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Shale Gas

The Facts about the Environmental Concerns

INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

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SHALE GAS

The Facts about the Environmental Concerns

Produced by:

INTERNATIONAL GAS UNION

UNION INTERNATIONALE DU GAZ

This document contains strictly technical information to be distributed during the 25th World Gas Conference in Kuala Lumpur, Malaysia, and has no commercial intent.

IGU foreword

The International Gas Union is pleased to present the publication “Shale Gas: The Facts about the Environmental Concerns.”

The shale gas revolution in North America, and now beyond, has had a profound impact on the short and long-term supply outlook for natural gas, and has reinforced the foundational role that natural gas plays today and will continue to play in the global energy mix of the future.

The rapid development of this resource, however, has attracted, and continues to attract, significant and at times extreme attention. This attention is particularly focused on the potential environmental impacts of the extraction process.

To date, sharply contrasting opinions about the environmental impact of shale gas development has characterized the debate. Therefore, a rational, objective, fact-based discussion of the environmental concerns that can lead to operational and regulatory approaches that ensure that this resource is developed in an environmentally responsible manner is required.

As such, the IGU believes it is time to present such an objective, fact-based assessment of the key environmental concerns that have surfaced related to shale gas. The IGU is also recommending a number of best practices that need to be adopted in order to improve the overall extraction process in a manner that protects the environment.

Datuk (Dr) Abdul Rahim Hashim
President, IGU

Torstein Indrebø
Secretary General, IGU

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SHALE GAS

The Facts about the Environmental Concerns

Hydraulic fracturing is a technique used to access natural gas deep underground in shale formations. Hydraulic fracturing, also known as fracking or hydraulic stimulation, involves injecting pressurized water-based fracturing fluid into geologic formations to allow natural gas to escape the shale and to flow to production wells.

The Production Process Comprises of Six Main Steps:

- Site development and preparation, which involves building access roads, production facilities and well pads.
- Vertical drilling to a depth of several thousand metres, where shale formations exist.
- Drilling horizontally from the end of the vertical well, sometimes with several horizontal wells extending in several different directions, once the vertical well is at the appropriate depth.
- Hydraulic fracturing of shale formations, using a fracturing fluid comprising of about 99.5 per cent water and sand, plus 0.5 per cent chemical additives.
- Recycling or the disposal of the wastewater that was used in the hydraulic fracturing process and any naturally produced water that is brought to the surface.
- Well completion and operation, the latter lasting up to a decade or more.

Hydraulic fracturing used to produce shale gas is key to maintaining an abundant supply of clean burning natural gas for years to come. The practice was developed in the late 1940s, and has been used extensively since the 1950s. Recent innovations have been able to combine vertical and horizontal drilling with hydraulic fracturing to cost effectively extract natural gas shale formations. Despite hydraulic fracturing's strong record of safety and efficacy, there are some environmental concerns surrounding the technique:

1. "Shale gas drilling takes up a larger land-use footprint than does conventional energy production."

2. "Hydraulic fracturing can have adverse effects on drinking water."

3. "Hydraulic fracturing uses enormous quantities of water."

4. "Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public."

5. "Hydraulic fracturing and associated wastewater disposal causes earthquakes."

6. "Disposal of wastewater harms the environment."

7. "Air emissions related to shale gas production are worse than those created by burning coal."

8. "Shale gas extraction is not regulated."

This publication will address each one of the above environmental concerns, laying out the facts and context related to the concerns, as well as a set of recommendations for best practices for the shale gas industry going forward.

PART I - Executive Summary

Process Steps and Environmental Concerns to be addressed:

PROCESS STEP: Site development and preparation

1. "Shale gas drilling takes up a larger land use footprint than does conventional production"

PROCESS STEP: Vertical drilling and effect on drinking water

2. "Hydraulic fracturing can have adverse effects on drinking water"

PROCESS STEP: Horizontal drilling

No environmental concerns raised

PROCESS STEP: Hydraulic fracturing and water use

3. "Hydraulic fracturing uses enormous quantities of water"
4. "Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public"

PROCESS STEP: Disposal of wastewater

5. "Hydraulic fracturing and associated wastewater disposal cause earthquakes"
6. "Disposal of wastewater harms the environment"

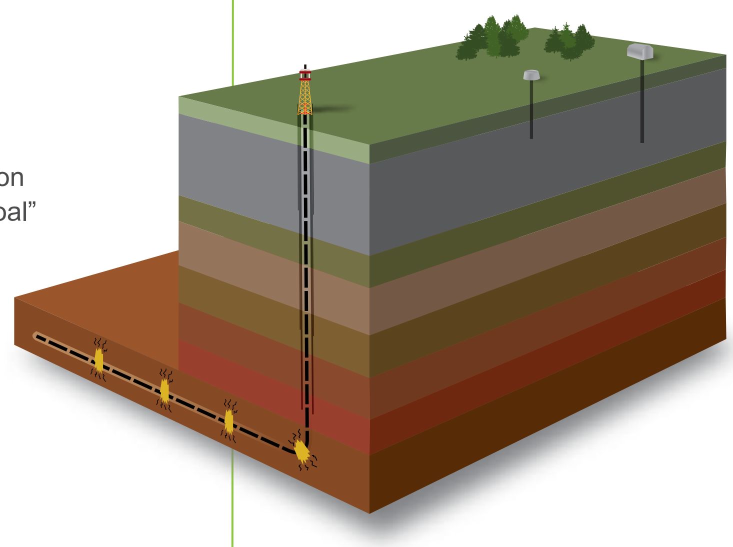
PROCESS STEP: Well completion and abandonment

No environmental concerns raised

CONCERNS: Air emissions and regulations

7. "Air emissions related to shale gas production are worse than those created by burning coal"
8. "Shale gas extraction is not regulated"

Hydraulic fracturing used to produce shale gas is key to maintaining an abundant supply of clean burning natural gas for years to come.



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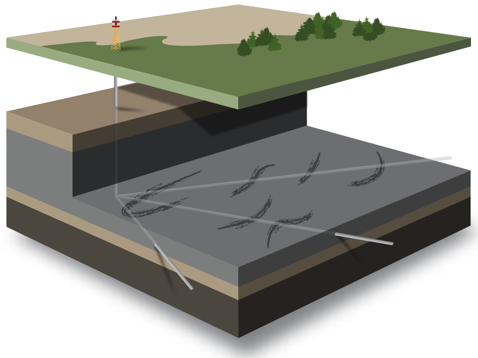
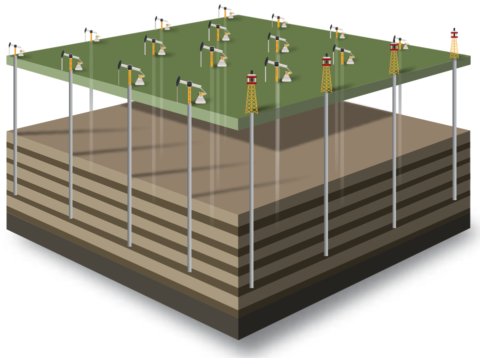
A

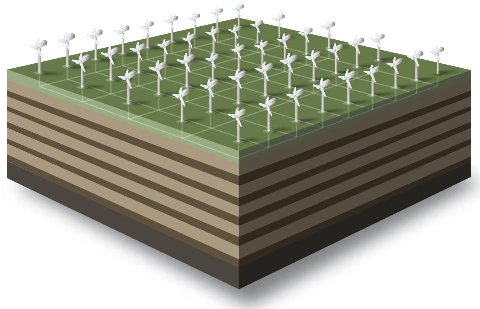
Shale Gas



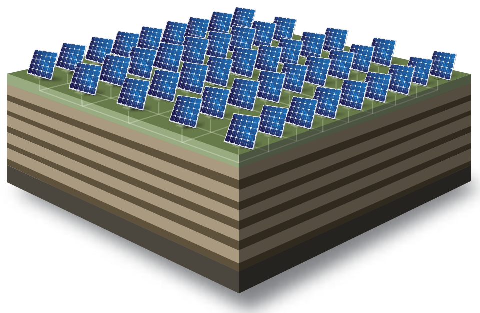
Conventional Gas



Wind



Solar



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1. PROCESS STEP:

Site development and preparation

The Concern:

"Shale gas drilling takes up a larger land-use footprint than does conventional energy production."

The Facts:

- Shale gas production requires a drastically smaller land-use footprint than conventional natural gas drilling and other forms of energy production, such as solar and wind power.
- Current common practice is to drill multiple horizontal wells from one vertical well. This allows for higher natural gas production from each well and a smaller land-use footprint.

The Context:

- Land use by energy extraction: shale gas, conventional gas, wind, solar. *(see graphic A)*

Recommended Industry Best Practices:

- Select, plan and operate well sites in a manner in which local community and land use impacts are kept to a minimum.
- Continue to maximize the number of vertical wells per well pad to further reduce the total land-use footprint.

2. PROCESS STEP:

Vertical drilling and effect on drinking water

The Concern:

"Hydraulic fracturing can have adverse effects on drinking water."

The Facts:

- Vertical drilling is a well-established practice and millions of wells have been safely drilled through aquifers with no significant issues.
- Groundwater is protected during vertical drilling by a combination of the protective casing and cement.
- The few extremely rare cases where groundwater was affected were due to faulty well casing installations, not hydraulic fracturing. These situations were resolved immediately and with no significant impact on groundwater.
- Most natural-gas producing shale formations are 3,000 to 4,500 metres underground. Domestic use water aquifers are typically less than 300 metres underground. There is no physical path between the shale formations and the aquifers; therefore fresh water contamination is not possible through hydraulic fracturing.

The Context:

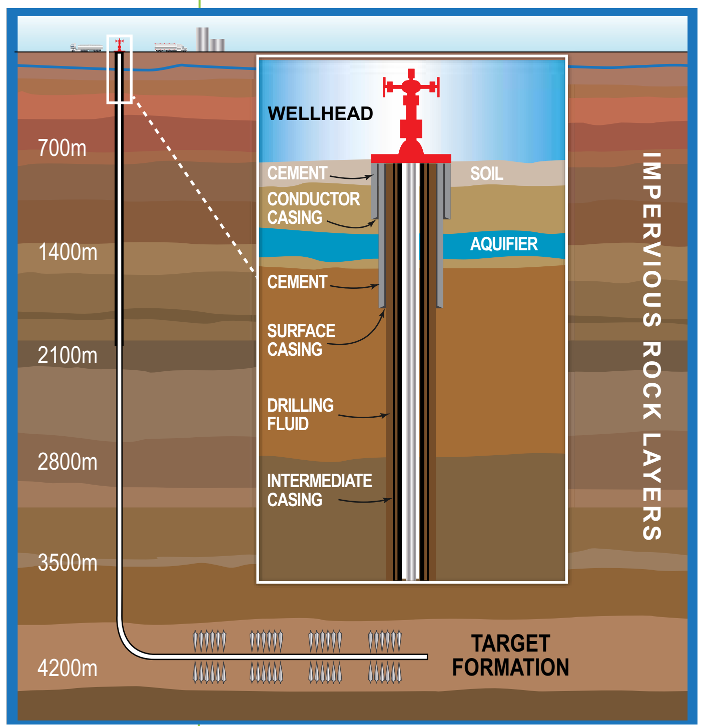
- Distance between the wellhead, aquifer and target shale formation.
- Proper well-bore design. *(see graphic B)*

Recommended Industry Best Practices:

- Study local geology to identify sub-surface drinking water sources within 250 metres of well site prior to drilling.
- Where water sources exist within 250 metres of the well site, test water before, during and after drilling to monitor water integrity.
- Quality assurance programs to ensure proper well-bore design, construction practices are followed and well integrity testing is undertaken during the life of the well.
- Maintain rigorous oversight of sub contractors, quality assurance programs, contractual expectations, auditing and training to ensure standards are met.
- Set minimum well depths.

B

Well-bore Design



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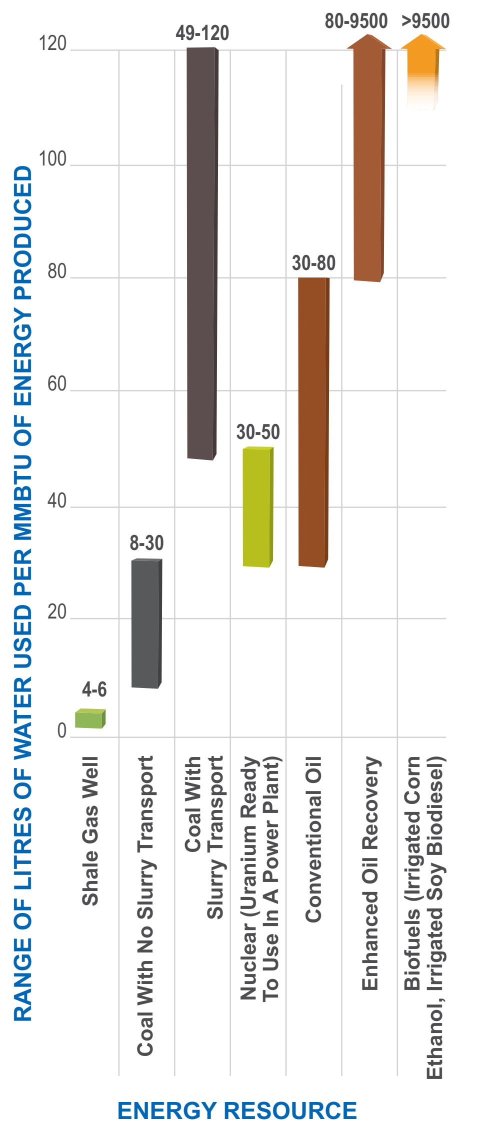
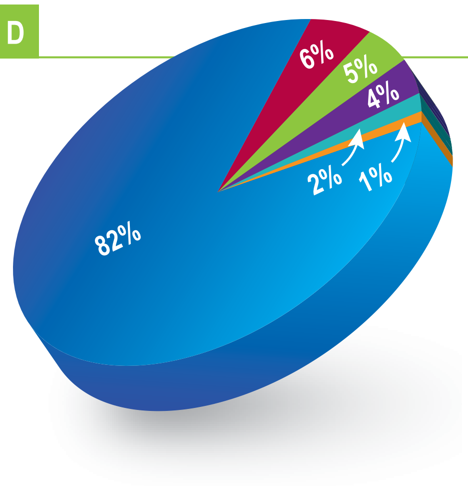
C

Comparison Chart



D



3. PROCESS STEP: Hydraulic fracturing and water use

The Concern:

"Hydraulic fracturing uses enormous quantities of water."

The Facts:

- Shale gas production requires less water than conventional production of oil and other forms of energy. The amount of water used to produce energy by source ranges from five litres (1.3 gallons) per MMBTU for shale gas to more than 9,500 litres (2,500 gallons) per MMBTU for biofuels.
- Hydraulic fracturing of a single well consumes 11 million litres to 19 million litres (3 to 5 million gallons) of water, depending on specific geology and fracturing requirements.
- The industry is attempting to reduce the amount of water used by improving the overall hydraulic fracturing process and reusing water when possible.
- The sourcing and use of water is heavily regulated.

The Context:

- Shale gas requires the least amount of water to produce the same amount of energy: 1 MMBTU. *(see graphic C)*
- Water used in shale development is a fraction of the total water usage for agricultural, industrial and recreational purposes. *(see graphic D)*

Recommended Industry Best Practices:

- Collect and disclose water usage data.
- Continually reduce, re-use and recycle water to mitigate overall water requirements.
- Invest in viable technology enhancements to reduce water usage.

Percent of Water Use

- Municipal/Public (82.5%)
- Industry and Mining (4.5%)
- Natural Gas Production (less than 1%)
- Irrigation (6%)
- Power Generation (4%)
- Livestock (2%)

For illustrative purposes only.

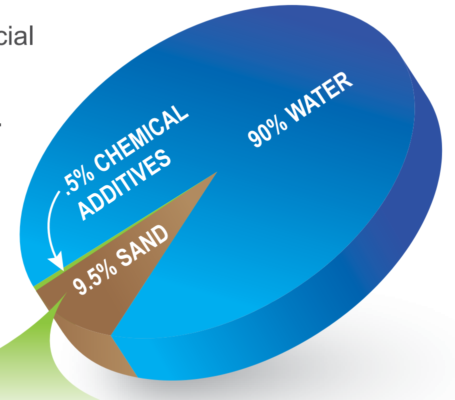
4. PROCESS STEP: Hydraulic fracturing fluids

The Concern:

"Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public."

The Facts:

- Hydraulic fracturing fluid is typically comprised of more than 99.5% water and sand, and 0.5% chemicals.
- A typical fracture treatment will use 3 to 12 additive chemicals, depending on the characteristics of the water and the shale formation being fractured.
- Many of those chemicals are present in common household and commercial applications. Some, used in extremely low concentrations, are toxic.
- The hydraulic fracturing fluid is controlled and doesn't contact fresh water.
- Industry is taking steps to voluntarily disclose more information about the chemical composition of fracturing fluid and several American states have established mandatory reporting requirements.



The Context:

- Typical chemicals present in fracturing fluid.

COMPOUND	PURPOSE	COMMON APPLICATION
ACIDS	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
SODIUM CHLORIDE	Allows a delayed breakdown of the gel polymer chains	Table salt
POLYACRYLAMIDE	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
ETHYLENE GLYCOL	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
BERABE SALTS	Maintains fluid viscosity temperature increases	Laundry detergent, hand soap, cosmetics
SODIUM/POTASSIUM CARBONATE	Maintains effectiveness of other components such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
GLUTERALDEHYDE	Eliminates bacteria in water	Disinfectant, sterilization of medical and dental equipment
GUAR GUM	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
CITRIC ACID	Prevents precipitation of metal oxides	Food additive; food and beverages, lemon juice
ISOPROPANOL	Used to increase the viscosity of the fracture fluid	Glass cleaner, anti-perspirant, hair colouring

Recommended Industry Best Practices:

- Fully disclose fracturing fluid additives.
- Invest in "green" or non-toxic alternatives to current additives.

For illustrative purposes only.

The intensity of seismic activity from hydraulic fracturing is typically 100,000 times less than levels detectable by human beings.

5. PROCESS STEP:

Hydraulic fracturing and wastewater disposal

The Concern:

"Hydraulic fracturing and associated wastewater disposal cause earthquakes."

The Facts:

- The intensity of seismic activity from hydraulic fracturing is typically 100,000 times less than levels detectable by human beings.
- There may be an extremely remote possibility of a relatively minor seismic event based on specific geology.
- In 2011 more than 250,000 hydraulic fracturing stages were completed. A few seismic events were reported to have been linked to the hydraulic fracturing jobs: A low-level quake in the U.K. was attributed to hydraulic fracturing and two cases in Ohio were related to injecting wastewater underground for disposal. Though discernible by humans, there was no physical damage from these events. Links between the seismic events and the shale gas projects have not been scientifically proven.

The Context:

- Microseismic Events from Hydraulic Fracturing vs. Earthquakes. *(see graphic F)*

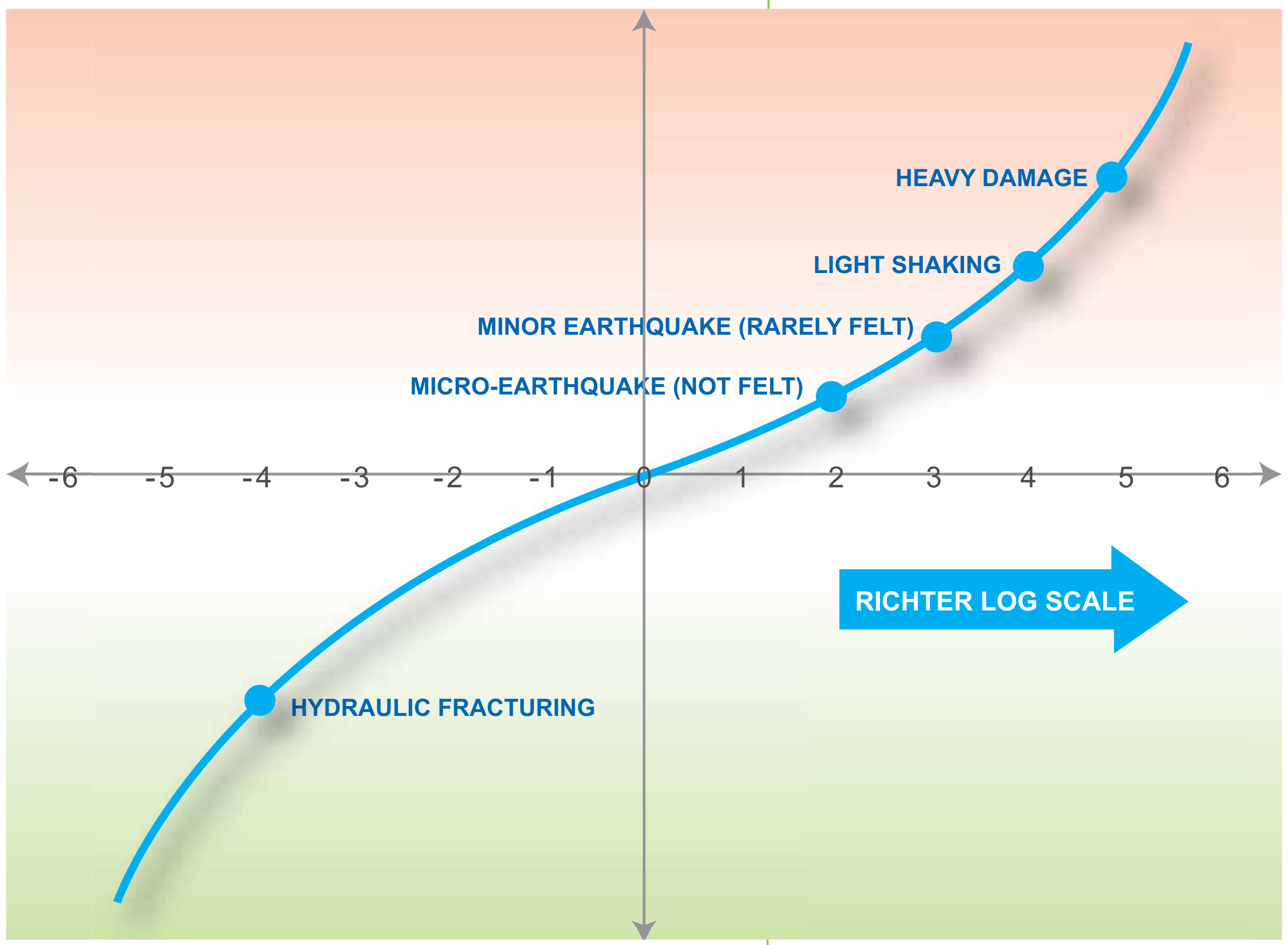
Recommended Industry Best Practices and Policies:

- Review local geology for potential fault lines prior to drilling for well site and wastewater injection.
- Monitor the process with very sensitive instruments so that operations can be halted if necessary.

For illustrative purposes only.

F

Microseismic Events from Hydraulic Fracturing vs. Earthquakes



For illustrative purposes only.

The percentage of wastewater that is recycled is increasing as companies become more adept at handling this waste and onsite treatment technologies become more readily available.

6. PROCESS STEP:

Disposal of wastewater

The Concern:

"Disposal of wastewater harms the environment."

The Facts:

- Wastewater from hydraulic fracturing is managed in a variety of ways, including: reuse, disposal through injection in deep underground wells, treatment at a local facility and storage in large steel tanks or in deep, lined pits.
- Underground injection is the primary disposal method for most shale gas projects.
- New wastewater treatment facilities are being built where underground disposal is not an option.
- The percentage of wastewater that is recycled is increasing as companies become more adept at handling this waste and onsite treatment technologies become more readily available.

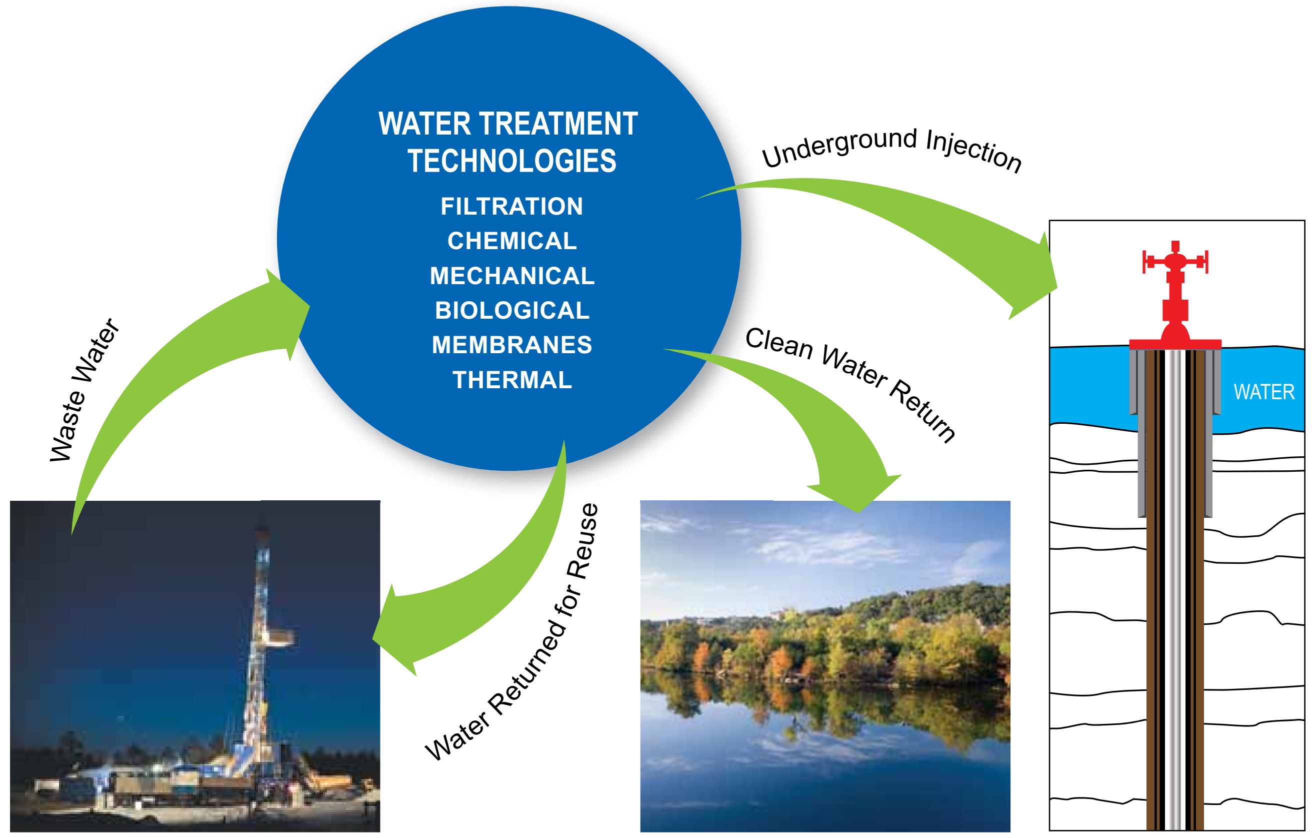
The Context:

- Managing wastewater through reuse, treatment and injection. *(see graphic G)*

Recommended Industry Best Practices:

- Use deep-ground injection wells or treat water at proper wastewater treatment facilities.
- Use "closed loop" or "covered containment systems" to minimize environmental impact.
- Document and review policies for handling and disposal of wastewater.
- Ensure proper regulations and compliance to proper wastewater disposal requirements exist.

G



For illustrative purposes only.

A number of reputable studies find that producing electricity from natural gas creates 36 to 47% lower emissions than producing electricity from coal.

7. CONCERN:

Air emissions

The Concern:

"Air emissions related to shale gas production are worse than those created by burning coal."

The Facts:

- A number of reputable studies find that producing electricity from natural gas creates 36 to 47% lower greenhouse gas emissions than producing electricity from coal.
- Howarth et al of Cornell University published a paper in 2011 stating that the life-cycle greenhouse gas emissions for shale gas are higher than those for coal, due to fugitive and vented emissions of methane during the production and transportation of natural gas. This cast doubts on whether natural gas from shale is a better fuel source than coal to combat climate change.
- Many other similar studies, however, have found that life-cycle greenhouse gas emissions from shale gas for electricity generation are significantly lower than from coal. The Howarth study varied from most other analyses due to:
  1) a higher global-warming potential used for methane instead of the widely accepted value used by the Intergovernmental Panel on Climate Change,
  2) the data sources were not from the U.S. Environmental Protection Agency, and
  3) failing to consider the potential for methane mitigation.

The Context:

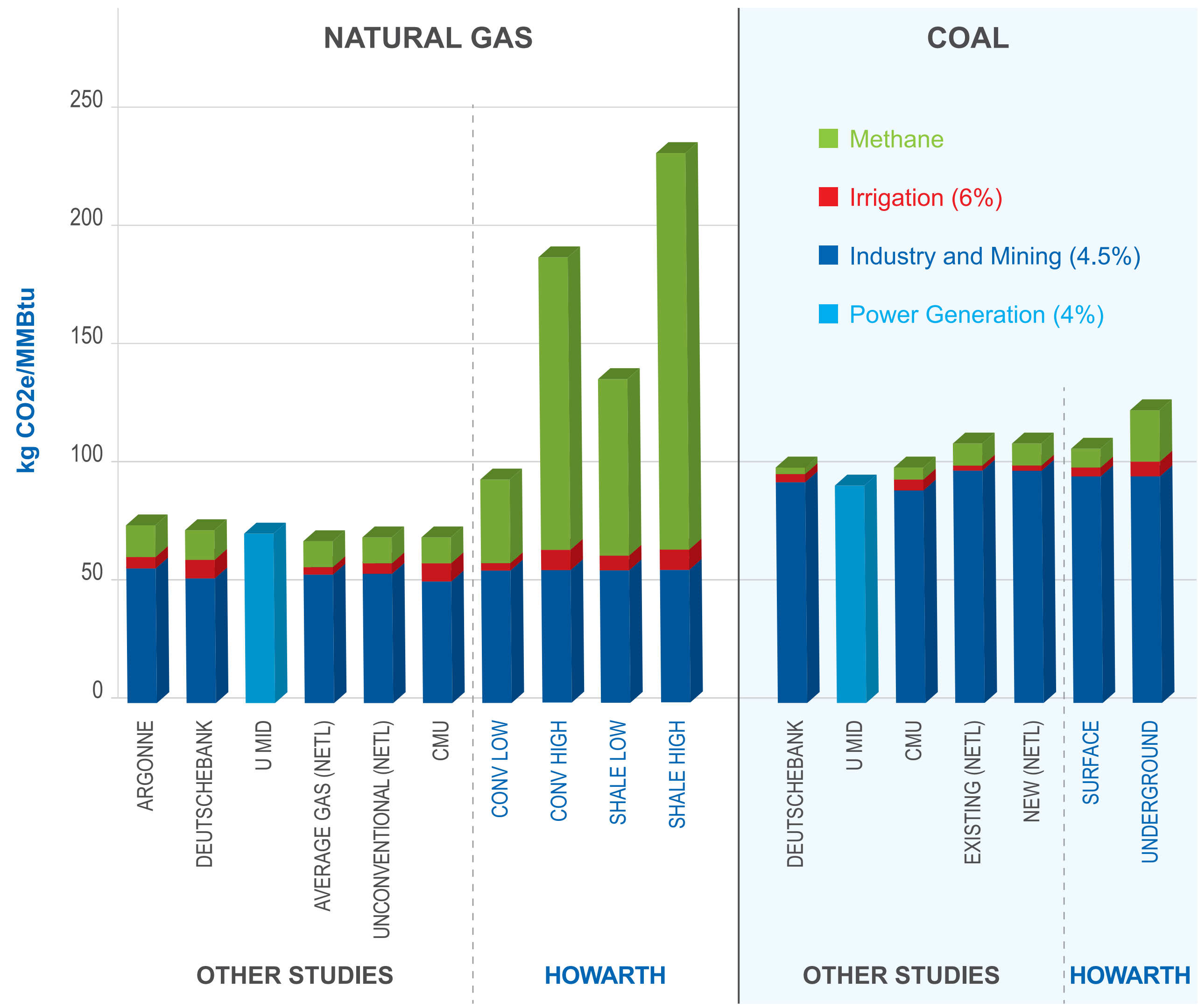
- The Howarth study was an anomaly in its findings of extremely elevated methane gas emissions for shale gas production. *(see graphic H)*

Recommended Industry Best Practices:

- Mitigate fugitive emissions by requiring operators to employ green-completion systems to maximize resource recovery and minimize methane releases to the environment.

H

Natural Gas & Coal Life-Cycle Emission Study Comparisons



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Other Regulatory Bodies:

ALGERIA
l'Agence Nationale de Contrôle et de Régulation des Activités dans le domaine des Hydrocarbures

ARGENTINA
National Institute for Water and the Environment

CANADA
Environment Canada

CHINA
Ministry of the Environmental Protection of the People's Republic of China

EUROPE
European Environmental Agency

POLAND
Inspectorate for Environmental Protection

UNITED STATES
Environmental Protection Agency

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8. CONCERN:

Regulation

The Concern:

"Shale gas extraction is not regulated."

The Facts:

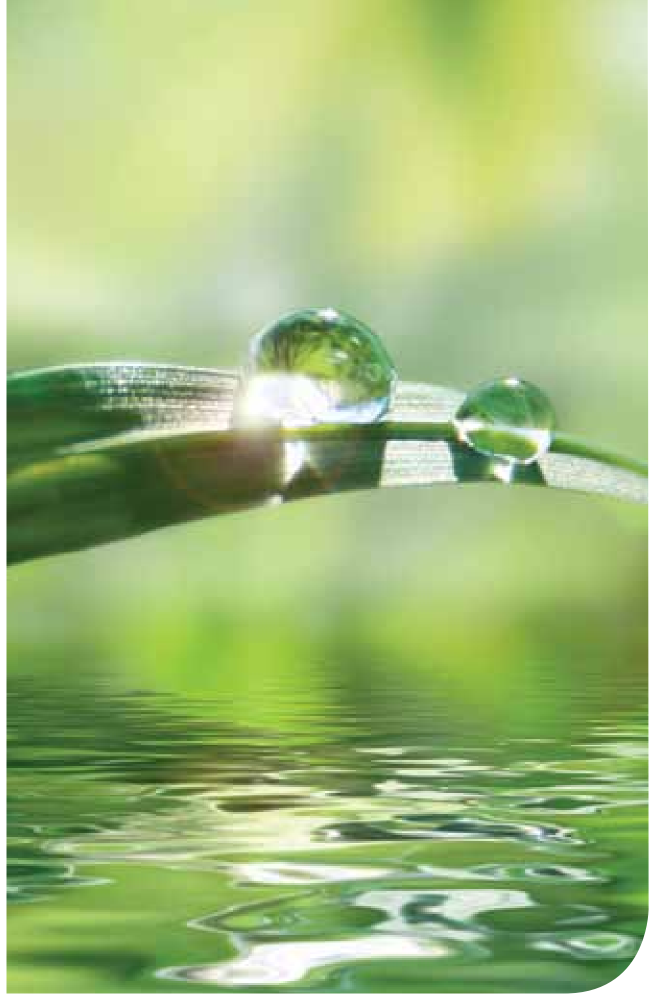
- In North America, specific, dedicated regulations pertaining to shale gas extraction are evolving. However, an extensive set of laws govern and regulate various aspects of shale gas development through many different and often interconnected regulatory bodies. In the United States, these include: the National Environmental Policy Act, the Clean Water Act, the Clean Air Act, the Safe Drinking Water Act.
- In all other jurisdictions where shale gas is being produced or its production is being contemplated, similar regulations apply.

The Context:

- Some of the regulatory bodies whose laws and regulations govern the shale gas industry. *(see list on left)*

Recommended Industry Best Practices:

- Encourage the development of smart shale gas regulations that protect the environment, public health and safety while realizing the full economic and environmental benefits of expanded shale gas development.
- Employ best drilling practices, research and invest in new technologies.
- Maintain appropriate oversight, inspection and enforcement of all existing regulations.



PART II - Detailed Report

The Facts about the Environmental Concerns

The following section presents a detailed review of the process steps and environmental concerns to be addressed, including the relevant references

PART II - Detailed Report

Process Steps and Environmental Concerns to be addressed:

PROCESS STEP: Site development and preparation

1. "Shale gas drilling takes up a larger land use footprint than does conventional production"

PROCESS STEP: Vertical drilling and effect on drinking water

2. "Hydraulic fracturing can have adverse effects on drinking water"

PROCESS STEP: Horizontal drilling

No environmental concerns raised

PROCESS STEP: Hydraulic fracturing and water use

3. "Hydraulic fracturing uses enormous quantities of water"
4. "Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public"

PROCESS STEP: Disposal of wastewater

5. "Hydraulic fracturing and associated wastewater disposal causes earthquakes"
6. "Disposal of wastewater harms the environment"

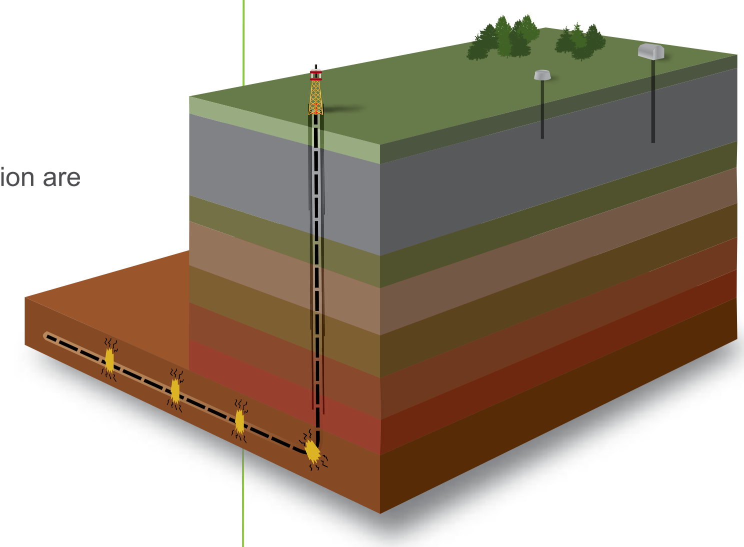
PROCESS STEP: Well completion and abandonment

No environmental concerns raised

CONCERNS: Air emissions and regulations:

7. "Air emissions related to shale gas production are worse than those created by burning coal"
8. "Shale gas extraction is not regulated"

The following section presents a detailed review of the process steps and environmental concerns to be addressed.



For illustrative purposes only.

Thanks to horizontal drilling, the actual land-use footprint required to produce natural gas from shale is dramatically smaller than that required to produce traditional oil and gas, and electricity from wind and sun.

CONCERN 1:
"Shale gas drilling takes up a larger land-use footprint than does conventional energy production."

Although shale gas production takes place deep underground, the practice requires some alteration of the surface land. Wells have to be built, as do access roads and production facilities. However, thanks to the technique known as horizontal drilling, the actual land-use footprint required to produce natural gas from shale is dramatically smaller than that required to produce traditional oil and gas, and electricity from wind and sun.

Land use by energy extraction: conventional gas, shale gas, wind, solar. *(see graphic A)*

Current practices for shale gas production involve drilling one vertical well to a depth of several thousand metres, with several horizontal wells emanating from there. This technique allows for far greater areas of shale to be accessed underground, while disturbing far less surface land, as it requires fewer wells, access roads and production facilities.

The following examples demonstrate the difference in surface land disturbance for vertical wells versus horizontal wells:

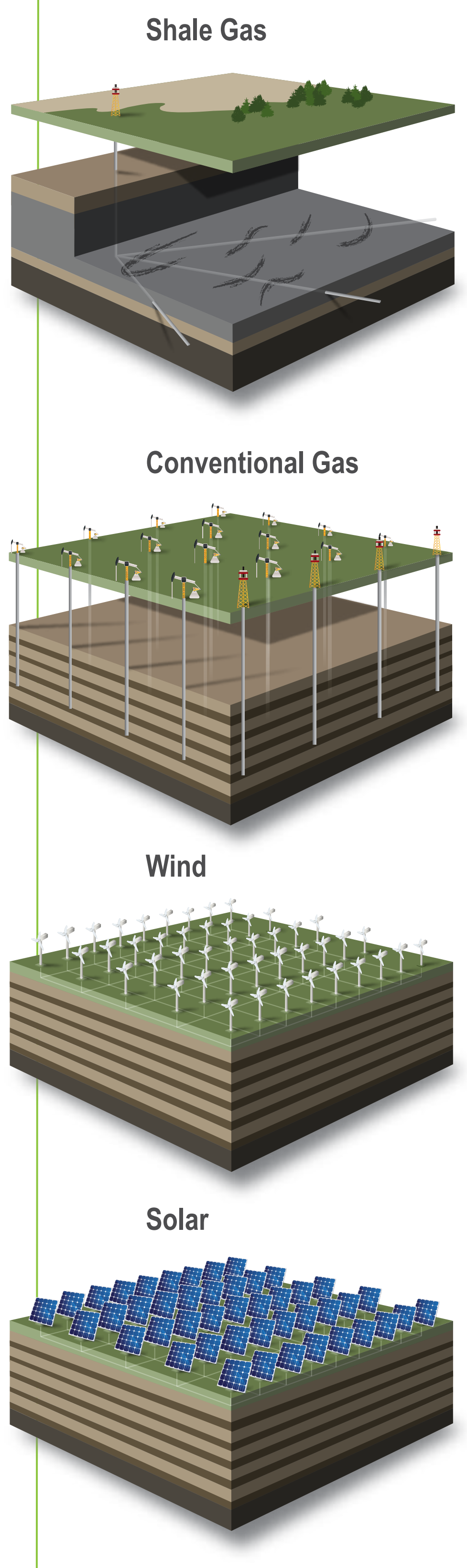
- Shale gas producers can drill up to 12 horizontal wells from one vertical well. The U.S. Department of Energy (DOE) reports that just six to eight horizontal wells from one vertical well can access the same or greater shale reservoir volume as more than 16 conventional vertical wells – each requiring its own well pad.[1]
- The DOE also states that when drilling conventional vertical wells, it is typical to install 16 well pads and drill 16 vertical wells per 2.6 square kilometres (one square mile) versus just one well pad in the same area when drilling horizontal wells.
- The same reports also shows that 16 conventional vertical wells would disturb approximately 0.3 square kilometres (0.12 square miles) of surface land, while a four-well horizontal well pad for shale gas production would disturb only 0.03 square kilometres (0.01 square miles) – more than 10 times less than the vertical wells – and access the same volume of shale gas.

It is significant to note that the number of horizontal wells drilled from a single well pad will continue to increase as producers become more adept at using this technique.

As the shale gas industry evolves, producers are finding even more ways to reduce the amount of surface land disturbance, such as drilling multiple vertical wells from one single well pad, and multiple horizontal wells from each of those vertical wells. While each of these multi-well pads is larger than a single-well pad, the combined space that they take up, for the amount of gas accessed, is significantly less than the space needed for multiple single-well pads. Therefore, it is recommended to continue drilling multiple vertical wells on a single well pad to further reduce the land-use footprint.

Another recommendation is that producers select, plan and operate well sites in a manner that keeps community and land-use impacts to a minimum. Each well site should be developed considering the natural environment, as well as the existing population and infrastructure.

A



For illustrative purposes only.

There is no physical path between naturally occurring water in aquifers and water injected for hydraulic stimulation of shale formations.

CONCERN 2:
"Hydraulic fracturing can have adverse effects on drinking water."

The process of hydraulic fracturing for shale gas production involves drilling vertical and horizontal wells thousands of metres under ground and injecting water, sand and additives into the shale formations to prop them open and extract natural gas. Some people believe that because the wells pass through aquifers to reach the shale, and because water and chemical additives are injected into the wells, drinking water sources could be affected. However, studies prove that the chances of water being affected by drilling and hydraulic stimulation of the shale formations, when done properly, are extremely remote.

There has been some widespread concern about possible water contamination from hydraulic fracturing – including elevated methane levels in water wells and chemicals likely related to hydraulic fracturing found in groundwater. In fact, the National Ground Water Association has said conclusively that properly executed hydraulic fracturing does not lead to groundwater contamination. The American organization's 2011 report on the issue says that while no widespread water quality or quantity issues have been definitively documented that are attributable to hydraulic fracturing and related activities at oil and gas sites, there have been isolated cases where faulty casing installations (including poor cement bonds) or poor management of materials/chemicals at the surface are suspected as having negatively impacted groundwater, surface water, or water wells.[2]

Vertical Drilling is a Well-Established Process:

Large-scale hydraulic fracturing has been around for more than six decades and millions of hydraulic fracturing jobs have been completed with no significant effects on drinking water.[3]

Groundwater is protected during vertical drilling by using proper well-bore design: a combination of a protective casing and cement. It also highlights the fact that aquifers lie within about 300 metres of the earth's surface, whereas shale formations are normally 3,000 to 4,500 metres underground.

It's important to note that there is no physical path between naturally occurring water in aquifers and water injected for hydraulic stimulation of shale formations. *(see graphic B)*

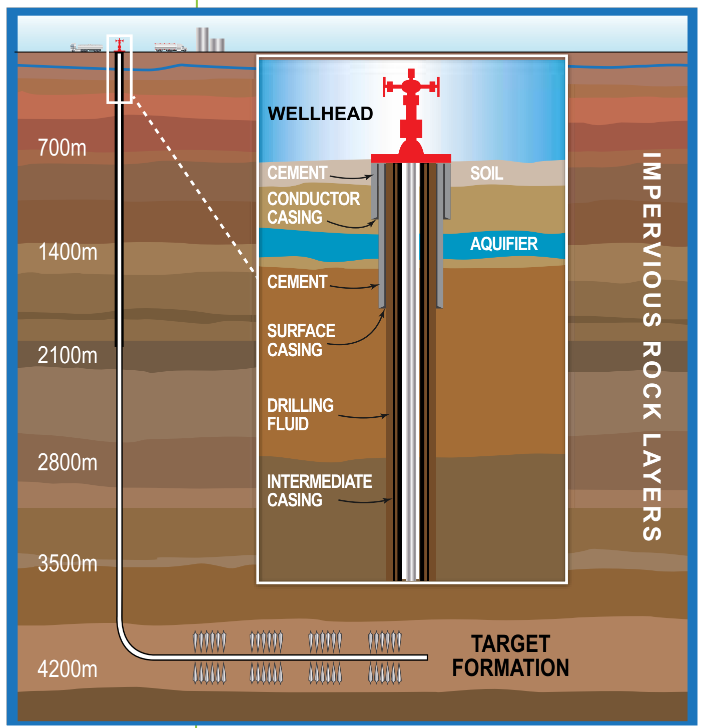
In order to ensure that groundwater is protected, a number of best practices should be followed relating to shale gas production and water before, during and after drilling and hydraulic fracturing take place.

- Prior to drilling, it is recommended to identify sub-surface drinking water sources that lie within 250 metres of the intended well site. If water sources are present within the 250-metre radius, water should be tested before, during and after each drilling to monitor water integrity.
- A further recommendation is that minimum well depths be set in order to ensure that hydraulic fracturing takes place a significant distance from water aquifers.
- Lastly, a quality assurance program needs to be in place to ensure that the proper well-bore design and construction practices are followed. During the life of the well, integrity testing should be performed regularly.

It is also imperative to maintain rigorous oversight of all parties and practices involved in the production process – subcontractors, quality assurance, audits and training programs – to ensure that everyone is meeting or exceeding standards and that accidents don't happen.

B

Well-bore Design



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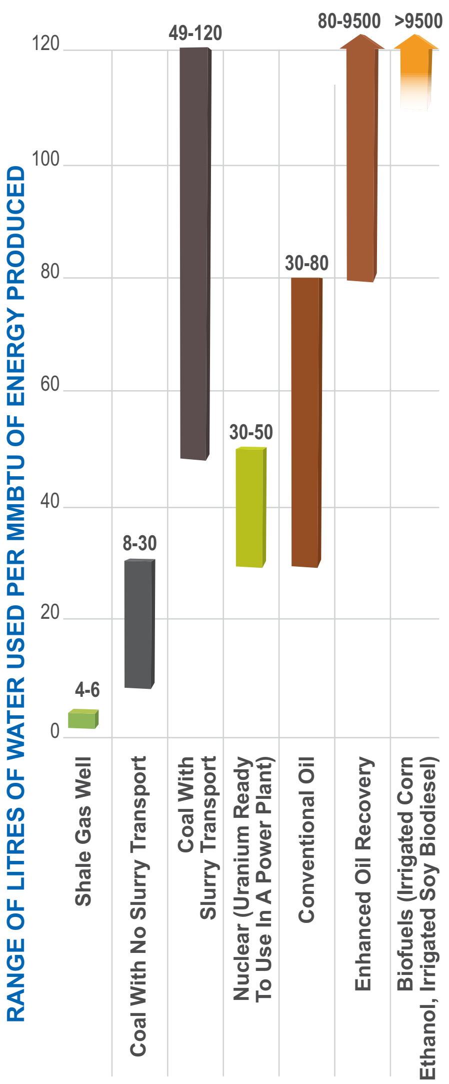
C

Comparison Chart



For illustrative purposes only.

CONCERN 3:
"Hydraulic fracturing uses enormous quantities of water."

Water is a key input for shale gas production. It can take about 11 million litres (3 million gallons) of water to hydraulically stimulate a well.[4] In 2011, over 17,000 horizontal wells were hydraulically fractured for shale gas extraction. Undoubtedly, that's a large amount of water, and it has raised concerns about possible depletion of local water supplies and the need to regulate water usage. But the amount of water used in shale gas production needs to be viewed in context of other industrial, commercial and agricultural water uses.

Typically, the amount of water used in shale development is a fraction of the total water usage for agricultural, industrial and recreational purposes. *(see graphic D)*

Shale gas production also requires less water per unit of energy produced than conventional production of oil and gas and other forms of energy. The amount of water used to produce energy by sources ranges from five litres of water (1.3 gallons) per MMBTU for shale gas to more than 9,500 litres (2,500 gallons) per MMBTU for biofuels such as ethanol from corn or biodiesel from soybeans.

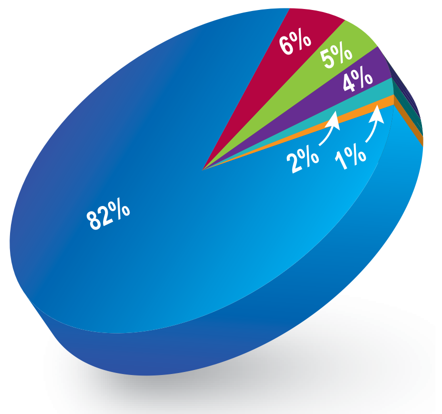
The chart on the left shows that shale gas requires the least amount of water to produce the same amount of energy: 1 MMBTU. *(see graphic C)*

As for concerns about water regulation and the possible depletion of local water supplies, it is important to remember that the sourcing and use of water – whether it is sourced from local drinking water supplies or nearby groundwater – is highly regulated in most jurisdictions.

As well, even though the amount of water used in hydraulic stimulation is already lower than that used in the production of many other fuels, the industry is constantly working on ways to further reduce overall water consumption by improving the hydraulic fracturing process and reusing water whenever possible.

It is recommended that the industry continues to reduce, re-use and recycle water to mitigate the overall volume of water required – supported by the ongoing collection of data and reporting on the amount of water used for shale gas production. It is also recommend that industry continue investing in technological enhancements to reduce the amount of water needed for hydraulic fracturing.

D



Even though the amount of water used in hydraulic stimulation is already lower than that used in the production of many other fuels, the industry is constantly working on ways to further reduce overall water consumption by improving the hydraulic fracturing process and reusing water whenever possible.

For illustrative purposes only.

CONCERN 4:
"Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public."

Hydraulic fracturing fluid is the key to opening up fissures in shale formations and extracting natural gas. About 90 per cent of that fluid is water and about 9.5 per cent is sand. The remaining 0.5 per cent of the fracturing fluid contains additives – many of which are present in regular household products, cosmetics and foods.

Hydraulic fracturing fluid will typically contain three to 12 additive chemicals.[5] But, because each hydraulic fracturing job is unique – in terms of the well depth, the characteristics of the water being used and the shale formation being fractured – the fracturing fluid is uniquely constituted for each job. Each component added to the water and sand mixture serves a specific engineering purpose such as reducing friction, preventing microorganism growth, reducing biofouling of the fractures and removing drilling mud damage.

The graphic on the right lists the additives typically present in hydraulic fracturing fluid, their purpose and other common uses for these additives. *(see graphic E)*

Many of the chemicals listed in graphic E are commonly used in our everyday activities. Some, which are used in extremely low concentrations for hydraulic fracturing, can be toxic in higher concentrations. This holds true for chemicals that are routinely added to our drinking water and foods. For example, chlorine is used by water treatment facilities to make water safe for human consumption. When handled safely and used in the right concentrations, it is safe for people to drink and workers to handle. However, at higher concentrations or if an accident occurs, chlorine can have serious effects on human health and the environment.

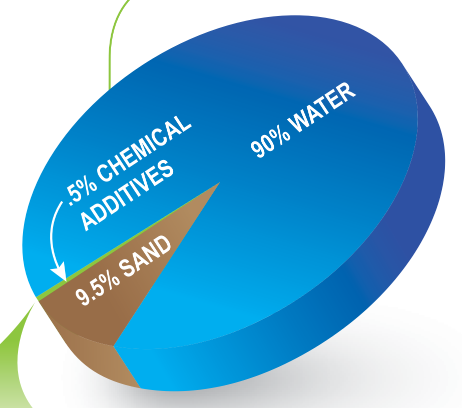
While production companies historically contended that the concentration of chemical additives in fracturing fluids was too small to be significant, and therefore not of interest to the public, the industry is taking steps to voluntarily disclose more information on fracturing fluid makeup. Several American states have established mandatory reporting requirements and the U.S. Department of the Interior is working on draft regulations that would require disclosure of chemicals used in hydraulic fracturing on public lands.

Hydraulic fracturing fluid is constantly controlled and does not come into contact with fresh water at any point in the hydraulic fracturing process.

Another key fact about hydraulic fracturing fluid is that it is constantly controlled and does not come into contact with fresh water at any point in the hydraulic fracturing process due to the cement and casing surrounding the wells.

It is recommended that the industry fully disclose all fracturing fluid additives so that the public knows which chemicals are being used, in what quantities, where and when. More investment is also recommended into "green" or non-toxic alternatives to the chemicals currently used in hydraulic fracturing fluid, such as UV light treatments to reduce the use of biocides and advanced dry polymer blender, which eliminates the need for hydrocarbon-based concentrates.

E



COMPOUND	PURPOSE	COMMON APPLICATION
ACIDS	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
SODIUM CHLORIDE	Allows a delayed breakdown of the gel polymer chains	Table salt
POLYACRYLAMIDE	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
ETHYLENE GLYCOL	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
BERABE SALTS	Maintains fluid viscosity temperature increases	Laundry detergent, hand soap, cosmetics
SODIUM/POTASSIUM CARBONATE	Maintains effectiveness of other components such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
GLUTERALDEHYDE	Eliminates bacteria in water	Disinfectant, sterilization of medical and dental equipment
GUAR GUM	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
CITRIC ACID	Prevents precipitation of metal oxides	Food additive; food and beverages, lemon juice
ISOPROPANOL	Used to increase the viscosity of the fracture fluid	Glass cleaner, anti-perspirant, hair colouring

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CONCERN 5:
"Hydraulic fracturing and associated wastewater disposal cause earthquakes."

Hydraulic fracturing for shale gas production involves drilling wells deep underground, injecting large quantities of water-based fracturing fluid in stages and then disposing of fluid – often underground. These activities have raised concerns about possible seismic events in nearby communities.

It's very difficult for geologists to link seismic events – earthquakes or other vibrations in the earth – to any one specific cause. The United States Geological Survey estimates that several million earthquakes occur around the world every year and that the vast majority of them go undetected because their magnitudes are so small or they are in very remote locations.[6] On the Richter scale, seismicity below a Richter level 3 is usually undetectable without sensitive instruments. And it is important to note that the Richter scale is logarithmic: A level 2 earthquake, for example, has a shaking amplitude 10 times less than a level 3 earthquake.

However, it has been proven that some human activities, including injecting fluid into deep wells, can cause seismic activity. If present, that seismic activity is usually so insignificant that it is noticed only by highly sensitive instruments, and is imperceptible to human beings.

The graphic on the right shows that the intensity of seismic activity from hydraulic fracturing of a shale gas well is typically 100,000 times less than levels detectable by human beings. *(see graphic F)*

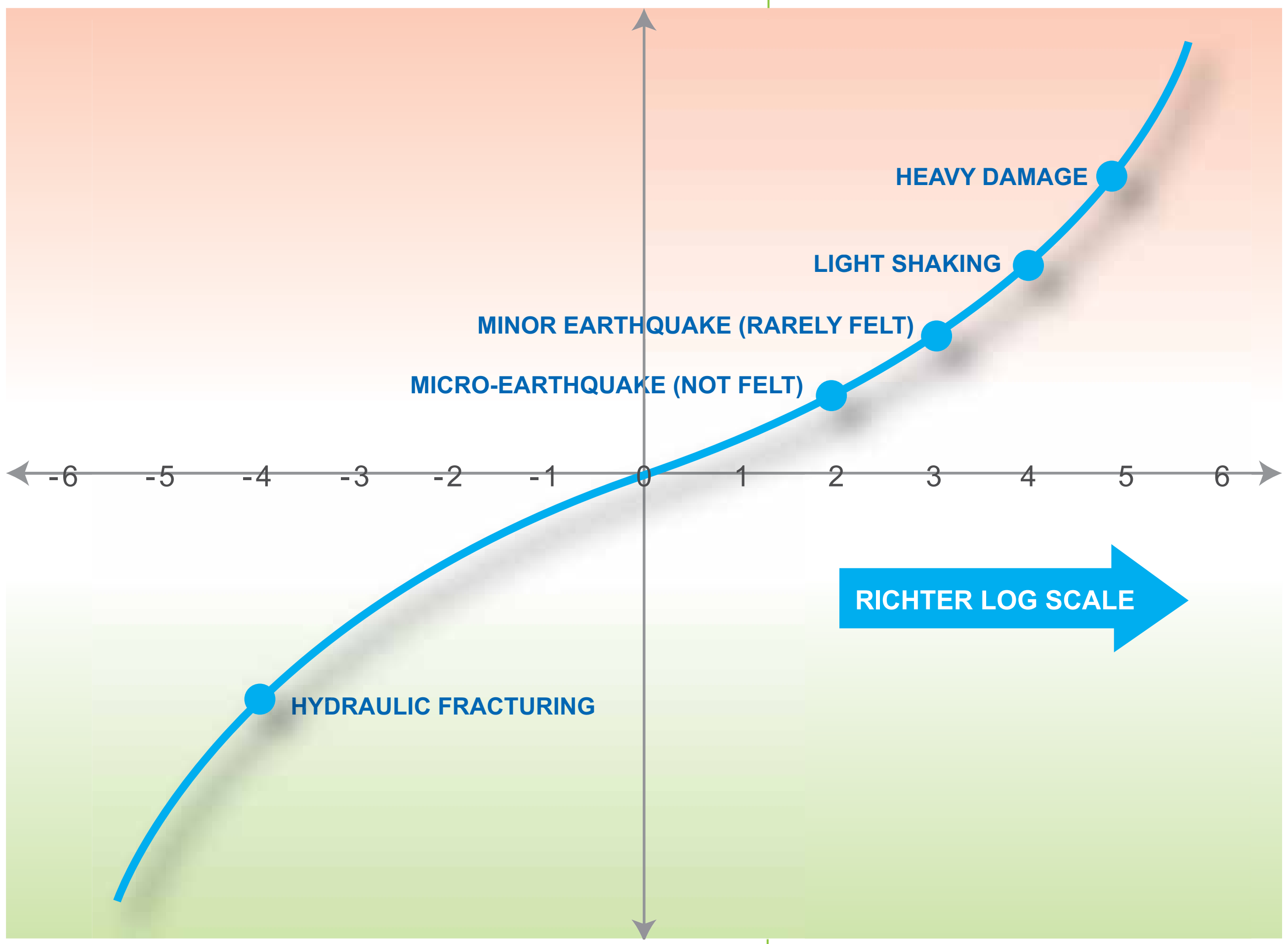
On extremely rare occasions, humans have reported feeling seismic activity related to shale gas production. In 2011 more than 250,000 hydraulic fracturing stages were completed, along with the requisite disposal of wastewater. During that time, a few seismic events were reported: two cases in Ohio were said to be related to underground disposal of wastewater[7] and a low-level quake in the United Kingdom was attributed to hydraulic fracturing, due to "an unusual combination of factors, including the specific geology of the well site coupled with the pressure exerted by water injection."[8] Though discernible by humans, there was no physical damage from these events, and links between the seismic activity and shale gas projects have not been scientifically proven.

Recommendation: Review the local geology for potential fault lines prior to drilling at well sites and wastewater injection sites.

It is widely agreed that a site's geology can have an impact on drilling. Therefore, to further ensure that shale gas production does not cause future tremors – regardless of their perceptibility – one recommendation is to review the local geology for potential fault lines prior to drilling at well sites and wastewater injection sites. Another recommendation is to monitor drilling and injection with ultra sensitive instruments so that operations can be halted if seismic activity occurs or seems likely to occur.

F

Microseismic Events from Hydraulic Fracturing vs. Earthquakes



For illustrative purposes only.

CONCERN 6:
“Disposal of wastewater harms the environment.”

After a hydraulic fracturing stage has been completed and the pumping pressure has been relieved from the well, water begins to flow back to the wellhead. This “flowback” is a mixture of the original hydraulic fracturing fluid – containing less than one per cent of chemical additives – and any natural formation water – containing dissolved constituents from the shale formation itself. The disposal of this wastewater and produced water has been the cause of some concerns.

Flowback from hydraulic fracturing is managed in three main ways: reuse, disposal through injection in deep underground wells and treatment in a local facility. *(see graphic G)*

Underground injection is currently the primary disposal method for wastewater from most shale gas projects in traditional production areas. The wastewater is discharged into deep disposal wells that are subject to individual review and permitting.

However, in some areas where shale gas drilling occurs, such as the Marcellus shale areas of New York and Pennsylvania, the geology is not conducive to underground injection. Therefore, shale gas projects in these areas have typically shipped their wastewater to local treatment facilities. While these facilities are expert at treating domestic wastewater, they may not be designed to treat the specific components of shale gas production wastewater, such as salts, inorganic chemicals and Naturally Occurring Radioactive Material (NORM). Due to these concerns, new wastewater treatment facilities are being built to specifically handle wastewater from shale gas wells. Wastewater can also be stored in large steel tanks or in deep, lined pits where it is allowed to evaporate.

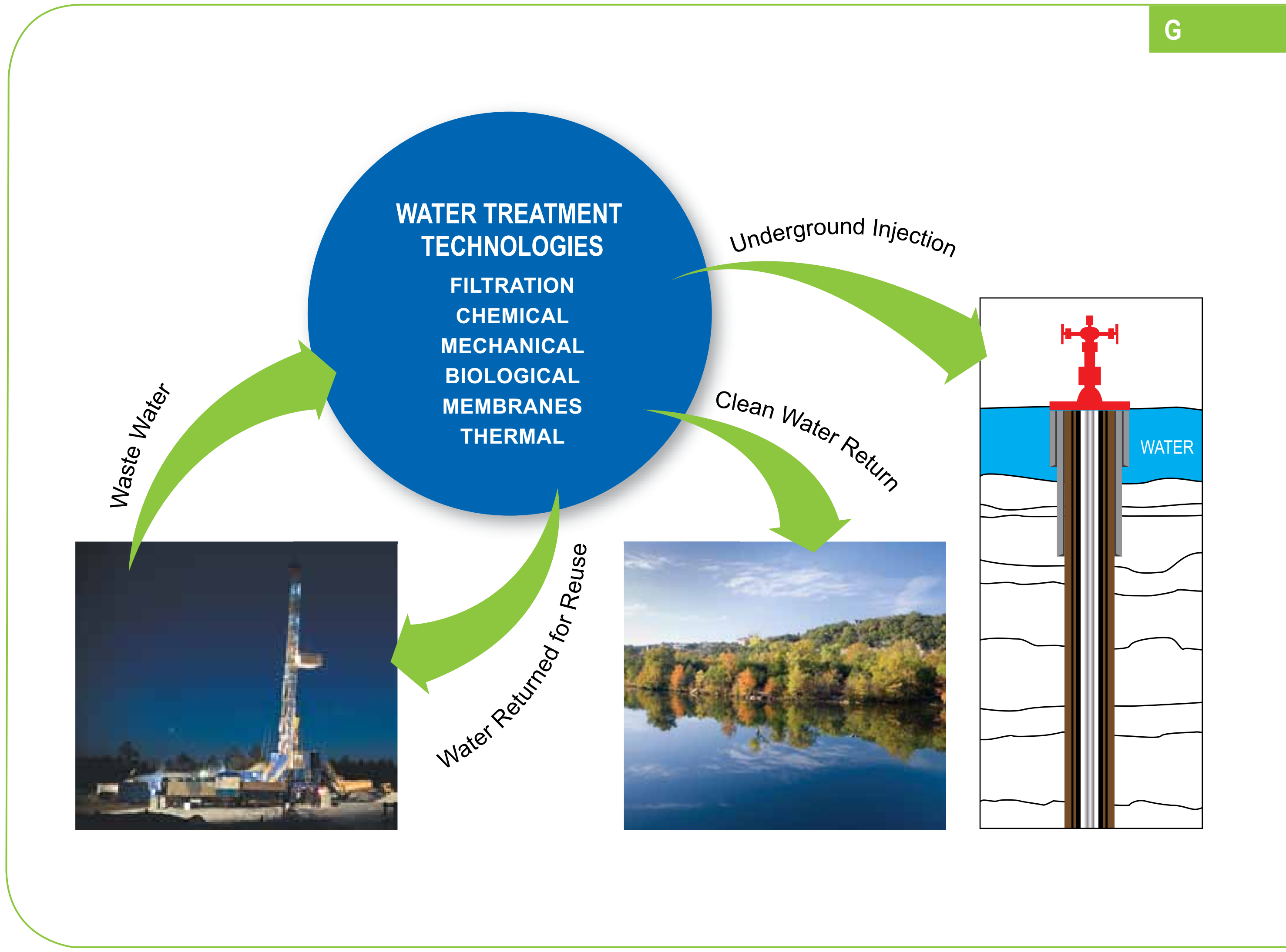
In addition, the percentage of water that is recycled and re-used for hydraulic fracturing stages is increasing, meaning that there is a lesser need for wastewater disposal.

Further, as the industry invests in researching ways to use less water for hydraulic fracturing itself, and eventually decreases the number of litres used for each stage, there will be less water to dispose of or treat at the end of the process.

The percentage of water that is recycled and re-used for hydraulic fracturing stages is increasing, meaning that there is a lesser need for wastewater disposal.

One recommended best practice is that wastewater is injected into underground wells where possible or treated at purpose-built shale gas wastewater treatment facilities. “Closed loop” or “covered containment” systems should also be used to minimize environmental impact.

It is also vital to document and review policies for handling and disposing of wastewater, to ensure proper regulations exist for wastewater disposal and strong enforcement is carried out.



For illustrative purposes only.

CONCERN 7:

"Air emissions related to shale gas production are worse than those created by burning coal."

When evaluating the overall merit and viability of any energy source, many people focus on the greenhouse gas emissions related to the production of that energy. Methane emissions from natural gas extraction, particularly shale gas, have been getting significant attention in recent months.

One study, published in 2011 by Howarth et al of Cornell University, claimed that the life-cycle greenhouse gas emissions of shale gas – that is, emissions that are associated with the production and transportation of the fuel to the end user – are higher than those of coal due to the fugitive and vented emissions of methane during the production and transportation of natural gas.[9] This particular study cast doubts on whether natural gas was in fact better than coal at combating climate change.

Many other similar studies, however, still maintain that greenhouse gas emissions from shale gas for electricity – including the life-cycle emissions – are significantly lower than from coal. In fact, a number of reputable studies find that producing electricity from natural gas creates 36[10] to 47[11] per cent lower emissions than producing electricity from coal. The reasons for the discrepancy are as follows:

- Howarth et al used a higher global-warming potential for methane than the widely accepted value used by the Intergovernmental Panel on Climate Change,
- Howarth et al used data sources that weren't from the Environmental Protection Agency (EPA), and
- Howarth et al failed to consider the potential for methane mitigation.

According to the EPA: "Compared to the average air emissions from coal-fired generation, natural gas produces half as much carbon dioxide, less than a third as much nitrogen oxides, and one percent as much sulfur oxides at the power plant."[12]

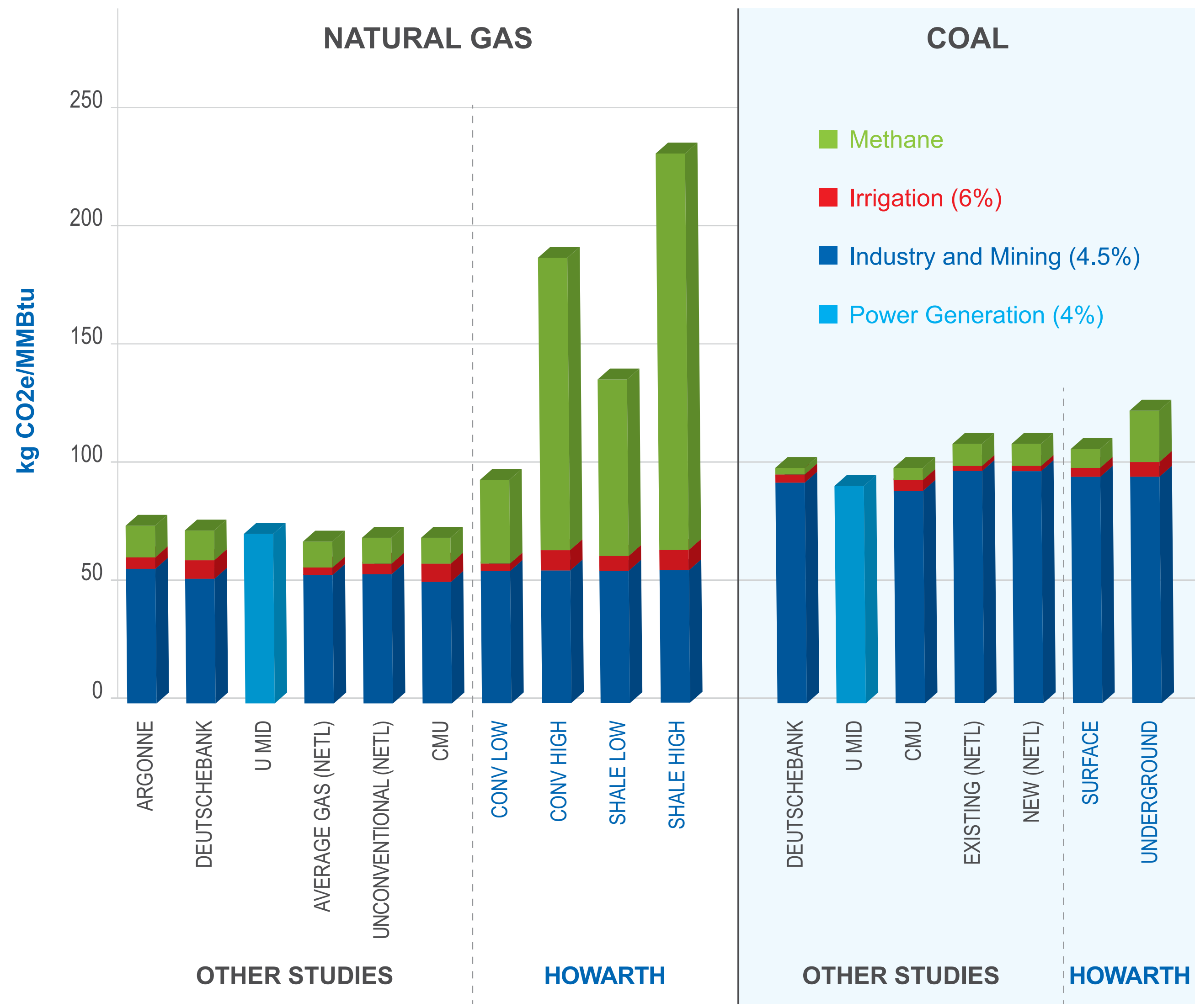
The graph on the right shows how the study by Howarth et al was an anomaly in its findings of extremely elevated methane gas emissions for shale gas production compared to several other similar studies. *(see graphic H)*

Even though we recognize that the Horwath et al study was an anomaly, it is recommended to continually strive for lower greenhouse gas emissions in our industry and, specifically, work toward mitigating fugitive emissions of methane by employing green-completion systems.

Producing electricity from natural gas creates 36 to 47 per cent lower emissions than producing electricity from coal.

H

Natural Gas & Coal Life-Cycle Emission Study Comparisons



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Other Regulatory Bodies:

ALGERIA
l'Agence Nationale de Contrôle et de Régulation des Activités dans le domaine des Hydrocarbures

ARGENTINA
National Institute for Water and the Environment

CANADA
Environment Canada

CHINA
Ministry of the Environmental Protection of the People's Republic of China

EUROPE
European Environmental Agency

POLAND
Inspectorate for Environmental Protection

UNITED STATES
Environmental Protection Agency

CONCERN 8: "Shale gas extraction is not regulated."

According to some environmental organizations, shale gas opponents and media reports, shale gas production is largely an unregulated industry. This misconception can lead to concern that shale gas producers are not acting in the best interest of the public at large or are even breaking laws.

In North America, specific, dedicated regulations pertaining to shale gas extraction are evolving, however an extensive set of laws govern and regulate various aspects of shale gas development through many different and often interconnected regulatory bodies. The industry adheres to the same laws and regulations that the conventional oil and gas industry does. In the United States the regulatory bodies include: the National Environmental Policy Act, the Clean Water Act, the Clean Air Act, and the Safe Drinking Water Act.

In all other jurisdictions around the world where shale gas is being produced or its production is being contemplated, similar regulations apply.

To the left are just a few of the regulatory bodies whose laws and regulations govern the shale gas industry.

In order for our industry to grow and gain more credibility in the eyes of the public, smart shale gas regulations must be developed for the future, regulations that protect the environment, public health and safety while realizing the full economic and environmental benefits of expanded shale gas development.

It is also imperative that producers employ best drilling practices, research and invest in new technologies and maintain appropriate oversight, inspection and enforcement of all existing regulations.

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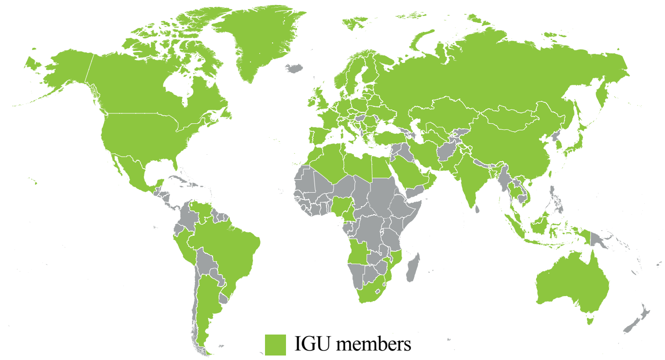
IGU

The International Gas Union (IGU), founded in 1931, is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate for gas as an integral part of a sustainable global energy system. IGU has more than 110 members worldwide and represents more than 95% of the world's gas market. The members are national associations and corporations of the gas industry. The working organization of IGU covers the complete value chain of the gas industry from upstream to downstream. For more information please visit www.igu.org.



INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

Office of the Secretary General
c/o Statoil ASA
0246 Oslo
Norway

Telephone: + 47 51 99 00 00
Fax: + 47 22 53 43 40
Email: secrigu@statoil.com
Website: www.igu.org