Case Study

In Pursuit of Solid Ground

Understanding the evidence on shale gas extraction in Canada

Council of Canadian Academies | Conseil des académies canadiennes

ASSESSING **EVIDENCE**
INFORMING **DECISIONS**

THE ISSUE (as of 2014)

As global population and income growth increase the demand for all sources of energy, including fossil fuels, climate change is creating demand for cleaner energy sources. Shale gas - a potentially inexpensive source of energy that could reduce greenhouse gas emissions - may hold promise of easing these opposing predicaments. Over the past few decades, technological advances have made shale gas extraction economically viable, increasing global interest in its development. However, there is ongoing concern about the nature and extent of the environmental impacts of shale gas development, including local and regional impacts on water, land, air and communities. Policies for shale gas development are being debated in a number of countries including the United Kingdom, United States, France, and Australia.

THE SCENARIO

You have been asked to provide evidence to inform your Minister of Environment's long-term policy on shale gas development. You are aware of a recent evidence-informed assessment undertaken by a panel of experts in Canada on this very issue, which you can use to inform your advice to the Minister. Your briefing should include the following considerations:

- *Who are the stakeholders that would be affected by shale gas development?*
- *What is the state of the evidence to inform recommendations?*
- *Do the mitigation options identified adequately reduce the potential environmental impacts?*
- *Should Canada consider developing shale gas as a bridge toward a low-carbon economy?*

THE CASE STUDY

To inform discussion of the scenario questions, the following background information on shale gas and its development in Canada is provided. The information, including figures, is from a 2014 expert panel assessment by the Council of Canadian Academies (CCA) that was carried out at the request of Canada's federal government.[1] The CCA tasked a multidisciplinary and multi-sectoral expert panel with the following question: What is the state of knowledge of potential environmental impacts from the exploration, extraction, and development of Canada's shale gas resources, and what is the state of knowledge of associated mitigation options?

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1 Council of Canadian Academies, 2014. Environmental Impacts of Shale Gas Extraction in Canada. Ottawa (ON): The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction, Council of Canadian Academies.

1 Shale Gas Extraction in Canada

Large scale commercial shale gas production was first made possible in the late 1990s when two technologies - horizontal drilling and hydraulic fracturing – were combined and adapted to fracture a larger volume of sedimentary rock deep underground. The innovation opened the door to wide-spread extraction of shale resources, beginning in the United States in the 1990s and in Canada in the early 2000s.

With natural gas meeting over 30% of Canada's energy needs, and with conventional reserves declining in Canada, shale gas offers the prospect of significant increases in production. In 2014 Canada was producing about 4 cubic feet per day (Bcf/d) compared to 35 billion Bcf/d in the United States.[2]

Although shale gas development in Canada has been concentrated in British Columbia and, to a lesser extent, Alberta, shale gas resources are also known to exist in Quebec, New Brunswick, Newfoundland and Labrador, and Nova Scotia, and likely in other regions as well. Extraction could provide opportunities for regions that have minimal experience with energy development. Sizable reserves exist on or near areas of Indigenous territories, as well as near rural communities.

Reproduced with permission from U.S. Energy Information Administration (EIA), 2011

Shale Plays (Oil and Gas) in North America

Known shale oil and gas plays in North America. Canada's largest reserves are located in British Columbia and Alberta, with smaller known deposits in Quebec, New Brunswick, Nova Scotia, and the territories.

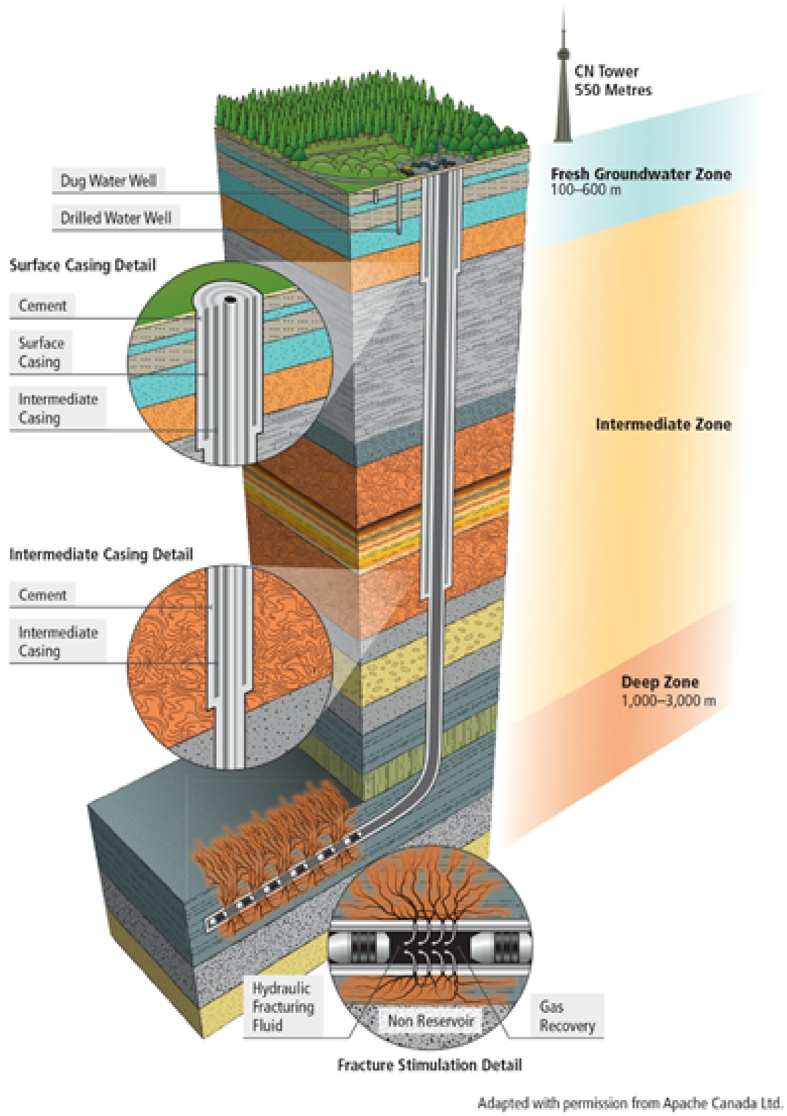
2 http://www.eia.gov/todayinenergy/detail.php?id=19991

What is shale gas?

Shale gas is a natural gas (mostly methane) that is tightly locked within low permeability sedimentary rock. Though the location of many shale gas resources has been known for a long time, only since the 1990s have technological advances made them accessible and their recovery economically viable.

Shale gas extraction requires the combination of brute force and sophisticated technology. The well itself comprises vertical shaft of a depth of 1.5 to 4 km, at the end of which is horizontal section drilled through the shale. Extraction occurs by injecting a mix of fluids, chemicals, and proppants (typically sand) into the well at extremely high pressure to fracture the target rock, and in the process increase the permeability of the shale. This process, called hydraulic fracturing, or fracking, enables the trapped gas to be released and flow to the wellbore.

Shale gas development requires: large amounts of water, chemicals, and proppants for hydraulic fracturing; land for well pads and ancillary facilities; energy to power the drill rigs, pumps, and trucks; and supporting infrastructure to gain access to the sites and extract and deliver the gas.



Well Construction Diagram for a Shale Gas Well

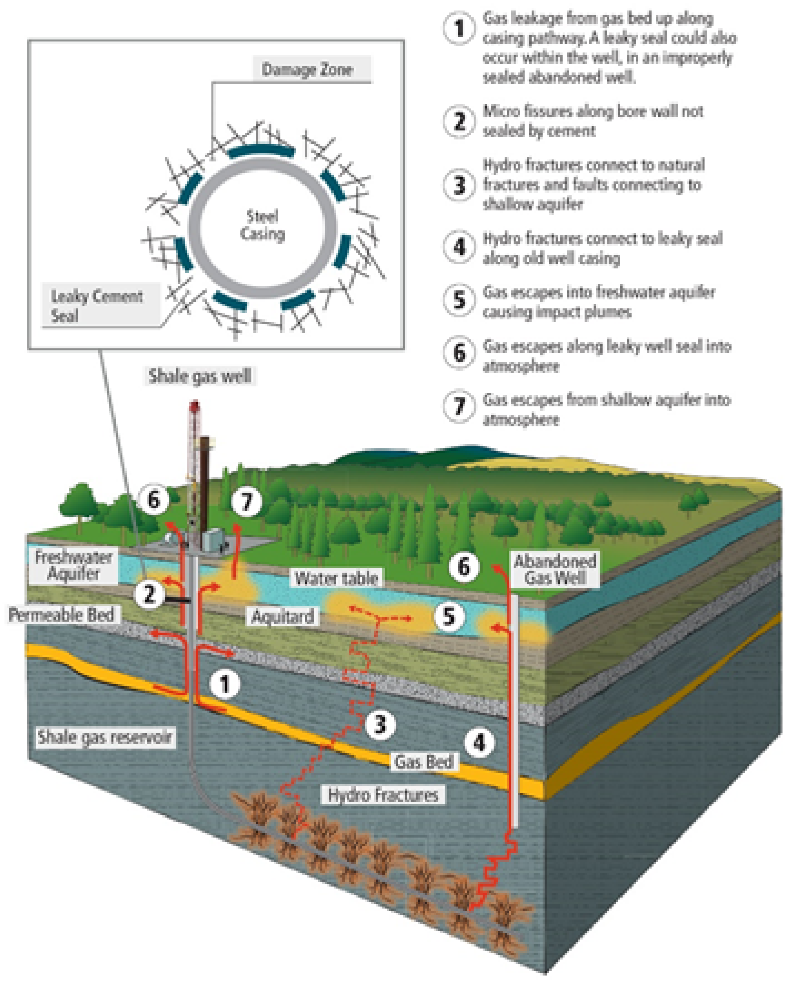
Schematic of a shale gas well, illustrating the various geological layers through which a well is drilled and the relative depth at which hydraulic fracturing occurs. Some laterals (the horizontal part of the well) are much longer than shown in this diagram and can reach up to 3 kilometres. The first two insets show the various casings (the steel tubing) that are inserted into the well and cemented into place. The bottom inset highlights a stage, a section of pipe between two packers that has been perforated in order to inject the hydraulic fluid to fracture the shale.

2 Environmental Impacts of Shale Gas Extraction

The Panel focused on four main categories of impacts – water, air emissions, land, and human health – stemming from the extraction of shale gas and related infrastructure. Of particular concern are water contamination and gas emissions, both of which are related to well integrity (i.e. the degree to which wells are sealed, which prevents leakage). The Panel was challenged by the rapidly evolving information and were cautious in assessing impacts far into the future based on minimal and continually changing evidence. Indeed, a central challenge for the panel was the fact that the main long-term impacts of shale gas development will only become evident after the passage of decades or longer, a challenge that was compounded by the lack of baseline measurements for current shale gas developments.

2.1 Water

The impact of shale gas development and production on water was recognized by the Panel as the most significant environmental concern. Groundwater can be affected by gas leakage from wells, and from the accidental surface releases of fracturing chemicals and wastewater (including from wastewater ponds), which may also affect surface water resources. In addition, hydraulic fracturing, by injecting water and fracking chemicals in large quantities deep into the ground, results in large quantities of polluted wastewater which can include naturally occurring radioactive materials. Disposing of this wastewater economically and safely is a major challenge, as cleaning it can be complicated and expensive. The optimum method for disposal is to inject wastewater deep into the geological formation. This method is used in British Columbia but is not possible in all shale gas-containing regions of Canada because of the geological conditions.



Courtesy of G360 Centre for Applied Groundwater Research, University of Guelph

Conceptual Groundwater Contamination Pathways

There are several pathways by which potable groundwater could become contaminated by shale gas development, as shown in the schematic above. Note that this schematic is not to scale and does not imply that any of these pathways are necessarily present at any given site. The pathway marked by a dashed line is hypothetical as there is no known case of migration of hydraulic fracturing fluids from the deep shale zone to the groundwater level directly through the overburden rock.

The timing of water withdrawal is also a particular concern for some regions where there are several competing uses for freshwater (e.g., agriculture, the environment, communities). Recent advancements, however, have led to a reduction in the freshwater needed for fracturing; for example, saline water is now an option for fracturing in some regions.

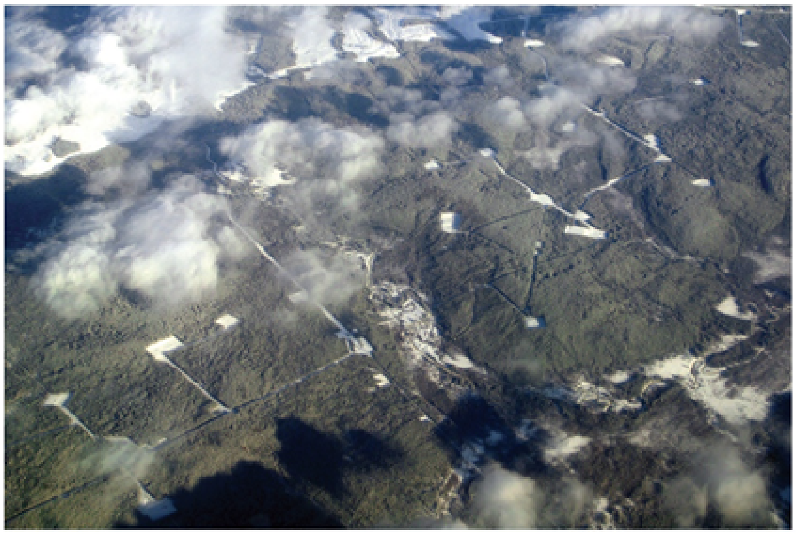
2.2 Greenhouse gas emissions

Shale gas is a fossil fuel whose production and use result in emissions of carbon dioxide and methane, both greenhouse gases (GHGs) that contribute to climate change. As a natural gas, it burns more cleanly than other fossil fuels, emitting about half the carbon dioxide than coal. Shale gas holds the promise of reducing global GHG emissions but only if natural gas extracted from shale replaces coal in electricity generation. If shale gas displaces low-carbon fuels, such as nuclear energy or renewables, including hydro-electricity, the potential GHG reduction benefits of shale gas disappear.

The overall reduction of GHG emissions is lessened by the leakage of methane, which has a stronger GHG effect than carbon dioxide. Methane can leak from shale gas production and transmission, as well as from abandoned wells, leakage from which can increase over time due to cement failure. There is also concern that an abundance of low cost methane gas from shale development could reduce incentives for investing in low carbon alternatives. The net impact of shale gas globally on GHG emissions will therefore depend on control of methane leakage and on broader energy and climate policies.

2.3 Land

Shale gas extraction has regional and cumulative effects that extend beyond the well or well pad. These may include deforestation and the disruption of ecosystems from fragmentation and edge effects due to access roads and well pad construction, and adverse effects on existing land uses, such as agriculture. With technological advances allowing for longer horizontal wells, more wells can now be placed on fewer pads, reducing the overall environmental footprint.



Courtesy of Hayley Dunning

Shale Gas Infrastructure in Northeastern British Columbia
An aerial view of landscape disturbance caused by shale gas development in northeastern British Columbia.

The process of injecting wastewater at high pressure is also associated with unintended seismic events. Most experts judge this risk to be low when injection is done in suitable geological formations; micro-seismic monitoring during operations, along with careful site selection and management, can further diminish this risk.

2.4 Human Health

Shale gas extraction is associated with a range of health risks stemming from waste products, air pollution, psychological impacts, and community disruption, though there are significant knowledge gaps in understanding these impacts. With regard to waste products, many of the waste chemicals (e.g., hydrocarbons, BTEX chemicals (benzene, toluene, ethylbenzene, and xylene), brine, arsenic) are associated with health impacts, though these chemicals are often used in very low concentrations. There are several potential pathways to exposure including leaks or spills that contaminate people via well water or the food chain. As for related air pollutants (e.g. particulate matter, nitrogen oxides, volatile organic compounds), these may lead to a small increase in the risk of cancer and other diseases such as neurological and respiratory effects for those living in close proximity.

Shale gas development can bring positive impacts to local communities, providing a stimulus to local economies arising from jobs for local residents, and customers for local businesses. However, these benefits may be offset by “boom-town” effects in regions that previously did not have oil and gas developments. Such negative impacts include a rise in income inequality, health and safety issues related to a large increase in truck traffic, and the difficulty in adapting local services to the influx of a transient workforce. Finally, impacts on psychological and social well-being have been linked to human health impacts (e.g., fatigue, headaches).

3 Mitigation Options

The shale gas industry has made progress in mitigating some environmental impacts. Through research and development, the industry has been able to reduce water use, land disruption, the volume and toxicity of chemicals used, and methane emissions.

Properly designed management strategies can support responsible shale gas development. The Panel identified aspects of an effective framework for managing the risks posed by shale gas development:

- ☑ Equipment and products used must be designed in compliance with specifications, and tested and maintained for reliability.
- ☑ Equipment and processes used to develop and operate shale gas sites must have comprehensive and rigorous safety management.

- The development of shale gas must be based on science-driven and outcome-based regulations with strong performance monitoring, inspection, and enforcement.
- Drilling and development plans must reflect local and regional environmental conditions, including existing land uses and environmental risks.
- Environmental data should be transparent and available to all stakeholders. Public engagement should occur throughout development.

4 Policy Considerations

There has been much public concern in Canada about the environmental impacts of shale gas development. Moreover, these impacts differ by region and are influenced by such factors as population density, local water usage, regulation, Indigenous rights and titles, and whether the resources are situated on private land, as is common in the east, or on provincially owned lands as is typical in the west.

Insufficient data poses challenges for understanding impacts and risks

In most instances, shale gas development has proceeded without the collection of sufficient environmental baseline data. This makes it difficult to identify and characterize impacts, or to dismiss impacts that are perceived to be inappropriately associated with development. Past monitoring in Canada and elsewhere indicates that gas leakage into aquifers and the atmosphere is frequent enough to raise concern. Possible environmental and health effects of shale gas development may take decades to become apparent, underlining the need for long-term monitoring and adaptive management.

Contrasting views on shale gas development as a bridge to a low carbon economy

There are contrasting views on how shale gas development could affect GHG emissions. Proponents argue that shale gas will have a desirable impact on climate change because natural gas releases less carbon dioxide when burned than coal/oil; others maintain that methane leakage lessens these benefits and that further development of shale gas resources may increase consumption (due to cheap gas), negating the benefits, and reinforcing the patterns of fossil fuel dependency that drive climate change. Though clean energy is becoming increasingly cost competitive with traditional fossil fuels, they remain more expensive and require significant infrastructure investment. Furthermore, clean energy still face technological hurdles related to intermittency (e.g., when the sun doesn't shine or the wind doesn't blow), transmission, and storage. Some propose that natural gas could serve as a bridge – from coal and oil to renewables – if one expects cost reductions and technological advances in clean energy to be slow (say a decade or two away). Others raise concern that investing in shale gas as a bridge may delay development of renewable resources.

Challenge in balancing local, regional, provincial, and national concerns

Shale gas development poses challenges for governance. Its benefits are primarily regional or national, while many of the adverse impacts – on water, air quality, land - are local. Decisions on development also need to consider Indigenous rights and title issues, differences in social context, and the fact that many questions remain about environmental impacts for which there are no answers due to limited study or monitoring. Some provinces, which in Canada have jurisdiction over shale gas development and its regulation, are therefore engaged in a "go-slow" approach allowing time to collect and respond to new information.

Acknowledgements

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