

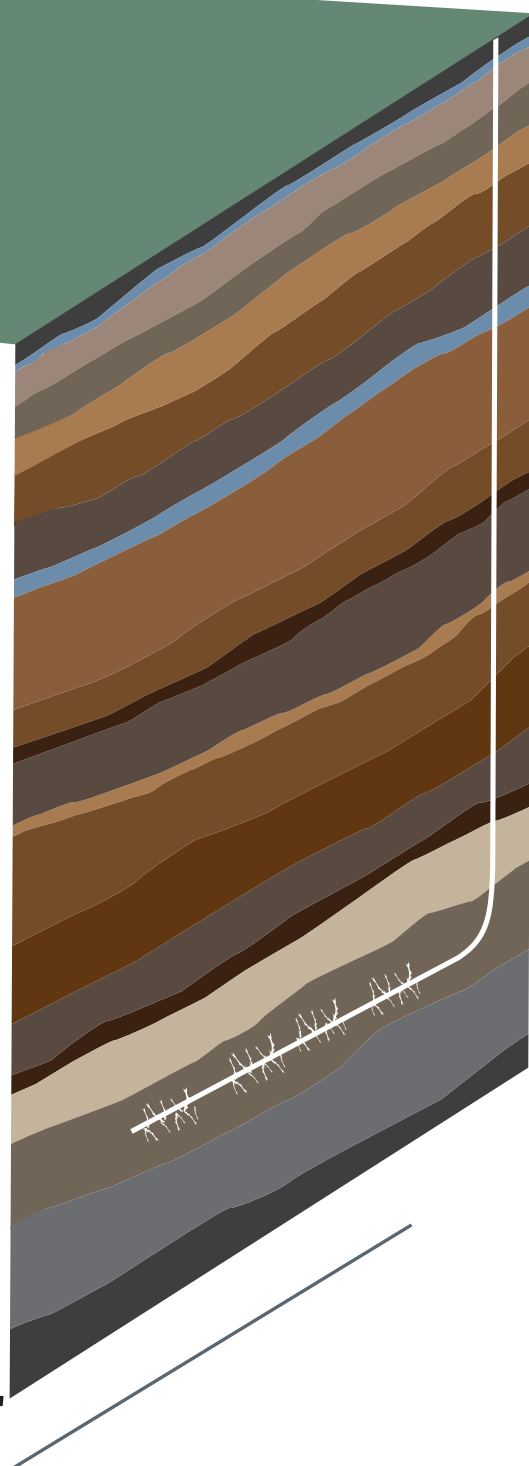


**International
Association
of Oil & Gas**

Version 2
Updated May 2014

SHALE GAS & HYDRAULIC FRACTURING

ENSURING A SAFE,
CLEAN, SECURE
& COMPETITIVE
ENERGY SOURCE
FOR EUROPE





WE ARE WORKING FOR SAFE, SUSTAINABLE EXPLORATION & DEVELOPMENT IN EUROPE

Successful exploration of gas from shale could potentially provide Europe with an additional source of **secure and competitive energy** that could make an immediate and positive impact on reaching the EU's ambitious CO₂ reduction targets. OGP members are committed to work for its safe, responsible development in Europe.

WHAT IS GAS FROM SHALE?

It is natural gas that can only be economically extracted from sedimentary shale rock through the combined use of horizontal drilling and hydraulic fracturing. It shares many of the advantages of natural gas that has been produced safely in Europe for many years.

GAS FROM SHALE...

- Is an **affordable, efficient** energy source.
- Has a **smaller environmental footprint** with lower GHG emissions and a lower surface footprint than other conventional energy.
- **Reduces CO₂ emissions.** Between 2007 and 2012 the US cut CO₂ emissions by 450 million tons thanks to the shift from coal to gas in power generation.
- **Is abundant.** IEA estimates show that reserves of natural gas extracted from unconventional sources, like gas from shale, coal bed methane and tight gas almost double recoverable gas resources (using current technology and economic models).
- Has potential for **economic benefits** such as increased employment, tax revenues and royalties.
- Contributes to supply diversity and security for Europe by increasing **domestic supplies**.

RESPONSIBLE DEVELOPMENT

OGP acknowledges the importance of industry and authorities cooperating and establishing a dialogue to address public concerns through the open sharing of information and knowledge. Industry experience has demonstrated that early dialogue with local communities is the most important element of maintaining the trust necessary for successful development.

As part of our efforts to build trust OGP has developed a **Transparency Initiative** for European drilling projects. It has created a public hydraulic fracturing disclosure website where members of the public can search for nearby well sites that have been hydraulically fractured to see what chemicals were used to fracture natural gas resources on a well-by-well basis.

EXISTING REGULATION REDUCES RISK

European legislators have ensured that the exploration and production of natural gas in Europe is one of the most highly regulated processes in the world. In fact, gas from shale development is regulated by 14 different pieces of EU legislation, as well as a strong existing regulatory regime at national and local level. OGP and its members work within the effective implementation of existing regulations and recognise that this is an important factor in reducing risk for all gas operations.

You can find answers to the most frequently asked questions on hydraulic fracturing at

www.ogp.org.uk/fracturing

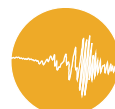
It is an online source of easy-to-understand answers to questions covering hydraulic fracturing and:



CHEMICALS



GREENHOUSE
GASES



SEISMICITY



WATER





...SHALE GAS OPERATIONS

Frequently asked questions about water

This document provides factual information about shale gas operations and water

1

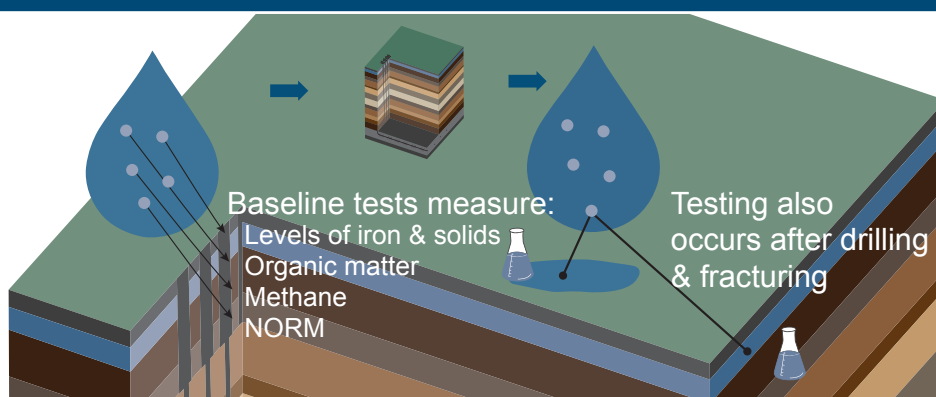
Do you sample groundwater when drilling and hydraulic fracturing a well?

OGP companies believe it is best practice to sample existing groundwater sources in a predetermined vicinity of a new well site both prior to and after drilling and fracturing, as well as during the production phase. Such testing is normally part of an Environmental Impact Assessment and/or part of the drilling permit.

Depending on applicable regulations, local conditions and operator's policies, the testing may include surface water such as rivers, ponds or lakes but also water wells to sample aquifers. Understanding the quality of water is an important component of water source management.

For example, The Polish Geological Institute tested 17 water wells and one creek in the vicinity of the *Lebien LE-2H* well before and after drilling and completion. They found no evidence of any change in surface or ground water quality.

FIGURE 1: GROUNDWATER IS TESTED BEFORE AND AFTER DRILLING AND COMPLETION



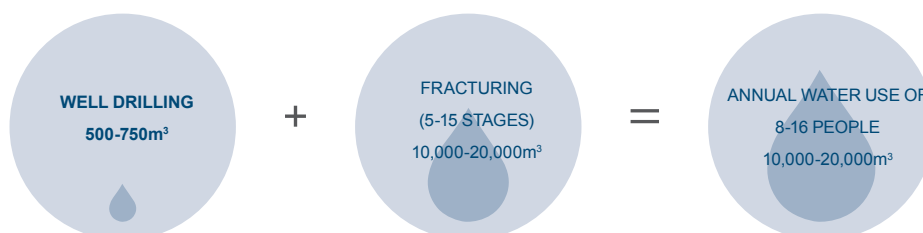
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How much water do you use to drill a well and to hydraulically fracture it?

To drill a vertical exploration well to a depth of about 3500m approximately 500 to 750 m³ of water will be used to formulate the drilling mud. To perform a multi-stage hydraulic fracturing operation one will use an average of 10,000 to 20,000 cubic metres (m³) of water. In Poland, the water used for the *Lebien LE-2H* well totalled approximately 18,000 m³ (to drill the well to a depth of 4,000 metres and perform 13 hydraulic fracture stages over a horizontal distance of 1,000 metres).¹

Note: 20,000m³ represents the annual water usage (direct and indirect) of 8 to 16 people.
http://www.waterwise.org.uk/data/resources/25/Water_factsheet_2012.pdf

FIGURE 2: TYPICAL WATER USE FOR HYDRAULIC FRACTURING OPERATIONS IN EUROPE





...SHALE GAS OPERATIONS

Frequently asked questions about water

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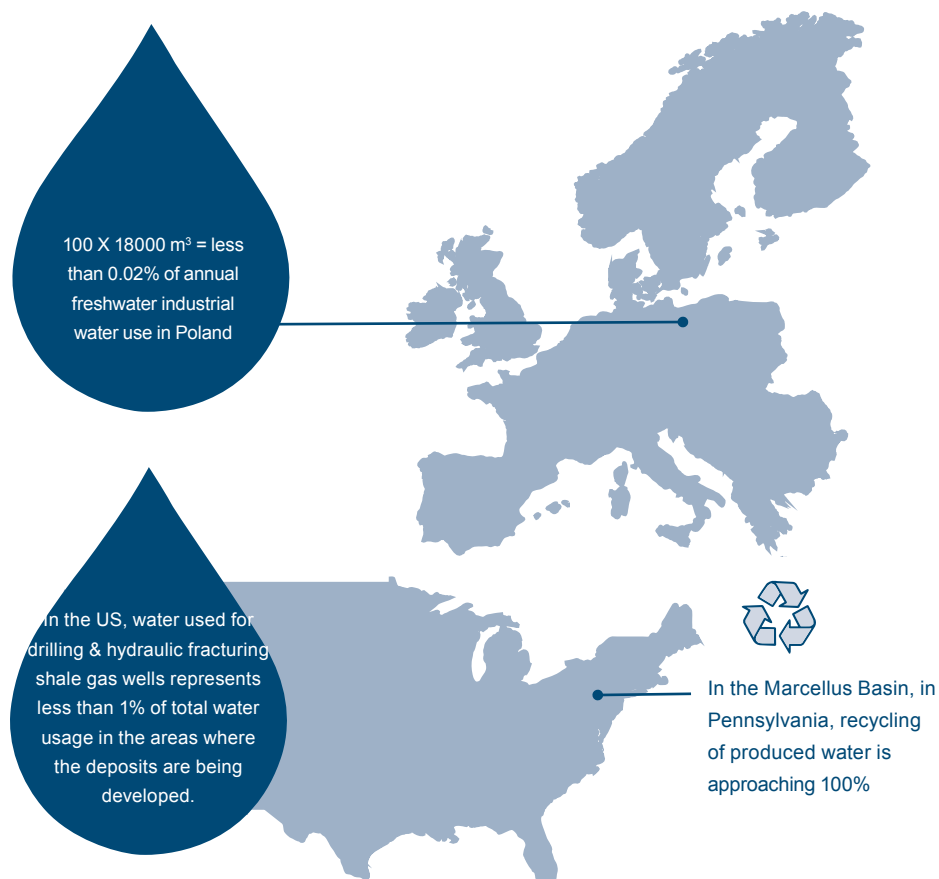
How much water is used to develop a typical shale gas deposit?

According to the Massachusetts Institute of Technology, in the United States, water used for drilling and hydraulic fracturing shale gas wells represents less than one percent of total water usage in the areas where major shale gas deposits are being developed.³

Operations for a typical shale gas basin in early production phase could require drilling about 100 hydraulically fractured wells per year (multi-well drill pads with 10–20 wells). At 18,000 m³ per well (and assuming no water re-use) it would result in annual water use of less than 0.02% of annual industrial water use in Poland⁴.

Water from shale gas operations is commonly re-used. Between 20 and 40% (sometimes up to 70%) of the water injected in the geological formation as part of a hydraulic fracturing treatment is recovered on the surface and stored. Typically the water recovered approximately 2-5 weeks after a hydraulic fracturing treatment is known as **flowback water** (see Section 5). Gas wells will also deliver to the surface water bearing the gas formation. This water is typically non-potable (salty) and is known as **produced water**. The reuse of produced and flowback waters reduces the amount of water needed. In the Marcellus Basin in Pennsylvania, some operators reuse nearly 100% of the flow back/produced water, while in other basins the reuse is less prevalent than in the Marcellus, is generally increasing.

FIGURE 3: EXAMPLES OF WATER USAGE IN SHALE GAS OPERATIONS





...SHALE GAS OPERATIONS

Frequently asked questions about water

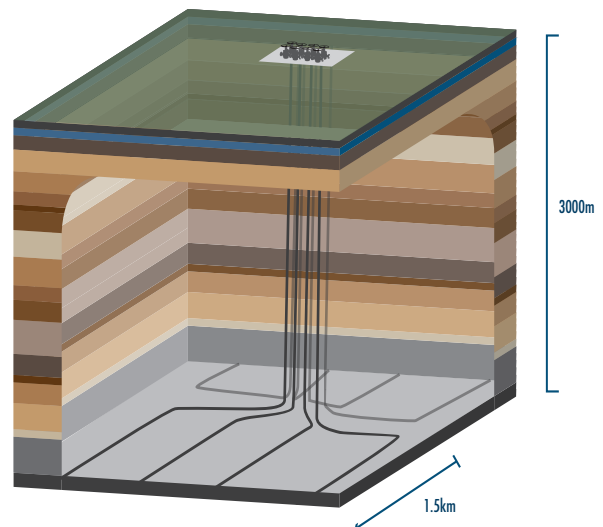
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4

Reducing the surface footprint:

Figure 4 shows a typical example of a multi-well pad development. In this case, 8 horizontal multifractured wells have been drilled from a single pad. This technology reduces the surface footprint while efficiently producing the resource. The hydraulic fracturing process normally lasts 3-5 days and takes place after the eight wells have been drilled, cased and cemented, and the drilling rig has been removed.

FIGURE 4: MULTIPLE HORIZONTAL WELLS FROM SINGLE PAD

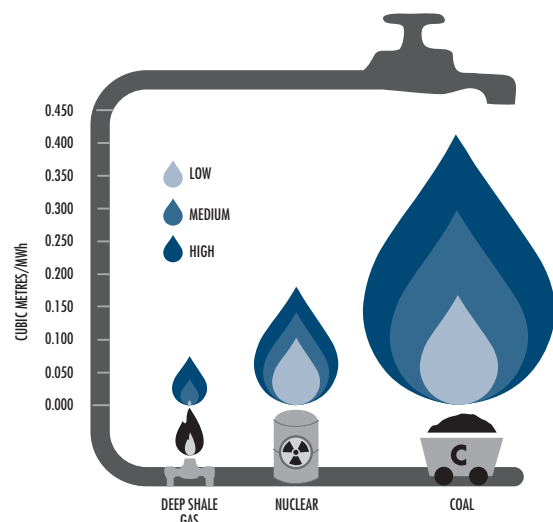


5

Energy water intensity:

The most widely metrics used to quantify the level of water used in shale production, is energy water intensity which compares the volume of water used to produce a fuel to the amount of energy produced (e.g. cubic meters of water per megawatt hour). There is consensus among researchers that the energy water intensity of shale gas is relatively small compared to that of other types of fuels. This has been documented by the Groundwater Protection Council for the US Department of Energy and a comparison of energy water intensity for the production of various sources of energy is shown in Figure 5.⁵

FIGURE 5: ENERGY WATER INTENSITY





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Frequently asked questions about water

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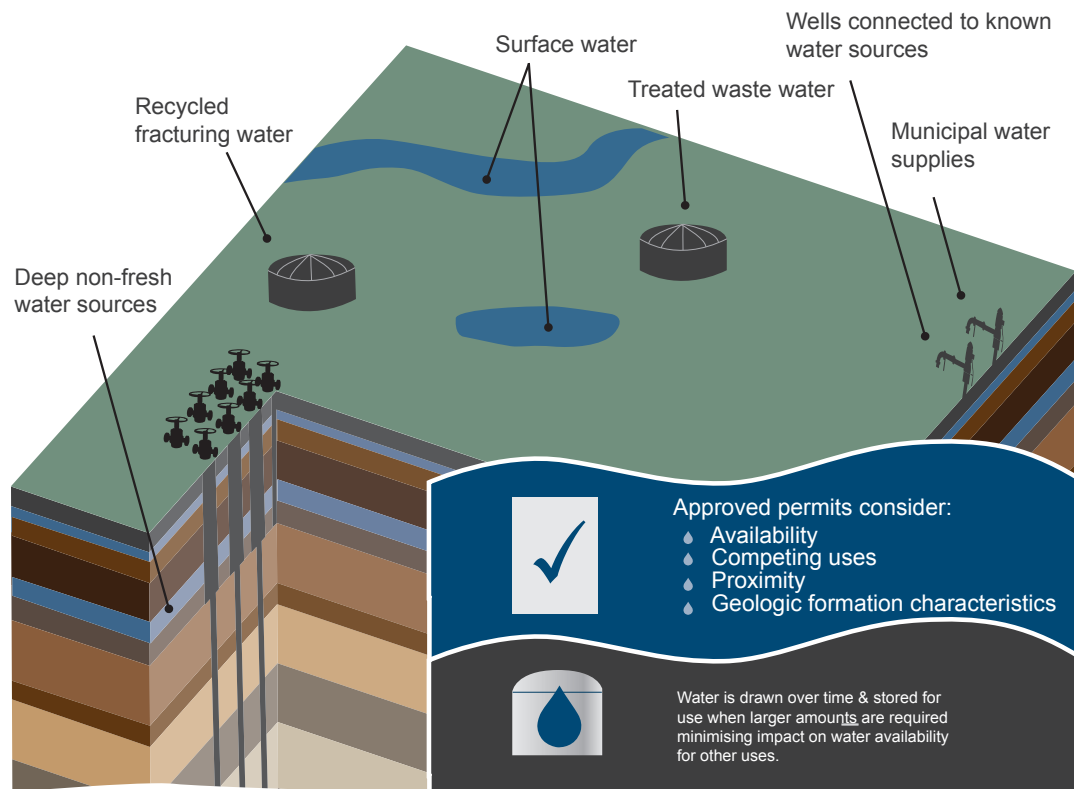
Where do you get the water required to drill a well and hydraulically fracture it?

Before drilling and fracturing a well, operators commission comprehensive studies to evaluate the sustainability of the water supply and to develop a resources management plan. This process includes consideration of volume and water quality requirements, regulatory and physical availability, competing uses, proximity, means of transport and characteristics of the geologic formation to be fractured (including water quality required to fracture it). The range of water sources available can include:

- freshwater water sources produced from water wells specifically drilled
- surface water, such as rivers and lakes
- municipal water supplies
- treated waste water
- deep non-fresh water sources
- recycled water from earlier fracturing operations

FIGURE 6: A WATER SUPPLY EVALUATION IS COMPLETED PRIOR TO DRILLING

The range of water sources might include:





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Frequently asked questions about water

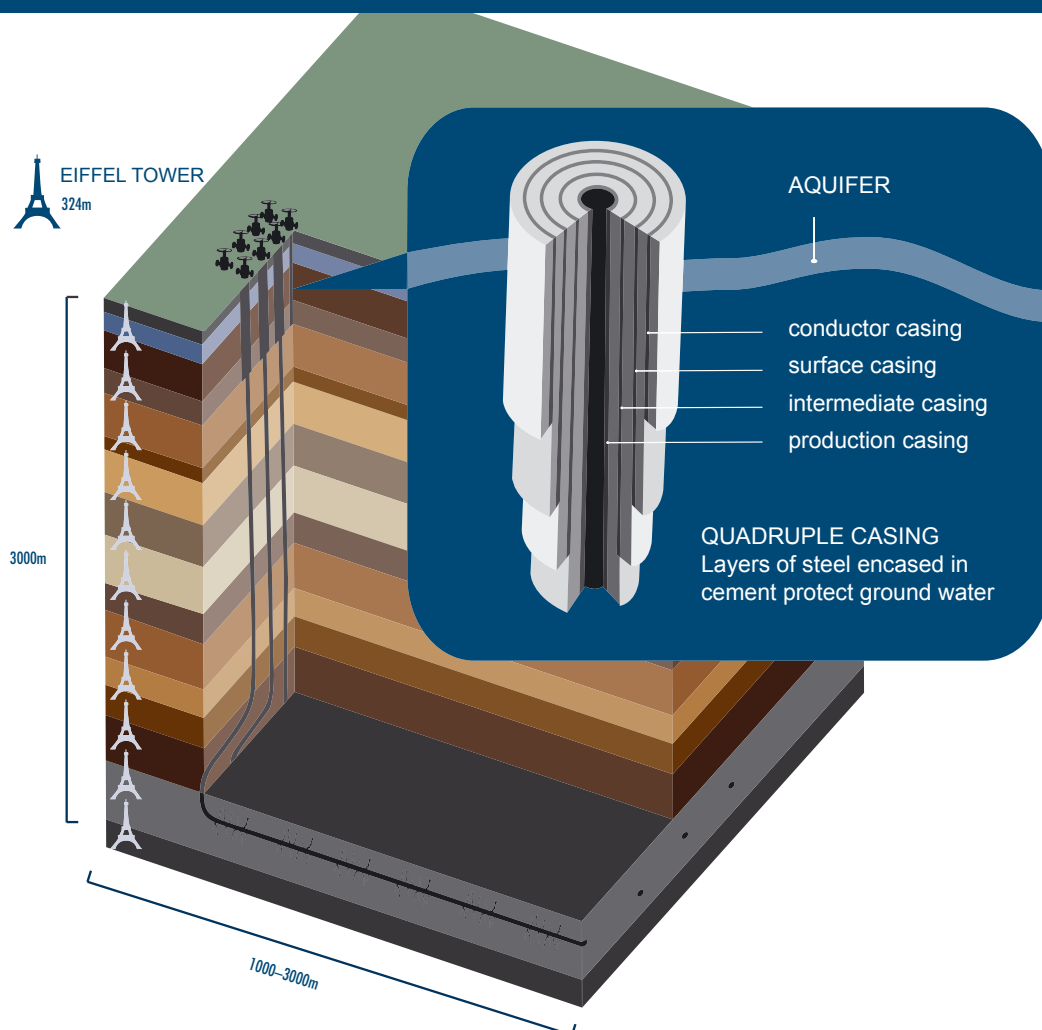
This document provides factual information about shale gas operations and water

OGP supports the on-line disclosure of the chemical additives used in hydraulic fracturing and has developed a website where companies operating in Europe can disclose the chemicals used in their wells: ngsfacts.org Similar initiatives are www.fracfocus.org in the United States or are currently listed on several of our member's web sites.

The fluid injected into the shale formation bearing gas creates fractures that allow the trapped gas to flow to the wellbore. The hydraulic fracturing process only stimulates the geologic formation of interest. The extent of such fractures generates small seismic events. They can be measured by using highly sensitive seismic recorders and allow to map the vertical fracture extension. Typically the fracture zone extends a few tens to a few hundred meters upward from the well bore. According to several thousands of seismic measurements, the probability that any fractures extend vertically upward beyond 1000 feet (350 metres) is nearly nil. This is because layered sedimentary rocks provide natural barriers to the progression of the fracture and prevent any water, gas or chemicals from reaching a shallow water source⁶. Figure 8 (above) shows through a series of micro seismic measurements performed in the United States the extent of the fracture top⁷.

For a typical European shale gas well such results leave a distance of 1 to 3 kilometres between the top fracture and the water source. Figure 9 provides a scale illustration of the distance between the ground water aquifers and the rock formations that are being fractured.

FIGURE 9: WELL CONSTRUCTION AND DISTANCES EXAMPLE





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9

Can drilling fluid affect our drinking water?

Although the well bore penetrates water sources near the surface, it is protected from produced water or hydrocarbons by multiple layers of impermeable cement and steel casing. As shown at the top of Figure 9, integrity of each cemented casing is tested prior to hydraulic fracturing. This type of well design and construction is a standard oilfield technique that prevents hydrocarbons from entering any water source.

10

Is hydraulic fracturing a mature technology?

Hydraulic fracturing has been used in over 1 million wells world-wide since the 1940's⁸ and comprehensive studies have found no historical cases in which hydraulic fracturing has contaminated drinking water⁹. The UK Department of Energy and Climate Change (DECC) concluded early 2012 that "In the light of the robust controls in place to protect the environment and ensure safe operation, DECC see no need for any moratorium on shale gas development". This is also the view of the (UK) Energy and Climate Change Select [parliamentary] Committee, which held an inquiry into shale gas in 2012 and took evidence from government, regulators, the British Geological Survey, the oil and gas industry. The UK Energy and Climate Change Select committee also concluded that hydraulic fracturing does not pose a direct risk to water sources, provided that the well-casing is intact. Any risks that do arise are more likely to be related to the integrity of the well, and are no different to issues encountered when exploring for and producing hydrocarbons from conventional geological formations¹⁰.

11

Can you recover the water used in hydraulic fracturing?

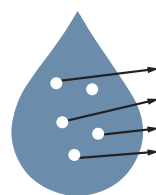
This depends on the geology of the shale formation. During hydraulic fracturing typically 20% to 40% of the water used is recoverable in the first 2-5 weeks of production. This is termed "flowback" water. The flowback water flows to the surface and is separated from the natural gas. This water may contain suspended clay particles, dissolved inorganic components from the shale, inorganic compounds from the hydraulic fracturing fluids and hydrocarbons from the reservoir as well as sand and silt particles from the shale or proppant. Some of the time, producing gas wells will also deliver water to the surface from the gas bearing formation,

FIGURE 10: CAN USED WATER BE RECOVERED?

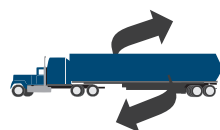
Water flows to the surface & separates from the gas



Water is shipped to processing facility or recycled at surface & re-used



iron & solids
organic matter
methane
NORM





...SHALE GAS OPERATIONS

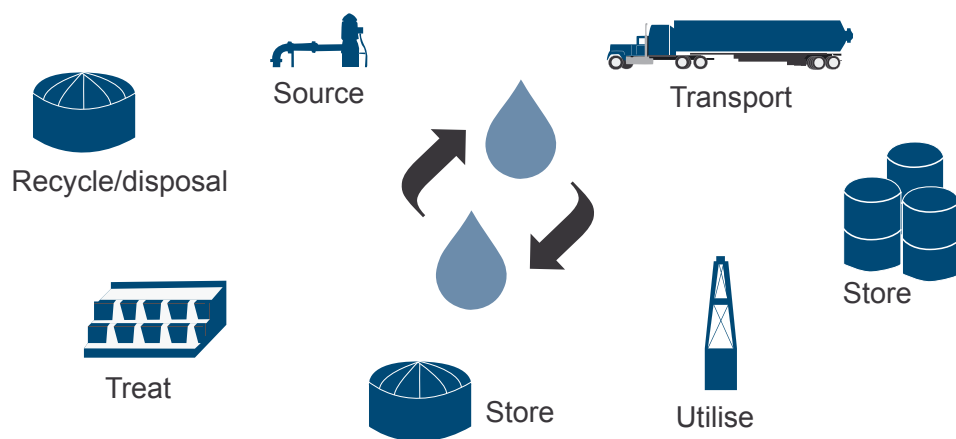
Frequently asked questions about water

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the water is typically non-potable (salty) and is known in the industry as produced water. Appropriate government authorities issue permits for handling and disposal of flowback/produced water. This procedure is consistent with the EU Mining Waste Directive.

The water can then be shipped to licensed water processing facilities or recycled at the surface and re-used for subsequent hydraulic fracturing operations. As a reference, the British Columbia Oil and Gas Commission has estimated that 20% of the water used in hydraulic fracturing for the Horn River Basin, Canada comes from the reuse of flowback water¹¹. Various treatment technologies allow the produced water to be reused for other drilling and hydraulic fracturing operations or other industrial uses.

FIGURE 11: VARIOUS WATER MANAGEMENT STEPS



12

Does the water used in drilling or hydraulic fracturing have radioactive material in it?

Some rocks naturally contain trace levels of minerals that are radioactive. Depending on the regional and sedimentary environment, water used in the exploration and production process (whether in typical sandstone reservoirs or shale) may contain low levels of radioactivity through contact with this naturally occurring radioactive material (or 'NORM'). NORM is also found in the air, soil, water, and in many of our foods at low (normal) background levels.

Any radioactive material exceeding regulatory requirements that would be leached from the subsurface during drilling, hydraulic fracturing or production operations and flown back up the well bore would be contained and disposed of at certified waste treatment/disposal facilities. NORM contained in flowback and produced waters typically presents very low risks. In a recent study of outflow from treatment plants or water used in the Marcellus Basin in Pennsylvania, the test results showed that treated water contained levels of radioactivity lower than normal background levels.¹²



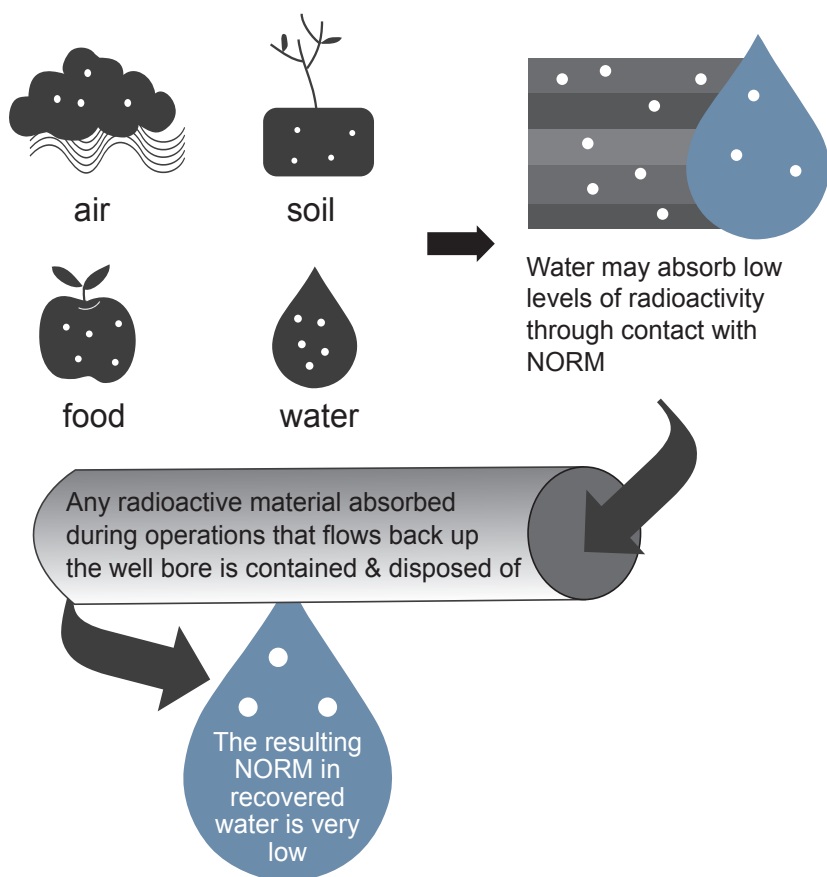
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Frequently asked questions about water

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FIGURE 12: WHAT IS NORM?

Naturally Occurring Radioactive Material is found in:



References

¹ Polish Geological Institute – Environmental impact of hydraulic fracturing treatment performed on the Lebien LE-2H well, 2012

² http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Water_statistics

³ Polish Geological Institute – 2010 figures

⁴ Massachusetts Institute of Technology – The Future of Natural Gas, 2011

⁵ Ground Water Protection Council, for U.S. Department of Energy

⁶ Richard J. Davies et al – Hydraulic Fractures, How far can they go? Durham Institute, Marine and Petroleum Geology, 2012

⁷ Kevin Fisher – "Data Confirm Safety of Well Fracturing," The American Oil & Gas Reporter, July 2010

⁸ SPE – Hydraulic Fracturing, History of an Enduring Technology, 2010

⁹ USDOE and GWPC Study – State Oil and Natural Gas Regulations Designed to Protect Water Resources, 2009

¹⁰ UK Department of Energy and Climate Change – http://www.decc.gov.uk/en/content/cms/meeting_energy/oil_gas/shale_gas/shale_gas.aspx

¹¹ Campbell Matt Horne and Karen Campbell – Shale gas in British Columbia: Risks to B.C.'s water resources, Pembina Institute, September 2011

¹² Pennsylvania Department of Environmental Conservation – <http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=16532&typeid=1>

...SHALE GAS OPERATIONS

Frequently asked questions about chemicals

This document provides factual information about shale gas operations and chemicals

1

Are you prepared to carry out baseline testing of drinking water sources? What is typically included in baseline testing?

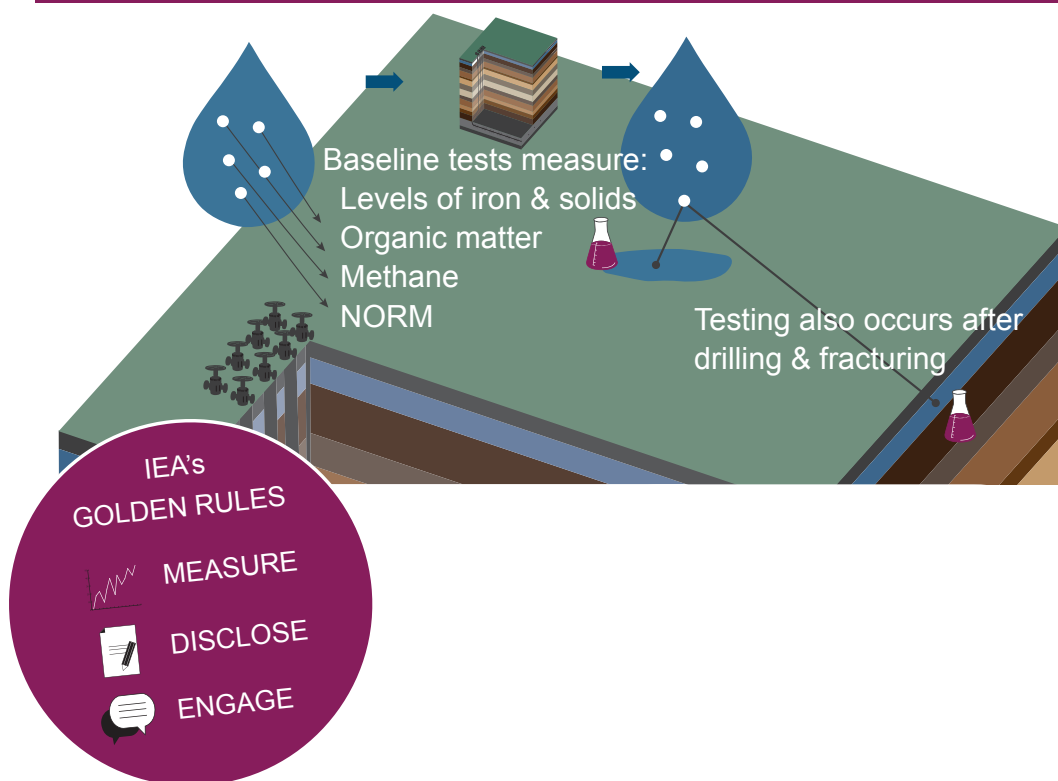
OGP companies believe it is best practice to sample existing groundwater sources in a pre-determined vicinity of a new well site both prior to and after drilling and fracturing. Depending on applicable regulations, local conditions and operator policies, the testing may include water wells and surface water such as rivers, ponds or lakes in the immediate vicinity of the planned well. Such testing is normally part of an Environmental Impact Assessment and/or part of the drilling permit. Baseline testing is also one of the IEA's "Golden Rules for a Golden Age of Gas" (Measure, Disclose, Engage)

Providing authorities with a clear understanding of the chemical status of water sources before and after drilling and completion is an important part of water source management and should be done in line with local laws and regulations. Authorities may then choose to make this information publicly available to local communities.

Baseline tests typically include measuring levels of iron, solids, organic matter, naturally occurring radioactive material (or 'NORM') and methane.

Measuring baseline methane is an important way to differentiate between thermogenic methane originating from an oxygen deficient environment and biogenic methane that can be found in environments such as lakes, ponds and shallow water sources/water wells before development activities even commence.

FIGURE 1: GROUNDWATER IS TESTED BEFORE & AFTER DRILLING AND COMPLETION





...SHALE GAS OPERATIONS

Frequently asked questions about chemicals

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2

Are you prepared to disclose chemicals in fracturing fluids publicly?

Yes, we are committed to keeping people well informed about additives used in their local area. Many OGP members who are active in shale gas exploration in Europe already disclose information via various industry initiatives or on their company websites, even though the number of shale gas fracturing operations in Europe is currently very small.

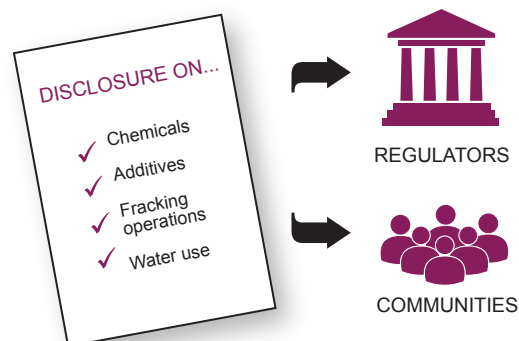
In order to address the need for greater transparency, OGP supports the public disclosure of the additives used in hydraulic fracturing (such as fracfocus.org in the United States or as currently listed on several of our members web sites). The full disclosure of fracturing fluid additives and volumes is one of the IEA's "Golden Rules for a Golden Age of Gas" (Measure, Disclose, Engage).

3

What proportion of the fracturing fluid is made up of chemicals?

All hydraulic fracturing fluids contain a small proportion of additives. These fulfil very specific purposes, such as controlling the physical properties of the fracturing fluids and its interaction with the formation rocks and fluids, controlling rust or reducing bacteria levels and to improve the overall productivity of the well. On average, chemical additives make up only 0.5% of a fracturing fluid. Most of the chemicals are used in everyday life by individuals as food additives, in personal hygiene products or in household cleaners

FIGURE 2: OGP SUPPORTS PUBLIC DISCLOSURE



4

Are you prepared to register your fracturing fluid additives under REACH?

Yes. All additives in fracturing fluids that exceed the one metric tonne threshold and other requirements set by REACH must be registered at ECHA by the manufacturer or importer.

5

Are you prepared to list components by proportion/ by %?

Yes, OGP supports the public online disclosure of the additives used in hydraulic fracturing (such as ngsfacts.org in Europe, fracfocus.org in the United States or as currently listed on several of our members websites), which includes maximum component concentrations.



...SHALE GAS OPERATIONS

Frequently asked questions about chemicals

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6

Are you prepared to disclose specific details of individual fracturing operations?

Yes, OGP supports the public on-line disclosure of the additives used in hydraulic fracturing on-line (such as ngsfacts.org in Europe, fracfocus.org in the United States or as currently listed on several of our members' websites), which includes well-by-well statistics.

7

Are you prepared to disclose water use per well?

Yes, OGP recognises the importance of appropriately managing and conserving water. It is accepted industry practice in the United States to disclose how much water has been put into a well during hydraulic fracturing and OGP supports this practice.

It is also important for operators to record water usage and in some countries, such as Poland, operators must measure and report all water used in order to comply with the terms of permits.

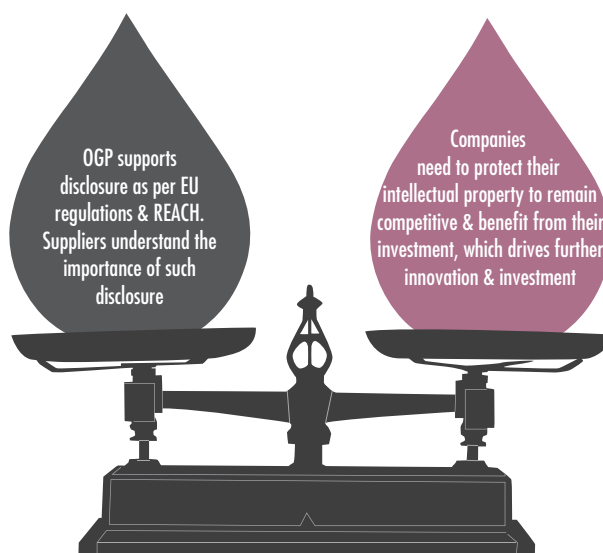
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What is your position with regard to “intellectual property”?

OGP supports the public disclosure of additives used in fracturing operations consistent with the European regulatory structure and REACH processes. Our suppliers are already aware of the importance of public disclosure of additives and are in dialogue with our members about the best way to do this for European audiences.

Geologic and reservoir characteristics such as mineralogy, rock strength, permeability, reservoir fluid composition, pressure, and temperature are just a few of the factors considered in selecting an appropriate fracturing fluid. Service companies have developed a number of different hydraulic fracturing fluid recipes to more efficiently induce and maintain productive fractures. These solutions have unique characteristics and therefore the exact concentrations of some additives are protected as proprietary information. OGP recognises that intellectual property rights

FIGURE 3: STRIKING A BALANCE ON DISCLOSURE



OGP supports disclosure as per EU regulations & REACH. Suppliers understand the importance of such disclosure

Companies need to protect their intellectual property to remain competitive & benefit from their investment, which drives further innovation & investment

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Frequently asked questions about chemicals

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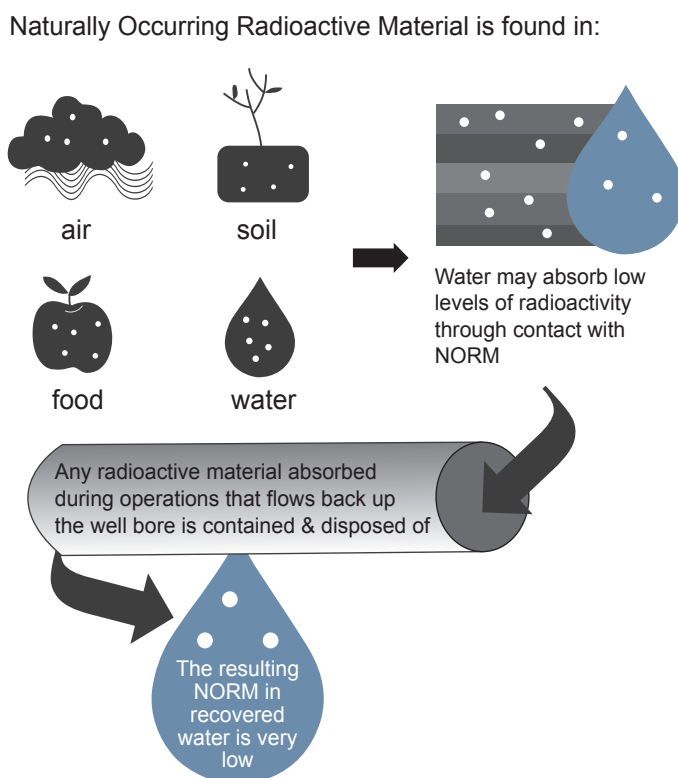
are critical for businesses – these rights enable business to benefit from their investments and remain competitive in the global marketplace. Any disclosure process needs to include protection for the intellectual property represented in some chemical makeups and concentrations in the hydraulic fracturing fluid. We believe fracfocus.org in the United States has managed to provide unprecedented amounts of information on hydraulic fracturing fluids, including even non-hazardous constituents, while protecting vital intellectual property that allows for continued innovation and, hence, improvement.

9

What is NORM?

A NORM is Normally Occurring Radioactive Material that is also found in the air, soil, water, and in many of our foods at normal background levels. Some rocks naturally contain trace levels of minerals that are radioactive. NORM in water used in the exploration and production process typically presents very low risks. A recent Pennsylvania Department of Environmental Conservation study of the outflow from treatment plants for water used in the Marcellus Basin in Pennsylvania showed that treated water contained levels of radioactivity lower than normal background levels. Depending on the regional geological and sedimentary environment, water used in the exploration and production process (whether in typical sandstone reservoirs or shale) may absorb low levels of radioactivity through contact with this naturally occurring radioactive material. Any radioactive material that is absorbed from the subsurface during drilling, hydraulic fracturing or production operations and flows back up the well bore is contained and disposed of at certified waste facilities.

FIGURE 4: WHAT IS NORM?



...SHALE GAS OPERATIONS

Frequently asked questions about seismicity

This document provides factual information about shale gas operations and seismicity

1

Does hydraulic fracturing increase the risk of earthquakes?

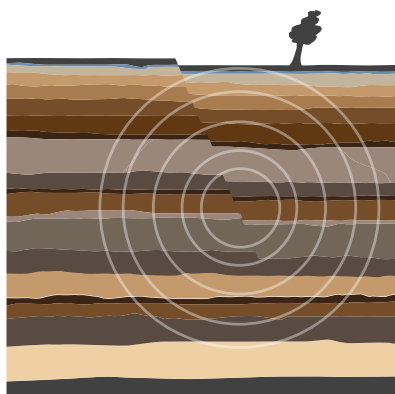
No. A recent study from the Department of Environmental Conservation of New York State reached the conclusion:

"There is a reasonable base of knowledge and experience related to seismicity induced by hydraulic fracturing. Information reviewed in preparing this discussion indicates that there is negligible increased risk to the public, infrastructure, or natural resources from induced seismicity related to hydraulic fracturing. The microseisms created by hydraulic fracturing are too small to be felt, or to cause damage at the ground surface or to nearby well".

2

What are the magnitude and intensity ranges of earthquakes (natural seismicity)?

FIGURE 1: EARTHQUAKE CAUSED BY FAULT SLIP



Earthquakes occur when ruptures or fractures in the earth slip along a plane, such as a fault or joint, releasing energy as seismic waves that can cause shaking and movement of the ground at the surface

Earthquake is a term used to describe the ground shaking and radiated seismic energy caused by sudden slip on a fault, or by volcanic or magmatic activity, or by other sudden release of built up stress in the earth.

The effect of an earthquake can vary from minute tremors not felt at the surface to extreme ground shaking causing very heavy damage. The strength of an earthquake can be expressed in terms of both *magnitude* and *intensity* as described below.

The Magnitude Scale² is related to the amount of seismic energy released at the hypocenter of the earthquake. It is based on the measurement of the amplitude of the earthquake waves recorded on instruments which have a common calibration. The Magnitude Scale is a base10 logarithmic scale obtained by calculating the logarithm of the amplitude of seismic waves measured by a seismograph. For example, a magnitude 4 earthquake generates a seismic wave amplitude 10 times larger (or 31 times more energy release) than a seismic amplitude created by a magnitude 3 earthquake.

The Modified Mercalli Intensity scale² is based on the observed effects of ground shaking on people, buildings, and natural features. It varies from place to place within the disturbed region depending on the location of the observer.

The relationships between the effect of an earthquake and its magnitude and intensity scales are summarized in Table 1.

...SHALE GAS OPERATIONS

Frequently asked questions about seismicity

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TABLE 1: MAGNITUDE AND INTENSITY SCALES – TYPICAL EFFECTS AND FREQUENCY OF EARTHQUAKE²

Perceived Shaking	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
		Vibration similar to the passing of a truck	Felt indoors by many, outdoors by few during the day	Felt by nearly everyone; many awakened	Felt by all				
Potential Damage	None			Very Light	Light	Moderate	Moderate to Heavy	Heavy	Very Heavy
				Some dishes, windows broken	Some instances of fallen plaster and heavy furniture movement	Slight to moderate damage in well-built ordinary structures	Considerable damage in ordinary substantial buildings with partial collapse	Great Damage in substantial buildings with partial collapse. Buildings shifted off foundations	Most masonry and frame structures destroyed with foundations. Rail bent
Modified Mercalli Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+
Richter Magnitude	<2	2 to 2.9	3 to 3.9	4 to 4.9	5 to 5.9		7+		
						6 to 6.9			
Frequency of Worldwide Occurrence	Continual	1,300,000 per year (est.)	130,000 per year (est.)	13,000 per year (est.)	1,319 per year		134 per year	15 per year	1 per year

3

What is induced seismicity?

Induced seismicity is the phenomenon where human activity alters the frequency of occurrence and the magnitude of seismic events from natural levels.

Industrial activities that can induce seismicity include:

- Construction (e.g., impounding water behind a dam, tunneling, pile driving)
- Mining activity (e.g., quarrying, coal mining)
- Industrial presses
- Heavy vehicle movements (e.g., vibrating rollers)
- Underground injections for fluid disposal
- Oil and gas operations
- Geothermal energy production

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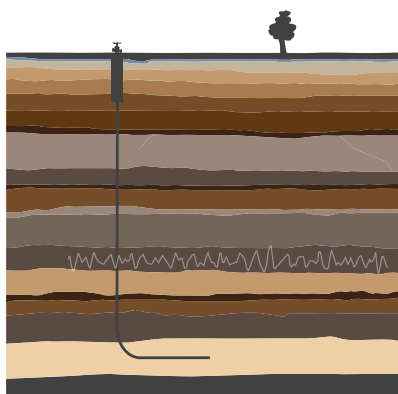
Frequently asked questions about seismicity

This document provides factual information about shale gas operations and seismicity

4

What is hydraulic fracturing?

FIGURE 3: HYDRAULIC FRACTURING



Hydraulic fracturing releases energy deep underground, creating low levels of seismic activity that generally cannot be felt at the surface

In shale gas operations, hydraulic fracturing is a part of well completion process and involves injecting a fluid into a formation at a pressure sufficient to generate a crack or fracture. Shale gas is produced by drilling horizontally and hydraulically fracturing a target shale formation, typically one to three kilometers beneath the surface. Hydraulic fracturing operations involve many injection stages with each stage lasting a few hours and the total operation may last up to 5 days per well. This completion process results in injection of water, proppant (sand) and a small concentration of chemical additives into the shale under controlled pressures to create fractures, enhancing the formation surface area exposed thus improving the natural gas and liquids flow to the surface.

5

What are the risks of induced seismicity from hydraulic fracturing?

Hydraulic fracturing releases energy deep underground, creating extremely low levels of seismic activity typically below minus 0.8 (-0.8) on the Richter scale that generally cannot be felt at the surface. The energy release by this extremely low level of seismicity is less than 0.01% of an earthquake of magnitude 2. Moreover, it is a temporary process, generally lasting only a few hours.

Over one million wells have been hydraulically fractured worldwide. Until the end of 2013, there are only three known cases —Bowland shale near Blackpool (UK), Horn River in British Columbia (Canada), and Eola in Oklahoma (USA), where hydraulic fracturing could be linked to the occurrence of seismic events with magnitude between 2 to 3.8 (at most equivalent to vibration of a passing truck—see Table 1). In these rare cases, a number of risk factors coincided, including the potential for re-activation of existing faults.

In addition, a study by the Nation Research Council of the National Academies (USA) made the following findings on hydraulic fracturing and induced seismicity: *“The process of hydraulic fracturing a well as presently implemented for shale gas recovery does not pose a high risk for inducing felt seismic events”*³. Other recent governmental or academic studies lead to similar conclusions ^{4,5,6,7}.

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Frequently asked questions about seismicity

This document provides factual information about shale gas operations and seismicity

6

What happened in the Blackpool area of the UK in 2011?

In the UK, hydraulic fracturing was suspended at Cuadrilla Resources' Preese Hall exploratory site after a magnitude 1.5 event on 27 May 2011 in the Blackpool area and in light of a preceding magnitude 2.3 event on 1 April 2011^{5, 8, 9}.

At that time the British Geological Survey (2011) commented: "We understand that fluid injection, between depths of two to three kilometres, was ongoing at the Preese Hall site shortly before both earthquakes occurred. The timing of the two events in conjunction with the fluid injection suggests they may be related. It is well-established that fluid injection can induce small earthquakes. Typically, these are too small to be felt."

In a recent report, the UK Department of Energy and Climate Change (DECC) recognises the low level of risk of induced seismicity below 3 on the Richter scale. Such events are "unlikely to cause structural damage" and therefore the DECC could "see no reason why Cuadrilla Resources Ltd. should not be allowed to proceed with their shale gas exploration activities. DECC went on to recommend cautious continuation of hydraulic fracture operations, at the Preese Hall site."¹⁰ In December 2012, the UK government announced its decision to allow hydraulic fracturing to resume.

7

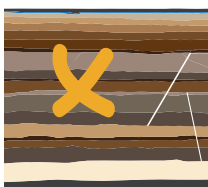
What measures are taken to further reduce the potential risk of induced seismicity from HF in active tectonic areas?

Sound pre-planning and surveying are measures that should be taken into account by operators and reviewed by the regulator^{10, 11}. We support the inclusion of best practice in developing guidelines appropriate for local conditions, which would enable exploration and production while addressing public concerns. OGP is happy to offer assistance to the development of these guidelines.

FIGURE 3: SOUND PRE-PLANNING & SURVEYING CAN MITIGATE RISK IN AREAS PRONE TO SEISMICITY



Geological risk assessments should be conducted prior to drilling fluid disposal wells



Faults with large, pre-existing stress in brittle rock formations should be avoided



Proper limits on flow rate should be set



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Frequently asked questions about seismicity

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8

Is it likely that seismic activity would damage well integrity and lead to leakage?

A study by the Department of Environmental Conservation of the New York State considers it very unlikely, based on the existing track record of earthquakes in oil and gas producing areas of the United States¹². In addition, the National Resource Council released a 225-page report on induced seismicity in June 2012 that reinforces this position¹³.

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See also: US Geological Survey Website
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- ⁴ Worldwatch Institute, Natural Gas and Sustainable Development Initiative — Addressing the Environmental Risks from Shale Gas Development — Mark Zoback, Saya Kitasei and Bradford Copithorne, (July 2010)
- ⁵ A report by researchers at the Tyndall Centre University of Manchester — Shale gas: an updated assessment of environmental and climate change impacts, (January 2012)
- ⁶ New York State Department of Environmental Conservation Division of Mineral Resources — Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program (2011)
- ⁷ *Both carbon sequestration and liquid waste injection can induce seismic activity. Induced seismic events caused by deep well fluid injection are typically less than a magnitude 3.0 and are too small to be felt or to cause damage. Rarely, fluid injection induces seismic events with moderate magnitudes, between 3.5 and 5.5, that can be felt and may cause damage. Most of these events have been investigated in detail and have been shown to be connected to circumstances that can be avoided through proper site selection (avoiding fault zones) and injection design* (Foxall and Friedmann, 2008). Department of Environmental Conservation, New York State - Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program (September 2011)
- ⁸ Preese Hall shale gas fracturing — Review & recommendations for induced seismic mitigation (April 2012)
- ⁹ Shale gas extraction in the UK: a review of hydraulic fracturing, Royal Society and Royal Academy of Engineering (June 2012)
- ¹⁰ Preese Hall shale gas fracturing — Review & recommendations for induced seismic mitigation (April 2012)
- ¹¹ US department of Energy — Protocol for Addressing Induced seismicity Associated with Enhanced Geothermal Systems, DOE/EE-0662, (January 2012)
- ¹² *Wells are designed to withstand deformation from seismic activity. The steel casings used in modern wells are flexible and are designed to deform to prevent rupture. The casings can withstand distortions much larger than those caused by earthquakes, except for those very close to an earthquake epicenter. The magnitude 6.8 earthquake event in 1983 that occurred in Coalinga, California, damaged only 14 of the 1,725 nearby active oilfield wells, and the energy released by this event was thousands of times greater than the microseismic events resulting from hydraulic fracturing. Earthquake-damaged wells can often be re-completed. Wells that cannot be repaired are plugged and abandoned* (Foxall and Friedmann, 2008). *Induced seismicity from hydraulic fracturing is of such small magnitude that it is not expected to have any effect on wellbore integrity.* Department of Environmental Conservation, New York State — Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program 6-326, (September 2011)
- ¹³ National Research Council - Induced Seismicity Potential in Energy Technologies (2012)



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Frequently asked questions about Green House Gases

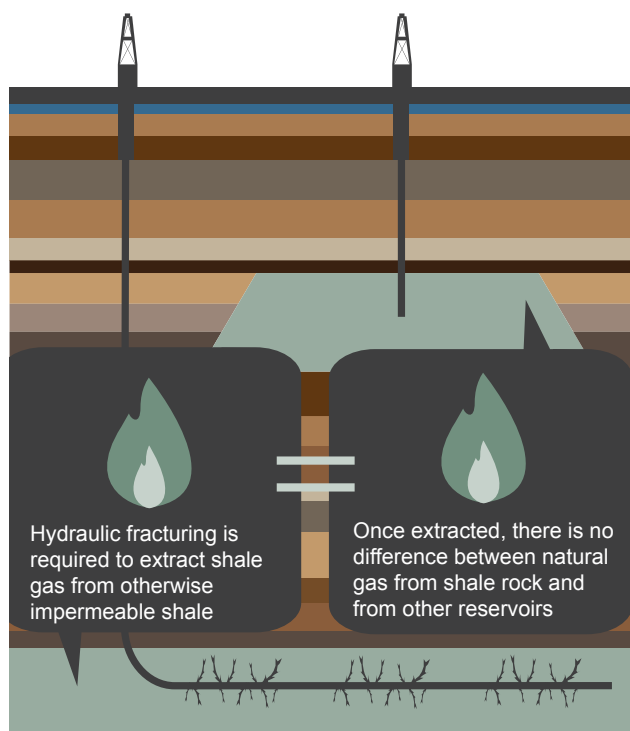
This document provides factual information about shale gas operations and GHG

1

What is shale gas and what is the difference between natural gas from shale and from other reservoirs?

Shale gas is natural gas produced from sedimentary shale rock composed of organically rich mud and clay. There is no difference in the natural gas produced from shale reservoirs and conventional sources, such as sandstone, siltstones, limestone or dolomite reservoirs. Natural gas is essentially a combustible mixture of hydrocarbon gases predominantly consisting of methane (CH₄).

FIGURE 1: SHALE GAS IS NATURAL GAS



Shale rock formations are found miles below the earth's surface. Generally, the rock qualities for fluid storage and flow capacity decrease as depth increases due to the pressures exerted by the earth's weight. At great depths, there may not be sufficient permeability to allow hydrocarbons to flow from the targeted formation into the wellbore. Hydraulic fracturing operations are essential to increase the interconnectivity (permeability) between pore spaces in the formation in order to allow the hydrocarbons to be exploited. Extraction of these resources on a commercially viable basis has been made possible by the combination of two conventional techniques called 'horizontal drilling' and 'hydraulic fracturing'. Without hydraulic fracturing, the shale rock is simply too impermeable and valuable gas would remain locked underground.

2

How does the Greenhouse Gas (GHG) footprint of shale gas compare to that of conventional gas?

The Green House Gas (GHG) footprint of shale is comparable to that of natural gas produced from other types of reservoirs.

Several studies have emerged in the past four years to estimate life-cycle emissions associated with natural gas production, including shale gas. Given the early history of shale gas production and assumptions involved in their estimates, results of these studies may vary and uncertainties in the GHG estimates are recognized by these studies.

A study carried out by Prof William Griffith et al. of Carnegie Mellon University concludes that the lifecycle footprint of shale gas from the Marcellus formation is only 3% higher than that of average conventional gas in the United States¹. The U.S. Argonne National Laboratory² estimated that shale



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gas life cycle emissions are of the same magnitude as those of conventional natural gas¹. Two recent independent studies by the EPA and The University of Texas arrived at similar conclusions in that the overall total emission from gas produced from shale and conventional reservoirs are comparable. The University of Texas study, led by Dr. Allen, found that 2011 methane emissions from shale were 0.42% of natural gas produced in the US. In comparison, the 2011 national emission inventory, reported by the EPA in 2013, estimates methane leakage at 0.47% of total US natural gas production^{3,4}.

From these studies, it is clear that estimating and comparing the life-cycle GHG emissions from natural gas production by conventional reservoirs and shale formations is a challenge due to a lack of reliable data on emission rates for some of the phases and activities involved in shale gas production. In general, the life-cycle of natural gas involves a number of phases, with varying amounts of GHG emissions through each phase, as outlined below:

- **Exploration.** The same geophysical and geological methods are used to explore for shale gas and conventional gas.
- **Drilling and Completions.** The only area where emissions from shale gas may differ from gas produced from sandstone reservoirs is in the extraction process after drilling has been completed. The difference in GHG emissions is only marginal due to the use of more energy-intensive equipment to process produced gas into pipeline quality natural gas.

In addition, emissions of methane may occur following hydraulic fracturing and during well completion. Some methane discharge can occur during the “flowback” step when the formation fluids return to the surface with the hydraulic fracturing fluids (primarily water), immediately prior to the well being routed to a gas/liquid separator, especially if using open disposal pits.

An industry practice known as reduced environmental completions (REC), or green completions, can be used to limit GHG emissions from flowback activities. RECs involve routing gas during flowback from the gas/liquid separator to a gas gathering line. If a gas gathering line is not available flowback gas can be routed to a flare to reduce GHG emissions. However, GHG emissions can also occur from flaring prior to being pipeline ready.

- **Production, gathering and processing.** There is no difference between the production, gathering and processing of natural gas from different reservoirs.
- **Transportation and Distribution.** There is no difference between the transportation of natural gas from different reservoirs. Emissions in this phase are dependent upon the mode of transportation (truck, pipeline or LNG), the distance to the consuming market, and the complexity of gas distribution. On average, transport-related emissions would be lower within Europe than in Russia and most parts of the US, due to the proximity of these resources to consumers⁵.
- **Combustion.** Over three quarters of the life-cycle emissions of natural gas are generated during the combustion by the end-user. There are no additional emissions in the combustion of shale gas compared to those of natural gas from other types of reservoirs.

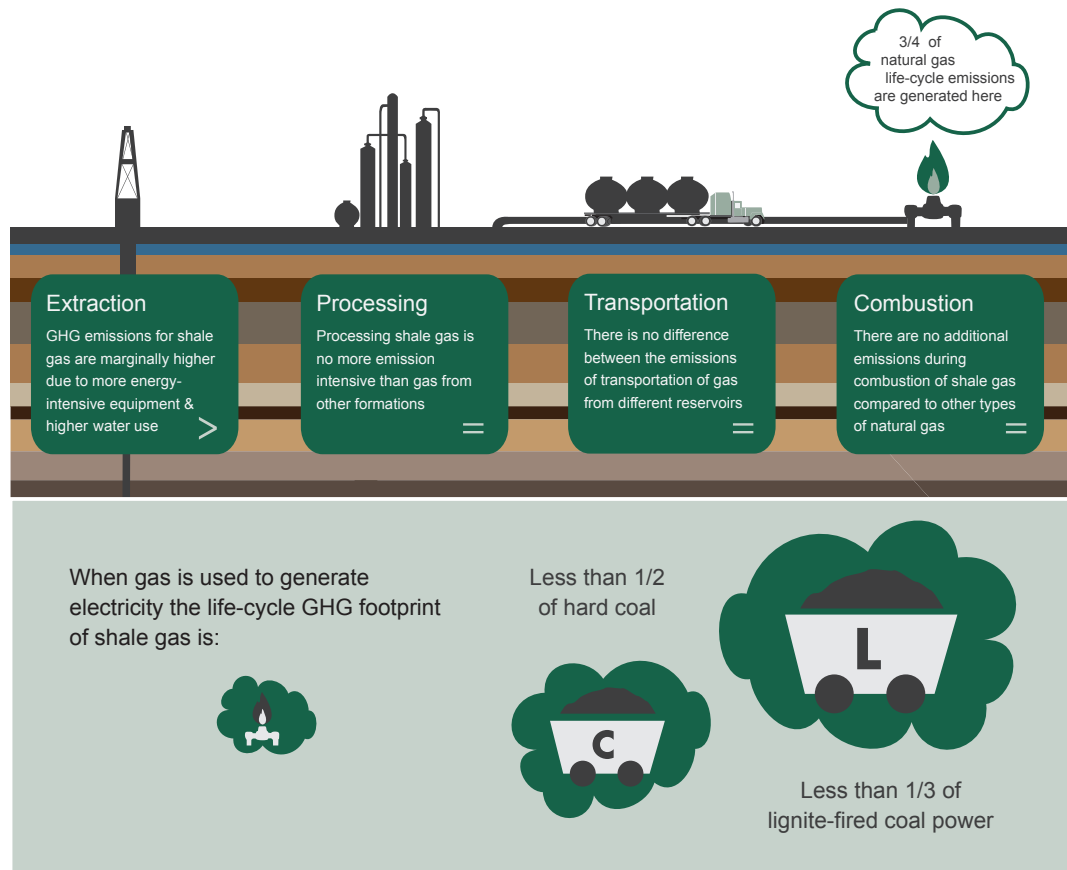


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FIGURE 2: SHALE GAS GHG FOOTPRINT IS COMPARABLE TO GAS FROM OTHER RESERVOIRS



3

Is the emissions footprint of shale gas less than other energy sources, and can it be further reduced?

Yes. The life-cycle GHG footprint of shale gas is less than half that of hard coal and less than a third of lignite-fired coal power Industry⁶. Tighter pollution controls and technologies instituted by the industry have already reduced the emissions of methane (CH₄) and carbon dioxide (CO₂) from natural gas production. The gas industry is committed to further reduce emission from the life-cycle of shale gas in the future^{7,8}.

Preference for natural gas as energy source instead of coal or biomass also has an important positive effect on today's air quality. Burning gas emits very low emissions of nitrogen oxides and sulfur dioxide – reducing acid rain and smog – and virtually no emissions of mercury or particulates (PM2.5 or fine dust). Compared to coal, shale gas results in a 400-fold reduction of PM2.5, a 4,000-fold reduction in sulphur dioxide, a 70-fold reduction in nitrous oxides (NO_x), and more than a 30-fold reduction in mercury^{9, 10}.



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The 2013-published EU (UK)-centered study¹¹ provides few quotable comparative emission estimates, including:

“The carbon footprint (emissions intensity) of shale gas extraction and use is likely to be in the range 200 – 253 g CO₂e per kWh of chemical energy, which makes shale gas’s overall carbon footprint comparable to gas extracted from conventional sources (199 – 207 g CO₂e/kWh(th)), and lower than the carbon footprint of Liquefied Natural Gas (233 - 270g CO₂e/kWh(th)). When shale gas is used for electricity generation, its carbon footprint is likely to be in the range 423 – 535 g CO₂e/kWh(e), which is significantly lower than the carbon footprint of coal, 837 – 1130 g CO₂e/kWh(e).”

Further improvements are expected to cut emissions from the drilling and production phases by utilising additional or more efficient equipment and practices to prevent or capture CH₄ emissions. Implementation of rigorous preventative maintenance programs also helps reduce emissions.

- **Use of efficient equipment.** The use of natural gas or electricity instead of diesel to power engines and equipment at the well-site is a potential source of emission reductions. Similarly, the use of pipelines instead of trucks for the transport of water to and from the well-site can, under certain conditions, further reduce the life-cycle carbon footprint of shale gas.
- **Reduced Emission Completion (REC) well technologies.** The water returned from the hydraulic fracturing treatment may contain high concentrations of methane, some of which may be flared or vented at the well-site. Reduced Emission Completion (REC) technologies — also known as green completions — are techniques that separate and capture methane emitted during well completions and flowback. This technique uses a system of piping, separators and sometimes dehydration equipment to capture the gas during a completion, clean it and send it to the sales line instead of flaring or venting it. This technology requires that a pipeline be laid up to the well-pad and is now applied to many new gas wells in the United States. This technique uses a system of piping, separators and sometimes dehydration equipment to capture the gas during a completion, clean it and send it to the sales line instead of flaring or venting it. This technology is now used in the majority of new wells in the United States.

Use of REC depends on the characteristics of the basin and the area it is located, but with advanced and proper planning of field development, including gas pipeline construction and installation and coordination with drilling, the industry is striving to reduce emissions.

- **Monitoring.** Responsible monitoring of all phases of operations allows for timely identification of leaks and fast response mechanisms to reduce emissions.
- **Carbon capture and storage.** Carbon capture and storage technologies have the potential to reduce life-cycle emissions from natural gas to very low levels. These technologies are not cost-effective at present, but a number of pilot projects are on-going and the technology is expected to be commercially viable after 2030 if a favourable regulatory, commercial and political framework is in place.

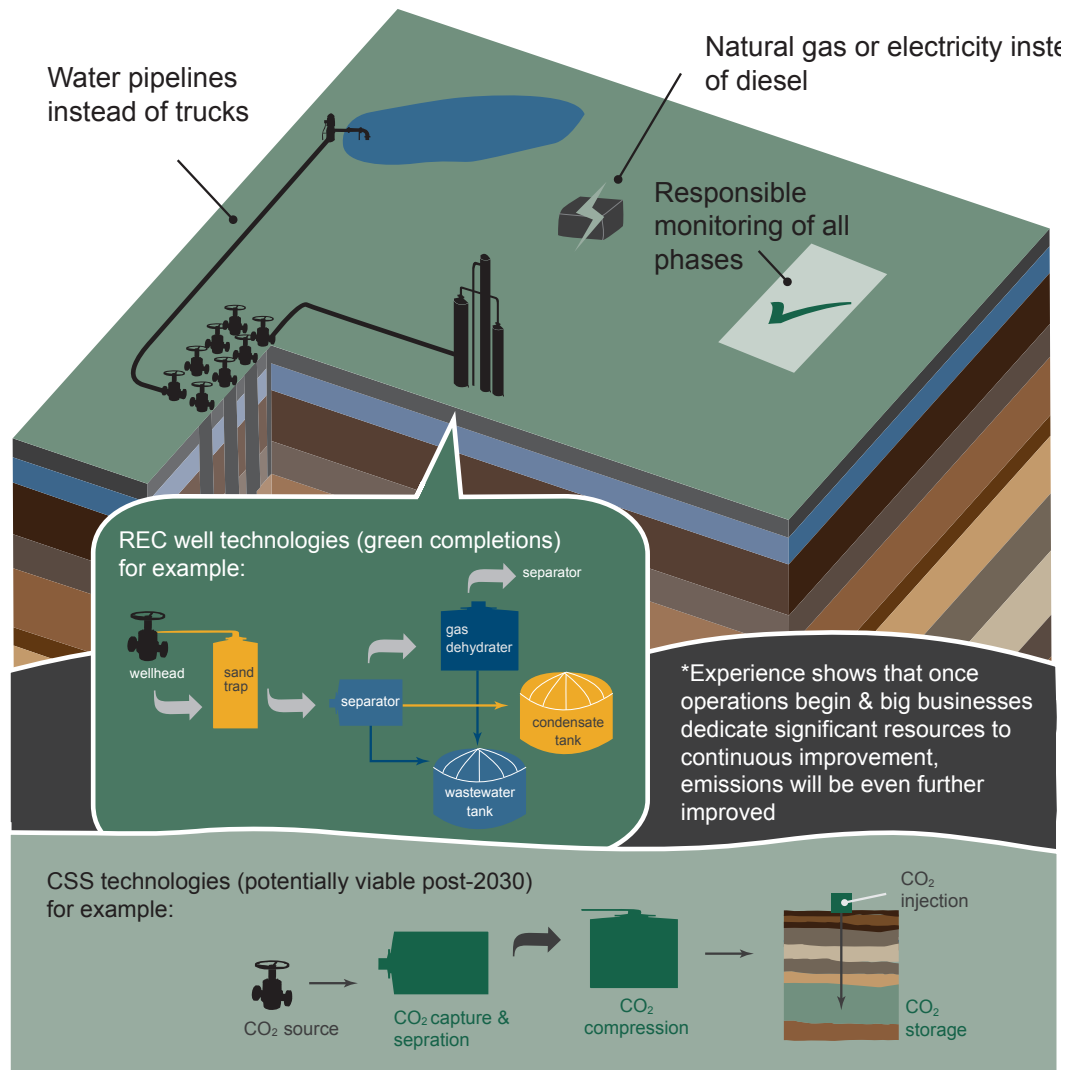


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FIGURE 3: FURTHER REDUCING THE SHALE GAS GHG FOOTPRINT*



4

How can burning shale gas help regulators efforts to reduce emissions?

On a well-to-wires basis, natural gas power plants emit around half the CO₂ of coal power plants. The relative emission rates depend on the type of gas plant and the type of coal plant being compared. Natural gas, including shale gas, is a critical fuel for many countries to further reduce national emissions of greenhouse gases¹² (as recognised for example in the EU Energy Roadmap 2050¹⁴).



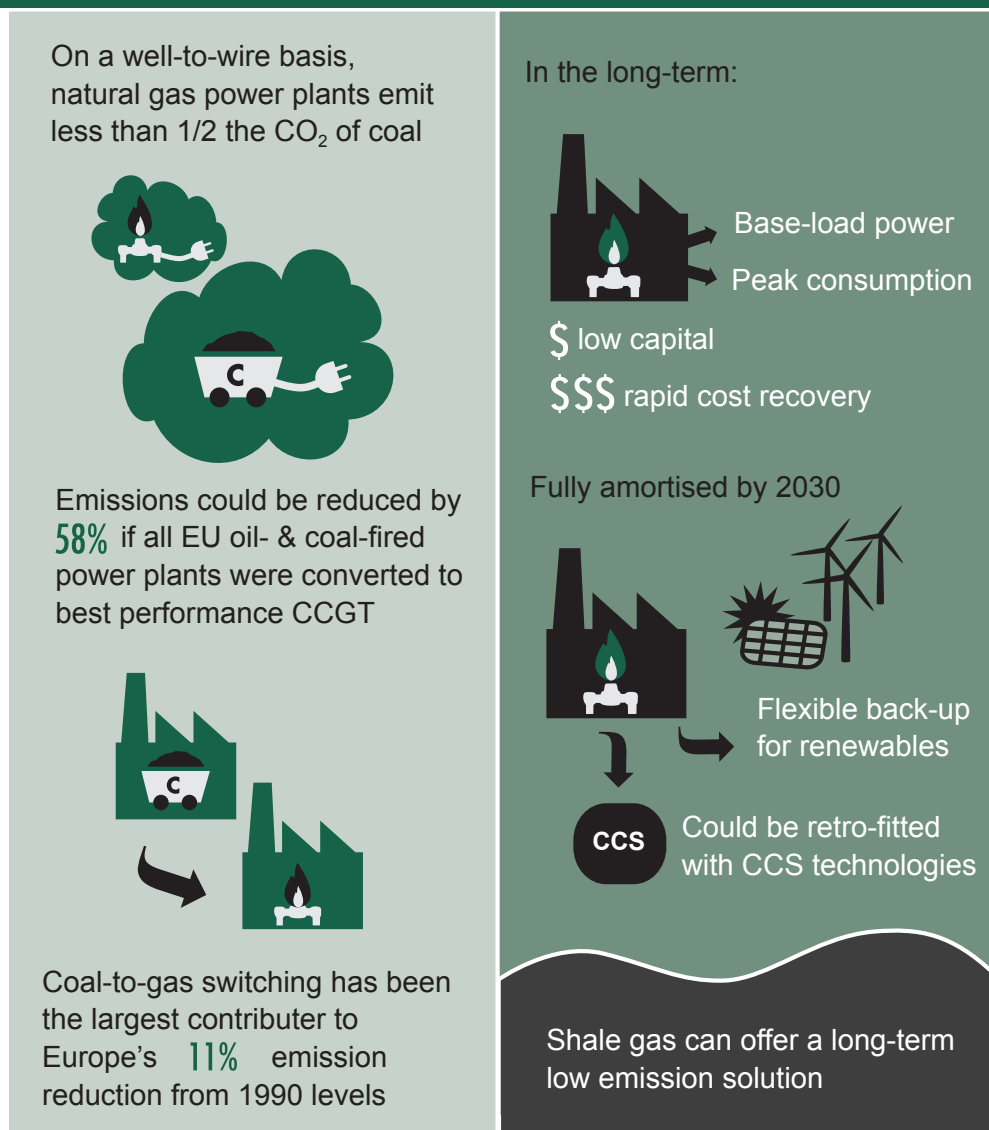
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Coal-to-gas switching has been the largest contributor to the United States' ¹³ and Europe's GHG emission reductions in the last several years. Europe achieved emission reductions of 11% reductions from 1990 levels due to fuel-switching. IHS-CERA calculated that emission reductions of up to 58% could be achieved if all EU oil- and coal-fired power plants were converted simultaneously to best performance combined cycle gas turbines (CCGT). In the long-term, investment in natural gas, including shale gas, will not drive investment away from renewable sources. Gas-fired power plants can serve both for base-load power generation and peak consumption and are characterised by relatively low capital requirements and rapid cost recovery. After 2030, European gas-fired power plants should be fully amortised and could serve as a flexible back-up for variable renewables such as wind and solar or be retrofitted with Carbon Capture and Storage (CCS) technologies, offering a long-term low-emission solution.

FIGURE 4: GAS FROM SHALE CAN HELP THE EU REDUCE ITS EMISSIONS





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5

Is the current European regulatory framework relating to high emission standards adequate?

Yes. Natural gas developments in Europe are tightly regulated activities. The current European regulatory framework already covers emissions resulting from the extraction, processing, transportation and combustion of shale gas with the EU Emission Trading Scheme (ETS), the Industrial Emissions Directive and various emission performance standards.

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ABOUT OGP

OGP represents the upstream oil & gas industry before international organisations including the International Maritime Organization, the United Nations Environment Programme (UNEP), Regional Seas Conventions and other groups under the UN umbrella. At the regional level, OGP is the industry representative to the European Commission and Parliament and the OSPAR Commission for the North East Atlantic. Equally important is OGP's role in promulgating best practices, particularly in the areas of health, safety, the environment and social responsibility.

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