CAPE
Canadian Association
of Physicians
for the Environment

Association Canadienne
des Médecins
pour l'Environnement
ACME

Fractures in the Bridge

UNCONVENTIONAL (FRACKED) NATURAL GAS, CLIMATE CHANGE AND HUMAN HEALTH

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FRONT COVER PHOTO: iStock – Natural gas well in rural British Columbia

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INTRODUCTION AND BACKGROUND

The growth in exploitation of unconventional oil and natural gas (UOG) has raised concerns about the impacts of this development on human health and the environment. The main differences between the extraction of UOG and conventional oil and natural gas are: 1) the use of long, deep wells combined with directional and horizontal drilling across the geological formation; and 2) the use of high-volume hydraulic fracturing (fracking) where a mixture of sand, chemicals, and fluid is injected into the well under very high pressure to shatter the rock formation and release the oil or natural gas trapped in the rock.

Canada is the world's fourth largest producer of natural gas and oil respectively, responsible for about five percent of global production of each. Coalbed methane, shale and tight gas are unconventional natural gas resources that can be found across Canada. In 2018, about 71 per cent of the natural gas produced in Canada was unconventional gas – tight gas, shale gas, or coalbed methane. About 70 per cent of Canada's marketable gas reserves are unconventional shale and tight gas reservoirs. The oil sands, which are also an unconventional source of oil, use extraction techniques that are different from fracking, so they are not included in this paper.

The number of jurisdictions around the world that have adopted a ban or moratorium on unconventional oil and natural gas (UOG) development is increasing.

The regulatory framework for oil and gas development in Canada is complex with federal, provincial, territorial and Indigenous governments each having a role to play. In Canada, provinces are the primary regulator of the development of energy resources within their boundaries. The number of jurisdictions around the world that have adopted a ban or moratorium on UOG development is increasing. These include Bulgaria, France, Germany, Ireland Netherlands, Uruguay, Northern Ireland, Scotland, England and Wales in the United Kingdom, and six US states. In Canada, the following provinces have a partial or complete moratorium on hydraulic fracturing: New Brunswick, Newfoundland and Labrador, Nova Scotia, Prince Edward Island, and Québec.

CONCERNS RELATED TO HYDRAULIC FRACTURING

Over 1,000 different chemicals have been used in hydraulic fracturing fluids. The chemicals vary in toxicity with many lacking basic toxicity data. Some are known or suspected carcinogens, reproductive or developmental toxicants, or endocrine disruptors. Proprietary concerns obstruct access to information about the constituents of specific fracturing fluids.

Horizontal drilling and hydraulic fracturing for unconventional natural gas is a water-intensive process. Water use has been increasing to improve well productivity. There is potential for adverse impacts on water courses, wildlife and drinking water sources from water withdrawals made in areas, or at times, of low water availability.

Risks of water contamination are primarily related to well construction and management of wastewater. Failures in well integrity can allow the migration of substances from the well into the surrounding groundwater or air. Contamination of surface and shallow ground water can also occur from spills, leaks, and/or the disposal of inadequately treated wastewater. Many of these adverse impacts are more likely to occur with abandoned and orphan wells.

Negative impacts on drinking water quality are possible. The lack of monitoring, including baseline monitoring before operations begin, makes it difficult to determine the cause of elevated concentrations of various contaminants in ground and surface waters around UOG wells. However, there have been instances in which contamination could clearly be linked to hydraulic fracturing activity.

Drilling wells and extracting gas can also release naturally occurring radioactive materials (NORMs) and bring them to the surface where they can expose humans and other forms of life to radiation. When wastewater is stored in surface impoundments and evaporates, these contaminants can become more concentrated. Wind can disperse these particles into the air, making them a risk for human health.

There are several sources of air pollutants at a well site: diesel equipment and trucks, flaring, and general fugitive emissions including the volatilization of components of fracturing fluids at different stages of their use. Oil and gas operations are a source of nitrogen oxides (NO_x) and volatile organic compounds (VOCs), which are precursors of ground-level ozone. Studies in the United States have identified UOG operations as important contributors to ground-level ozone concentrations. In addition, high levels of various toxic chemicals – such as radon, hydrocarbons, benzene, polyaromatic hydrocarbons (PAHs), and heavy metals – have been found near UOG wells.

There have been many instances of earthquakes caused by hydraulic fracturing and the injection of fracturing water into deep wells in Canada. While many of these earth movements are too small to be felt, stronger events are possible. For example, an event of 4.6 moment magnitude was recorded on August 17th, 2015 in the Beg-Town area in the North Montney BC and was attributed to UOG developments.

HEALTH STUDIES

Work in the oil and gas industry can be dangerous. In the United States, the risk of death in this sector is seven times the average risk for industry as a whole. In addition to safety risks such as vehicle collisions, explosions, fires, and falls, risks to workers include exposure to a wide range of chemicals. In the US, exposures above occupational exposure limits have been recorded for both benzene and silica. In the case of silica these exceedances were up to 20 times the prescribed limits.

Studies of populations living near UOG operations in the US have identified over 30 different negative health outcomes including adverse birth outcomes, birth defects including congenital

A 2016 review concluded that there is moderate evidence for an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer from occupational or community exposure to oil and gas activities.

heart defects and neural tube defects, cancer, cardiovascular diseases, dermal effects, gastrointestinal symptoms, neurological effects, psychological impacts and respiratory illnesses.

A 2019 review of health studies directed at unconventional natural gas development found the strongest evidence for adverse impacts on: pregnancy; birth outcomes such as high-risk pregnancy, preterm births and possibly low birth weight; and asthma exacerbation.

When health studies for conventional and unconventional oil and gas extraction were considered together, a 2016 review concluded that there is moderate evidence for an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer from occupational or community exposure to oil and gas activities.

Theses reproductive findings are supported by cellular studies which indicate that chemicals found in oil products, fracking fluids and waste products have estrogenic, androgenic and progestorenic effects. They are also supported by animal studies conducted in labs.

A few studies have also looked at the potential impacts of fracking on cancer incidence. While the results are mixed, there is evidence which suggests that fracking may increase the risk of acute lymphocytic leukemia (ALL) among children whose mothers live in close proximity to oil and gas wells during pregnancy. One case-control study found that children diagnosed with ALL were 3 to 4 times more likely to live in areas with active oil and gas wells than children with non-hematologic cancers. It also found that the association increased as the density of oil and gas wells increased.

These cancer findings are supported by: a meta-analysis which found a statistically significant association between maternal exposure to solvents, paints and petroleum products during pregnancy and childhood ALL; occupational studies that have linked leukemia in adults occupationally exposed to benzene; and a biomonitoring study conducted in northeastern BC which found high levels of benzene metabolites in the urine of pregnant women who live in close proximity to fracking wells.

COMMUNITY-LEVEL IMPACTS

Effects related to stress and psychological distress have also been documented. While the quality of studies has improved, overall, the evidence is still limited because of the lack of accurate measures of exposure. While there is insufficient information to determine a protective level of noise from oil and gas operations, evidence indicates that the level of noise from these operations can be above those that have been found to have negative effects in other situations.

Communities near UOG development can experience a "boom town" effect where there is sudden growth in population and economic activity related to the development of a natural resource followed by a hollowing out of the community once the development phase ends or the resource is depleted. The rapid changes from an influx of people (often predominantly young, unattached males), industrial-type activity, and the changes to the local landscape, can be a traumatic experience for people who live in the community.

Indigenous people in Canada, who often have poorer health status than other populations in Canada, are among the people most frequently and deeply affected by UOG development. This development impacts their traditional food supply, and disturbs the lands and waters that support their health and well-being, and which are also at the core of their cultural and spiritual identity. Integrating a health and equity impact assessment (HEIA) into the decision-making process is critical to identifying and mitigating the potentially adverse impacts of UOG development on vulnerable populations are considered and that initiatives are put in place to promote health equity should the development proceed. Such assessments, at present, are rarely carried out in depth.

Development of oil and natural gas impacts wildlife in a variety of ways that can be especially critical for species at risk. Conversion of lands to human uses reduces available habitat, associated road and pipeline networks can fragment habitat, and increased human activity can impact animal behaviour. These factors can reduce populations, decrease survival, and increase mortality among local animal populations.

Indigenous people in Canada, who often have poorer health status than other populations in Canada, are among the people most frequently and deeply affected by unconventional oil and natural gas development.

Smoking beaver over a wood fire in northern Ontario *Photo by Dan Tobias*

CLIMATE CHANGE

Natural gas, which is mostly methane, used to be viewed as a bridge fuel to a lower carbon future. However, that was before evidence demonstrated that significant quantities of methane can be released as fugitive or intentional emissions during the drilling, extraction, transportation and use of natural gas. When it comes to climate impacts, these emissions are far more harmful than carbon dioxide (CO_2) as methane's global warming potential is 86 times that of CO_2 over a 20-year timeframe.

Several studies suggest that releases of methane from the oil and gas sector have been greatly underestimated. Since 2007, global methane emissions have been rising, which will make it even more challenging to meet the goals of the Paris Agreement on climate change. Evidence indicates that unconventional oil and gas development in North America is contributing to this increase. This reinforces the urgent need to end reliance on unconventional oil and gas.

Lastly, winning the fight against climate change requires a deep decarbonization of our energy systems. A number of countries, including Canada, have announced their intention of becoming net-zero emitters by 2050. This requires the elimination of most, if not all, fossil fuels from our energy system. Natural gas is a fossil fuel that contributes to climate change. There are now more cost-effective, zero-carbon options for a large number of end-uses (e.g. electricity generation, transportation). We must phase out our use of natural gas and stop investing in infrastructure that relies upon it.

CONCLUSIONS AND RECOMMENDATIONS

Taking into account: the increasing evidence of adverse health, environmental and community impacts from unconventional oil and gas development; the need to respect and honour commitments made to the Indigenous peoples of Canada; the contribution of unconventional oil and gas development to climate change; Canada's commitment to drastically decrease its carbon emissions by 2030; and the significant health impacts associated with the continued use of fossil fuels; a rapid and just transition away from natural gas and oil extracted with fracking to clean and equitable renewable energy sources is needed.

CAPE recommends that:

1 **Each province and territory with unconventional natural gas and oil reserves should declare a moratorium on new development of those reserves with fracking;**

2 **Each province and territory that is currently extracting unconventional natural gas and oil reserves with fracking should:**

   a) Develop and implement a strategic plan to phase out existing production to meet the goals stipulated in the 2015 Paris Agreement and in accordance with the findings of the 2018 Intergovernment Panel on Climate Change (IPCC) report;

b) Ensure that health and equity impact assessments (HEIA) are conducted to inform the phase-out schedule for existing natural gas and oil wells that involve fracking; and

c) Develop and implement strong regulations which ensure that: oil and gas assets reaching their end of life are not offloaded; tight timelines are applied to their decommissioning; and land reclamation is held to standards that will prevent adverse impacts on the environment, wildlife and/or communities;

3 The federal, provincial and territorial governments:

a) Phase out all subsidies that are provided to the development or promotion of unconventional natural gas and oil reserves that are extracted with fracking to meet the goals stipulated by the 2015 Paris Agreement and the findings of the 2018 IPCC report;

b) Develop programs and policies to increase energy efficiency and develop clean and equitable renewable energy sources to transition away from reliance on all fossil fuels including natural gas to meet the goals of the 2015 Paris Agreement; and

c) Develop and fund, a just transition plan, in collaboration with workers and communities affected by the transition from fossil fuels which includes: bridge funding for older workers nearing retirement; retraining for younger workers; and community investments in new technologies and industries to revitalize and transform affected communities.

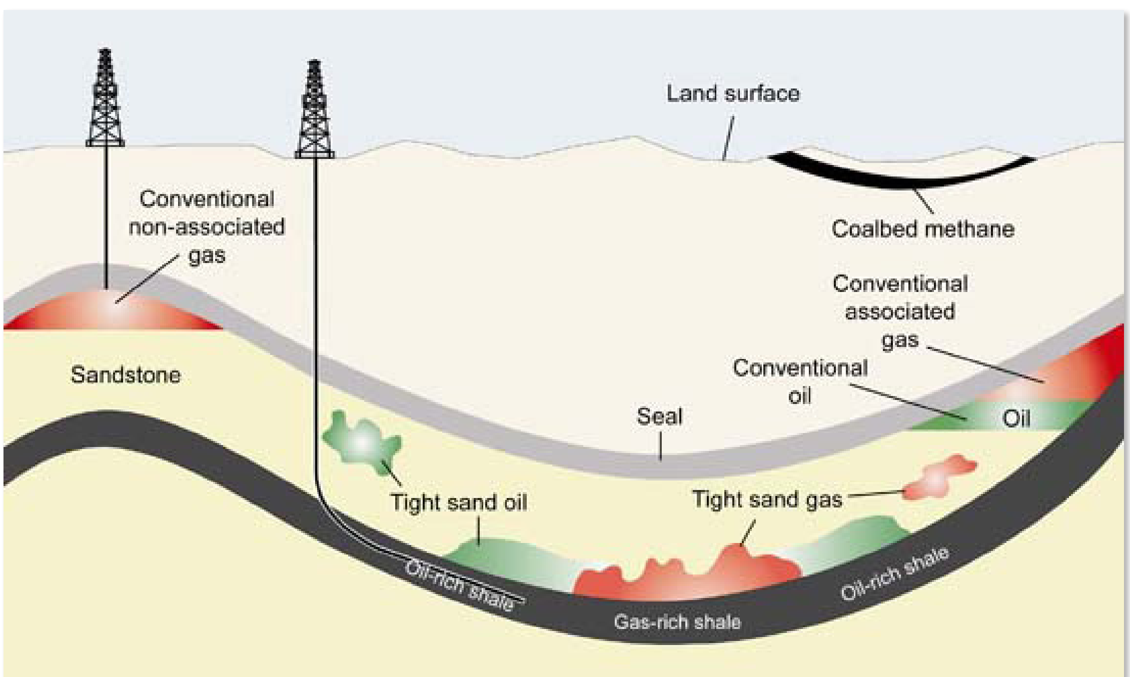

FIGURE 1: Unconventional and Conventional Oil and Gas Deposits. *Source:* Canada Energy Regulator (2011), Modified from Energy Information Administration and United States Geological Survey

Glossary of Terms

OIL AND GAS SECTOR TERMS

Conventional	Oil and gas found in conventional reservoirs, such as porous and permeable rock
Fracking	High-volume hydraulic fracturing used on unconventional reservoirs
Oil & Gas	Refers to both conventional and unconventional oil and gas resources
Tight rock	Low-permeability sandstone, shale or coal seams
Unconventional	Oil and gas found in unconventional reservoirs, usually characterized by low-permeability (e.g. sandstone, shales and coal seams)
UOG	Refers to unconventional oil and gas activities developed using fracking
UNGD	Refers to unconventional natural gas development

CHEMICALS/POLLUTANTS

BTEX	A mixture of benzene, toluene, ethylbenzene and xylene
DPM	Diesel particulate matter
CO_2	Carbon dioxide – primary greenhouse gas
CH_4	Methane – greenhouse gas and primary component of natural gas
GHG	Greenhouse gas
NORMs	Naturally occurring radioactive materials
NO_x	Nitrogen oxides
PAHs	Polyaromatic hydrocarbons
PM	Particulate matter – airborne liquid or solid particle
$PM_{2.5}$	Fine particulate matter – airborne liquid or solid particle – less than 2.5 microns in size
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
VOCs	Volatile organic compounds

HEALTH & ENVIRONMENTAL IMPACTS, PROCESSES & UNITS OF MEASUREMENT

ALL	Acute lymphocytic leukemia
HIA	Health Impact Assessment
HEIA	Health and Equity Impact Assessment
L_{eq}	Unit of measurement for sound – not weighted by frequency
L_{den}	An average of day-evening-night time sound levels with a penalty of 5 dBA during evening hours and 10 dBA during night-time hours
dBA	Decibels – unit of measurement for sound – weighted for the human ear
M	Motion – unit of measurement for seismic activity – using the Modified Mercalli Scale

ORGANIZATIONS

ECCC	Environment and Climate Change Canada
HC	Health Canada
CER	Canada Energy Regulator
NRCan	Natural Resources Canada
OWA	Orphan Well Association
WHO	World Health Organization
Review Panel	BC Review Panel struck by the BC Minister of Energy, Mines and Petroleum Resources

Introduction

The recent rapid expansion of unconventional oil and gas (UOG) extraction has raised concerns about its impact on human health and the environment. Assessing the risk of this extraction is challenging and made more difficult by the rapidly changing technology and regulatory framework, complex and varied geological formations where wells are found, the impact of other activities in the surroundings including past oil and gas operations, and a changing climate (Review Panel, 2019).

Until recently, few health studies had been conducted on the impact of natural gas and oil extraction from unconventional reservoirs. This delay is not surprising as adverse impacts are often only recognized well after exposure has occurred. The evidence now available indicates that various adverse health outcomes may be associated with UOG activities. These include preterm births, low birth weights, asthma exacerbations, chronic sinus inflammation, migraines, fatigue, and dermatologic disorders (Gorski and Schwartz, 2019).

Different terms are used in the paper:

- **UOG is used when studies or data refer to unconventional oil and gas activities;**
- **UNGD is used when studies or data refer to unconventional natural gas development specifically;**
- **When "oil and gas" is used it refers to both conventional and unconventional resources.**

This review highlights what is known about the potential impacts of UOG development on health and the environment. It summarizes the evidence found in recent systematic reviews or authoritative assessments. Key studies, as well as newer evidence, are cited as necessary. A search was conducted on Ebsco, Ovid, Google Scholar and the Internet on 14 April 2019 and updated on 3 June 2019. The search terms "fracking", "shale gas" or "unconventional natural gas" were combined with the term "health" to identify documents published from 2014 to the present. The Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (CHPNY and PSR, 2019) was also consulted to help identify useful documents.

This review begins by giving background information on hydraulic fracturing, UOG development and regulatory oversight in Canada. It outlines the concerns related to hydraulic fracturing – chemicals used; naturally occurring radioactive materials (NORMs); end-of-life management and orphan wells; water quantity and quality; air quality; induced earthquakes; and worker health and safety.

Results of the available health studies are then summarized with attention directed at: vehicle collisions; asthma; impacts on the heart, central nervous system, and urinary tract; reproductive effects; cancer; mental health; and sexually transmitted infections. Community level impacts, including noise and light pollution, ecological impacts and cumulative effects are then discussed. Finally, issues of equity and contribution of UOG to climate change are highlighted.

Background

CONVENTIONAL AND UNCONVENTIONAL OIL AND GAS

Oil and gas are described by the type of geological formation where they are found. Conventional oil and gas occur in pools of porous and permeable rock trapped below an impermeable formation. Unconventional sources include those found in low-permeability (tight) sandstone, shale and coal seams. These reservoirs are more difficult to exploit, but advances in technology have made them more economical to extract (USEPA, undated; NRCan, 2016).

WHAT IS HYDRAULIC FRACTURING?

High-volume hydraulic fracturing is part of the process used to extract oil and gas from unconventional reservoirs. It involves the injection of large amounts of fluid, usually water, sand, with various additives at very high pressure into a well to release oil or natural gas from very tight rock (NYSDEC, 2015). It is often used with directional or horizontal drilling to capture the oil or gas from the geological formation. Hydraulic fracturing has enabled the extraction of oil and gas at very high pressure from unconventional reserves.

HOW DO EXTRACTION PRACTICES DIFFER?

There are several differences between methods used to extract conventional and unconventional oil and gas. For UOG, a number of wells can be drilled from a single well pad (a multi-well pad). This reduces the total number of pads and surface area needed, but because each pad is larger, there is far more intense industry-like activity occurring around them (NYSDEC, 2015). This intense activity can change the character of rural and semi-rural areas, impair air and water quality, increase noise and traffic, alter natural habitats, and affect places of cultural, historical and spiritual significance in a negative way.

UOG is extracted using directional or horizontal wells. These wells are usually longer than vertical ones and so generate larger volumes of drilling waste (cuttings) that need to be disposed of (NYSDEC, 2015). Drilling cuttings are the ground-up rock generated during the drilling process. They return to the surface as part of the drilling mud which is mostly a mixture of water and clay.

Compared to conventional wells, UOG often uses significantly more water in the initial well preparation as well as a variety of different chemical additives, which raises concerns about impacts on air and water quality. The amount of water used in UOG is increasing as more effort is needed to extract the oil or gas (Hughes, 2019).

LIFE CYCLE OF UNCONVENTIONAL OIL AND GAS DEVELOPMENT

The life cycle of UOG extraction includes:

- Initial exploration followed by construction of the well pad. This phase consists of land disturbance, clearing of trees and altering other lands to construct well pads, access roads, and other supporting infrastructure.
- Then there is the drilling phase, which uses heavy machinery to drill wells that result in large quantities of drill cuttings.
- Once the well has been drilled, a mixture of water, sand and various additives is injected at very high pressure into the well to create paths in the rock for the oil or gas to migrate to the well. Hydraulic fracturing is part of "well completion," which is the preparation of the well for production.
- Once the well is ready for production, drilling and well completion equipment will be removed and equipment installed to capture the oil or gas that is then transported to the compressor stations, gathering lines, and ultimately into the distribution system.
- Once the well is no longer producing, the well is plugged and closed, and the area around the well pad is required to be restored (NYSDEC, 2015; Srebotnjak, 2018).

Risks to health and the environment can occur at any of these stages.

UNCONVENTIONAL OIL AND GAS DEVELOPMENT IN CANADA

Canada is the world's fourth largest producer of natural gas, responsible for about five percent of global production of each (NRCan, 2019A). In 2018, Alberta produced about 69 per cent of the natural gas in Canada while British Columbia and Saskatchewan produced 29 per cent and 2 per cent respectively (NRCan, 2019A).

Shale and tight gas resources are found across Canada. The main formations are:

- **Muskwa, Otter Park and Evie (Horn River Basin) (BC)**
- **Evie, Muskwa and Otter Park (Cordova Embayment) (BC)**
- **Muskwa and Besa River (Liard Basin) (BC and YT)**
- **Montney (BC and AB)**
- **Duvernay (AB)**
- **Kettle Point (ON)**
- **Utica (QC)**
- **Frederick Brook (NB)**
- **Horton Bluff (NS)**
- **Canol (YT) (NRCan, 2016)**

Canada's natural gas markets are integrated with those of the United States (US). As such, while still a net exporter, Canada also imports gas from the US. In 2018, about 71 per cent of the natural gas produced in Canada came for unconventional reserves (NRCan, 2019A). Currently most of Canada's unconventional gas is produced in northeastern British Columbia. About three quarters of Canada's marketable reserves are unconventional shale and tight gas reservoirs (NRCan, 2016). The Canada Energy Regulator (CER) estimates that by 2035, tight and shale gas production together will represent 80 percent of Canada's natural gas production (NRCan, 2016).

Three quarters of Canada's oil production is in Alberta. Saskatchewan and Newfoundland and Labrador are also important oil producers (NRCanB, 2019). The development of tight

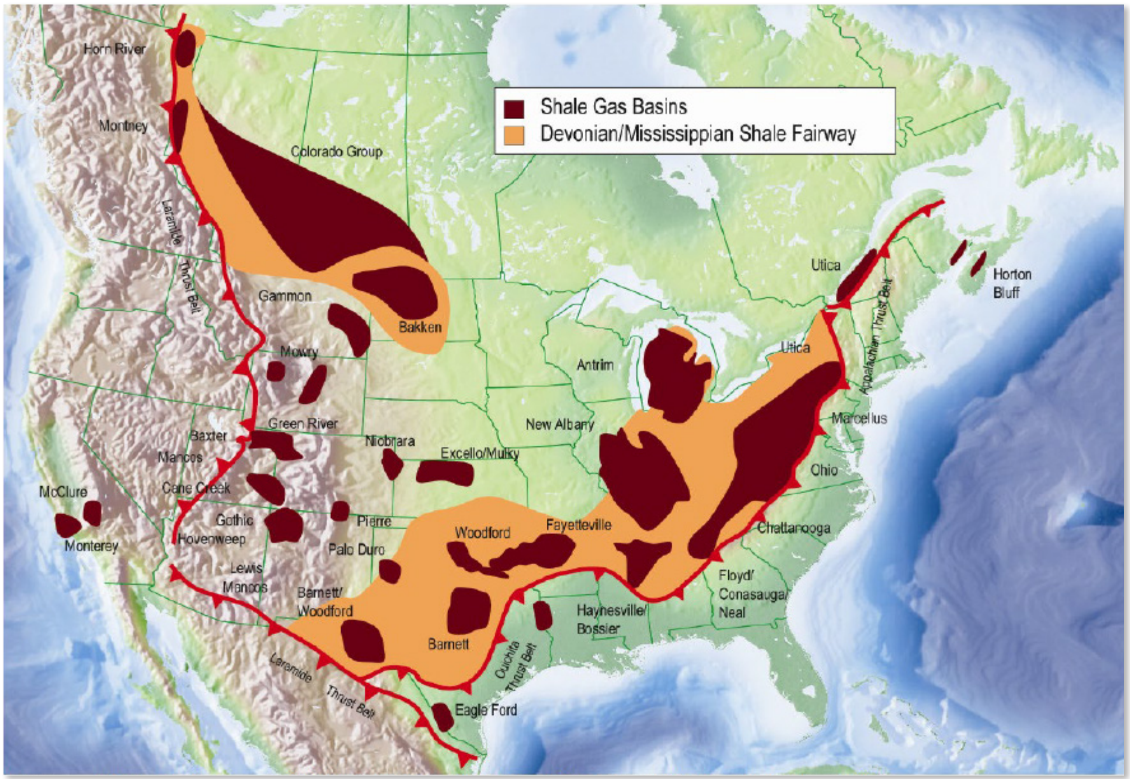

FIGURE 2: Map of North America Shale Gas Basins and Plays. *Source:* Canada Energy Regulator, 2009.

oil reservoirs is still at an early stage in Canada. Estimates of Canada's shale and tight oil resources vary. In 2014, it was estimated that 10 percent of oil production came from tight reservoirs (NRCan, 2016). Ninety-seven per cent of Canada's oil reserves are in the oil sands (NRCan, 2016). While they are also an unconventional oil source, the extraction techniques used are different from fracking, so they are not included as an "unconventional oil" source in this paper.

REGULATORY OVERSIGHT IN CANADA

In Canada, provinces are the primary regulator of the development of energy resources within their boundaries. While there are differences among US states and Canadian provinces, the regulatory regimes where UOG is currently occurring are comparable across North America (Kniewasser and Riehl, 2018). Federal departments and agencies are involved in the following aspects (NRCan, 2017):

- Natural Resources Canada (NRCan) is the department that provides expertise and policy leadership on the development and management of natural resources in Canada;
- Environment and Climate Change Canada (ECCC) has regulatory authority for pollution prevention and habitat protection under the *Canadian Environmental Protection Act*, 1999 (CEPA 1999), *Species at Risk Act* and the *Migratory Birds Convention Act*;
- Health Canada (HC) and ECCC are responsible for assessing risks associated with

environmental pollutants and chemicals under CEPA 1999. This includes the regulation of listed air pollutants and greenhouse gases (GHGs);

- The Canada Energy Regulator (CER) regulates energy trade and the construction and operation of interprovincial and international pipelines. It has primary regulatory authority over oil and gas development in Nunavut, parts of the Northwest Territories, and the offshore areas of British Columbia, the Arctic and the East Coast that are not governed under the Canada-Newfoundland and Labrador Offshore Petroleum Board and the Canada–Nova Scotia Offshore Petroleum Board;
- Indian Oil and Gas Canada is a special operating agency that manages and regulates oil and gas resources on Indigenous reserve lands which are mostly below the 60th parallel.

See the **Appendix** for an overview of the provincial and territorial regulatory frameworks.

BANS OR MORATORIA ON FRACKING

Jurisdictions in various parts of the world have instituted bans or moratoria on hydraulic fracturing as a precautionary measure (See Table 1).

TABLE 1: Jurisdictions that have adopted a moratorium or ban on unconventional oil or gas development.
Source: CHPNY and PSR, 2019 and Syal R., 2019

NATIONAL OR SUB-NATIONAL AUTHORITY	YEAR
Argentina – Entre Ríos	2017
Australia – Tasmania	2018
Australia – Victoria	2016
Bulgaria	2012
Canada – New Brunswick	2015 (partial moratorium)[1]
Canada – Newfoundland & Labrador	2013
Canada – Nova Scotia	2014
Canada – Prince Edward Island	2017
Canada – Québec	2013 (partial moratorium)[2]
France	2011
Germany	2016
Ireland	2017
Netherlands	2015
Spain – Castilla Leon	2015
UK – Northern Ireland	2015
UK – Scotland	2015 (extended indefinitely 2017)
UK – Wales	2015
UK – England	2018 (announced)
Uruguay	2017
USA – Connecticut	2019 (pending)
USA – Maryland	2017
USA – New York State	2014
USA – Oregon	2019
USA – Vermont	2012
USA – Washington State	2019

1 On June 5, 2019, an Order in Council amended the regulation to exempt certain parcels of land from the prohibition (New Brunswick, 2019).
2 Source: NRCan (2017).

Concerns Related to Hydraulic Fracturing

CHEMICALS USED

More than 1,000 different chemicals have been used in fracturing liquids as proppants, biocides, surfactants, viscosity modifiers, and emulsifiers. Information on a large number of additives is not disclosed to protect intellectual property rights. The chemicals used during hydraulic fracturing vary greatly based on various site-specific considerations (Review Panel, 2019).

The most commonly used chemical is hydrochloric acid (Sibrizzi and LaPuma, 2016). Fracking liquid usually contains small amounts of 3-12 additives; specific substances used vary depending on the rock formation and the chemical composition of the water being used (FracFocus.ca). The chemicals vary in toxicity, with many lacking basic toxicity data. Some are known or suspected carcinogens, reproductive or developmental toxicants, or endocrine disruptors (Bolden et al., 2018; Elliott et al., 2017b; Saunders et al., 2018; Webb et al., 2014).

More than 1,000 different chemicals have been used in fracturing liquids. These include known or suspected carcinogens, reproductive or developmental toxicants, and endocrine disruptors.

Determining the toxicity of this mixture is difficult: "the challenge as a toxicologist is that there is no 'standard formula' for these fluids" (Review Panel, 2019). Hydraulic fracturing fluids and wastewater from UOG development contain hundreds of substances with the potential to contaminate drinking water. Elliott and colleagues (2017a) evaluated 1021 chemicals found in hydraulic fracturing fluids, wastewater or both, for potential reproductive and developmental toxicity. Toxicity information was lacking for about 75 percent of the chemicals. For the remaining 240 substances, 43 percent (103) of the chemicals had evidence of reproductive toxicity, 40 percent (95) had evidence of developmental toxicity, and 17 percent (41) had evidence for both reproductive and developmental effects. Only 42 percent (67) of the chemicals with known reproductive or developmental potential had drinking water quality guidelines.

NATURALLY OCCURRING RADIOACTIVE MATERIALS

Geologic formations that contain oil and gas deposits also contain naturally occurring radionuclides, which are referred to as naturally occurring radioactive materials (NORMs). These include uranium-238, thorium-232, radium-226, potassium-40 lead-210, polonium-210 and various decay products (Review Panel, 2019).

The extraction process for oil and gas concentrates these substances and brings them to the surface where they can expose humans and other forms of life to radiation. Wastes that contain these substances are classified as Technologically Enhanced Naturally Occurring Radioactive Material

(TENORM). The management of these wastes is a provincial matter (Review Panel, 2019).

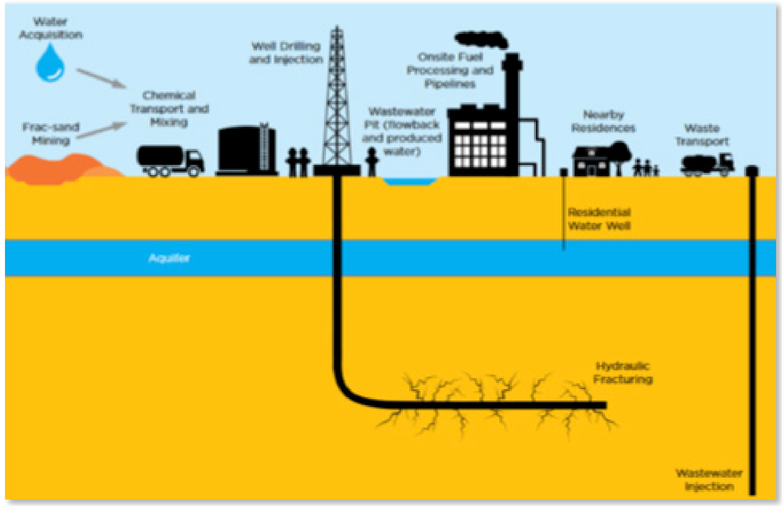

FIGURE 3. Steps in Unconventional Oil and Gas Development.
Source: Union of Concerned Scientists, 2015.

At times, flow-back and produced waters from some shale formations contain levels of NORMs several hundred times above drinking water standards (CSST, 2016). The BC Review Panel noted the lack of data to assess the exposure to and risk from NORMs, as well as the limited capacity to effectively manage wastes containing NORMs. If wastewater is stored in surface impoundments it evaporates, which concentrates these contaminants even further. Concentrations as high as 425 Bq/L have been measured. Wind can make these particles airborne which becomes a risk to health. In BC, wastes that exceed the maximum threshold (δ 70 Bq/g; radium-226 δ 5 Bq/g)[3] must be shipped out of the province for treatment in an approved hazardous waste facility (Review Panel, 2019)[4].

END-OF-LIFE MANAGEMENT AND ORPHAN WELLS

Deterioration of the well casing in the long-term, especially once the well is no longer in production, has been identified as a possible way in which groundwater can become contaminated or by which methane can be released into the air (Review Panel, 2019). In its report, the BC Review Panel noted that there is insufficient information to assess this risk.

Structural failure and deterioration of the well casing is a common cause of contamination of groundwater and release of methane into the air.

Once a formation is depleted and no longer capable of producing at a profitable level, the well is abandoned. At that stage the well is permanently plugged with cement to prepare the site for restoration to its pre-drilling conditions.

Wells that are deserted, usually as the result of the owner's insolvency or bankruptcy, are called "orphan wells". This means that there is no entity responsible for the decommissioning of the well or other infrastructure such as dams or impoundments (Review Panel, 2019).

The BC Review Panel expressed the concern that if this infrastructure fails, it could result in harm to the environment (Review Panel, 2019). Of course, when contaminants are released into the

3 δ (delta) refers to the incremental dose, the dose in addition to natural background and medical exposures.
4 Health Canada has developed guidelines for the management of NORM (Health Canada, 2014).

environment, they can present a risk to people as well. Currently, the majority of inactive and orphan wells in BC are conventional wells. This could change as the number of wells in unconventional gas reservoirs increases. While there are financial mechanisms to cover the cost of restoration and reclamation of orphan oil and gas infrastructure, it is unclear if these are sufficient to fully meet the needs and prevent contamination of the environment (Review Panel, 2019).

In Alberta, where the Orphan Wells Association (OWA) has been established to decommission orphan wells and restore the land to its original condition, there are concerns about is ability to keep up with demand. Alberta has recently estimated that, of the more than 300,000 wells in the province, at least 167,000 are inactive, abandoned or orphaned (Davis, Anthony. 2019). This means that more than half of the wells in Alberta are currently waiting for decommissioning and reclamation. In April of this year, an organization called the Alberta Liabilities Disclosure Project estimated the cost of cleaning up Alberta's oil and gas wells would be between $40 billion and $70 billion using documents accessed with freedom of information laws.

WATER QUANTITY

Horizontal drilling and hydraulic fracturing for unconventional natural gas is a water-intensive process. The amount of water required varies by geological formation, well depth and length, and the formulation of fracturing fluids (Hughes, 2019; Kniewasser and Riehl, 2018). However, water use for hydraulic fracturing has been increasing as a way to improve the productivity of the well. Since 2010, water use in the US increased three-fold to an average of 12 million US gallons or 45,425 cubic metres per well in 2018 (Hughes, 2019). There is also the potential of adverse impact on water courses, wildlife and drinking water sources from water withdrawals made in areas, or at times, of low water availability (Review Panel, 2019; USEPA, 2016).

Since 2010, water use for fracking in the US has increased three-fold to an average of 12 million US gallons per well in 2018.

Water use intensity is the amount of water used to produce a unit of fuel. In Alberta, from 2013 to 2017, the average intensity for hydraulic fracturing was 0.4 barrel[5] of water for 1 barrel of oil-equivalent. This compares to 0.2 for in-situ recovery, 0.8 for enhanced oil recovery, and 2.6 for the tar sands. However, water intensity in hydraulic fracturing has increased by more than 250 per cent over this period – it took 0.59 barrels of fresh make-up water to produce one barrel of oil equivalent in 2017 (AER, 2017). Compared to other extraction techniques that use water on an ongoing basis, hydraulically fractured wells use water only for the hydraulic fracturing itself.

Only a small amount of the water used in hydraulic fracturing is recycled – about 4 percent in Alberta (AER, 2017). Based on 2015 data, about 38 percent of fluids used in a well return to the surface as produced water in BC. Of that, about 40 percent, or 15 percent of total water used, is reused in further hydraulic fracturing operations. The remainder is usually stored on-site and then trucked for disposal in injection wells (Kniewasser and Riehl, 2018).

5 One US petroleum barrel equals 158.99 litres or 0.159 cubic metres

WATER QUALITY

Risks of water contamination are primarily related to well construction and management of wastewater (Kniewasser and Riehl, 2018). Studies have reported an association between the location of wells in which natural gas is produced with hydraulic fracturing and elevated concentrations of methane, arsenic, selenium, strontium, and total dissolved solids in water (TDS) (CCST, 2016). However, there is no consensus as to whether these elevated levels are naturally occurring or caused by hydraulic fracturing processes, defects in well production, abandoned wells, or a combination of these mechanisms. Knowledge gaps include limited water quality or biological monitoring data; limited groundwater and permafrost information; and poor information on the chemical composition of produced waters (Review Panel, 2019).

Contamination of surface water and shallow groundwater can occur from spills, leaks, and/or the disposal of inadequately treated wastewater (Review Panel, 2019; CCA 2014; U.S. EPA, 2016; Vengosh et al., 2014). In addition to flowback water that reaches the surface during and after hydraulic fracturing, contaminants from accidental surface releases, either at well pads where the chemicals are stored and used, or along transportation routes, can impact water sources. Grant and colleagues (2016) found higher accumulation of methyl mercury in aquatic life close to gas wells in the Marcellus shale basin.

The failure of liners in containment ponds poses a risk of contamination to ground and surface water as well (Review Panel, 2019). Compromised or failed structural integrity of cement in oil and gas wells and well bores are considered the most likely pathway for groundwater contamination (CCST, 2016). While well integrity is a concern for all types of wells, it is reasonable to assume that higher induced pressure and multi-stage fracturing could result in more long-term damage in or deterioration of fractured wells.

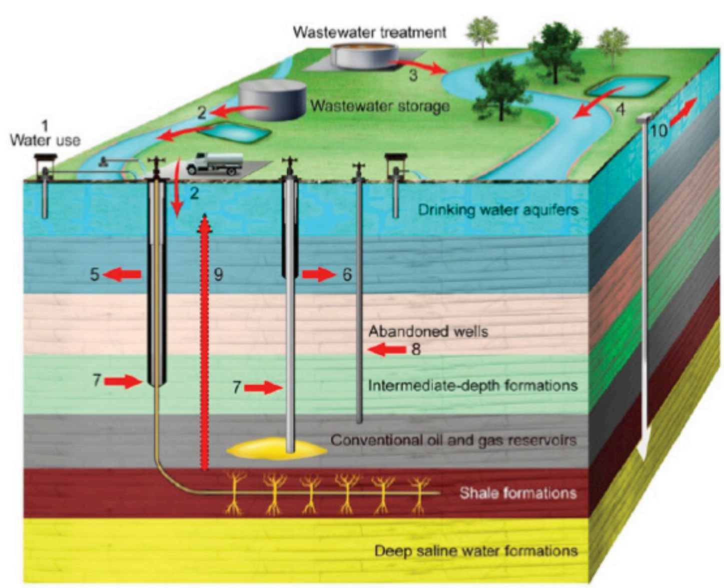

FIGURE 4: Potential Pathways for Contamination of Drinking Water and Ground Water from Hydraulic Fracturing. *Source:* Newfoundland and Labrador Hydraulic Fracturing Review Panel, 2016.

Wastewater from hydraulic fracturing has very high levels of "total dissolved solids". The main substances in this brine are sodium, chlorides, bromides, bicarbonates, sulfates, calcium, magnesium, barium, boron, strontium, radium, hydrocarbons, and heavy metals (U.S. EPA, 2016).

There have been instances in which contamination of surface and ground water could clearly be linked to hydraulic fracturing activity.

Fracking in British Columbia
Photo by Don Pettit

One of the challenges when assessing the risk of water contamination from hydraulic fracturing is the inadequacy of on-going monitoring that occurs. This means it is not possible to assess if the presence of contaminants near a well is of natural origin or the result of UOG activities. While it is thought that the potential for shallow groundwater to be contaminated from vertical migration of hydraulic fracturing fluid or wastewater in injection wells is very low, more studies are needed to confirm that this cannot occur along pre-existing faults, or via neighbouring wells or other pathways (Review Panel, 2019). However, negative impact on drinking water quality is possible. There have been instances in which contamination of surface and ground water could clearly be linked to hydraulic fracturing activity (USEPA, 2016).

AIR QUALITY

There are several sources of air pollution at a well site: diesel engines that emit nitrogen oxides (NO_x), fine particulate matter (PM2.5), volatile organic compounds (VOCs), and polyaromatic hydrocarbons (PAHs); flaring which generates NO_x, particulate matter (PM), and VOCs; and general fugitive emissions that contain VOCs that come from the oil or gas (CSST, 2016; Saunders et al., 2018). In addition, there is the volatilization of components of fracturing fluid from flowback fluids, proppant injection, venting and flaring. In their review Saunders and colleagues (2018) concluded that while the impact of a single well on local air quality is likely to be negligible, the cumulative impact of a large cluster of wells could be significant.

Several studies in the US have identified oil and gas activities as a source of ozone precursors (NO_x and VOCs) in the surrounding area. Studies in Colorado, Pennsylvania, Texas, and Wyoming have identified UOG operations as important contributors to ground-level ozone concentrations (CCST, 2016; Saunders et al., 2018; Pfister and Flocke, 2017).

VOCs also include toxic components such as methylene chloride, various endocrine disruptors, and PAHs (CCST, 2016). Colborn and colleagues (as cited in CCST, 2016) found higher levels of these pollutants in areas closer to oil and gas wells. The VOCs were highest during the drilling phase. In a study in Weld County, Colorado, venting and condensate tank flashing emissions accounted for the majority of VOC emissions (CCST, 2016).

In a review of the literature, Bolden and colleagues (2018) identified 48 studies with information on air quality impacts of UOG. Ethane, benzene and n-pentane were the chemicals most frequently detected. Twenty-one of the chemicals found in the air were endocrine disrupters or substances with reproductive or neurological effects. These substances included benzene, toluene, ethylbenzene, xylene, several PAHs, and mercury.

Several studies have found high levels of certain pollutants near wells where hydraulic fracturing has occurred. These include higher concentrations of indoor radon hydrocarbons including benzene, PAHs and heavy metals (Paulik et al., 2018; Saunders et al., 2018; Wright and Muma, 2018). Exposure of workers to silica dust is also a concern (see below).

Using ambient monitoring data, a study in Wyoming estimated the risk to residents from exposure to air pollution near UOG wells. Aliphatic hydrocarbons, benzene, trimethyl benzene and xylene accounted for most of the non-cancer risk. Benzene was the major contributor to cancer risk, which was estimated to be 10 cases per million for people living closer to the well (within half a mile or 800 m) compared to 6 cases per million for residents living further away (McKenzie et al., 2012).

In the assessment of potential health impact of oil and gas facilities in the Denver Julesberg Basin, Colorado, McKenzie and colleagues (2018) estimated that people living within 500 ft (152 m) of oil and gas facilities could be exposed to levels of benzene and alkanes above acute and chronic health benchmarks. Benzene was the substance most responsible for cancer risk with a lifetime excess cancer risk estimate of 8.3 cases per 10,000 exposed.

The risk of exposure to benzene in the McKenzie study is supported by the results of a biomonitoring study of 29 pregnant women in northeastern BC, some of whom had high levels of benzene metabolites in their urine (Caron-Beaudoin et al., 2018). Compared to a reference population, these women also had higher levels of barium, aluminum, manganese and strontium in their urine and hair (Caron-Beaudoin et al., 2019). Women who identified themselves as Indigenous had higher levels of contaminants than non-Indigenous participants in the study. The authors of these studies have identified the need for further investigation to confirm a risk from UOG operations.

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INDUCED EARTHQUAKES

There have been many instances of earthquakes caused by hydraulic fracturing and deep-well injection of waste in Canada (Review Panel, 2019; Atkinson et al., 2016). While many of these earth movements are too small to be felt, stronger events are possible.[6] The start of hydraulic fracturing

6 Earthquakes with a moment magnitude above M1.5 (Modified Mercalli Scale) can be felt; movements of less than 4 are not expected to cause structural damage (Review Panel, 2019).

in December 2013 increased the frequency of earthquakes around Fox Creek, Alberta (Schultz et al., 2018). The largest recorded induced event in BC was on August 17th, 2015 in the Beg-Town area in the North Montney – its magnitude was M4.6 (Review Panel, 2019).

Of the earthquakes recorded in the Western Canada Sedimentary Basin between 2010 and 2015, 62 percent of earthquakes with M≥3 were induced by hydraulic fracturing and 31 percent by wastewater disposal; only 7 percent were natural earthquakes (Atkinson et al., 2016; Review Panel, 2019). Since 1985, two natural earthquakes with M≥3 were recorded in northeast BC, as compared to 133 earthquakes with M≥3 induced by fluid injection (hydraulic fracturing or liquid waste disposal) (Review Panel, 2019). The risk of induced seismic activity is affected by several factors. Of these, the underlying geology and the volume of fluid injected are considered the most important (Schultz et al., 2018).

The BC Review Panel (2019) noted that the impacts of induced seismicity include "nuisance, destruction of the peaceful enjoyment of land, and possible mental health issues resulting from felt events, damage to critical infrastructures, and loss of wellbore integrity." While, until now, these induced earthquakes have not resulted in damage to structures in BC, it is not known if they could in the future. An Earthquake related to the injection of large volumes of wastewater into deep disposal wells as large as M5.7 was recorded in Oklahoma (CCST, 2016).

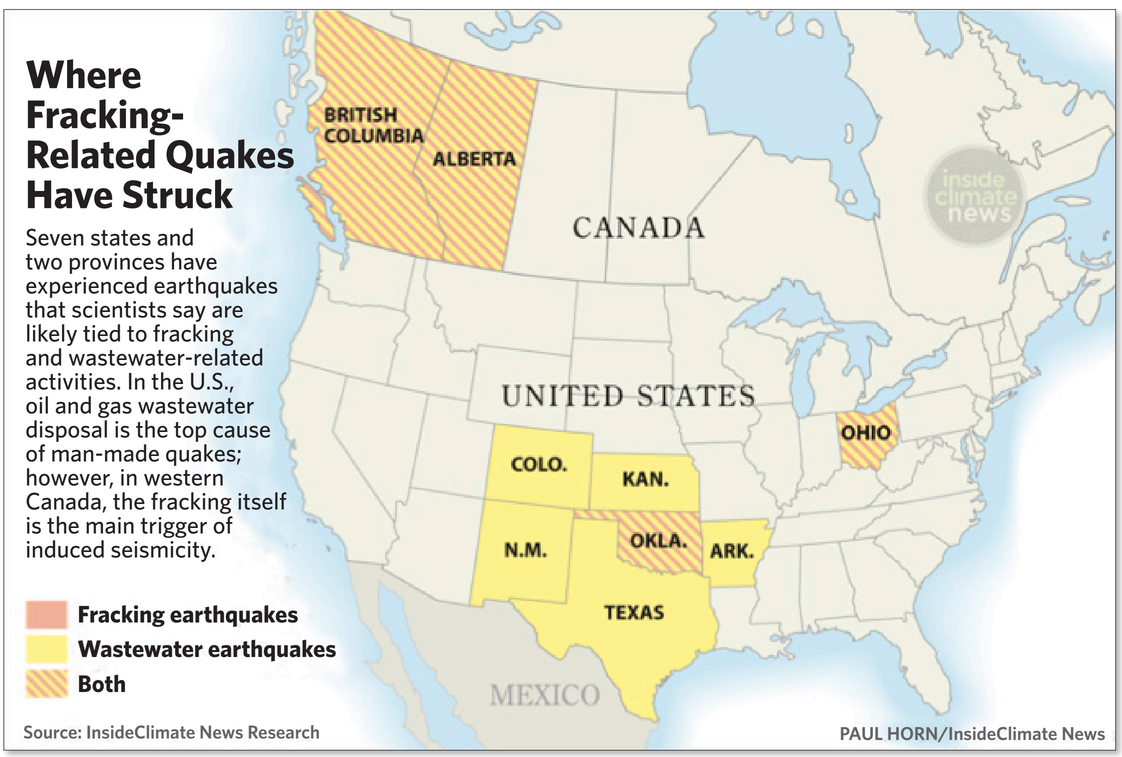


FIGURE 5: Sites of Fracking-Related Earthquakes, Inside Climate News. https://insideclimatenews.org/news/05082015/alberta-earthquakes-tied-fracking-not-just-wastewater-injection-canada

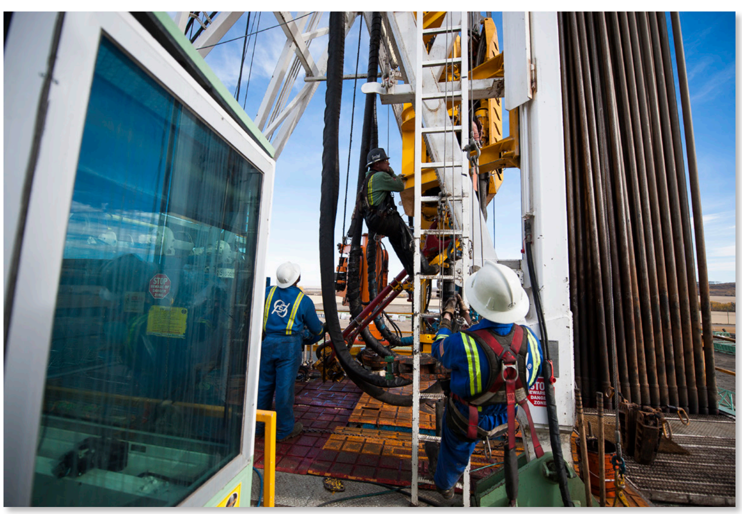
WORKER HEALTH AND SAFETY

Work in the oil and gas industry is dangerous. Data from the US show that the risk of death among workers in this sector is two-and-a-half-times higher than the risk for workers in construction and seven times higher than the risk for industrial workers as a whole (INSPQ, 2015).

Risks in this industry include: exposure to chemicals (e.g., VOCs, chemical compounds of drilling fluids and sludge, crystalline silica, hydrogen sulphide, and PAHs); physical risks such as intense noise, vibration, radiation, and extreme temperatures; biological risks; ergonomic risks related for example to handling and work postures; psychosocial risks related to variable work schedules, night work, and being in a remote location; and safety risks such as vehicle collisions, explosions, fires, and falls (INSPQ, 2015).

Major chemical concerns include exposure to carcinogens such as benzene; BTEX (a mixture of benzene, toluene, ethylbenzene and xylene) which is neurotoxic; diesel particulate matter (DPM) which causes irritations, pulmonary inflammation and crystalline silica which is fibrogenic and carcinogenic. Other risks include exposure to ionizing radiation, intense noise, and musculoskeletal disorders from excessive physical effort and the use of vibrating tools (INSPQ, 2015). In the US, exposures above occupational exposure limits have been recorded for benzene. For silica, exceedances were up to 20 times prescribed limits (Saunders et al., 2018).

While sand (silica) is commonly used as a proppant, ceramic beads are also used. A study of 100 workers in a ceramic proppant manufacturing plant found this sample of workers had better lung function than a comparison group selected from the Third National Health and Nutrition Examination Survey (Wright and Muma, 2018).



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Health Studies

Studies of populations living near UOG operations in the US have identified 32 negative health outcomes associated with these activities, such as adverse birth outcomes, birth defects, cancer, cardiovascular diseases, dermal effects, gastrointestinal symptoms, neurological effects, and respiratory illnesses (Bamber et al., 2019).

Many symptoms that have been associated with hydraulic fracturing are very common: eye irritation, rashes, nasal irritation, sinus inflammation, fatigue, headaches, diarrhea, and vomiting (Wright and Muma, 2018). It is difficult to determine the root cause of these symptoms.

The strongest evidence for a link between fracking and health is for adverse impacts on pregnancy, birth outcomes, and asthma exacerbation (Gorski and Schwartz, 2019). Effects related to stress and psychological effects have also been documented (Gorski and Schwartz, 2019).

While the quality of studies has improved, overall, the evidence base is still limited (Bamber et al., 2019). In part, this is because the widespread deployment of hydraulic fracturing is recent. Other challenges include the rapidly changing industry practices, the limited availability of information on the chemicals used in hydraulic fracturing processes, the varying geological characteristics of the different plays, and the difficulty of separating out the effects of exposures to other sources of pollutants and other potentially confounding factors (Review Panel, 2019; Gorski and Schwartz, 2019; Wright and Muma, 2018).

> ***The strongest evidence for a link between fracking and health is for adverse impacts on pregnancy, birth outcomes, and asthma exacerbation.***
> ***—GORSKI AND SCHWARTZ, 2019***

While the small size and high population density of Pennsylvania have made it easier to conduct studies there, the unique characteristics of the area limits one's ability to extrapolate these findings to other locations. More high-quality studies are needed to confirm correlations found in current studies (Bamber et al., 2019). The sections below give highlights of the available evidence.

VEHICLE COLLISIONS

Some studies have looked at the impact of hydraulic fracturing on vehicle collisions (Wright and Muma, 2018). A study in Pennsylvania estimated that collisions involving heavy trucks increased by about 10 percent for every 10 new wells drilled. However, there were no significant differences in fatal or non-fatal injuries between areas with and without drilling activity. A study in Colorado also found that the rate of motor vehicle collisions increased in areas that experienced increasing drilling activity.

ASTHMA

A study in Pennsylvania looked at the health records of over 35,000 patients with asthma. It found a positive association between the degree of UOG activity near a patient's home and mild, moderate and severe asthma exacerbation. This association was strongest for mild exacerbation during the production phase of the well (Rasmussen et al., 2016). Comparing areas with and without UOG development, another study in Pennsylvania found increased hospitalizations for asthma among young children and adolescents near natural gas wells (Willis et al., 2018). There was also an association with exposure to air levels of 2,2,4-trimethylpentane, formaldehyde, and x-hexane.

IMPACTS ON HEART, CENTRAL NERVOUS SYSTEM AND URINARY TRACT

In their review, Bamber and colleagues (2019) concluded that the evidence on cardiovascular impacts is mixed. A study by Jemielita and colleagues (2015) suggests an association between the number and density of wells and hospital admissions for heart disease in Pennsylvania. However, Peng and colleagues (2018) did not find such an association.

A study in Pennsylvania suggested an association between the density of UOG wells near a person's residence and hospital admissions for neurological conditions (Jemielita and colleagues, 2015). Due the low quality of this study, Bamber and colleagues (2019) rated the level of evidence as insufficient to draw any conclusions (outcome not sufficiently studied).

In an analysis of analyzed 2003-2014 hospitalization rates in Pennsylvania for several health outcomes Denham and colleagues (2019) found an association between well density and hospitalization for kidney infections, ureter stones, and urinary tract infection in adult females. They concluded however that more study is needed to confirm a causal link between UNDG and the genitourinary system.

REPRODUCTIVE IMPACTS

Systematic reviews of the health studies have led reviewers to conclude that the strongest link between UOG and health impacts are for reproductive impacts (Bamber et al., 2019; Gorski and Schwartz, 2019).

A systematic review by Balise and colleagues (2016), which examined 45 original published research articles related to oil and gas extraction activities and human reproductive effects, concluded that there is moderate evidence for an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer from occupational or community exposure to oil and gas activities.

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The findings, while not conclusive, are strong preliminary evidence that unconventional natural gas development is associated with adverse birth outcomes from pregnancies in UNGD areas.

They concluded that there was insufficient or inconsistent evidence to draw conclusions about increased risk of low birth weight, stillbirth, sex ratio, and birth outcomes associated with paternal exposure, testicular cancer, female reproductive tract cancers, and breast cancer.

Gorski and Schwartz (2019) identified good quality studies that assessed reproductive impacts of exposures to UNDG specifically. They found that the strongest evidence was for an increase in preterm birth and low birth weight. Low birth weight has consistently been shown to be a risk factor for numerous negative outcomes including long-term complications such as cerebral palsy, blindness, deafness, developmental delay (Stanford Children's Health).

While some studies have found associations between UNGD and other adverse reproductive outcomes the evidence is less strong. The authors conclude: "The findings, while not conclusive, are strong preliminary evidence that UNGD is associated with adverse birth outcomes from pregnancies in UNGD areas" (Gorski and Schwartz, 2019).

For example, McKenzie and colleagues found a positive association between greater density and proximity of natural gas wells within a 10-mile radius of the mother's home and a greater prevalence of congenital heart defects (McKenzie et al, 2019) and possibly neural tube defects (McKenzie et al, 2014).

Experimental studies provide supporting evidence (Bamber et al., 2019; Balise et al., 2016; Gorski and Schwartz, 2019). Cellular studies indicate that chemicals found in produced water, oil slurry, wastewater, hydraulic fracturing fluids, and oil products have estrogenic, androgenic, and progesteronic effects (Balise et al., 2016). In addition, studies in mice have found adverse developmental and reproductive health outcomes exposed to a mixture of chemicals used in hydraulic fracturing fluids (Kassotis et al., 2015; 2016).

CANCER

A few studies have looked at the potential impacts of fracking on cancer. While the results are mixed, there is evidence which suggests that fracking may increase the risk of acute lymphocytic leukemia (ALL) among children when their mothers live in close proximity to wells during pregnancy.

A case-control study conducted in Colorado, that examined children aged 5 to 24 years, found that children diagnosed with ALL were 3 to 4 times more likely to live in areas with active oil and gas wells, than children with non-hematologic cancers. It also found that the association increased as the density of oil and gas wells increased, suggesting a link between proximity of oil and gas wells and ALL. This study did not find an association with non-Hodgkin's lymphoma (McKenzie et al., 2017).

Benzene, which has been detected in the air around fracking wells, is a known carcinogen associated with leukemia among exposed workers (Zhou et al., 2014). A biomonitoring study conducted in northeastern BC, which found high level of benzene metabolites in the urine of some pregnant women, also suggests that benzene exposure is occurring near fracking sites (Caron-Beaudoin et al., 2018). In addition, a meta-analysis found a statistically significant association between maternal exposure to solvents, paints, and petroleum products during pregnancy and childhood ALL (Zhou et al., 2014). This evidence supports the finding of an association between UNG facilities and ALL.

A Texas Department of State Health Services cancer cluster investigation did not find an increase in incidence of childhood leukemia subtypes, childhood brain and central nervous system cancers in counties with UOG activities but did find a higher than expected incidence of breast cancer (Werner et al., 2015; TDSHS, 2014). In a more recent laboratory study, exposure to a mixture of chemicals emitted from UOG facilities resulted in changes to breast tissue of adult female mice (Sapouckey et al., 2018). The authors concluded there is a need to assess the impact of UOG chemicals on the long-term health of the mammary gland.

Finkel (2016) assessed the incidence of bladder and thyroid cancers and leukemia in Pennsylvania and found higher than expected bladder cancer incidence for both men and women in counties with shale gas activity; no increase was found in counties with the fewest producing wells.

In their review, Bamber and colleagues (2019) assessed the weight-of-evidence for childhood leukemia as mixed. The evidence for other childhood cancers (cancer incidence, non-Hodgkin's lymphoma, central nervous system tumours) adult leukemia, urinary bladder cancer and thyroid cancer was considered insufficient.

While the results are mixed, there is evidence which suggests that fracking may increase the risk of acute lymphocytic leukemia (ALL) among children when their mothers live in close proximity to wells during pregnancy.

MENTAL HEALTH

Many studies have examined the mental health impacts of hydraulic fracturing (Hirsch et al., 2018). A central theme is that of mental distress, or as Davidson (2018) describes, trauma.

Residents report experiencing stress from the large changes an influx of workers and industrial-like operations have on the community and the environment. Industrialization, increase in traffic, and other changes in the community disrupt the sense of place. The increase in crime, violence, sexual assault, sex work, and use of illicit drugs often seen in towns experiencing industrial booms negatively impacts community cohesion. These can affect well-being. Effects include anxiety, stress, a feeling of powerlessness, fatigue, sadness, depression, as well as sleep disturbances. Given the historical attachment to, and dependency on, the land they live on, Indigenous people and farmers are more likely to experience psychological distress (Hirsch et al., 2018). Casey and colleagues (2018) found an association between UOG development and depression and concluded that UOG may be associated with adverse mental health.

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The psychological impacts may be mediated by a person's perception: people who consider UOG development as beneficial are more likely to experience positive emotions and an increased sense of well-being as compared to people who consider hydraulic fracturing a harmful activity (Hirsch et al., 2018).

SEXUALLY TRANSMITTED INFECTIONS

There have been reports of an increase in sexually transmitted infections in communities where UOG development has occurred. A study in Pennsylvania found a 20 percent increase in the reported incidence of gonorrhea in the Marcellus Shale geologic region as compared to a 2-3 percent increase in the overall population (Komarek and Cseh, 2017 as cited in Wright and Muma, 2018).

OTHER STUDIES

A survey conducted in Pennsylvania found an association between self-reported symptoms of chronic sinus infections, migraines and fatigue and degree of hydraulic fracturing activity. The association was stronger for participants that reported more than one symptom (Tustin et al., 2017 as cited in Wright and Muma, 2018). A study reported irritation, unease, and fatigue among children exposed to noise from UOG activities (Coram et al., 2014 as cited in Hirsch et al., 2018).

Community-Level Impacts

Proponents emphasize the economic benefits of UOG development – lower natural gas prices, increased employment, and contribution to overall economic growth. However, many authors highlight that these benefits are often overstated (Buse et al., 2019; Saunders et al., 2018). In addition, these benefits are not equally distributed. Local communities often bear additional costs from the negative impacts related to this development. For example, there have been cases where the influx of workers has led to large increases in housing costs, especially in rural areas, which disproportionately impacts people living on low incomes. The transformation of rural or natural landscapes can have a negative impact on agriculture, vacation destinations, and the local tourism industry (Adgate et al., 2014; NYSDEC, 2015; Saunders et al., 2018).

Negative social effects from energy extraction have been documented in both Canada and the US (Adgate et al., 2014; Aalhus, 2018; Brisson et al., 2013; Buse, 2019). Depending on the context, communities can experience a "boom town" effect. This occurs when there is sudden growth in population, often of predominantly young males, accompanied by ramped-up and economic activity related to the development of a natural resource that is then followed by a hollowing out of the community once the development phase ends or the resource is depleted. During the boom, communities experience increased pressure on existing infrastructure, a reduction in affordable housing, and reduced access to services (such as, childcare, recreational programs, or health and social services). In addition, communities can experience a rise in homelessness, crime, substance abuse, domestic violence and sexually transmitted infections. When the boom ends, stresses and associated health impacts related to unemployment, economic hardship, local business closures, property devaluation, and net out-migration may occur.

Lack of familiarity with UOG and low levels of trust between residents and proponents of development (i.e. industry and government officials) can result in tensions within the community, reduce community cohesion and affect mental health (Adgate et al., 2014). Residents express a

Residents have reported losing the feeling of a tight-knit community and sense of place as a result of the industrialization and change in character of their community.

feeling powerless about changing demographics, disruptions in their environment and lack of support from the authorities (APHA, 2018; Hirsch et al., 2018). Residents have reported losing the feeling of a tight-knit community and sense of place as a result of the industrialization and change in character of their community (APHA, 2018; Davidson, 2018; NYSDEC 2015). The increase in traffic, especially of trucks, can reduce the sense of safety on the roads and the peacefulness of the area (NYSDEC, 2015).

Several factors influence whether a development proposal is seen as a positive or negative change to a community: trust in industry and government officials; familiarity, which includes working in the resource industry; being a direct beneficiary of the activity either through employment or increased business opportunity; race and gender; and political identity (CCA, 2014; Hirsch et al., 2018; Mayer, 2016; Olawoyin et al., 2016; Veenstra, et al., 2016). Of these different factors, a study in Colorado concluded that the most important factor that explained the perception of UOG development as positive was trust in the industry (Mayer, 2016).

NOISE

Until recently the main concern with regards to noise was hearing loss. However, more recent evidence indicates that levels of noise not associated with hearing loss also impact health. Based on this evidence the World Health Organization (WHO) (2009; 2011) has recommended keeping average night-time noise levels (e.g. 11:00 pm to 7:00 am) to 40 decibels (dBA) and average day-time noise (e.g. 7:00 am to 11:00 pm) to 55 dBA.

These levels are intended to prevent various negative impacts on health, for example, heart disease, cognitive impairment (e.g. memory in adults or learning in children), sleep disturbance, and mental health (such as annoyance, depression, quality of life). The WHO (2018) makes recommendations for specific transportation sources and suggests that noise from wind turbines should be kept to a maximum of 45 dBA L_{den}.[7]

Noise from UOG activities has been reported as a source of psychological distress, as well as poor academic performance in children (Hirsch et al., 2018). While there is insufficient information to determine a protective level of noise from oil and gas operations, evidence indicates that the level of noise from these operations can be above those that have been found to have negative effects in other situations (Hays et al., 2017).

A study in West Virginia measured the average sound level ($\mathbf{L}_{eq}$ or equivalent continuous sound pressure) at a control residence 3500 ft (1067m) from a compressor station to be 51.4 dBA. This compares to measurements of 63.15 dBA at 1000 ft (305 m) and 54.09 dBA measured between 2000 and 2500 ft (610-762 m). Another study in Wyoming recorded noise at levels between 58 and 75 dBA one mile (1.6 km) from a compressor station and 54 dBA at 1.25 mi (2 km) (Hays et al., 2017). Noise impacts were assessed near an environmentally sensitive area of Wyoming. Predicted median sound levels at 100 m were 62 dBA for an active drill rig, 56 dBA for an injection

7 L_{den} refers to an average of day-evening-night time levels with a penalty of 5 dBA during evening hours and 10 dBA during night-time hours.

well complex, 54 dBA for a compressor station, and 50 dBA for a well pad with 21 well heads and a generator (Hays et al., 2017). The 2015 New York State environmental impact estimated noise levels from different activities that could occur at 50 and 2000 ft (15 and 610 m). The results were as follows: access road construction 89-57 dBA; well pad preparation 84-52 dBA; horizontal drilling 76-44 dBA; hydraulic fracturing 104-52 dBA (NYSDEC, 2015).

LIGHT POLLUTION

Brisson and colleagues (2013) note that light pollution from flaring and intense lighting during exploration, drilling and well completion can be a nuisance. Light pollution, which can include constant illumination from fracking operations, may contribute to stress and disrupt sleep (Hirsch et al., 2018). Exposure to light at night, even dim light, suppresses melatonin, reduces sleep quality and disturbs biorhythms (Cho et al., 2015).

While the evidence is still limited, night-time exposure to exterior lighting has been associated with an increased risk of breast cancer in women and prostate cancer in men (Chepesiuk, 2009; Cho et al., 2015). Though the evidence of health impacts of exposure to outdoor light is still limited, it suggests that light pollution related to UOG activities, if not controlled, could affect health.

ECOLOGICAL IMPACTS

Development of oil and natural gas impacts wildlife in various ways. These impacts can be especially critical for species at risk.

Conversion of lands to human uses (infrastructure, buildings etc.) reduces available habitat. Associated road and pipeline networks can fragment habitat. And, increased human activity, light and noise can impact animal behaviour. These factors can reduce populations, decrease survival, and increase mortality among local animal populations.

There is also evidence which indicates that oil and gas development has contributed to population declines of caribou, decreased survival of elk and increased grizzly bear mortality.

For example, increased nutritional and psychological stress on caribou has been observed. There is also evidence which indicates that oil and gas development has contributed to population declines of caribou, decreased survival of elk and increased grizzly bear mortality (Northrup and Wittemyer, 2013). Reduced abundance of birds around oil and gas development infrastructure has also been documented. Other impacts include changes in songbird territory as the result of seismic exploration and contamination or death among birds landing on wastewater ponds.

The California Council on Science and Technology's review (CCST, 2016) did not identify information on the impacts of hydraulic fracturing on plants and wildlife. Though the nature of the risks of UOG are similar to other oil and gas operations, their magnitude is larger. The larger amount of flowback and produced waters during unconventional drilling could increase the risk of exposure to chemicals used in hydraulic fracturing.

Similarly, given the greater truck traffic associated with UOG development, the risk of road mortality of various wild animals, including species at risk, could be higher than the risks from conventional well activities (CCST, 2016). New York State's impact statement (NYSDEC, 2015) highlights the importance of wetlands for a range of ecological services such as flood control, surface and groundwater protection, wildlife habitat, open space, and water resources. UOG development could disturb such areas and impair surface water quality which would have an impact on aquatic and terrestrial life.

CUMULATIVE EFFECTS

People and the environment are subject to multiple stressors at the same time. These can be various pollutants from a single facility or the combined impact of various different facilities in an area. Indigenous peoples have noted that past authorizations for resource development (such as, mining, forestry, oil and gas) have a cumulative impact and negatively affect their quality of life and impinge on their Aboriginal and treaty rights (CCA, 2014).

Approval mechanisms typically only deal with one issue and one site at a time. To address this, the BC government has developed a Cumulative Effects Framework to help guide approvals of the use of natural resources. The BC Auditor General's 2015 review identified several limitations including the lack of clear direction or powers to manage cumulative effects. It also reported that legislation and directives do not effectively support the management of cumulative effects (Bellringer, 2015). The BC government website indicates that the government is acting on the Auditor General's recommendations (Government of BC, undated).

HEALTH EQUITY

Socio-economic factors are important drivers of disparities in health and well-being. The positive and negative impacts of development are not equally distributed throughout the population (Aalhus, 2018). Often, people who are vulnerable are more negatively affected by resource development (CCA, 2014). People who are more likely to be living in poverty in Canada include

Health Equity Impact Assessment (HEIA) is a process that brings into focus the social determinants of health of a proposal and considers the potential positive and negative impacts on health and their distribution. Principles and practices that lead to a successful process include:

- **Meaningful community engagement and participation that makes a difference to the outcome (a process of co-learning, co-management that improves life control)**
- **Addressing all facets of sustainable development — economic, environmental, social — and their impact on physical, mental, emotional, spiritual and cultural wellness**
- **Respect for human rights including the Free, Prior and Informed Consent of Indigenous peoples affected before proceeding with the proposal**
- **Integration of traditional and local knowledge and understanding**
- **A focus on inequities experienced by vulnerable populations including those of gender, race, disability, and social status**
- **Considerations of the impacts on the full life course of people**
- **Adaptive management that is both iterative and flexible (Adapted from Aalhus, 2018).**

Indigenous people, women, single parents, and individuals with lower levels of education or health disabilities (ESDC, 2016). People living in rural and remote communities, as a rule, have poorer health than people who live in cities. In addition, boom and bust cycles associated with resource development increase health inequities (Aalhus, 2018).

While employment is often considered a positive impact of resource development, it is not necessarily so for everyone. In spite of the high employment and income from the resource boom, there continues to be a disparity in health status of people living in northeastern BC compared to the rest of the province (Aalhus, 2018). Resource development can increase disparities between the poorest and richest members of a community. The best jobs may go to people who are only there temporarily. The wealth flows primarily to men. Women who are employed in the industry are frequently paid less and face barriers due to lack of childcare. Resource development can make it difficult to maintain and participate in traditional activities that are important to the health of Indigenous communities. Paid employment can create imbalances in the status and power relations between men and women, especially in Indigenous communities (Aalhus, 2018).

The impacts of resource extraction on the social determinants of health are complex and interactive and can result in cumulative effects on the health and well-being of individuals and communities. They can be particularly hard on Indigenous communities in Canada who often have poorer health outcomes compared to their non-Indigenous counterparts (Aalhus, 2018). Not only are many unconventional deposits on accepted or claimed traditional territories (CCA, 2014), their development impacts the lands and waters that support the health and well-being of Indigenous people, and that are also at the core of the cultural and spiritual identity of those people (Aalhus, 2018).

Resource development can make it difficult to maintain and participate in traditional activities that are important to the health of Indigenous communities.

Ice fishing in Saskatchewan
Photo by Dan Tobias

Life control is an important determinant of health (Adler and Rehkopf, 2008). The lack of meaningful consultation between proponents of resource development starting at the exploration stage can increase the sense of powerlessness of individuals and communities affected by a proposed development. Consultation is a way to give affected communities a say and can contribute to a sense of control. For consultation to be meaningful to Indigenous communities, it must integrate their understanding of health and wellness: holistic well-being that "encompasses the physical, spiritual, mental, economic, emotional, environmental, social and cultural wellness of the individual family and community."[8]

"While Indigenous peoples have been able to negotiate access to specific benefits from resource development, including contracts for community-owned businesses, a much greater share of the benefits goes to non-Indigenous people or flows out of the region entirely. At the same time, Indigenous peoples bear a particular and harsh burden from resource development on their lands, including the dramatic loss of access to their traditional territories and the rapid transformation of their economies. This contributes to further social strain on communities already severely harmed by largely unaddressed discriminatory government policies of the past."

—AMNESTY INTERNATIONAL, 2016

8 From The Transformative Change Accord: First Nations Health Plan as cited in Aalhus, 2018.

Climate Change

The role of natural gas in the transition to a lower-carbon economy is debated. Many have promoted its use as a bridge fuel to a lower-carbon economy to reduce GHG emissions by replacing more carbon-intensive fossil fuels (MIT, 2011; Raimi, 2018).

This view developed because CO_2 emissions from natural gas-fired electricity generating stations are 50 to 60 per cent lower than emissions from coal-fired generating stations and CO_2 emissions from natural gas-fuelled vehicles are 15 to 20 percent lower than emissions from gasoline-fuelled vehicles (UCS, 2013). This is however, an incomplete and misleading measure of natural gas' contribution to climate-related emissions.

First of all, natural gas is composed almost entirely of methane, which is a short-term climate pollutant with a warming potential 34 times greater than that of CO_2 over a 100-year period and 86 times greater than CO_2 over a 20-year period (Howarth, 2014).

Secondly, most natural gas development releases tangible amounts of methane during production, whether voluntary (venting), through flaring (combustion of methane that would have been otherwise vented) or involuntary (fugitive) (CCA, 2014). The magnitude of this "leakage" was not well understood and measured until recently (Alvarez et al., 2018; Miller et al., 2013; Sanchez and Mays, 2015; Staddon and Depledge, 2015).

Several empirical studies conducted in recent years have demonstrated that actual methane emissions from UOG are underreported in national inventories, and in some cases by as much as an order of magnitude. For example, a study in northern BC based on mobile air monitoring estimated that the gas wells in the Montney area are releasing 111,800 tonnes of methane per year. This is much more than the official government estimates for all of BC (78,000 tonnes) even though this region represents about 55 percent of the production for BC (Atherton et al., 2017). When accounting for these emissions using a life-cycle analysis, the relative advantage of natural gas is much less and, in some cases, disappears altogether.

Howarth (2014) concluded that natural gas from both conventional and unconventional wells has a larger carbon footprint than either coal or oil, especially if it is used for commercial or residential heating.

The purpose and efficiency of natural gas' use also has to be considered when assessing its contribution to climate emissions. Using the 20-year warming potential of methane, leakage rates need to be lower than 2.8 percent for a natural gas generating station to have a climate advantage over a coal-fired generating station (Howarth, 2014) and lower than 1 and 1.5 per cent respectively for natural gas-fuelled vehicles to have an advantage over diesel-fuelled and gasoline-fuelled vehicles (Deyette et al., 2015). Using the 20-year warming potential for methane, Howarth (2014)

Several empirical studies conducted in recent years have demonstrated that actual methane emissions from UOG are underreported in national inventories, and in some cases by as much as an order of magnitude.

Fracking in British Columbia
Photo by Don Pettit

concluded that natural gas from both conventional and unconventional wells has a larger carbon footprint than either coal or oil, especially if is used for commercial or residential heating.

In 2015, 192 countries agreed to keep global warming well below 2 degrees C and to pursue efforts to limit the temperature increase even further to 1.5 degrees C (UNFCCC, 2015). The need for a rapid reduction in GHG emissions between now and 2030 with a goal of reaching net-zero emissions by 2050 has been highlighted in the recent report prepared by the Intergovernmental Panel on Climate Change (IPCC, 2019).

Since 2007, global methane levels have been rising, which will make it even more challenging to meet the goals of the Paris Agreement (Nisbet et al., 2019). Evidence indicates that UOG development in North America is contributing to this increase (Howarth, 2019) reinforcing the need to end reliance on UOG.

Lastly, winning the fight against climate change requires the elimination of carbon-based fuels from our energy systems. A number of countries, including Canada, have announced their intention of becoming net-zero emitters of GHGs by 2050. This requires the elimination of most, if not all, fossil fuels from our energy systems. There are now more cost-economic, zero-carbon options available for most end-uses. For example, a 2019 report found that a combination of renewables is now cheaper than natural gas for electricity generation, even in the absence of subsidies or a carbon tax (Gorkski and Jeyakumar, 2019).

Conclusions

The rapid expansion of UOG development has adversely affected many communities in Canada and raised concerns about the negative impacts to human health and the environment from the use of hydraulic fracturing for the extraction of oil and natural gas from the rock formations where they are found.

Environmental studies have found that hydraulic fracturing can have a broad range of negative impacts on water availability, water quality, air quality and seismic activity. They have found that hydraulic fracturing can release naturally occurring radioactive materials from groundwater, and a large array of chemicals that are used in hydraulic fracturing fluids. The BC Review Panel noted that there are still too few data to accurately assess the risk to human health and the environment, in particular due to the lack of monitoring before, during and after UOG activities occur. Other challenges include the rapidly changing industry practices, the limited availability of information on the chemicals used in hydraulic fracturing processes, and the varying geological characteristics of the different plays.

Health studies have identified several health impacts that could be associated with UOG. The strongest evidence is for adverse impacts on pregnancy, birth outcomes and asthma exacerbations. There is also evidence that UNGD may be associated with increases in birth defects, such as heart defects and neural tube defects, and ALL among children whose mothers live in close proximity to oil and gas wells during pregnancy. Effects related to stress and psychological distress have also been documented.

While the quality of studies has improved, overall, the evidence base on adverse health impacts of UOG is still limited. It is therefore not possible to conclude if these associations are the result of UOG development or due to other factors (Bamber et al., 2019; Gorski and Schwartz, 2019; Hirsch et al., 2018; McMullin et al., 2017; Saunders et al., 2018; Werner et al 2015; Wright and Muma, 2018). At the same time, while there are some unique features of UOG that may pose additional risks, many of the risks and impacts of UOG exploitation are similar to the effects observed around other oil and gas operations and resource extraction activities (Aalhus, 2018; CCST 2016).

Natural gas has been promoted as a lower-carbon alternative to other fossil fuels such as coal because substantially less CO_2 is emitted when it is burned. However, given the methane leakage that can occur during its extraction, transportation, storage and use, and its powerful climate warming potential, it is no longer considered a lower-carbon alternative. Lower natural gas prices that have occurred due to increased production from unconventional reservoirs have acted as a disincentive to investment in renewable energy and energy efficient technologies and locked some of our infrastructure into a high-carbon economy for longer. However, recent research demonstrates that renewables no longer require subsidies or carbon policies to be more cost-effective than natural gas in North America.

UOG development can also have social and equity impacts on communities. In particular, Indigenous peoples are among the ones most affected. Not only are many unconventional gas deposits in accepted or claimed traditional territories, Indigenous communities and people in Canada often have poorer health outcomes compared to their non-Indigenous counterparts. The development of UOG resources impacts the lands and waters that support their health and well-being, which are also at the core of their cultural and spiritual identity. Health and equity impact assessment (HEIA) is a tool that can be used to ensure that the health and well being of vulnerable populations are taken into account in the decision-making process and to identify ways to enhance health equity.

Natural gas is a fossil fuel that contributes to climate change. There are now more cost-effective, zero-carbon options for a large number of end-uses (e.g. electricity generation, transportation). We must phase out our use of natural gas and stop investing in infrastructure that relies upon it.

Lastly, winning the fight against climate change requires a deep decarbonization of our energy systems. A number of countries, including Canada, have announced their intention of becoming net-zero emitters by 2050. This requires the elimination of most, if not all, fossil fuels from our energy system. Natural gas is a fossil fuel that contributes to climate change. There are now more cost-effective, zero-carbon options for a large number of end-uses (e.g. electricity generation, transportation). We must phase out our use of natural gas and stop investing in infrastructure that relies upon it.

Taking into account: the increasing evidence of adverse health, environmental and community impacts from unconventional oil and gas development; the need to respect and honour commitments made to the Indigenous peoples of Canada; the contribution of unconventional oil and gas development to climate change; Canada's commitment to drastically decrease its carbon emissions by 2030; and the significant health impacts associated with the continued use of fossil fuels; a rapid and just transition away from natural gas and oil extracted with fracking to clean and equitable renewable energy sources is needed.

Recommendations

CAPE recommends that:

1 **Each province and territory with unconventional natural gas and oil reserves should declare a moratorium on new development of those reserves with fracking;**

2 **Each province and territory that is currently extracting unconventional natural gas and oil reserves with fracking should:**

a) Develop and implement a strategic plan to phase out existing production to meet the goals stipulated in the 2015 Paris Agreement and in accordance with the findings of the 2018 Intergovernmental Panel on Climate Change (IPCC) report;

b) Ensure that health and equity impact assessments (HEIAs) are conducted to inform the phase-out schedule for existing natural gas and oil wells that involve fracking; and

c) Develop and implement strong regulations which ensure that: oil and gas assets reaching their end of life are not offloaded; tight timelines are applied to their decommissioning; and land reclamation is held to standards that will prevent adverse impacts on the environment, wildlife and/or communities;

3 **The federal, provincial and territorial governments:**

a) Phase out all subsidies that are provided to the development or promotion of unconventional natural gas and oil reserves that are extracted with fracking to meet the goals stipulated by the 2015 Paris Agreement and the findings of the 2018 IPCC report;

b) Develop programs and policies to increase energy efficiency and develop clean and equitable renewable energy sources to transition away from reliance on all fossil fuels including natural gas to meet the goals of the 2015 Paris Agreement; and

c) Develop and fund, a just transition plan, in collaboration with workers and communities affected by the transition from fossil fuels which includes: bridge funding for older workers nearing retirement; retraining for younger workers; and community investments in new technologies and industries to revitalize and transform affected communities.

Appendix: Overview of Provincial and Territorial Oil and Gas regulations

BRITISH COLUMBIA

In British Columbia the management of land and water for oil and gas activities is centralized in the BC Oil and Gas Commission (BCOGC). The main statute governing oil and gas activities in BC is the *Oil and Gas Activities Act* (OGAA) and its associated regulations such as the Drilling and Production Regulation (DPR) and the Environmental Protection and Management Regulation (EPMR). These set out the requirements industry has to meet when undertaking activities related to oil and gas development and production (Review Panel, 2019). For example, to protect water resources there are requirements for setbacks, well construction and drilling practices, wastewater storage and disposal, spill response, underground injection procedures, surface water withdrawal limits during low-flow periods, disclosure of fracturing fluid chemicals, abandonment of inactive wells, and a regional water strategy, among others (Kniewasser and Reihl, 2018).

In addition, industry needs to comply with other federal, provincial and municipal requirements that may apply to part of the life cycle of the oil and gas production process and is expected to apply industry recommended practices (IRP) including Canadian Standards Association guidelines (Review Panel, 2019).

ALBERTA

The Alberta Energy Regulator is the single regulator that regulates oil and oil development in Alberta. Its mandate is "to ensure the safe, efficient, orderly, and environmentally responsible development of oil, oil sands, natural gas, and coal resources over their entire life cycle (NRCan, 2017)." It makes decisions with respect to the following: energy development applications; industry compliance, enforcement, and monitoring; project closure; and other aspects of energy development. A large number of laws, regulations and directives set out the requirements industry must follow at the exploration, development, production and concluding stages. There are provisions related to water management, groundwater protection, wellbore integrity, air quality, noise, light, and induced seismicity (NRCan, 2017).

SASKATCHEWAN

The Petroleum and Natural Gas Division of the Ministry of Economy is the provincial regulator of oil and gas activities in Saskatchewan. Oil and gas activities are subject to a range of requirements, including environmental assessment, environmental reporting and abandonment and reclamation liability management. More information is available on the Saskatchewan government website.

MANITOBA

"The Petroleum Branch (Branch) of Manitoba Mineral Resources administers provisions under *The Oil and Gas Act* and *The Oil and Gas Production Tax Act* relating to exploration, development, production and transportation of oil and gas. The Branch develops, recommends, implements and administers policies and legislation to provide for the sustainable development of Manitoba's oil and gas resources. The Branch deals with matters relating to well spacing, production allowables, pool designations, saltwater disposal, enhanced recovery projects and unitization (NRCan, 2017)."

ONTARIO

"Petroleum and natural gas exploration and development in Ontario is currently regulated under the *Oil, Gas and Salt Resources Act*, Regulation 245/97, and the Provincial Operating Standards. The disposition of provincially-owned oil and natural gas rights is managed under Part IV of the *Mining Act* (Regulation 263/02). The Ontario Ministry of Natural Resources and Forestry is the lead government ministry regulating petroleum and natural gas exploration and development in the province (NRCan, 2017)." In Ontario, the Ministry of Natural Resources and Forestry has indicated that "it would not approve any application to use high-volume hydraulic fracturing unless the regulations were strengthened to protect the public and the environment. Any enhancements to Ontario's rules to properly regulate shale development must first be brought forward for appropriate consultation with stakeholders, Aboriginal communities and the public (NRCan, 2017)."

QUÉBEC

"In Québec, oil and gas exploration activities require the obtaining of permits and authorizations issued by the Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (MDDELCC) and the Ministère de l'Énergie et des Ressources naturelles (MERN). The MERN is responsible, in particular, for the application of the *Mining Act* and the Regulation respecting petroleum, natural gas and underground reservoirs (NRCan, 2017)."

NEW BRUNSWICK

"Exploration activities for oil and natural gas in the Province of New Brunswick are regulated by two main departments, the Department of Energy and Mines (DEM) and the Department of Environment and Local Government (DELG)… DEM regulates operational activities for the exploration of all oil and gas resources including seismic surveys, drilling, well completion, and hydraulic fracturing. DELG regulates all exploration activities, except seismic operations, and ensures that the environment is protected with respect to those activities. The following departments are also involved in making determinations about moving projects forward for approval: the Department of Public Safety (DPS), the Department of Transportation and Infrastructure (DTI), the Department of Tourism, Heritage, and Culture (THC), the Department of Natural Resources (DNR), and the Aboriginal Affairs Secretariat (AAS) (NRCan, 2017)." Applicable acts and regulations include the *Oil and Natural Gas Act*, *Clean Air Act*, *Clean Water Act*, and *Clean Environment Act*.

NOVA SCOTIA

"All activities fall under the provincial *Petroleum Resources Act*. The Act is administered under the supervision and management of the Nova Scotia Department of Energy and gives the Minister the authority to create subsequent regulations. Under the Act, there are several regulations, including the Petroleum Resources Regulations, Onshore Petroleum Geophysical Exploration Regulations and the Onshore Petroleum Drilling Regulations (NRCan, 2017)." In September 30, 2014, the Nova Scotia government introduced amendments to the *Petroleum Resources Act* to prohibit high-volume hydraulic fracturing for onshore shale gas (NRCan, 2017).

Departments and agencies involved during the approval process for petroleum exploration and activities include the Nova Scotia Department of Environment, Department of Natural Resources, Transportation and Infrastructural Renewal, Labour and Advanced Education, and the Office of Aboriginal Affairs (NRCan, 2017).

PRINCE EDWARD ISLAND

In Prince Edward Island oil and natural gas exploration and exploitation activities are regulated under the *Oil and Natural Gas Act* (NRCan, 2017).

NEWFOUNDLAND AND LABRADOR

There are two regulatory regimes for oil and gas in Newfoundland and Labrador – one for onshore, the other for offshore resources. Onshore oil and gas activities are regulated under the *Petroleum and Natural Gas Act* and regulations (for example, Petroleum Regulations and Petroleum Drilling Regulations). Oil and gas activities must also comply with the *Environmental Protection Act* and the *Water Resources Act*. The Canada–Newfoundland and Labrador Offshore Petroleum Board regulates offshore oil and gas activities as set out in the Canada–Newfoundland and Labrador Atlantic Accord (NRCan, 2017).

NUNAVUT

Petroleum exploration and production in Nunavut are regulated by the federal government through the *Canada Petroleum Resources Act*, *Canada Oil and Gas Operations Act*, and *Canadian Energy Regulatory Act*. The CER and Crown-Indigenous Relations and Northern Affairs Canada are the two agencies involved in this process. Petroleum activities in the Nunavut Settlement Area are also subject to the requirements of the Nunavut Land Claim Agreement (NRCan, 2017).

NORTHWEST TERRITORIES

There are two regulators for oil and gas development in the Northwest Territories. Offshore development and activities in the Inuvialuit Settlement Region remain under federal jurisdiction administered through the CER. The Office of the Regulator of Oil and Gas Operations oversees the other activities under territorial jurisdiction. The *Petroleum Resources Act* and the *Oil and Gas Operations Act* mirror the equivalent *Canada Petroleum Resources Act* and *Canada Oil and Gas Operations Act* (NRCan, 2017).

YUKON

In Yukon, oil and gas activities are regulated under the *Oil and Gas Act*. Exploration and production of shale oil and gas resources are regulated under the Drilling and Production Regulations. Provisions under the *Waters, Environment and Lands Acts* would also apply (NRCan, 2017).

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