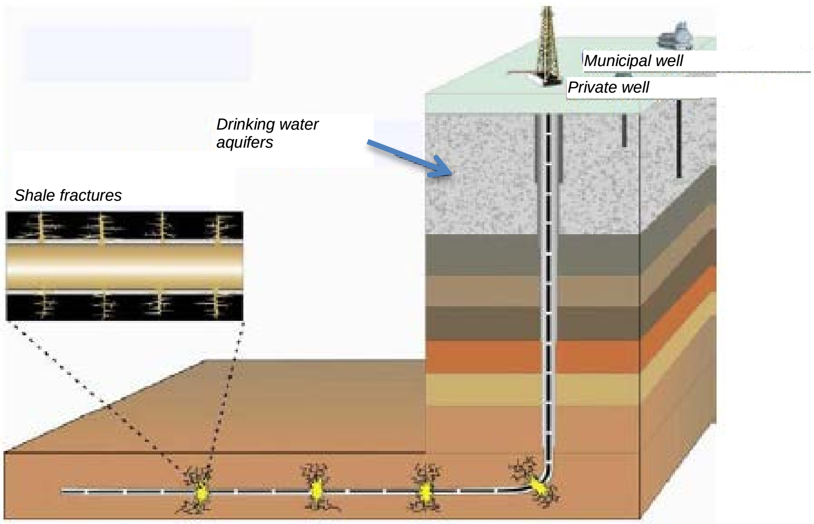
Factsheet / April 2013

Shale gas – Information on hydraulic fracturing ("fracking")

Shale gas is natural gas – mainly methane – trapped within the micropores of shale formations or adsorbed onto the shale (sedimentary rock). In Europe, known deposits exist in the UK, France, the Netherlands, Germany, Poland, the Baltic States and Scandinavia. In Switzerland, deposits are suspected to lie in the Permo-Carboniferous trough of Northeastern Switzerland, below Lake Geneva, and in Lower and Middle Jurassic strata, e.g. in Canton Fribourg. In view of the depletion of conventional energy resources and as a result of advances in drilling technology, the exploitation of shale gas reserves – long considered unviable – now appears to be economically attractive. In Switzerland and in Southern Germany, debates have been prompted by the awarding of concessions north of Lake Constance and the suspension of drilling licences in Canton Fribourg. This factsheet is intended to provide an overview of the current state of scientific knowledge in this area.

Principle and methods

The rock strata in which shale gas is trapped are almost impermeable to gas flow. It is therefore necessary not only to drill into, but also to fracture the rock under pressure ("fracking") so as to open the tiny pores where the gas is held. First, a vertical borehole is sunk to a depth of 1–3 km. Around 150 m above the target formation, horizontal drilling begins, with the shaft typically extending over a distance of 600 m to 1.2 km [1, 2]. During drilling, the borehole is lined, usually with steel pipes cemented into place, to form a casing. Finally, the wellhead is installed. The shale gas is then extracted by injecting fracturing fluids under high pressure (345–690 bar [1], but also up to 1000 bar [2]). These fluids generally consist of 98% water and sand, with various chemical additives (e.g. acids) making up the other 2% [1]. The function of the sand is to prop open the fractures created in the rock, allowing the shale gas to be released. Chemical additives are used, for example, to facilitate penetration of the sand into the fractures, to prevent the growth of bacteria (producing gases which could contaminate the shale gas), or to inhibit corrosion of the steel tubing.



Principle of shale gas extraction (source: EPA 2010).

The fracturing operation is usually carried out in a number of stages. Starting at the far end of the horizontal shaft, the casing is perforated and fracturing fluids are pumped at high pressure into the rock. The fractures generated may be 100 m long and some tens of metres high [2]. This process is repeated 8 to 13 times until the shale gas has been fully recovered along the length of the horizontal shaft. In the wellhead, the shale gas is separated from the flowback fluid, which is then removed for off-site treatment/disposal or stored in surface ponds.

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Eawag: Swiss Federal Institute of Aquatic Science and Technology

Potential environmental impacts

Induced seismicity

Earthquakes may sometimes occur in association with shale gas drilling operations. It is to be assumed that the hydrogeological effects of artificial extension fractures are similar to those of shear fractures induced by pressure and/or acid in geothermal drilling. In the Blackpool area (UK), two earthquakes were recorded by the British Geological Survey (magnitudes 1.5 and 2.3 on the Richter scale) [1]; an independent report [3] concluded that it was highly probable that these events were triggered by hydraulic fracturing and also estimated that an event with a maximum magnitude of 3 would be possible in a worst-case scenario. This would be comparable to the geothermal earthquake recorded in Basel on 8 December 2006 (maximum magnitude 3.4). Here, however, drilling was carried out in a zone already subject to subsurface stresses. In principle, the creation of artificial fractures in geothermal drilling must also be expected to produce extension and shear fractures, leading to seismicity of the same type and magnitude as is associated with hydraulic fracturing for shale gas extraction. But the tremors induced – though numerous – will generally be much smaller. In addition, drilling for deep geothermal energy is usually conducted at a greater depth than drilling for shale gas reserves. The effects of fractures therefore tend to be less marked at the Earth's surface. Finally, in the case of geothermal drilling, it appears to be possible to do without additives altogether, using only pressurized water.

Data on subsurface geology obtained from shale gas (test) drilling should be made available to the public – at the latest when concessions have been awarded.

(Eco)toxicological relevance of substances used

A list of chemicals used in fracturing fluids in the US was compiled for an Environmental Protection Agency (EPA) project studying the potential impacts of hydraulic fracturing on drinking water resources [4]. It includes several hundred items. However, only a limited number of additives are used at each site. In Germany, Exxon Mobile is using fracturing fluids in test-drilling operations – around 20 chemicals selected to meet the needs of each particular site [5]. According to the EPA, hydraulic fracturing with a water volume of 11.5 million litres requires the use of 55–230 tonnes of chemical additives. This estimate matches the fracturing fluid compositions published by Exxon Mobile [5]. Some of these substances are of (eco)toxicological concern: they are classified as toxic to the aquatic environment, toxic to humans, carcinogenic, mutagenic and/or toxic to reproduction [1]. In a statement issued in 2011 [2], the German Federal Environment Agency (UBA) focuses, by way of example, on two additives used in Germany (octylphenol ethoxylates and petroleum). At wastewater treatment plants and in the environment, octylphenol ethoxylates (used as surfactants) are partly converted to octylphenol, which can disrupt the endocrine system in fish and adversely affect reproduction. Petroleum distillate hydrotreated light is a substance of variable composition, whose risk potential varies accordingly. Other substances used – biocides (e.g. isothiazolinones), cross-linking agents (e.g. borates or methanol) and breakers (e.g. sodium bromate) – may also be toxic to humans and the environment. However, given the low percentage of additives in fracturing fluids, the mixtures themselves are not generally to be classified as hazardous [5]. In general, only limited information is available on the additives; the biocides used in the US have not yet been registered for this application under EU chemicals legislation (REACH).

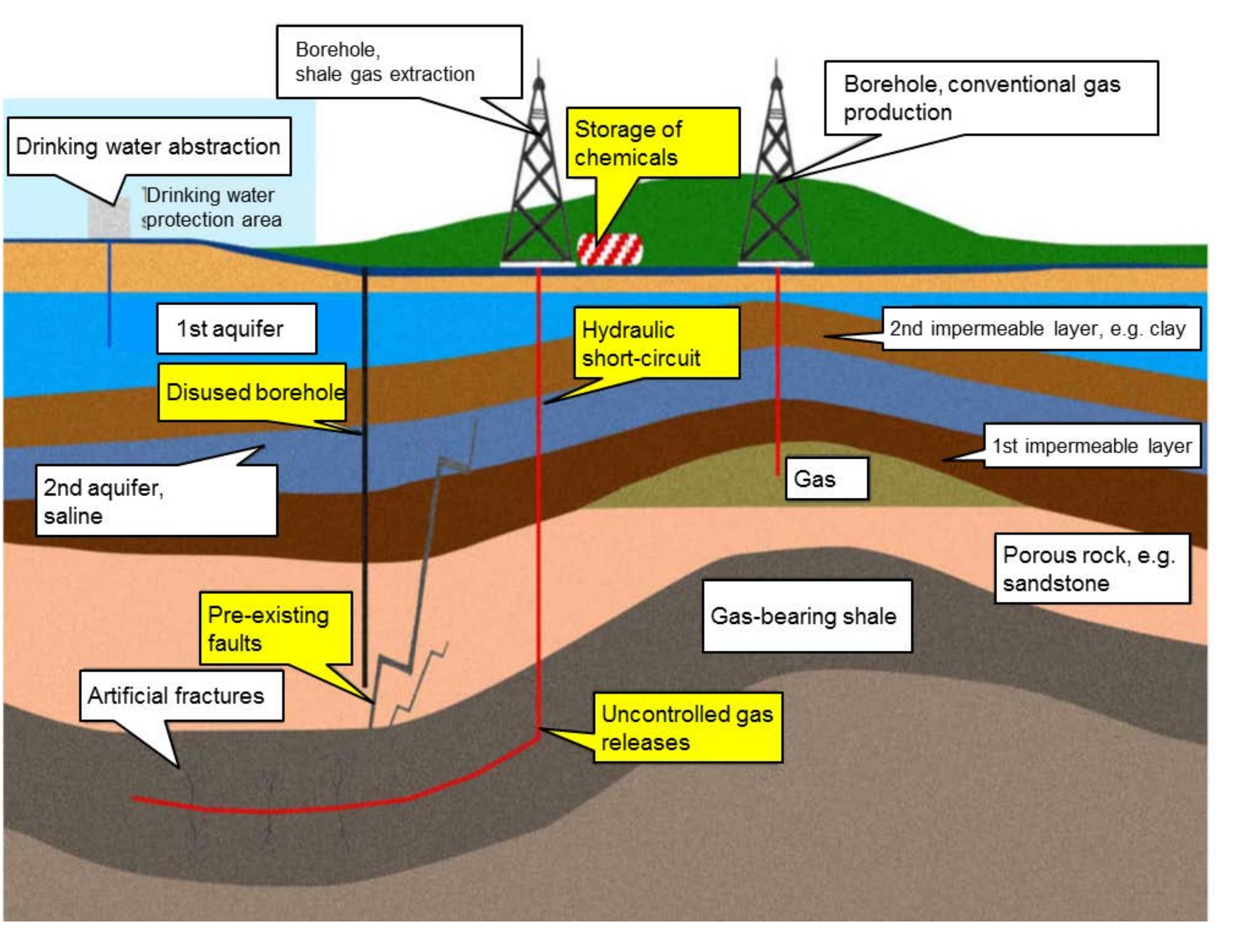
Potential for groundwater contamination

In hydraulic fracturing – as in conventional gas production – operational failures may lead to contamination of groundwater or surface waters. There are three possible sources of contamination:

- the fracturing fluids described above
- extracted shale gas itself
- water returned to the surface during production, known as "produced water" (containing dissolved, in some cases toxic, substances occurring naturally in the target formations, e.g. uranium, radium, arsenic, sulphur) and salts.

Contaminants from all three sources may reach aquifers by passing through leaks in the casing or flowing upwards outside the casing – the most likely pathway for groundwater contamination according to the report of the Tyndall Centre for Climate Change Research [1]. Cementation of the steel casing in the borehole offers good protection against contamination via this pathway. In the US, this has not been implemented at all shale gas drilling sites, and contamination of drinking water with methane has already

occurred via this route [1]. As good-quality cementing is difficult to achieve in very deep boreholes, even cementation cannot always provide complete protection. Contamination of aquifers may also occur via disused boreholes.
Even under high pressure, the spread of fracturing fluids and produced water during the fracturing process only amounts to tens of metres. Thus, unlike shale gas itself, vertical transport beyond these distances is not to be expected during hydraulic fracturing [10]. How far fracturing fluids are transported laterally in aquifers lying above the gas-bearing shale formation depends on the usual parameters, such as the porosity of the strata, or on exchange processes between the aquifer and solid rock. Degradation processes in the subsurface may give rise to new problems, such as excessive oxygen consumption in groundwater, which promotes the dissolution of iron salts or calcium carbonate. If such water comes into contact with oxygen again (at the surface), the formation of precipitates may render it unfit for use, or complicate treatment processes. For this reason, before hydraulic fracturing operations are commenced, chemical/biological degradation processes in the subsurface should be studied and material flows should be analysed (in particular, methane, wastewater and fracturing fluids). The expected extent of artificial fractures should be determined by geomechanical tests, and groundwater monitoring should be established for specific substances. In the event of incidents, the storage of hazardous chemicals and the disposal of flowback may also pose risks to groundwater.



Potential risks to groundwater (yellow) source: UBA 2011).

Water requirements

Estimates of total water requirements for a single well with a horizontal shaft vary between 7 and 29 million litres [1,6] – the equivalent of the capacity of 7–29 indoor swimming pools. These requirements cannot always be met by available groundwater or surface water resources, although this is not likely to be a limiting factor in Central Europe. Around half of the water used (20–80%) can be recovered from the well, and some of this can be reused in fracturing fluids [1]. The other half – including the additives – remains in the well.

Disposal of flowback and potential risks for surface waters

Flowback from wells is a mixture of fracturing fluids and produced water. The latter is classified by the UBA as hazardous to water, partly because it may contain radioactive substances [2]. Flowback may also contain reaction products of additives used in fracturing fluids and organic substances from the target formation (e.g. toluene and benzene). According to the UBA, treatment at municipal plants is not an option, given the composition of the wastewater. Indeed, a study carried out in Pennsylvania [11] showed that shale wastewater cannot generally be adequately treated at municipal plants. For example, effluents were found to contain elevated concentrations of barium, strontium, bromides, chlorides and benzene. Flowback from hydraulic fracturing operations would therefore have to be treated by the operators at special facilities, as is already the case today for industrial wastewater or seepage water from hazardous waste landfills.

In Germany, flowback is currently injected – after treatment – into underground rock formations (up to several thousand metres deep). These are mainly former well sites. In the UK, the Environment Agency has said that the disposal of flowback must be subject to authorization, with radiological impacts also being taken into account. In Switzerland, infiltration of substances that could contaminate (ground)water is prohibited under Article 6 of the Water Protection Act and, under Article 24, fluids hazardous to water are not to be stored in underground caverns if they could come into contact with groundwater. If appropriate management is assured for fracturing fluids, additive storage, fluid mixing and flowback storage/disposal (this requires further study), then there should be no risks for surface waters. However, experience from the US has shown that contamination of surface waters may occur as a result of accidents or unlawful behaviour.

Uncontrolled gas releases

The greatest uncertainty attaches to the estimation of methane migration in the subsurface. As well as convective transport, diffuse emissions of methane are conceivable. Under unfavourable conditions, methane could enter regional groundwater systems and subsequently also groundwater close to the surface. This point requires further investigation. In any event, the approval of the water authorities must be obtained for any hydraulic fracturing projects.

Surface installations and impacts of operations

Operation of a drilling site requires access roads, storage tanks, wastewater ponds, rainwater retention basins, storage sites for drilling equipment, parking areas for trucks, and space for temporary office and living accommodation [2]. Land requirements have been estimated at around 1 ha (excluding roads) [1]. When a well is decommissioned – usually after 3–6 years – part of this area is vacated again [2]. Heavy traffic is to be expected during the construction and operation of a well. For a 6-well pad, the total number of truck visits is estimated at 4,300–6,600 [1]. In addition, drilling is a major source of noise and light pollution, since drilling is required 24 hours a day [1].

Effects on the energy sector

As a result of shale gas production since about 2005, the US is no longer dependent on imports of natural gas. The resultant global oversupply has led to a collapse in gas prices. With the technical availability of shale gas, the prospect of fossil fuel shortages has receded. However, estimates of recoverable reserves vary widely. The International Energy Agency estimates that natural (conventional and unconventional) gas resources will last for the next 250 years. At the same time, it points out that not all shale gas reserves are recoverable. As regards Europe, experts estimate that shale gas reserves could last for 35–190 years at current rates of gas consumption; similarly rough estimates of Switzerland's reserves assume that demand could be met for 15–30 years [10]. In Germany, according to the Federal Institute for Geosciences and Natural Resources (BGR), technically recoverable reserves could supply the country's natural gas requirements for 13 years [8].

Greenhouse gas emissions

Extraction of shale gas causes greater emissions of carbon dioxide (CO_2) than conventional gas production. The actual amount depends on the number of drillings and the energy required for fracturing and transportation of water, wastewater and equipment. CO_2 emissions for the operation of a shale gas well are estimated at 348–438 tonnes [1, 2]. Depending on the total amount of shale gas extracted, this is equivalent to 0.14–1.63 tonnes of CO_2 per terajoule, or 0.5–6 grams of CO_2 per kilowatt-hour [2]. This needs to be set against the additional effort involved in transporting conventional gas over long distances (e.g. from North Africa or Siberia), which may amount to as much as 60 grams of CO_2 per kilowatt-hour [2]. In the overall assessment of greenhouse gas emissions, fugitive methane emissions (occurring during extraction and after closure of a well) must also be taken into account. Methane has 21 times the global warming potential of CO_2. Initial calculations suggest that uncontrolled releases of just 1.5% of the shale gas extracted would represent emissions of 195 grams of CO_2-equivalents per kilowatt-hour. In this case, shale gas would be more detrimental to the climate than oil and almost as detrimental as anthracite [2].

Political regulation

In its response to Reimann's parliamentary motion (February 2013), the Federal Council emphasizes that it has no legal authority to make decisions concerning drilling projects planned in Constance (Germany) or any drilling projects which may be proposed in Switzerland. Decisions on the former rest with the state of Baden-Württemberg, and on the latter with the cantonal authorities. It remains unclear whether drilling for shale gas will actually take place in the Constance region. In a statement issued in December 2011 [2], the UBA set out a number of minimum requirements for shale gas extraction, focusing in particular on the protection of groundwater. For example, the UBA says that no licences should be granted in areas where drinking water is abstracted, pointing out that the additives employed have not yet been registered for use in shale gas extraction in accordance with European chemicals legislation (REACH). Although concessions have now been awarded, specific activities on the ground have not been authorized. The Baden-Württemberg state parliament's call for a moratorium on shale gas extraction was rejected in Germany's lower house of parliament (Bundestag) [8]. Discussions have yet to be held on a nationwide ban on shale gas extraction in drinking water abstraction and water protection areas; in addition, there is at present no legal requirement in Germany to conduct an environmental impact assessment for shale gas extraction, as it is covered by mining law. The UBA and Baden-Württemberg are pressing for measures to close this legal gap.

In Switzerland, under no. 21.7 of the Annex to the Environmental Impact Assessment Ordinance, an EIA for shale gas extraction would have to be conducted by the canton concerned. In 2011, Cantons Fribourg and Vaud decided that exploration and hydraulic fracturing for shale gas extraction on their territory would be suspended indefinitely. In March 2013, a study entitled "Energy from the earth's interior: Deep geothermal energy as the energy source of the future?" was initiated by the Centre for Technology Assessment, the Swiss Federal Office of Energy, the Commission for Technology and Innovation, and the Swiss Academy of Engineering Sciences (see Links). Under the original plan, the impacts of shale gas extraction were also to be assessed in this project [12]. The project is being led by the Paul Scherrer Institute.

At the EU level, there is no agreed position on shale gas extraction. While hydraulic fracturing is already taking place in the UK and test-drilling is planned in Denmark, a law banning hydraulic fracturing was passed in France in 2011. At present, the only country where shale gas is produced on a significant commercial scale is the US. Here, intensive production first became possible when a legal amendment exempted hydraulic fracturing from the Safe Drinking Water Act [9]. Following numerous incidents in recent years, a US Environmental Protection Agency (EPA) project is currently studying the potential impacts of hydraulic fracturing on drinking water resources [4]. Some of the incidents have been attributed to a lack of – or inadequate – cementation of steel tubing in boreholes [1].

Links

- Shale gas and climate change: http://www.tyndall.ac.uk/communication/news-archive/2011/shale-gas-expansion-would-jeopardise-climate-commitments
- British Geological Survey, Blackpool earthquake: http://www.bgs.ac.uk/research/earthquakes/BlackpoolMay2011.html
- United States Environmental Protection Agency; Natural Gas Extraction – Hydraulic Fracturing: http://www2.epa.gov/hydraulicfracturing
- Reimann motion: http://www.parlament.ch/d/suche/seiten/geschaefte.aspx?gesch_id=20124262
- Global list of fracking bans and moratoriums: http://keeptapwatersafe.org/global-bans-on-fracking
- Study “Energy from the earth’s interior: Deep geothermal energy as the energy source of the future?”; Centre for Technology Assessment TA-Swiss (initiated in March 2013); http://www.ta-swiss.ch/en/projects/mobility-energy-climate/deep-geothermal-energy/
- Chemical Use In Hydraulic Fracturing: http://fracfocus.org/water-protection/drilling-usage

References

[1] Broderick J, Anderson K, Wood R, Gilbert P, Sharmina M, Footitt A, Glynn S, Nicholls F, 2011. Shale gas: an updated assessment of environmental and climate change impacts. A report by researchers at the Tyndall Centre, University of Manchester. Report commissioned by The co-operative. http://www.tyndall.ac.uk/sites/default/files/coop_shale_gas_report_update_v3.10.pdf

[2] German Federal Environment Agency (UBA): Einschätzung der Schiefergasförderung in Deutschland – Stand Dezember 2011. Stellungnahme. http://www.umweltbundesamt.de/wasser-und-gewaesserschutz/publikationen/stellungnahme_fracking.pdf

[3] De Pater and Baisch (2011): Geomechanical study of bowland shale seismicity – synthesis report, prepared for Cuadrilla Resources by Dr. C.J. de Pater and Dr. S. Baisch, 2 November 2011. Cited in [1]

[4] Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. PROGRESS REPORT. US Environmental Protection Agency. Office of Research and Development Washington, DC December 2012. EPA/601/R-12/011. http://epa.gov/hfstudy/pdfs/hf-report20121214.pdf

[5] http://www.erdgassuche-in-deutschland.de/technik/hydraulic_fracturing/fracmassnahmen.html

[6] Arthur JD, Bohm B, Layne M, 2008: Hydraulic fracturing considerations for natural gas wells of the Marcellus shale. The Ground Water Protection Council 2008 annual forum, Cincinnati, OH, September 21-24, 2008, 16 pp. Cited in [7]

[7] Gregory KB, Vidic RD, Dzombak DA, 2011: Water management challenges associated with the production of shale gas by hydraulic fracturing. Elements 7: 181-186.

[8] IBK (International Lake Constance Conference), Kommission Umwelt, 2012: Fracking im Bodenseeraum – Diskussionspapier zuhanden der IBK-Regierungschefkonferenz vom 07.12.2012.

[9] Waxmann HA, Markey EJ, DeGette D, 2011: Chemicals used in hydraulic fracturing. United States House of Representatives, Committee on Energy and Commerce, Minority Staff, April 2011.

[10] Burri P and Leu W: Unkonventionelles Gas; Brückenenergie oder Umweltrisiko? Gefahren, Chancen und Nutzen. Aqua & Gas No. 9 / 2012.

[11] Ferrar KJ et al.: Assessment of Effluent Contaminants from Three Facilities Discharging Marcellus Shale Wastewater to Surface Waters in Pennsylvania (Environmental Science & Technology, March 2013; Doi: 10.1021/es301411q)

[12] Centre for Technology Assessment TA-Swiss, 2012: Background paper (in English) and expert comments on the study “Energie aus dem Innern der Erde: neue Versorgungsformen für die Schweiz? – Schiefergas und Tiefengeothermie als Energieträger der Zukunft” [Energy from the earth’s interior: New resources for Switzerland? – Shale gas and deep geothermal energy as energy sources of the future]. http://www.ta-swiss.ch/?redirect=getfile.php&cmd%5Bgetfile%5D%5Buid%5D=2003

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