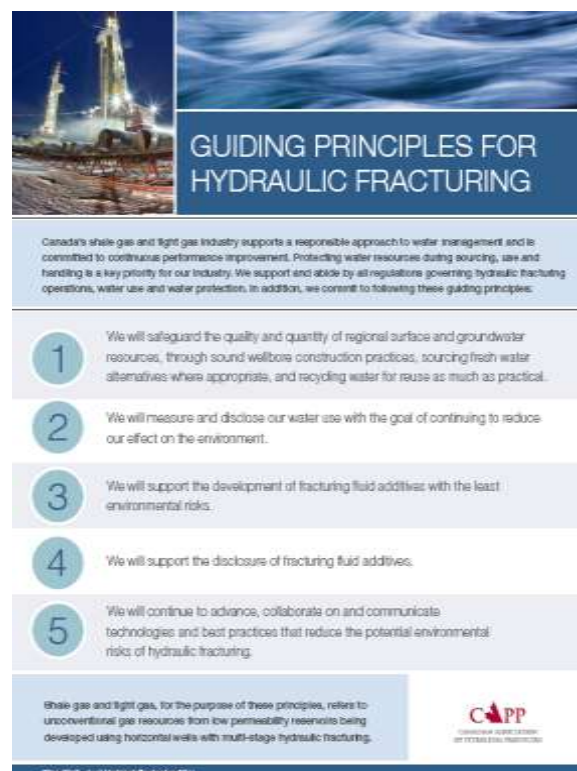
Source: IEA, *Golden Rules for a Golden Age of Gas*, 2012

The rapid advancement of shale resource technologies and processes has contributed to several jurisdictions undertaking major reviews or studies, and some have already proceeded in using their legislative authority to enhance and revise existing legislation, issue directives, and develop guidelines, as appropriate, to ensure the safe and environmentally responsible development and extraction of the resource. Canadians have raised concerns related to groundwater contamination, disposal of fracturing fluids, induced seismicity, greenhouse gas emissions such as methane venting and leaking, and others. Public awareness, engagement and disclosure are important considerations for policy-makers, regulators and operators as they consider opportunities of shale resource development in Canada.

In 2012, the Canadian Association of Petroleum Producers (CAPP) released voluntary Canada-wide *Hydraulic Fracturing Operating Practices* which were developed in concert with gas producers in support of CAPP's *Guiding Principles for Hydraulic Fracturing* (2011). The 7 operating practices include:

- Fracturing Fluid Additive Disclosure.
- Fracturing Fluid Additive Risk Assessment and Management.
- Baseline Groundwater Testing.
- Wellbore Construction and Quality Assurance.
- Water Sourcing, Measurement and Reuse.
- Fluid Transport, Handling, Storage and Disposal.
- Anomalous Induced Seismicity.

Similar initiatives have also occurred or are underway in countries like the U.S. For example, the U.S. Secretary of Energy's Advisory Board released a report in November 2011 on recommendations to address the safety and environmental performance of shale gas production, and the U.S. Environmental Protection Agency (EPA) released a Progress Report in December 2012 on its *Study on the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources* (see below for additional information in text box).



Source: Canadian Association of Petroleum Producers (CAPP), 2012

U.S. Environmental Protection Agency (EPA) Study: Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

In 2009, Congress requested the EPA to conduct scientific research to examine the relationship between hydraulic fracturing and drinking water resources.

In December 2012, the EPA released a Progress Report that describes 18 projects underway to answer research questions related to the five stages of the hydraulic fracturing water cycle.

EPA has established a transparent, peer-reviewed process and is undertaking consultations with a broad range of stakeholders. The EPA has designated the report as a "Highly Influential Scientific Assessment", which will undergo peer review by an independent and external federal advisory committee, an ad hoc expert panel and review by individual experts.

The final report is expected in late 2014.

Methodology and analysis

The Methodology – A Scan of Existing Information on Shale

In order to determine the current state of knowledge, information and expertise on shale resource development in Canada, an assessment was done of technology research and development projects, as well as other scientific, technical, policy and regulatory initiatives, that the federal, provincial, and territorial governments have completed or have underway related to shale resource development in Canada. This analytical scan of the material and the associated Compendium (Annex B) of projects and initiatives is a stock-taking exercise which can perhaps contribute to existing collaboration between jurisdictions.

Analysis

The analytical scan shows governments are engaged in a broad range of activities in supporting shale development in Canada. There are four categories of initiatives across jurisdictions that can support knowledge sharing and lay the foundation for strengthened collaboration. They are:

- A. Policy and regulatory developments.
- B. Understanding and assessing the resource base.
- C. Managing environment impacts.
- D. Public awareness, engagement and disclosure.

A) Policy and Regulatory Developments

Unless on federal lands or offshore, shale gas and oil extraction is a provincial responsibility. However, it could involve areas of federal mandate which apply to other industrial activities, including the assessment and regulation of chemical substances, environmental emergencies, and provisions of the *Canada Water Act*, *Species at Risk Act* and the *Fisheries Act*.

Provinces' efforts to develop their energy sector in general, including shale resources, have motivated the review and modernization of provincial oil and gas regulations and policy. This includes completed work in British Columbia to modernize and enhance the regulation of oil and gas activities under British Columbia's *Oil and Gas Activities Act (OGAA)*, enacted in 2010. This modernization has resulted in a comprehensive and effective regulatory regime that ensures safe and responsible development of its oil and gas resources and better reflects technologies for unconventional gas. The modernized regime features new requirements for the oil and gas industry to consult and notify land owners and other affected parties of proposed activities, and that they be conducted prior to submission of an application for a permit to British Columbia's Oil and Gas Commission. The regime also includes a new permitting system for activities and a modernized compliance and enforcement system which includes the introduction of administrative monetary penalties and significantly higher penalties for offences.

Other jurisdictions are also undertaking research and consultation to update regulations for ensuring continued safe operations of shale developments, protection of the environment, resource conservation, and effective engagement with the public.

The assessment shows the overall goal is to ensure policy and regulatory frameworks reflect the changing nature of technology, its application, and the understanding of the potential risks. A common approach is building on the existing foundation of oil and gas related legislation and regulations. As noted above, British Columbia completed a modernization of its regulatory framework, and New Brunswick released in 2013 a new set of rules for the responsible management of oil and gas activities which relied heavily on Alberta's existing regulatory directives. New Brunswick has also just released an *Oil and Natural Gas Blueprint* which outlines how the province will adapt the framework for managing this sector for the long term, using the principle of continuous improvement, informed by regular reviews of its regulations, policies and procedures in consultation with industry, the public and other stakeholders.

Four other provinces (Alberta, Ontario, Quebec, and Nova Scotia) are in the process of undertaking reviews of shale resource issues and/or modernizing their regulatory frameworks to reflect developments in shale resource technologies. These reviews have built in processes for public input. For example, Alberta has proposed a new regulatory approach outlined in the *Regulating Unconventional Oil and Gas in Alberta*. It builds on 15 existing regulatory directives for the oil and gas sector and included a public comment period. In Nova Scotia, a Review Committee is examining the potential environmental impacts of hydraulic fracturing, and asked the public to provide written comments on the scope of the review, and the public will have an opportunity to comment on any regulatory changes that may be proposed. Also, New Brunswick, prior to releasing its new set of rules, undertook major public consultation based on a set of draft recommendations. Ontario will also provide an opportunity for the public to provide input and comments on any proposed regulatory changes.

In March 2011, the Quebec Minister of Sustainable Development, Environment and Parks announced an expert committee would carry out a Strategic Environmental Assessment (SEA) for shale gas development in the province, as recommended by Quebec's Bureau d'audiences publiques sur l'environnement (BAPE) in a February 2011 report. The purpose of the SEA is to understand and document the environmental, economic and social repercussions of the potential exploitation of shale gas in Quebec, for which a final report is to be submitted to the government by November 2013. Several supporting studies are being conducted at the request of the Committee and are being publicly released as they are completed.³⁸

Policy and regulatory developments are not just confined to provincial governments. The Government of the Northwest Territories is developing a *Policy Framework* and *Guidelines* around the application of hydraulic fracturing in the NWT. As per a Yukon government motion passed in its legislature on November 27, 2012, a public dialogue will include three components, one of which is

³⁸ <http://ees-gazdeschiste.gouv.qc.ca/documentation/>

to respond positively to the joint request by the Yukon Conservation Society and Northern Cross Yukon for the government to work with the Yukon Environmental and Socio-economic Assessment Board to improve clarity around assessment of oil and gas projects.

The increased activity among provincial and territorial oil and gas regulators related to policy and regulatory frameworks recognizes the scale of development involving advanced hydraulic fracturing technologies has the potential to be much larger than experienced in the past, although the technologies being deployed are not necessarily new. Revised and new approaches must deal with the challenge of higher concentrations of infrastructure and extraction in a region, and the associated scale and accumulation of risks. For example, in recognizing these issues, Alberta is recommending moving from a well-by-well approach to regulation to an approach that focuses more collectively on activities within an overall resource “play”.

Similarly, an Area-based Analysis approach has already been developed by the British Columbia Oil and Gas Commission and an overview document about this approach was released in April 2013 for public feedback. A draft analysis for the Liard Basin has been completed and First Nations engagement on the Liard Basin and on the overall approach commenced May 2013. A series of reports (e.g., Surface Land-use Reports, Area-based Analyses and State of the Play) will be produced for each identified unconventional basin beginning with Liard as the initial basin. The Montney, Cordova and Horn River basins will follow and potentially the rest of northeast British Columbia.

Within their respective approaches, both British Columbia and Alberta have recognized the respective differences in the attributes of shale resources compared to those of conventional natural gas, such as the large known aerial extent of the shale resource, which allow for more planned development. The various attributes in question are shown in Table 2 for conventional versus unconventional natural gas resources.

Table 2 – Unconventional vs. Conventional Resource Development³⁹

Attribute	Conventional (NG)	Unconventional (NG)
Pool Size	Small and irregular	Large and continuous
Drainage	One vertical well could drain a gas spacing unit (GSU)	Limited, as one vertical well drains <1/4 GSU
Well Type	Vertical wells access and exploit sufficient pool reserves per GSU	Horizontal wells required to develop large resource potential per GSU
Reserve Life	5 - 10 years	20+ years
Tenure Size	Varied - related to target pool size	Generally much larger tracts required
Wells	Individual surface disturbance for each well with minimal location flexibility	Individual surface disturbance accommodates multiple wells with flexibility
Access	Difficult to predict need and location	Potential to plan future access road location
Facilities	Difficult to predict size and location	Growth and location can be modeled
H ₂ S (Sour) Gas	Significant in many plays	Limited or not present
Development Predictability	Very low/random	High/focused

The review of existing regulatory frameworks and potential future changes or revisions has identified a number of common themes that has received particular focus by provincial and territorial regulators. These include:

Risk-based approach: A risk-based approach to modernizing regulations is prevalent amongst jurisdictions such that an assessment of hazards and risks is dictating the evolving regulatory framework for unconventional resource development. All stages from exploration to production to well abandonment are considered. In particular, well casing integrity is becoming a major focus of attention given its importance in ensuring groundwater is not put at risk. An overall principle (e.g., highlighted by Alberta and British Columbia) is that regulatory responses are proportional to the level of the risk posed by shale development.

³⁹ Area-based Analysis Overview, British Columbia Oil and Gas Commission, April 2013.

Enhanced oversight related to water protection: More stringent oversight, including reporting requirements, regarding water use and treatment is being implemented. This work includes requirements such as monthly data on water withdrawal and metered data on water production and other flowback fluids as well as the NorthEast Water GIS-based hydrology decision-support tool (both in British Columbia). This also includes enhanced monitoring of surface water and management planning for water resources, such as a hierarchy of preferred water sources, conservation and recycling, and an assessment of proposed water sources (New Brunswick). Another approach is setting out additional subsurface requirements for hydraulic fracturing that includes ensuring well integrity with new requirements for the equivalent of a dual-barrier system to contain and isolate fracture fluids (Alberta and New Brunswick). As discussed later on, British Columbia requires the disclosure of hydraulic fracturing fluids through its registry FracFocus.ca, as do Alberta and New Brunswick (utilizing an equivalent registry tool).

Requirements for public consultations: Public and stakeholder engagement is occurring at the time when the regulatory frameworks are being developed. This involves the release of discussion papers for public comment, the development of research and technical papers to support consultations and public review and input to broad environmental and strategic reviews. For example, in British Columbia, its OGAA was a product of extensive consultations that began in 2002 through the Oil and Gas Regulatory Improvement Initiative which involved communities, local governments, First Nations, companies, landowners, environmental organizations and industry associations. Furthermore, on-going public consultation requirements are integral to British Columbia's new oil and gas regulatory framework. In Alberta, public input is solicited prior to the final release of new and revised directives. Most recently, public input was provided for the *Directive 083 Hydraulic Fracturing-Subsurface Integrity and Regulating Unconventional Oil and Gas in Alberta A Discussion Paper*.

Ongoing review of regulations: Regulators already reflect elements of continual improvement within existing regulatory frameworks. This is often complemented by provisions for the ongoing gathering of scientific information to better understand the risks and how to manage them.

Annex A summarizes key developments that different jurisdictions highlighted in terms of addressing policy and regulatory frameworks largely in response to shale resource development, or its potential.

B) Understanding and Assessing the Resource Base

Jurisdictions are undertaking significant work to assess and better understand their shale resources. This work can largely be organized into two main categories:

- Assessment and characterization of the shale resource.
- Evaluating water and surficial resources for use in resource extraction.

Assessment and characterization of the shale resource

The main purpose of research work undertaken across jurisdictions is to gain a better understanding of the geological setting that hosts shale resources in order to assess, characterize, and evaluate their potential as a resource ‘play’ on a region-, basin-, or formation-specific basis. It also includes evaluating the geological/geochemical parameters of the shale resource which is carried out in many jurisdictions. Certain jurisdictions have undertaken major assessments on a broader regional- or basin-scale (e.g., British Columbia and Alberta). This includes British Columbia, Alberta and the National Energy Board cooperating in a resource assessment of the Montney formation, expected for public release in 2013. Other jurisdictions such as NWT have also undertaken regional scale studies of shale oil and gas potential. Ontario is establishing a baseline characterization for shale resources located close to surface to inform a broader range of policy discussions.

While the results are ultimately location specific, a number of common elements in their assessment approach (not unlike for conventional resources) could be drawn out, which include from outcrops, cores and geophysical work: a) analyzing thickness, mineralogical composition, structural/pressure settings, and porosity of the shale resource; b) understanding the geochemical parameters such as total organic content and the thermal maturity level of the organic matter, which are suggestive of hydrocarbon potential; and c) relying on existing geological data.

Evaluating water and surficial resources for use in resource extraction

The principal focus of the work is to assess water availability and examine potential water sources in more detail. This focus reflects an essential component of shale gas development given a large volume of water is used for drilling and hydraulic fracturing. An overall driver is that, as the demand for water increases, there is an increasing need to locate and characterize water systems, including aquifers, in more detail for the purposes of establishing whether sufficient and viable water sources are available, as well as for establishing best practices for water use. In Canada, the extent of both potable (generally within 250 metres of the surface) and non-potable aquifers is largely unknown in areas of low water and oil and gas well density.

Research to Assess Canada's Shale Resources

The Geological Survey of Canada (GSC) undertakes research work to contribute to consistent methodologies for both operators and regulators.

- Developing a Canadian methodology for assessing natural gas and liquids resource potential in shale plays that can be performed independently by governments. Application of consistent methodology will provide resource information to meet regulatory and exploration needs, and could help regulators and industry reduce production risk and prioritize drilling targets. The methodology includes a volumetric approach for in-place resource estimation, a productivity-based approach for recoverable resources, a mechanism for updating estimates using production or analog data, and a statistical method for comparing geological characteristics; and
- Working on new methods to better characterize organic matter within unconventional petroleum rocks. The aim is to fill a significant knowledge gap on the role of organic matter in the development of porous space, conduct of the hydrocarbon through the formations, permeability, thermal maturity and the generation potential of hydrocarbons.
- Applying detailed geological and geochemical information to assess the integrity of the cap rock units between the deep target shales and the shallow groundwater aquifers in eastern Canada (QC, NB and NS).
- Hosted a 2013 workshop for resource assessment practitioners at which participants, including British Columbia, Alberta and the NEB, agreed to share practices and data, and support further development of the new GSC resource assessment methodologies.

In mapping information on sub-surface aquifers for water supply, data is also gathered that can be used to assess the capacity of deep saline aquifers to safely accept injection of fluids used in the drilling and hydraulic fracturing processes. Some existing geological information from the oil and gas sector can be used. Basin-scale characterization of relevant aquifers, such as the on-going work in the Northwest Territories and in other jurisdictions, will identify potential aquifers from current stratigraphic knowledge using existing oil and gas well data (e.g., well logs, cores, sample cutting).

Shale Gas Potential and Occurrence of Natural Gas in Water Wells

The Ontario Ministry of Northern Development and Mines' Ontario Geological Survey (OGS) is undertaking regional geoscience studies of Southern Ontario. Results of the regional geologic description help document the bedrock's potential to host natural gas and to characterize the natural gases. The purpose of the study is to understand the natural connection between Ontario's shale rock formations and implications for groundwater quality in southern Ontario, an area where there has been no shale gas extraction development. These OGS geoscience projects involve regional assessments of baseline ground water quality, regional bedrock geology, and gas potential in the bedrock. The OGS studies cannot be used to evaluate economic potential, which would require more, and different, studies.

A concentration of research work in northeastern British Columbia provides an important opportunity for knowledge-sharing with other jurisdictions. Such work has included researching the shallow subsurface strata, such as potential aquifer-hosting bedrock formations, developing water management tools and conceptual hydrological models for all of northeastern British Columbia, taking into account information on surface and subsurface factors that can vary significantly across a particular study area (e.g., precipitation, evapotranspiration). Over the eight years of shale gas development in northeast British Columbia, there has been no reported case of contamination of water.

In addition to the work described above in understanding and assessing the resource base, a few additional studies in this category have focused on assessment of surficial geology which supports shale development. For example, the Geological Survey of Canada (GSC) completed a few studies under its Geo-Mapping for Energy and Minerals (GEM) program, in collaboration with British Columbia, to provide geoscience information to better understand the types and distributions of sand deposits of potential use for fracturing across the landscape, as well as assessing the potential for geohazards that could impact surface infrastructure. NWT is also assessing potential sand deposits for fracturing.

The GSC, in collaboration with the NWT and other partners, also developed a seismic tool designed to provide near-surface geoscience information that supports identification of aggregate resources considered critical for infrastructure development (e.g., roads) and fracture sand sources, and which was also used to assess geohazards such as landslides and ground ice occurrences.

C) Managing Environmental Impacts

Governments have conducted extensive research work to characterize and monitor the effects of shale oil and gas development on water, air and land. Specifically, such work has involved baseline water characterization and water consumption, evaluating surface and groundwater impacts, potential for induced seismicity from hydraulic fracturing and/or deep re-injection of flow back fluids, air quality effects and land-use impacts.

Baseline water characterization and water consumption

Evaluating the characteristics of surface and groundwater resources prior to resource development is critical for undertaking a risk-based approach to their management and protection. This includes obtaining a 'baseline' (pre-development) understanding of the linkages between the hydrocarbon and groundwater resources, the location, depth, size and quality of regional aquifers and the quality and renewal rate of surface water bodies. As highlighted above with work being undertaken by the Ontario Geological Survey, this baseline water assessment analysis can be done in conjunction with efforts to evaluate the overall shale resource potential.

During development, effective monitoring involves ongoing testing of surface and groundwater to detect changes in water quality that could be attributable to industrial activity. There is ongoing research for developing geochemical tracers that will enable reliable and unambiguous detection of leakages from fractured shale formations as well as pinpointing the origin and source of naturally-occurring dissolved methane in groundwater. As well, other research will monitor *in situ* water quality in an area of shale development in British Columbia. Additionally, cumulative regional water withdrawals also need to be monitored to minimize the impact to aquatic ecosystems. A commonly applied principle in British Columbia is that 15 per cent of mean monthly runoff within a water basin can be allocated without harm to the aquatic eco-system and current and anticipated withdrawal volumes for shale gas development in British Columbia are less than 1 per cent of that available allocation.

Efforts are continuing to determine the optimal parameters for fracturing at each distinct geological location. This includes such considerations as choice of completion method, number of fracture stages per well, pressure requirements, horizontal length of the well and anticipated water returns. Water use can be expected to vary between basins because variable geology can have a significant influence on the method of fracture treatment used. It is possible that large volumes of water may be required for a variety of different treatments that could have a significant cumulative water impact in the region. Moreover, for some shales, other fluids (CO₂, nitrogen, propane, foams, etc.) can and sometimes must be used for fracturing at somewhat higher costs.

Proper regulatory oversight of hydraulic fracturing must ensure water sourcing, transportation, recycling, storage and disposal are managed effectively to mitigate risks to surface water and non-saline groundwater sources. Alberta's approach to augmenting its current regulatory approach includes:

- Promoting water conservation: update the Oilfield Injection policy to conserve the allocation of fresh water for hydraulic fracturing operations.
- Safeguarding water quality: update and expand the Baseline Water Well Testing for Coalbed Methane program.
- Monitoring and knowledge building: add more wells to the Groundwater Observation Well Network to monitor groundwater quality and quantity.

Research on Water-Related Issues Related to Shale Development

The Geological Survey of Canada undertakes extensive research work on water-related issues, including:

- Indicators to detect groundwater impacts around a recent drilling site in southern Quebec;
- Characterizing deep sub-surface aquifers for water supply and disposal, supporting Northwest Territories gas development.
- Baseline surface water quality of river and streams in the Petitot Basin, British Columbia.
- Assessing and characterizing groundwater resources, for example in partnership with the Government of Quebec.
- Data on groundwater is available to stakeholders through the Groundwater Information Network.

Induced seismicity of hydraulic fracturing

Induced seismicity is a unique challenge with hydraulic fracturing activities. One study (British Columbia Oil and Gas Commission) measured seismicity at the same time that hydraulic fracturing was occurring and found that hydraulic fracturing can induce seismicity by activating pre-existing faults which are at critical stress but that the fracture network created by fracturing in the cases studied was confined to the reservoir – i.e. no pathways were created to the surface. An ongoing federally funded project is aiming to build on this work and more fully understand the observed links between shale gas activity and induced seismicity, including how to quantitatively characterize the likelihood of major earthquakes being induced by fracturing. Results are intended to provide expert scientific-based knowledge and advice on the issue of shale gas fracturing and induced seismicity for consideration by regulatory authorities and other stakeholders. Acquisition of baseline low-level seismic data prior to shale gas development is also considered as a critical element with planned acquisition in various jurisdictions.

In 2009, Alberta initiated the Alberta Microseismicity project with the goal to monitor natural and induced seismicity to compile a comprehensive earthquake catalogue of Alberta. An earthquake catalogue (seismic database) will help understand the natural seismicity patterns and recognize unusual patterns from anthropogenic activities. In addition, a baseline of natural seismicity will be developed to help identify future unusual seismic activity.

The province is working with the federal government and Alberta universities to install seismic stations, develop regional and site-specific seismic velocity models and monitor stations in near-real time. Through partnerships in Canada and the U.S., Alberta has access to monitoring data from seismic stations from five networks:

1. Canadian National Seismograph Network (CNSN), owned and operated by the Geological Survey of Canada;
2. Alberta Telemetered Seismograph Network (ATSN), owned and operated by the University of Calgary;
3. Canadian Rockies and Alberta Network (CRANE), owned and operated by the University of Alberta;
4. Montana Regional Seismograph Network (MRSN), owned and operated by the Montana Bureau of Mines and Geology; and
5. U.S. Array Reference Array, owned and operated by the U.S. Geological Survey.

Council of Canadian Academies Study on Shale Gas

In September 2011, the federal Minister of the Environment has asked the Council of Canadian Academies to provide an evidence-based and authoritative assessment on the state of knowledge of potential environmental impacts from the exploration, extraction and development of Canada's shale gas resources. The Council will also assess the current state of knowledge regarding associated mitigation options, and was scheduled to complete its study in 18-24 months.

Air quality effects

As with water resources, baseline information and ongoing monitoring of regional air quality is crucial to attributing observed trends to industrial activity. A scan of existing research and studies found there are a limited number of studies on this aspect of shale resource development. Based on current understanding, there is no evidence to conclude emissions from multi-stage hydraulic fracturing vary significantly as compared to conventional oil and gas developments. Natural Resources Canada's GHGenius model found overall lifecycle greenhouse gas emissions from shale gas currently being produced in Canada are on average four percent greater than those from conventional natural gas but 29 to 38 percent lower than other fossil fuels such as gasoline, diesel, and coal.

Jurisdictions with the most developed shale gas industry (notably British Columbia) are producing an annual inventory of venting and flaring emissions from oil and gas operations. One jurisdiction (New Brunswick) is testing ambient air quality of regions where shale gas development is expected, and re-sampling the air quality during the various phases of development with a view to study atmospheric conditions as well as levels of various air pollutants. Other federal research, for example, is ongoing work to develop tracer technology that could reliably detect if there is any leakage of natural gas and/or fracturing fluids from hydraulically fractured shale gas fields. There is also an initiative led by the Canadian Standards Association (CSA) to develop a national standard on venting and flaring which may provide a common approach for regulators.

In 2012, British Columbia initiated the North East Air Monitoring Project, a three-year phased air monitoring and community engagement project, which represents a partnership between the provincial government, the British Columbia Oil and Gas Commission and the oil and gas industry operators in northeast British Columbia. The Canadian Association of Petroleum Producers has committed funding for Phase 1 with potential funding for Phases 2 and 3.

Land-use impacts

Cumulative land use impacts in areas of intense oil and gas development are being monitored. British Columbia has developed a standardized methodology for measuring surface disturbances that could serve as a template for similar studies in other Canadian jurisdictions. The methodology included the type of surface activity, including seismic lines for exploration, roads, pipelines, well pads, facilities, and other infrastructure and surface area used by each activity. The study observed that the surface footprint of shale gas development tends to be small, with seismic lines accounting for nearly the same area as the drill sites. It has been suggested the land-use footprint of shale gas development is not expected to be much more than the footprint of conventional operations, despite higher well densities, because advances in horizontal drilling technology allow for up to 10 or more wells to be drilled and produced from the same well pad.

Shale Gas Development and Land Use in British Columbia

The British Columbia Oil and Gas Commission developed a standardized methodology to measure the surface disturbance of oil and gas activities. Key components were:

- Use of existing datasets to estimate the net surface area used by oil and gas activities. Where possible, surface disturbances were attributed to sub-categories of industrial use, e.g. roads, seismic lines, wells, pipelines, etc.
- Data was provided by industry as part of provincial applications processes, supplemented by satellite imagery, government mapping and other sources.
- Data limitations meant that the methodology erred on the side of overestimating surface disturbances.
- Analyses will be updated as new data become available.

D) Public Awareness, Engagement and Disclosure

Jurisdictions have recognized the importance of public awareness and engagement and increasing transparency as shale resources are developed. Public consultations and engagement have occurred in the development of key policy and regulatory frameworks such as consulting the public on the scope of the environmental review process (Nova Scotia), soliciting feedback on proposed recommendations (Alberta and New Brunswick), commissioning research that will be in the public domain to help inform the strategic review and consultation process (Strategic Environmental Assessment and BAPE processes in Quebec), and launching a public dialogue around proposed shale oil and gas activities (Yukon).

Jurisdictions are also making concerted efforts to ensure a range of key stakeholders are included such as local communities and governments, First Nations, companies, landowners and environmental and industry organizations. Jurisdictions have ensured information is made accessible to the public through dedicated websites and staff, and accompanying major updates to legislation and regulatory frameworks with guidance materials, on-line resource kits, and advanced training materials and workshops.

Jurisdictions have also strengthened regulatory requirements for project developers to consult the public and address their concerns. This has included initiatives such as the requirement to consult landowners and other affected parties before submitting a permit application, a tribunal process to hear challenges to regulatory decisions, and requiring First Nations to be consulted specifically on short-term water use by the oil and gas sector (British Columbia). In general, jurisdictions are emphasizing the importance of early and meaningful engagement as part of the regulatory approval process.

A key development has been the increased emphasis on public disclosure of technical and scientific information with respect to shale development. One of the most prominent examples is FracFocus.ca. Implemented by British Columbia in 2012, it is a public registry where it is mandatory for project developers to disclose information on hydraulic fracturing operations, in particular the composition of fracturing fluids. As the first province to enforce this disclosure, FracFocus.ca was built to accommodate future participation by other jurisdictions to enable one national site for disclosure information. Two other jurisdictions require disclosure of all proposed and actual contents of all fluids used in the hydraulic fracturing process, as follows:

- Alberta: Alberta requires the disclosure of hydraulic fracturing fluids. As a result of amendments to *Directive 059: Well Drilling and Completion Data Filing Requirements*, well-specific summary hydraulic fracturing fluid information can be accessed via FracFocus.ca.
- New Brunswick: Public disclosure of additives used in hydraulic fracturing have been incorporated in section 11.3 of *Responsible Environmental Management of Oil and Natural Gas Activities in New Brunswick: Rules for Industry*, with disclosure requirements described in Appendix 19.

Furthermore, Alberta's proposed regulatory framework also emphasizes the need to understand and disseminate information more broadly on the extent of the resources in "play", capacity and reserve volumes, and other geological and reservoir characteristics. Additional examples are prescribed and standardized landowner notification distances for oil and gas facilities such as well pads and new access roads, and notification of seismic testing, including a description of an energy source to be used (New Brunswick).

Conclusions: Knowledge Sharing and Further Collaboration

The rapid emergence and growing importance of shale resources within the global and North American energy landscape highlights the important role of technology innovation in the energy sector. This report demonstrates that a broad technical understanding, consultations with the public, and informed policy and regulatory frameworks are in place or being pursued by governments in Canada to ensure management of shale resource activities is in the public's interest. There are areas of common interest and approach amongst jurisdictions in Canada, including:

- Building on and modernizing existing regulatory frameworks for oil and gas activities.
- Adopting a risk-based approach for regulating and managing development such as considering resource activity on a regional or 'play' basis, taking into account potential cumulative impacts.
- Gaining a better understanding of shale resources to meet exploration, regulatory and environmental needs.
- Strengthening the knowledge base on environmental impacts of shale development such as seeking a better understanding of both surficial and groundwater resources, including for managing their use, disposal, and protection.
- Recognizing the importance of public consultation with a broad range of stakeholders, both in developing regulatory frameworks and obtaining permits for projects; as well as the importance of public reporting and information disclosure (e.g., on use of fracturing fluids).

Certain jurisdictions have much more experience with shale resource development than others; in particular British Columbia, Alberta, and Saskatchewan. Their experience and knowledge is valuable to other jurisdictions considering the development of shale resources. The experience of other countries, in particular the U.S., also can provide important insights. For example, of interest to Canada is the ongoing study discussed earlier by the U.S. EPA to better understand any potential impacts of hydraulic fracturing on drinking water. A final draft report is expected to be released for public comment and peer review in 2014.

This report with its Compendium of existing and ongoing federal, provincial and territorial initiatives related to shale resources could serve as a tool for knowledge sharing between jurisdictions in Canada. Further opportunities to enhance knowledge sharing and federal, provincial, territorial collaboration on shale resource development should be considered. This report and Compendium on its own is a static 'snap shot' in time; but the research, findings, and initiatives being pursued across all jurisdictions will continue. These opportunities could include:

- Regularly updating the attached Compendium of research projects, technical studies, policy and regulatory developments, and other initiatives that jurisdictions have undertaken or are ongoing related to shale resource development. The Compendium could provide a valuable resource for enhancing knowledge sharing between jurisdictions.

- Establishing a new federal-provincial-territorial Knowledge Sharing Network that focuses on key research questions and technical issues related to shale resources and their development, which could also engage with other key stakeholders, e.g. universities.
- Promoting the use of key tools for sharing information and fostering collaboration (e.g., FracFocus.ca which was built by the British Columbia Oil and Gas Commission based on a U.S. version as well as a British Columbia-led initiative to develop a standardized methodology for measuring surface disturbances) across other jurisdictions in Canada.
- Sharing knowledge between Canada and the U.S. - e.g., under the umbrella of the existing Canada-U.S. Clean Energy Dialogue or other mechanisms - to enhance scientific understanding through discussion of findings from technical studies such as by the U.S. Environmental Protection Agency (EPA) on the impacts of hydraulic fracturing on drinking water and other areas for knowledge sharing between regulatory bodies.

Annex A: Policy and Regulatory Developments Across Jurisdictions

Jurisdiction	Policy/Regulatory Development	Key Aspects
British Columbia	<i>Updates to the Oil and Gas Activities Act</i> Legislation passed in 2010	<p>Modernized regulations for safe and environmentally responsible oil and gas exploration and development, through new:</p> <ul style="list-style-type: none"> • Consultation requirements • Permitting system • Compliance and enforcement system <p>New tribunal to hear challenges to regulatory decisions; and requirements to consult landowners and other affected parties before submitting applications. A single window approach is used.</p> <p>Authority and flexibility by regulator to approve and encourage innovation in technologies and processes.</p>
	<i>Directives by the British Columbia Oil and Gas Commission, and other regulatory requirements</i>	<p>Directives issued in 2011 on requirements to: consult First Nations on short-term water use applications, apply for permits to withdraw water from all sources, and submit monthly water use data.</p> <p>Directive issued in 2010 on monthly reporting, with metering, on the production and disposition of produced water and flow-back fluids.</p> <p>Mandatory public disclosure of ingredients used for hydraulic fracturing on FracFocus.ca public registry.</p>
	<i>Area-based Analysis: Overview Published in April 2013</i>	<p>The British Columbia Oil and Gas Commission continues to make improvements that promote positive environmental outcomes through more effective and efficient oversight.</p> <p>One such initiative - Area-based Analysis – evaluates oil and gas development opportunities by analyzing existing land-use, regulatory requirements, government policy and direction. The analysis then builds a landscape-level picture of the impact that oil and gas activity and other activities have on a particular region and the management tools available to the Commission.</p>

Alberta	<i>Unconventional Regulatory Framework Discussion Paper</i>	<p>New approach to regulating unconventional resources that builds on 15 existing Directives, including: protecting ground water through proper casing and cementing, well abandonment, and depth rules for using fracturing fluids; reporting on fracturing fluid ingredients; and the handling and storage of fracturing fluids.</p> <p>Based on the principle of risk-based regulation, where regulatory responses are proportional to level of risk.</p> <p>Key recommendations include changing from well-by-well regulation to an approach that regulates developments within an overall 'play'.</p> <p>Performance-based approach to achieve specific outcomes for public safety, environmental management, surface impacts, resource conservation, and minimizing cumulative effects.</p> <p>Public feedback was collected and is currently being reviewed.</p>
	<p><i>Directive 083: Hydraulic Fracturing – Subsurface Integrity</i></p> <p>Released on May 21, 2013</p>	<p>Risk to well-integrity must be managed by having the equivalent of a dual-barrier system to isolate fracture fluids, with monitoring</p> <p>Requirement for hydraulic fracturing risk assessment and risk management planning to prevent inter-wellbore communication and to protect non-saline aquifer.</p> <p>No fracturing within 200 metres horizontally from the surface location of a water well, and 100 metres vertically from the bottom of a water well or the top of the bedrock.</p> <p>Requirements by licensee to continually improve planning and execution of its operations.</p>
	<p><i>Amendments to the Directive 059: Well Drilling and Completion Data Filing Requirements</i></p> <p>Released on December 19, 2012</p>	<p>The changes include the following:</p> <ul style="list-style-type: none"> • New requirements for licensees to electronically report fracture fluid data, including service provider, fracture scenario, carrier fluid type, proppant type, and fracturing fluid chemical additive and ingredient information for wells that have been fractured after December 31, 2012; • Electronically report water source data, including source location, source type, diversion permit information, and volume for all water used in hydraulic fracturing

		<p>operations with water quality information required for groundwater sources;</p> <ul style="list-style-type: none"> • Report fracture fluid and water source data in daily records of operations; • Addition of protocols to provide limited protection of proprietary information associated with hydraulic fracturing fluids; • Clarification of the definition of a well when drilled and abandoned at a depth of 150 m or less; • Clarification and expansion on compliance assurance; • Replacement of the term “kickoff point” with “directional drill event.” <p>The well-specific summary hydraulic fracturing fluid information received by Alberta’s Energy Regulator as a result of the amendments to Directive 059 will be accessible via www.fracfocus.ca.</p> <p>Together, these steps reflect a commitment by the Alberta to improve transparency respecting hydraulic fracturing operations in Alberta and support the Government of Alberta’s participation in the New West Partnership, a collaborative endeavour among the provinces of British Columbia, Saskatchewan, and Alberta.</p>
Quebec	<p><i>Strategic Environmental Assessment (SEA)</i></p> <p><i>- On February 6, 2013, the Minister of Sustainable Development, Environment, Wildlife and Parks reappointed the BAPE to conduct an extensive public consultation which will build on the outcomes of the SEA.</i></p>	<p>Shale related operations and production temporarily suspended pending the outcome of the Assessment.</p> <p>Quebec is assessing the geology, hydrogeology and natural gas resource potential of Quebec’s shale gas formations as well as social and environmental impacts of potential shale gas development.</p> <p>Studies examine options for managing fracturing water, as well as hypothetical 25-year horizons for a range of possible shale gas development scenarios in Quebec.</p> <p>On May 15, 2013, the Minister of Sustainable Development, Environment, Wildlife and Parks presented Bill 37 establishing a moratorium prohibiting all drilling, injectivity testing and fracturing operations related to shale natural gas exploration or production in the territories of</p>

		municipalities located mainly in the St. Lawrence lowlands. The moratorium would remain in effect until a law establishing new rules for hydrocarbon exploration and production comes into force or for a maximum period of five years
Nova Scotia	<p><i>Environmental Review of Hydraulic Fracturing in Oil and Gas Operations</i></p> <p>Ongoing into 2014</p>	<p>Scope is primarily on water issues, including assessing potential risks to groundwater and water wells at each stage, considering need for baseline groundwater monitoring and water well survey data, use and effects on surface water, and technologies for water treatment.</p> <p>Environmental issues also under review include:</p> <ul style="list-style-type: none"> • Mixing of fracture fluids and additives, and the need for public disclosure. • Land impacts and potential soil contamination, including from transport, storage, and handling of fracturing fluids. • The need for site restoration requirements. • Financial security/insurance to ensure operator is able to address any associated risks. <p>Comprehensive review of how hydraulic fracturing is managed in other Canadian and U.S. jurisdictions was completed in March 2012.</p>
New Brunswick	<p><i>Responsible Environmental Management of Oil and Natural Gas Activities in New Brunswick: Rules for Industry</i></p> <p>Published in February 2013</p>	<p>Based on “Recommendations for Public Discussion” that was released for public comment in May 2012 as part of a four month review.</p> <p>Builds upon existing regulations with new requirements implemented as conditions to approval and certificate process.</p> <p>Requirements cover a broad range of issues at all stages from exploration to well abandonment, e.g., enhanced certification and training requirements, enhanced monitoring and management planning for water resources, air quality monitoring, an orphan well and environmental contingency fund, public disclosure of project information, and ongoing need to gather scientific information.</p> <p>Ensuring regulators, industry and New Brunswickers have access to common set of accurate information about oil and gas activities in New Brunswick such as through prescribed minimum notification radius for seismic testing and disclosure of all proposed and actual contents of all fluids used in the hydraulic fracturing process.</p>

		Informed a New Brunswick Oil and Natural Gas Blueprint released by the Government in May 2013.
	<i>The New Brunswick Oil and Natural Gas Blueprint</i> Published in May 2013	<p>The Blueprint is intended to provide a clear path forward for the oil and natural gas sector in New Brunswick.</p> <p>The document is focused on six key objectives: 1) Environmental Responsibility; 2) Effective Regulation and Enforcement; 3) Community Relations; 4) First Nations Engagement; 5) Stability of Supply; and 6) Economic Development.</p> <p>The Oil and Natural Gas Blueprint outlines how the province will adapt the framework for managing this sector for the long term, using the principle of continuous improvement, informed by regular reviews of its regulations, policies and procedures in consultation with industry, the public and other stakeholders.</p>
Ontario	<i>Review of Policy Framework respecting the use of high-volume hydraulic fracture treatment</i> To be determined	<p>Review and analysis of other jurisdictions' existing scientific information, legislation, regulations, and policies related to hydraulic fracturing.</p> <p>Gap analysis of Ontario's current policy framework.</p>
Northwest Territories	<i>Policy Framework and Guidelines</i> around the application of hydraulic fracturing and baseline information for the Sahtu Region	<p>The Government of the Northwest Territories (GNWT) is developing a <i>Policy Framework and Guidelines</i> around the application of hydraulic fracturing in the NWT.</p> <p>GNWT is collecting baseline environmental and socio-economic information in the Sahtu Region of the NWT through the Environmental Research Fund (ESRF).</p>
Yukon	<i>Public Dialogue</i>	<p>Responds to a request by stakeholders to improve clarity around assessment of oil and gas projects.</p> <p>Scientific review of any proposed oil and gas project at each of the following stages of development: exploration, production and reclamation.</p> <p>Work with the Vuntut Gwitchin First Nation and stakeholders to facilitate an informed public dialogue about the oil and gas industry, including risks and benefits of hydraulic fracturing, before any regulatory approvals or permitting allows the use of this activity in the Yukon.</p>