SHIP
SHALE GAS INFORMATION PLATFORM

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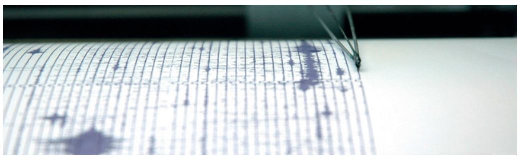


Shale Gas: Factual Scientific Argument For and Against

The scientific perspective of the expert network of the Shale Gas Information Platform SHIP

Andreas Hübner, Alexandra Vetter and Brian Horsfield (Eds.)

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Version 1.0

Editors

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Imprint

Helmholtz Centre Potsdam
GFZ German Research Centre for Geosciences
Telegrafenberg, D-14473 Potsdam
Published in Potsdam, Germany
2015
DOI: 10.2312/ship_book

Recommended citation, whole book

Hübner, A., Vetter, A. & Horsfield, B. (Eds.) (2015) Shale Gas: Factual Scientific Argument For and Against. Potsdam: GFZ German Research Centre for Geosciences.
DOI: 10.2312/ship_book

Recommended citation, single article

Wiese, B. (2015) Review of “Numerical assessment of potential impacts of hydraulically fractured Bowland Shale on overlying aquifers”. - In: Hübner, A., Vetter, A. & Horsfield, B. (Eds.) Shale Gas: Factual Scientific Argument For and Against. Potsdam: GFZ German Research Centre for Geosciences.
DOI: 10.2312/ship_00

About This Book

This E-book collates expert articles published on the Shale Gas Information Platform SHIP website (http://www.shale-gas-information-platform.org).

The Shale Gas Information Platform is a network of international experts who share their expertise on different aspects of shale gas. With News, Basic Information and Expert Articles, SHIP features the scientific perspective within the current debate, adding factual argument to the pros and cons discussed publicly. The network is brought together by the GFZ German Research Centre for Geosciences.

Most articles presented in this book are available in German and/or Polish on the SHIP website.

Motivation

While completely replacing fossil energy resources with renewable energies is the goal of nations worldwide, and also of the European Union, technical and economical arguments dictate that a diverse energy mix will remain in force for the foreseeable future. Natural gas currently features prominently in practically all national energy portfolios and, due to its low carbon footprint and flexible availability, is widely regarded as the most important bridge to a renewable energy future.

At the same time the discussion about the environmental impact of shale gas production is ongoing, and in some countries shale gas exploration is on hold until more knowledge emerges on the possible environmental impact of shale gas production.

Concerns exist about induced seismicity, leakage of gas through casing into aquifers, the potential toxicity of fluids used for hydraulic fracturing and the disposal of fluids returning to the surface. Opinions on environmental risk diverge strongly: Risks are minor and controllable according to industry, while environmental groups often claim the opposite.

The Shale Gas Information Platform SHIP aims to add a scientific perspective to the discussion on technical and environmental issues related to shale gas exploration and production. Inherent to science are transparency, dialogue and dispute. In this respect SHIP will not only showcase but also discuss what is known and what is not yet known about environmental challenges and potential risks. SHIP features current scientific results and best practice approaches and additionally builds on a network of international experts. The project aims to spark discussion among all stakeholders.

Institutional Background

The Shale Gas Information Platform was initiated by GFZ with funds from the German Federal Ministry of Education and Research (project "GeoEn") and own funds. Additional funds were granted by the Helmholtz Association of German Research Centres.

GFZ, the national research centre for Earth Sciences in Germany, is a member of the Helmholtz Association, which has about 38,000 employees working in 18 research centres and an annual budget of approximately 4 billion euro, making it Germany’s largest scientific organisation.

Contents

Interview with Brian Horsfield about shale gas and hydraulic fracturing

Brian Horsfield, GFZ German Research Centre for Geosciences

As a major research centre, the GFZ German Research Centre for Geosciences makes important contributions to a sustainable national and global energy supply, e.g. to use of deep geothermal energy, to use of the underground for different storage purposes and to the identification of reservoirs with conventional and unconventional energy sources. Research into hydrocarbons plays a significant role in this, because it is clear: The transition to energy supply from mainly renewable sources, as planned and initiated in the German "Energiewende", will take decades.

Fossil energy raw materials will remain important in the German, European and worldwide energy mix for many decades to come, and not only due to the worldwide continued rising energy demand. Natural gas plays an increasingly central role in this, because it is the cleanest fossil energy source for combustion. Energy research at the GFZ also deals with natural gas in shales, so-called shale gas, and examines issues that are also important for the shale gas production method of fracking (or its proper name: hydraulic fracturing).

SHIP: What happens in geological formations when large quantities of water, sand and chemicals are injected into them?

Prof. Horsfield: What happens is precisely what is intended: the pressure of the water on the rock causes a network of fine fractures to form in the rock, which improves the flow of gas or oil into the well. In order for fractures to form in the rock, the precisely metered pressure of the water must exceed a critical value, which depends on the prevailing stresses in the deep and the tensile strength of the rock. The propagation of the fractures in the rock can be optimised in advance by precise pre-fracturing geological investigations and computer models. The chemicals support the whole fracturing process, e.g. friction reducers enable the water to be more easily pumped into the deep, and biocides prevent bacterial growth in the fine fractures. The sand grains settle in the induced fractures and prevent them from closing again when the fracturing fluid is pumped back out of the well after the hydraulic fracturing.

SHIP: Is the process examined or tested at the GFZ?

Prof. Horsfield: At the GFZ, for example, the initiation and propagation of the fracture formation in shale under all kinds of different conditions are precisely examined in the laboratory. The results will be used to enable hydraulic fracturing to be carried out in a more targeted way than possible to date. Concepts for improved microseismic monitoring and the necessary tools are being developed at the GFZ, in order to track the fracture formation in rock during hydraulic fracturing even more precisely than before.

The industry-funded European scale project GASH has brought new insights into the shale gas potential of Germany and its neighbours, including novel concepts for secondary porosity formation and the identification of a new source of gas at both very high (>200°C) and very low (biogenic) geological temperatures. The BMBF-funded GeoEn project yielded new insights into the rock mechanical behaviour and nanoscale architecture of rock forming minerals and the chemistry of entrained fluids, thereby improving estimates of both in-place resource potential and the producibility of hydrocarbons.

In parallel to these activities we have devised and implemented a high profile Shale Gas Information Platform whose task is to present the general public and political sphere with facts, thereby pushing science to the fore, ahead of political rhetoric and misinformation from activists on both sides of the shale gas debate.

SHIP: What is the GFZ's attitude to hydraulic fracturing?

Prof. Horsfield: If the best technologies currently available and strict environmental standards are applied, the production of natural gas from shale using hydraulic fracturing appears to be possible in an environmentally compatible way. However, it is necessary to obtain more in-depth knowledge of several issues. The outstanding questions cannot only be addressed in the laboratory or with computer models, but must also be investigated in the field at research and/or exploration wells (not: production wells). It goes without saying, but should be clearly reiterated here once again: the research is carried out openly and unbiased and the results are published.

SHIP: In fracking, chemicals and high pressure are used to break up rock so that gas can escape. Does this endanger the groundwater?

Prof. Horsfield: Experience with the technology shows that with more than 100,000 shale gas wells worldwide and more than two million hydraulic fracturing operations (not only for shale gas production), there are only very few documented case of groundwater contamination with fracturing fluids, which entered groundwater from deeper geological formations.

Other sources of danger for the groundwater are improper surface handling of substances, leakages from wells or improper treatment or disposal of wastewater. It is known that groundwater has been contaminated by these pathways. But these risks are rather not related with the hydraulic fracturing itself, i.e. the fracture formation in the rock during shale gas production, they are related to overall oil and natural gas production.

Analysis of thousands of fracture operations for shale gas production shows that 99 % of the fractures are shorter than 350 m. In very exceptional cases they may reach a length of up to almost 600 metres. Therefore it is currently believed that a distance of 1000 metres between the portion of the well to be fractured and freshwater bearing rocks is sufficient to ensure safety of the freshwater.

How high the risk of groundwater contamination is depends on the respective geological conditions, which differ in every case. This can and must be clarified through regional and local geological pre-investigations.

SHIP: Is there a risk of triggering earthquakes?

Prof. Horsfield: The risk of triggering earthquakes large enough to be felt by humans as a result of hydraulic fracturing is classified as being low in scientific studies. Thorough geological pre-investigations, suitable management of the injection pressure and precise seismic monitoring during hydraulic fracturing can further reduce the risk. The reinjection of fracking fluids into geological formations has emerged as a trigger of perceptible earthquakes, rather than the fracking itself. The rate of pumping clearly must be managed properly when disposing of fluids in this way.

SHIP: Fracking is also criticised because it has a poor climate balance; a comparatively large amount of energy is used for the production. Is this really a shortcoming of the method?

Prof. Horsfield: We at GFZ have not carried out any research into this ourselves, but there are now very many scientific studies that show that greenhouse gas emissions during the production of shale gas are only slightly higher than those during the production of natural gas from conventional deposits. The crucial point lies elsewhere: the increasing use of natural gas overall, from conventional and unconventional deposits.

The International Energy Agency IEA determined that the greater use of natural gas alone is not sufficient to achieve the internationally agreed emission reduction targets. This would require a far more fundamental change in global energy use. This includes, above all, major efforts to improve energy efficiency, development of renewable energy and broad use of new technologies to reduce greenhouse gas emissions, possibly including "carbon capture and storage" (CCS). However, as long as fossil energy sources are still required, natural gas is the first choice en route to a sustainable energy supply.

SHIP: The USA is now relying on fracking to become autonomous in energy policy terms. Is there large potential for the process in other regions of the world?

Prof. Horsfield: Wherever large quantities of shale gas are thought to exist there is potential for large scale domestic production and reduced dependence on imports. However, whether this will actually come true ultimately not only depends on confirmation of the large deposits, but also on very many other factors tied to economics and politics.

SHIP: Are there not sufficient gas deposits worldwide, which can be tapped in conventional ways?

Prof. Horsfield: There are very large conventional natural gas deposits on Earth. However, approx. 40% of these deposits lie either in West Siberia or in the region of the Persian Gulf, and are therefore in regions which geopolitically speaking are relatively unstable. The same applies to part of the North African deposits. The search for other (domestic) natural gas deposits can definitely be justified. And current forecasts of the IEA assume that the demand for natural gas worldwide will increase sharply. If this proves to be true, shale gas will probably have an increasingly large role to play.

SHIP: Thank you!

Groundwater Protection

SHIP Expert Articles

Review of „Numerical assessment of potential impacts of hydraulically fractured Bowland Shale on overlying aquifers"

Author: Bernd Wiese

Centre for Geological Storage, GFZ German Research Centre for Geosciences

Published: August 06, 2015

Message of the Paper

In most studies it is concluded that contaminants migrate as high as the fractures extent, therefore the hydraulic fracture height is the critical parameter to consider. The authors state that horizontal groundwater flux dilutes the contaminants, such that the amount of upwelling contaminants becomes insignificant under the hydrogeological conditions in central Britain.

Detailed Review

The above paper aims to identify the conditions under which hydraulic fracturing of the Bowland Shale in central Britain could contaminate groundwater in St. Bees Sandstone (600-1000 m depth). This research is carried out using a numerical model of the subsurface up to 3000 m depth and comprises the ten main geological layers, mainly alternating high and low conductivity*1; the Bowland Shale is located at a depth between 2000 and 2500 m. The deep groundwater is over-pressured, i.e. it flows upwards and transports hazardous substances of natural or anthropogenic origin if a conductive pathway*2 exists. During hydraulic fracturing additional over-pressure is applied and upward directed hydraulic pathways are created. The model investigates, how these processes affect the water quality of aquifers that are above the Bowland Shale.

The first state of the model represents natural conditions, analogue to the situation before fracturing. The aquifers are well separated and there is no significant fluid flux between them. Hydraulic fracturing is then applied to the model, this means that hydraulic pathways and overpressure are created. Different scenarios for the fracture heights are applied. Some fractures have a vertical extent of 1850 m, while the highest known fractures have a length of 1100 m (Davies et al., 2012). For the simulated fracture heights, contamination of the St. Bees Sandstone is possible.

In most studies it is concluded that contaminants migrate as high as the fractures extent, therefore the hydraulic fracture height is the critical parameter to consider. The authors state that horizontal groundwater flux dilutes the contaminants, such that the amount of upwelling contaminants becomes insignificant under the observed geological conditions. The authors consider two further scenarios with a higher and lower hydraulic conductivity. Only for lower hydraulic conductivity the shallow groundwater becomes vulnerable.

This may appear as a paradox, but it occurs because a high conductivity is correlated with a high horizontal groundwater flow velocity. Here, the horizontal groundwater flow carries contaminants away from the fracture, and natural water from the respective aquifer flows upwards. The authors conclude that the observed and high hydraulic conductivities prevent upward flow of contaminants from the Bowland Shale horizon, even in case of very long hydraulic fractures.

It has to be emphasized that the model simulates the impact of just one well that is hydraulically fractured. The results cannot be directly transferred to commercial field exploitation with multiple wells. Fluid injection by multiple wells could increase general pressure in the Bowland shale (Keranen et al., 2014) and therefore enhance the upward fluid flux.

I have objections to this paper in respect to the scenarios. All three permeability scenarios use an implausible higy hydraulic gradient. This results in implausibly high flow velocities and therefore the barrier efficiency is highly overestimated. The barrier function is significantly lower if the flow velocity is reduced to realistic values.

Critique on flow model

The hydraulic conductivities of the respective layers are derived from field measurements in the respective depth, the horizontal hydraulic gradient of 5‰ is derived from literature data on shallow aquifers (<100 m) and is assigned to the entire model. Therefore a significant horizontal hydraulic flux establishes in the model. This flux replaces the fluid in the fractures that originates from lower layers with formation water and therefore inhibits the upwelling of contaminants.

I have two objections that this removal mechanism is largely overestimated. First of all, the authors only apply a flow vector perpendicular to the fracture, but with equal probability the flow vector may have the same direction. In the latter case the upward migrating contaminants would hardly be removed. This should be considered as worst case scenario.

As second, and more important point, the applied velocities appear far too high. The effective transport velocity is calculated by equation 1:

$$v_t = \Delta I_x \, K_h \, \frac{1}{\theta}$$

ΔI_x = horizontal hydraulic gradient, K_h = horizontal hydraulic permeability, θ = effective porosity of the respective layers.

Table 1: Horizontal hydraulic permeabilities and porosities as applied by Cai and Ofterdinger (2014) for the thee conductivity cases: low, reference, high. The porosity is identical for all cases. The transport velocities are calculated for a hydraulic gradient of 5‰. Velocities higher than 10 cm/y are marked bold.

	permeability m/s			porosity	transport velocity m/y		
	low	reference	high	reference	low	reference	high
Mercia Mudstone Group	1.00E-08	1.00E-07	1.00E-06	0.1	1.6E-2	1.6E-1	1.6E+0
Sherwood Sandstone Group	1.20E-06	1.20E-05	1.20E-04	0.23	**8.2E-1**	**8.2E+0**	**8.2E+1**
St. Bees Sandstone	8.10E-08	8.10E-07	8.10E-06	0.15	8.5E-2	**8.5E-1**	**8.5E+0**
Manchester Marl	1.00E-09	1.00E-08	1.00E-07	0.15	1.1E-3	1.1E-2	1.1E-1
Collyhurst Sandstone	7.90E-06	7.90E-05	7.90E-04	0.26	**4.8E+0**	**4.8E+1**	**4.8E+2**
Lower Coal Measures	1.70E-10	1.70E-09	1.70E-08	0.1	2.7E-4	2.7E-3	2.7E-2
Millstone Grit Group	7.90E-09	7.90E-08	7.90E-07	0.08	1.6E-2	**1.6E-1**	**1.6E+0**
Bowland Shale	6.00E-09	6.00E-08	6.00E-07	0.03	3.2E-2	**3.2E-1**	**3.2E+0**
Pendleside Limestone	1.60E-07	1.60E-06	1.60E-05	0.01	**2.5E+0**	**2.5E+1**	**2.5E+2**
Worston Shale	6.00E-09	6.00E-08	6.00E-07	0.03	3.2E-2	**3.2E-1**	**3.2E+0**

The resulting velocities appear far too high. The highest transport velocity is simulated in the Collyhurst sandstone for the high conductivity case. The velocity is 480 m/y and comparable to near surface velocities in the vicinity of a big waterworks (Wiese and Nützmann, 2009). It is not realistic for a deep aquifer. Garven (1995) analyses different processes that induce deep fluid flow in the subsurface. The highest velocities are between 0.1 and 100 m/y and occur for geologic processes that are not relevant for Great Britain. Consequently velocities below 0.1 m/y are considered within a realistic scale.

Garven (1995) analyses different processes that are responsible for the high groundwater flow. None of these is relevant to the Bowland shale area. Furthermore, it should be considered, that high fluxes equilibrate different hydraulic potentials and therefore typically correspond to low hydraulic gradients (Flewelling and Sharma 2014), at least in case of long existing pathways (Rozell, 2014), which is the case for the horizontal flow under consideration.

Cai and Ofterdinger (2014) apply a hydraulic gradient of 5‰ which is derived from shallow aquifers with a depths below 100 m (Schürch and Buckley 2002, Schürch et al., 2004). Shallow aquifers typically show high hydraulic gradients since they are affected by groundwater recharge and topography. Deep aquifers in contrast show less recharge and the topographic impact is much smaller. Deep aquifers also have much larger scales. On a distance of 500 km a 5‰ it would require an equivalent height difference of 2500 m water column, which is not realistic for the British Islands.

The horizontal hydraulic transport velocities as simulated by Cai and Ofterdinger (2014) are above a realistic scale. Therefore the removal mechanism for upwelling contaminants is overestimated. The Collyhurst sandstone, which represents the most effective barrier shows unplausibly high horizontal transport velocities for all three conductivity cases. For the reference and the high permeability case the velocity is unplausibly high in 7 of 10 layers. The interpretation that the horizontal flux acts as effective barrier for upwelling contaminants through hydraulic active fractures is not plausible.

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*1 conductivity: A high conductivity level means water (and other fluids) can flow easily through the rock, a low conductivity level means that a rock can be impermeable to water and other fluids.

*2 conductive pathway: a region with high permeability, but low spatial extent, such as an open fault or fracture.

Surface and groundwater contamination associated with modern natural gas development

Author: Physicians Scientists & Engineers for Healthy Energy

PSE* published the original article in March 2014. Republished on SHIP with permission.

Published: July 10, 2014

Documentation of water contamination associated with modern natural gas development is a complex issue. The list of studies reported here [PSE science summary] should be seen as conservative and limited reporting of water contamination, as it only contains evidence from peer-reviewed scientific studies and does not include incidences that exist in inspection records.

Differences in local geologies and hydrologic characteristics, land-use histories, industry practices, and monitored water contaminants can complicate comparisons across studies. Baseline conditions for water quality are often unknown or may have been affected by other activities. **Nonetheless, empirical evidence of surface and groundwater contamination as a result of modern natural gas operations is documented.**

Pennsylvania (*Marcellus*). Several studies indicate degradation of ground and surface waters in dense drilling areas of Pennsylvania. Studies[1,2] found significantly **higher concentrations of thermogenic methane** in private water wells within 1km of one or more natural gas wells (6 and 17 times on average, respectively).

An examination of water chemistry and isotope signatures[3] of effluents from a brine treatment facility, stream sediments near the discharge site, and surface waters downstream and upstream of the discharge site showed **elevated levels of chloride and bromide** in downstream waters consistent (combined with isotopic data) with produced-waters from Marcellus shale wells. Radium-228/Radium-226 ratios in downstream waters and near source sediments also closely matched ratios measured in Marcellus wastewaters. Radium-226 concentrations in near-source sediments (544-8759 Bq/kg) were found to be approximately 200 times greater that upstream and background sediments and in excess of U.S. radioactive waste disposal threshold regulations.

Texas (*Barnett*). A study of groundwater quality in the Barnett shale, TX[4] revealed significantly higher levels of heavy metals (strontium, selenium, arsenic) in private water wells located within 2km of active gas wells relative to private wells located further from drilling activity. This study was unique in that it used historical data from the region to create a baseline measure of groundwater quality before the expansion of natural gas operations. Arsenic, strontium, and selenium concentrations were also found to be significantly higher in active drilling areas relative to this historical baseline. Shallower water wells near drilling activity showed the highest levels of contamination. These findings suggest that mechanical disturbance (i.e. subsurface vibrations) of water wells, surface spills and/or faulty well casings/cement as possible causes of contamination.

Kentucky (*Appalachian*). A release of hydraulic fracturing fluids to a Knox County stream resulted in fish stress and mortality. Water chemistry analysis[5] of the impacted stream revealed **elevated conductivity, lowered pH and alkalinity, and toxic levels of metals**. Sampling of fish exposed to the contaminated water exhibited a high incidence of gill lesions consistent with impacts observed in fish exposed to low pH, dissolved heavy metals, or both. Among the species affected was the federally protected Blackside Dace**.**

Colorado (*Denver-Julesburg and Piceance*). An analysis of reported surface spills (Colorado Oil and Gas Conservation Commission, COGCC) within Weld County (Denver-Julesburg) and groundwater monitoring data associated with each spill[6] revealed BTEX (benzene, toluene, ethylbenzene, xylene) contamination of groundwaters. During a one-year period the authors noted 77 reported surface spills impacting groundwater; 62 of these records included BTEX analytical sampling during remediation. A large percent of samples show **BTEX concentration in excess of federal standards**. Another study of surface and groundwater samples from drilling-dense areas in the Piceance basin[7] showed higher estrogenic, anti-estrogenic, or anti-androgenic activities near oil and gas activity relative to reference sites with little or no natural gas developments.

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*Physicians Scientists & Engineers for Healthy Energy examine the empirical bases and assumptions of unconventional energy production as well as the energy transition from fossil fuels to renewable energies by fact-checking and disseminating carefully vetted, peer-reviewed, evidence-based information to the public.

Comment on ‘Hydraulic fracture height limits and fault interactions in tight oil and gas formations’

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Published: July 30, 2014

A short summary of the paper:

Flewelling et al., 2013, propose a worst-case scenario approach to determine the maximum possible hydraulic fracture height in tight oil and gas formations. The analysis is carried out in two parts:

1. A worst-case model is used to determine fracture height, based upon the volume of injected fluid used during hydraulic fracturing;
2. Shear displacement at faults, derived from the magnitude of microseismic events, is analyzed.

In part 1, a worst-case model is developed to show fracture growth. The volume of injected fluid is assumed identical to the opening volume of the created fracture. The maximum fracture height is calculated based upon assumptions of the fracture shape and opening width. It is a worst-case scenario approach in the sense that analysis of fluid loss is neglected, however, a true worst-case scenario model would consider pre-existing fractures; this model does not. The simulated fracture heights are compared with observed fracture heights (Fisher and Warpinski, 2011). Part 2 comprises the analysis of microseismic events and considers the fracture growth in pre-existing faults. The idea is that a positive correlation exists between the fracture height and the magnitude of a seismic event. The vertical extent of a fracture is deduced from the observed magnitude of microseismic events (based on data fromWarpinski et al., 2012). The authors conclude that it is physically implausible that fractures could create an hydraulic connection between deep black shales and shallow aquifers.

Several critical comments can be made on this paper:

Part 1: The assumptions on which the results are based are not implausible, but arbitrary to some extent. The shape of the fracture is assumed to be an ellipsoid, with a height of twice the length, without citation. Factors that may lead to an underestimation of the vertical fracture growth, e.g. different fracture shapes, are not discussed. A sensitivity analysis of the underlying assumptions is also not provided. Several observed fractures are up to 100 m higher than predicted by the so-called ‘worst-case approach’. The authors attribute this to overestimation of fracture growth in the dataset, due to shear displacement along pre-existing joints, faults and bedding planes. This is plausible under certain assumptions, however, no citation or at least conclusive consideration is given that would show the data from Fisher and Warpinski, 2011 did indeed overestimate fracture height. In the original article this effect is not addressed.

The authors claim the misfit between observed and simulated data occurs because their approach is more accurate than the data against which their approach is tested (paragraph 8). This argumentation is a circular argument and a basic contradiction.

Part 2: The authors also calculate shear displacement based upon seismic moments that were estimated by Warpinski et al., in 2012. The largest observed seismic events are not included in the analysis. The analyzed data include moment magnitudes smaller than -0.5, which is significantly below the observed magnitudes of 0.5 (given in paragraph 11) and 0.86 given in paragraph 3. Therefore, it is very likely that shear displacement is higher than calculated. Furthermore, a circular shear area is assumed; it is not considered that elongated shapes may increase fracture height. The papers conclusions suggest, however, that fault slip is also part of a worst-case scenario approach (paragraph 15, sentence 4: "...potential fault slip.").

In part 1 the authors name an upper limit of 10 m for shear displacement. In Part 1 the authors imply that seismic events may occur 100 m above a hydraulic fracture. This contradiction is not addressed. In paragraph 10, the authors state that fractures would not be expected to grow vertically at shallow depths. The cited reference, however, (Fisher and Warpinski, 2011, Fig. 6) shows that although the vertical fracture component decreases with decreasing depth, on average about 50% of the volume still belongs to vertical fractures. In contrast to the authors' statement, numerous entirely or predominantly vertical fractures do exist at shallow depths.

Conclusion

The paper displays an interesting approach for relating fracture growth to the volume of injection fluid. The theoretical considerations are plausible, but not sufficiently and critically discussed. Several presented values are contradictory. Instead the authors claim their approach provides more accurate data than the data against which their approach is tested (paragraph 8); this is a basic logical contradiction. The authors conclude that it is physically implausible that fractures could create a hydraulic connection between deep black shales and shallow aquifers. This conclusion is unjustified. The paper does not provide additional insight into the underlying datasets.

Chemicals in ‘fracking’ for the extraction of unconventional natural gas resources

Authors: Martin Elsner[1], Carsten Vogt[2], Anett Georgi[2], Frank-Dieter Kopinke[2], Wolfgang Calmano[3], Kathrin Schreglmann[1], Axel Bergmann[4], Bernhard Mayer[5], Franziska D.H.Wilke[6].

Published: April 28, 2014

The "Chemicals in Hydrofracking for Natural Gas Extraction" technical committee is a group of experts of the German Water Chemistry Society (specialist group of GDCh, Gesellschaft Deutscher Chemiker e.V.). It is our aim to form an independent committee of experts that deals with current research questions regarding the environmental chemistry and water chemistry of fracking chemicals. Our contributions are intended to assist in better understanding of processes, identification of risks and development of solutions.

Few technologies have established themselves as quickly in the USA as hydraulic fracturing ("Fracking") for the extraction of unconventional natural gas deposits. Within only a few years, shale gas has made the USA independent from imports, reduced natural gas prices and provided the chemical industry with low-cost raw materials. However, at the same time, the concern about possible environmental pollution has led to controversial public debates. The focus of these are on the chemicals that play a part in the fracking process. The aim of this brief article is to point out current knowledge gaps from the point of view of water chemistry.

Regarding the chemistry of fracking operations

In order to give stability to a drill hole, to cool the boring tool and remove drillings, bentonite (a clay material) or polymer-based drill mud are used. Newly drilled sections are immediately fitted with pipework for stability and to provide protection from shallow groundwater and the pipework is cemented in. At the depth of the gas deposit, the pipework is selectively perforated and the surrounded cement is dissolved with acid (e.g. HCl), where necessary, in order to come into contact with the shale. With actual hydraulic fracturing, a fracturing liquid is subsequently injected at high pressure, in order to create fine fissures and cracks, so that the enclosed gas can escape and be produced. In order to keep these open, proppants are used, such as sand, ceramic, etc. Friction reducers (e.g. water-based polyamide gels or guar rubber solutions) and surface-active substances (e.g. organosulphates) make the liquid 'slipperier' and ensure better wetting.

Cross-linked polymer substances (crosslinkers, e.g. ethanolamine mixed with borates and transition metal complexes) increase the viscosity in order to transport proppants. "Breakers" (oxidants, acids/base, enzymes and similar) subsequently "break up" the viscosity again, so that the gas can escape from the formation. Corrosion inhibitors (quinoline salts, sulphites), clay stabilisers (quaternary ammonium salts), iron complexing agents (e.g. citric acid) and biocides accompany the gas extraction and prevent plugging of the production well. Between 7 and 18 million litres of water are required for performing a single fracking operation. A significant part of this returns to the earth's surface as flowback, mixed with a rising proportion of formation water from deep underground.

Knowledge gaps regarding fracking chemicals and the biogeochemistry of the subsurface

Numerous fracking chemicals that are used in the USA are disclosed in Congress reports [1] and online databases (e.g. FracFocus; NGS Facts). Alphabetical lists show strong acids and base, oxidants and reducing agents, petroleum components and alcohols, fatty acids and their esters. Organosulphates and phosphates appear, as well as amines and quaternary ammonium salts. The large number of possible substances currently makes a systematic overview difficult. This is intensified by the fact that many substance cocktails are trade secrets and individual substances that account for less than 0.1% of the total volume do not need to be declared.

Therefore, the general public is not yet aware of a prominent part of the fracking chemicals. A cost-benefit dialogue, which has already been conducted for other substances (e.g. pesticides) ("Why is this substance used and not a more environmentally friendly alternative?") and would lead to more acceptance is only slowly beginning to play a part in public debates. [see SHIP News]

Furthermore, prior to the initial boring, it is also difficult to evaluate the biogeochemistry of the deep subsurface. Black shale is known for being able to contain a large amount of organic material, heavy metals and radioactive nuclides. Knowledge gaps exist regarding the mobility of organic compounds, of heavy metals and radioactive elements during hydraulic stimulation. In exactly the same way, the microbiology of the deep subsurface is still largely unknown. Microorganisms can either be introduced unintentionally with the fracking liquid or originate from the subsurface itself. Heat-resistant microorganisms can live in pore space and possibly be released by the hydraulic breakage of the rock. Not all of them are necessarily killed by biocides in the fracking liquid.

Knowledge gaps regarding the processes in the subsurface

At a high temperature, high pressure and high concentrations of salt, fracking chemicals can enter chemical reactions, which differ significantly from those that we are familiar with from shallow groundwater. In addition to this, there are changing redox conditions during the fracking process (due to the addition of oxidants and reducing agents), so that geogene substances can also possibly be transformed into new products. Both can lead to potentially new organic transformation products being formed in the subsurface. For the sorption, precipitation and release of inorganic substances such as heavy metals, their species is crucial.

In order to model this behaviour under conditions that prevail during the fracking process, the framework conditions are little known and furthermore dependent on the location. Therefore, it is not yet possible to forecast the release of problematic substances with certainty or to even prevent it through optimisation of the fracking process. Similarly, it is difficult to forecast microbial activity. On the one hand, e.g. microbial sulphide production can lead to corrosion, while on the other hand, microorganisms can also degrade fracking chemicals and therefore take on a natural cleaning function.

Need for research

Knowledge about the chemicals used, a characterisation of the conditions in the subsurface and research on the processes that are taking place there are important (a) for a hazard assessment (which substances would be released in the worst case?), (b) for optimisation of the fracking process (how can we avoid their release?), (c) for effective monitoring concepts (which substances should be look out for?) and (d) for secure and cost-efficient wastewater treatment (which substances need to be eliminated?). Water chemistry can potentially make important contributions to this. However, for these questions to be investigated, the industry must be willing to share information about fracking chemicals and provide independent scientific access to current fracking operations [2]. Future research in this field is therefore not only a scientific challenge, but also depends crucially on the requirements under which these contributions can be made at all.

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Assessment report on the impact of hydraulic fracturing on near-surface groundwater – Generic characterization and modeling

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Published: January 07, 2014

This text relies on the articles "Hydraulic fracturing in unconventional gas reservoirs: risks in the geological system part 1 & part 2" that was originally published in Environmental Earth Sciences, Part 1: September 2013; Part 2: May 2013.

Introduction

The study presented here is part of the ExxonMobil information and dialog process on the technology of hydraulic fracturing (Ewen et al., 2012). It is the first larger German study on the quantification of possible risks of groundwater contamination caused by substances transported into the groundwater area by frack fluids, initiated by the Injection of these fluids during the process of gas production from unconventional reservoirs. The topics discussed in the study are the results of the general duty of care principle for groundwater stipulated in the European Water Framework Directive and the corresponding laws and regulations on the one hand and the in-depth analysis of the topic of different societal interest groups on the other hand. In the US, where the technology has already been used on an industrial scale and under different legal framework conditions for a long time, there is evidence of possible or actual risks to groundwater. The goal of this and similar studies is therefore to prepare a catalog of requirements before hydraulic fracturing activities are carried out in Germany that evaluates the risks to the groundwater and minimizes these risks if the technology is applied.

Topics

The topics discussed in this study are related to the assessment of the risk of groundwater contamination caused by the transport of the fluids and additives in the overburden that are released during hydraulic fracturing and via existing permeable fault zones. Two time and space scales (depending on the process) are important for the transport of substances: the short-term (approximately 12 hours), local, vertical transport under high fluid pressures during hydraulic fracturing (*model scenario 1*) and the long-term (30 years) regional transport under the conditions of the regional hydraulic gradients (*model scenario 2*) in a deep aquifer system. The study also examines the possible migration of methane from its reservoirs into near-surface aquifers and into the atmosphere (climate relevance, *model scenario 3*) after the production phase. The study considers the different geological structures of the Lower Saxony Basin and the Münsterland Cretaceous Basin for different geological settings. These settings cover a spectrum of different geological constellations, where the size of the overburden and the presence of salt horizons and permeable fault zones were varied.

Methods

The deterministic approach selected for this study is based on the development and simulation of scenarios that require a basic understanding of the processes and adequate knowledge of system geometries and variables. A probabilistic approach was not possible due to the fact that the amount of comprehensive data sets that would be required for determining occurrence probabilities, extent of damage and risks was not available. In addition to the regional and local relevance of the study, approaches that can be applied in a more general context, that is to say to other sites, were developed. This includes the development of geological settings and the use of a specifically conservative approach while taking into account the impact of cumulative effects of factors that are unfavorable for the prognosis, i.e. that encourage substance migration.

This is why specific transport processes that are not determined by advection, such as matrix diffusion, sorption processes, and degradation processes were not included (1) even though they have a considerable "favorable" impact on contaminant migration. Instead, (2) while taking into account the hydrogeological plausibility of highest permeabilities and lowest effective porosities for (3) permeable fault zones between the actual fractured horizon and the near-surface aquifers were taken into account.

The operational framework conditions were selected such (4) that the maximum pressures can be maintained over the planned drilling period despite a loss of fluids into highly permeable structures above the fractured horizon which would be prevented by technical control mechanisms under real operating conditions. This means that the worst case scenarios are assumed in which large amounts of frack fluids would reach a permeable fault zone of the overburden. Moreover, (5) maximum possible upward-directed vertical pressure potential differences were considered for the simulation of regional transport in the Münsterland Cretaceous Basin.

The described cumulations of unfavorable factors for the distribution of substances in the individual scenarios are extreme cases that are physically possible and theoretically conceivable and are thus within the upper limit range of potentially negative effects of hydraulic fracturing.

One decisive factor for the migration of fluids is the fracture height, which is one of the framework conditions for estimating transport of substances. Based on microseismic measurements of 3000 individual hydraulic fracturing operations in different areas and under varying operational conditions, the Pinnacle Halliburton study (Fisher & Warpinski, 2011) shows that the hydraulically induced fracture heights do not exceed 1500 ft (approx. 500 m) and are usually significantly lower.

Aside from the comprehensive geological and hydrogeological inventory of the investigated areas, geological settings were selected based on the geological conditions that are significant for the distribution of substances in order to ensure that the natural geological heterogeneity is taken into account. The main criteria were the size of the overburden and the existence or absence of fault zones and salt horizons. The selection of the effective, advective transport parameters, the permeability and the effective porosity for lithologically clean units and faults was carried out based on comprehensive literature research. On the other hand, transmissivities for possible fault zones in the Münsterland Cretaceous Basin were estimated by means of mixture balance calculations. Here, the salinities of the near-surface groundwater, that are partly increased in the surroundings of the selected settings, and the salinity degree of the deep Cenoman/Turon aquifer were used. The usually increased salt contents of the overburden of the "Emscher Mergel", which is several hundreds of meters thick, were ignored in the light of the conservative approach.

Results

Based on the presented approach, the substance transport was simulated for the three model scenarios described above, the input variables and parameters were varied, and the following results were derived:

The *scenario 1* simulations (**transport during hydraulic fracturing**) resulted in a maximum vertical fluid transport of **50 m** under unfavorable conditions. This value is used to estimate minimum distances between the fracturing head and the near-surface groundwater.

For *scenario 2* (**regional transport, deep aquifer**) the Lower Saxony Basin was not considered because it can be presumed that there is a closed hydraulic system in the exploration areas and/or relevant depths. However, there is a regional hydraulic gradient in the Münsterland Cretaceous Basin facing southwest, which theoretical allows annual transport distances in the **1 to 25 meter** range depending on the model used. With high vertical pressure gradients, the worst-case scenario simulations exhibit a vertical migration for the considered time period. However, if factors such as matrix diffusion and sorption and degradation processes are realistically taken into account, it must be said that a significant reduction of the transported organic components is to be expected. Due to the overestimates that are the result of the specifically conservative approach, it is therefore not yet possible to make a final statement regarding the long-term migration of substances.

A **long-term migration** (*scenario 3*) of **methane** from a depleted gas reservoir through the overburden and into the atmosphere is possible based on conservative estimates: permeable fault zone, low residual saturation with low effective porosity, large volumes of gas that can be released, thin overburden, absence of salt horizons. However, there are still significant uncertainties regarding the input parameters. A site-specific evaluation is required in any case.

Recommendations

A recommended minimum distance of initially 1000 m between the perforation in the piping and the ground level can be derived from the maximum transport distances and hydraulically induced **fracture heights**: 500 m fracture height + 200 m vertical migration distance (= double mobilization of frack fluids à 50 m x safety factor of 2). The top 300 m (stress-relieved to loose near-surface zone of the overburden), including the 100 m thick near-surface aquifer, are not regarded as barrier-relevant.

To protect usable **deep aquifers**, a safety distance between the base of the groundwater aquifer and the piping perforation of 600 m is recommended: 500 m fracture height + 100 m vertical migration distance of the frack fluids (= 2 x fracking à 25 m (based on model calculations) x safety factor 2).

There are no recommendations for **methane migration** because there is not enough information on the source term. Generally, thick overburdens with a low permeability, in particular evaporite horizons, are always an effective barrier.

It is recommended to avoid hydraulic fracturing in drinking water protection zones 1 and 2, in mineral spring protection areas, in areas that are tectonically critically stressed, close to heavily-fissured or brittle zones or near old wells/shafts. Prior to each hydraulic fracturing procedure, a site analysis including a documentation of the existing condition is to be carried out and the site is to be monitored accordingly.

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Hydrogeology

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Published: December 18, 2013

Groundwater - raw material and resource

Groundwater is an important part of the water cycle that is controlled and affected by numerous processes. The underground groundwater circulation systems are of a complexity that is difficult to understand due to the fact that they cannot be accessed directly. This is why it is a particular challenge for scientists to record and describe groundwater systems and reproduce models of them. This includes the scientific characterization of factors and processes that have an effect on the quality and quantity of the groundwater and their development in space and time.

Groundwater is the most widespread and most used raw material in the world and provides the only access to water for people in many areas. The most important use of groundwater as a resource for human beings is as drinking water and raw water. Presently, more and more challenges for research keep arising that involve the use of georesources in deep groundwater systems (e.g. CO_2 storage, geothermal energy, unconventional gas reservoirs or energy storage) and the resulting effects on the valuable resource drinking water in the shallow groundwater systems that needs protection and preservation. This is why scientists focus on understanding the dynamic interactions between shallow and deep groundwater systems and their quantitative description through computer-based process simulations.

The term groundwater does not distinguish between fresh and saltwater. The latter is of little or no use, because it is not suitable for drinking or raw water supply. Groundwater generally comprises all water located beneath the earth's surface irrespective of its quality. The composition of groundwater, particularly its salt content, varies from one location to the other, and significantly alters with depth.

UNESCO surveys predict that as early as 2050 half the drinking water resources of the earth will be no longer usable due to salinization or anthropogenic pollutants. This shows the importance of preventive and restorative groundwater protection. The sustainable and responsible management of groundwater as a resource must be a top priority, not least to avoid crises and conflicts centred on water. Especially the use of georesources in deep groundwater systems is of great importance here, since it always has — or can have — an influence on shallow groundwater systems as well. The hydraulic connection of these two groundwater systems (shallow and deep) and existing paths of migration (fault zones and discontinuities) are not observed or researched either at all or to the extent necessary to date.

In December 2000, the European Water Framework Directive (EWFD) established a uniform framework for measures in the field of water policy among EU member states. The central goal of the directive is to establish good water conditions both in terms of quantity and quality and to maintain that condition in the future. One criterion for identifying the good quality of groundwater according to EWFD is the elimination of pollutants (also, for example, in the form of saline water intrusion).

In Germany, 70 % of drinking water and raw water come from groundwater sources. Shortages caused by excessive groundwater extraction are only an issue in a few areas of Germany. However, there is a negative influence on the quality in local and regional areas, in particular in Northern Germany. The use of groundwater in Northern Germany is complicated, in some areas even rendered impossible due to geogenic and anthropogenic contamination. One factor that poses a risk to our water supply is, for example, groundwater salinity.

A new area of research is the evaluation of the influence of the use of georesources in deep groundwater systems (e.g. the storage of CO_2 in saline aquifers or the production of unconventional hydrocarbon from shales) when looking at the threat to freshwater resources in shallow areas. In the future, this will be of vital importance for a sustainable groundwater management.

Interdependencies between deep and shallow groundwater aquifer systems caused by fracking

Fracking can create or reactivate hydraulic connections between the deep aquifer systems in the reservoir area and the shallow aquifers that are used for drinking water production. The risks that may be caused by this fact need to be examined individually for each site at which the hydraulic fracturing technology is to be used. If possible, the chance that frack fluids or reservoir fluids migrate into near-surface aquifers must be excluded.

Every evaluation of risks is specific to the location. This means that each selected site must be examined thoroughly to be able to make a statement regarding possible risks to near-surface groundwater systems. One key factor is that the sites are examined taking into account the barrier-function of the overburden.

In the North German Basin, one of the potential target areas for the production of shale gas, the underground is composed generally of characteristic sequence of hydrogeological layers. The usable freshwater resources are located in the shallow groundwater near the surface. Depending on the geology of an area, layers containing saltwater are located in a vertical distance of several tens of metres to a few hundred metres. Freshwater and saltwater are usually divided by low-permeability clay layers of large regional extend. These generally prevent the migration of freshwater from the upper into the lower layers and vice versa the upward migration of saltwater. As far as the production of unconventional natural gas through the technique of hydraulic fracturing is concerned, these layers form additional barriers that prevent the vertical migration of frack fluids. This is in addition to the multi-barrier-systems of caprocks directly above every potential reservoir, which are still necessary and must continue to be a requirement.

The risks are assessed by means of computer-based process simulations, with a reflection of the geological conditions of the underground that is as accurate as possible. This setup is then used to test a large spectrum of production scenarios. With this method, the flow of fluids and mass transport processes are quantified in connection with fracturing measures. As a rule, simulations are carried out using the so-called "conservative approach" taking into account the site-specific cumulative effect of individual adverse factors in order to determine the potential risks.

One of the questions that need to be taken into account is the development of cracks that may cause or reactivate hydraulic conductivities between shallow and deep groundwater aquifer systems if conditions are unfavourable. As a general rule, hydraulic fracturing aims to avoid generating cracks that extend outside the target formation. A theoretical estimate of the maximum length of cracks is possible based on practical reservoir engineering experience. According to these estimates the generation of cracks in aquifers that provide drinking water is not to be expected if the chosen target horizon is located deep enough.

Conservative simulation scenarios of related underground processes (taking into account mechanics, flow, transport and chemical reactions) overestimate possible transport distances in the simulation results due to the selected parameters and boundary conditions. In this way simulations are applied to minimize risks for specific situations in the field. Physically, however, the migration of reservoir fluids or frack fluids from the reservoir into adjacent groundwater systems cannot be excluded.

Nevertheless, I believe that the quality of the groundwater in the layers containing drinking water will not be affected as long as the geological barriers are fundamentally intact, the target reservoir for gas extraction is deep enough, hydraulic fracturing is done properly and all available safety measures are taken. The essential prerequisite for each potential site is the comprehensive exploration of the local geological and hydrogeological conditions regarding the potential conductivities for frack fluids. Only based on a comprehensive site investigation that always includes the drilling of one or more exploratory wells can a reliable risk evaluation be carried out.

A short summary of “Constraints on Upward Migration of Hydraulic Fracturing Fluid and Brine"

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Published: December 12, 2013

This paper by Flewelling & Sharma (2013) analyzes some general geological settings and their implications for fluid migration. The analysis is based on plausibility considerations. A central consideration is that high vertical permeabilities are correlated with low overpressure at reservoir depth because the pressure would have dissipated in the past. A high overpressure can only develop with low overburden permeability. This results in a low upward flux of saline groundwater under natural conditions, which is empirically proven since shallow aquifers generally show low salinity.

The authors cite studies that claim hydraulic fracturing does not create connections to shallow freshwater aquifers, because the short duration of overpressure does not induce relevant fluid flow. On a longer timescale, the authors imply that well operation causes a net volume reduction, which in turn reduces the deep pressure such that upward fluid flow cannot be expected.

The paper focuses on general geological settings, which are plausibly discussed. Since the conclusions are formulated in a very general form, the paper does not cover geological settings that show deviations from their general considerations. Such specific non-general conditions could include, for example, small basins with significant topography, hydraulic systems that are not in long-term equilibrium, special local geological features, or fluid convection that may be thermally induced.

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The Importance of Wellbore Integrity for Groundwater Protection in Shale Gas Well Construction.

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Published: June 22, 2012
Updated: July 18, 2015

Introduction

One of the major public concerns in shale gas development is the protection of groundwater from fluids that are flowing in a cemented steel casing from the shale gas reservoir to the surface. In the United States, more than 40,000 shale gas wells have been completed in the last two decades.

Following an intensive period of learning, the US shale gas industry slowly moved from prototyping to an economic and industrialized process in order to produce these previously inaccessible resources. This development process is still ongoing. Regulations as well as best practices from the oil and gas industry have had to be adapted to shale gas applications, and where necessary, new regulations defined.

Any onshore wellbore that is drilled for any purpose (oil, gas, water, geothermal, injection, and disposal) needs to have a seal to protect groundwater-bearing strata from drilling fluids, production fluids or work-over fluids. This is a major requirement that must be met - from the very beginning of the entire wellbore construction process and throughout the lifetime of the wellbore, but also for any time after final abandonment. Casing pipe and cement are the barriers that must guarantee groundwater protection.

The cement ensures a solid and continuous connection between wall rock and steel pipe and prevents fluid migration through the space between the casing and wall rock, called the annulus. The number of cemented steel layers to protect groundwater is variable and depends on well depth, rock types and other factors. A schematic sketch of the upper part of a typical well completion is displayed in Figure 1.

A wellbore that is drilled for shale gas production purposes has similar integrity requirements to those outlined above. Details on standard well completions and possible scenarios of well integrity failure and resulting leakage are addressed in chapter 3. Chapter 4 focuses on best practice recommendations for shale gas well completions.

It has been discussed that there is a high risk of hydraulically induced fractures penetrating overlaying rock formations, which may create migrations pathways for contaminants. The induced fractures could connect to naturally occurring, permeable faults, or interconnected pore spaces that may allow further fluid migration.

Scientific studies currently discuss the risk of liquids migrating upwards through the rock formations overlaying the fractured reservoir rocks[1]. While the risk of migration of liquids is probably extremely low, migration of gas, on the other hand, is a more likely scenario. Some studies suggest that natural gas from fractured reservoirs has entered into aquifers, but migration pathways are poorly constrained.[2]

It should be noted that the process of hydraulic fracturing itself bears little risk of groundwater contamination.[3] Most incidents that occur during shale gas production are attributed to procedures and operations peripheral to hydraulic fracturing, such as waste management and disposal as well as production, on-lease transport, and storage, e.g. of chemicals.[4]

Fig. 1: Sketch of a sequence of cemented casing pipes from a typical wellbore (not to scale).

Wellbore integrity and failure scenarios

Casing and cementing are the principal barriers that protect groundwater from fluids which flow in the well drilling and preparation phase or which are produced during the later production phase. To ensure long-term wellbore integrity, it is crucial that the cement composition demonstrates both the required chemistry of the slurry as well as the physical placement of that slurry into the wellbore. A typical wellbore is constructed from a series of concentric casing strings (Fig. 2).

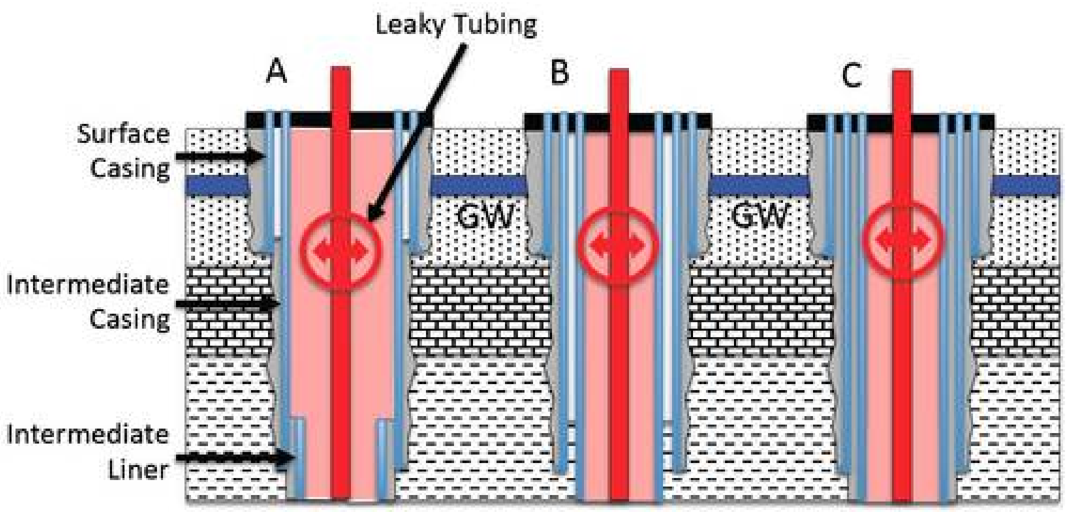

Fig. 2: Principal sketches of casing and cement in the upper part of a gas well. GW=groundwater

The casing strings overlap, especially in the upper sections of the well. Thus, multiple layers of steel and cement usually isolate groundwater-bearing zones. Several options for completion of the upper section of a well in the worst case scenario whereby the production fluid leaks through the production tubing are illustrated in Figure 2.

Steel and cement are shown to isolate the outside of the wellbore in the event of well integrity failure caused by a leaking production tubing, with option (A) showing, starting from the outer layers, cement followed by two casing strings.

The top of cement (TOC) of the surface casing is at the ground surface. Note that the TOC of the intermediate casing is some distance below the groundwater bearing rock formation. This is a standard well completion design which is often used for conventional oil and gas wells. Option (B) provides even more groundwater protection with two cement and three casing layers between the inside of the well and the outer, groundwater-rich rocks. Option (C) adds one additional barrier (cement) and thus can be classified as the strongest installation.

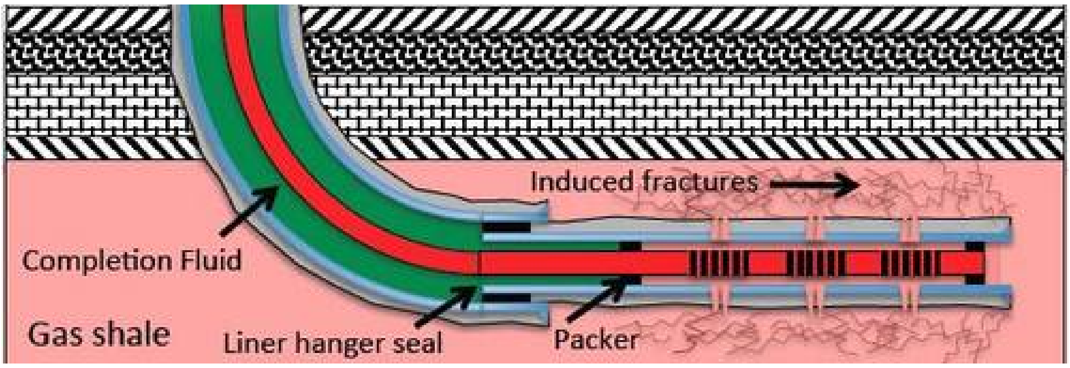

Fig. 3: Lower part of a hydraulically fractured natural gas well. The intermediate and production liners are cemented throughout, thus providing perfect zonal isolation between the inside of the well and the surrounding rocks.

Casing and cement do not only act as a barrier to fluids that flow inside the wellbore, they also prevent fluids from flowing into the annulus from outside. The isolation of the inside of the wellbore from the outer environment is generally known as zonal isolation, which is accomplished by a perfectly cemented annulus. Figure 3 shows a perfectly cemented annulus of the horizontal part of a shale gas well, allowing the fluids to flow only in the desired direction, from the induced fractures to the production tubing (Fig. 3).

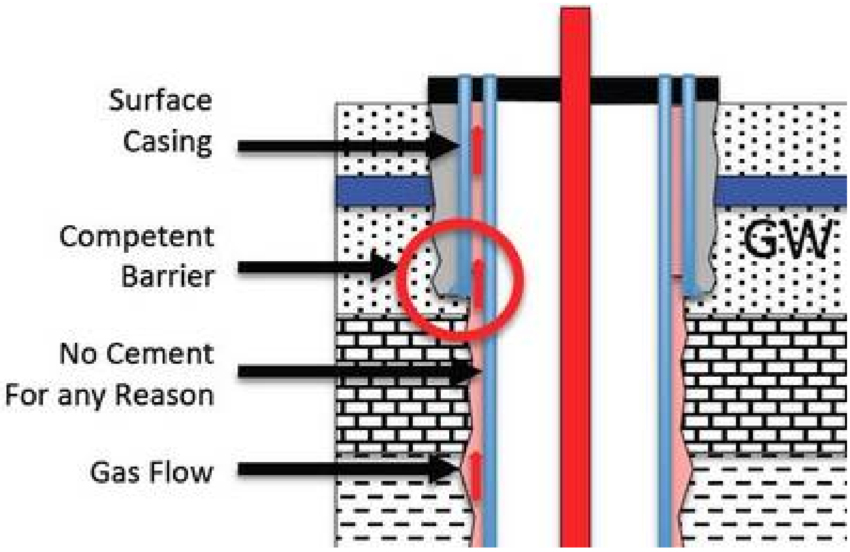

Fig. 4: Competent cement barrier at the casing shoe of the surface casing. If, for any reason, fluids rise along the annulus between the wellbore and the rock formation, the casing shoe of the adjacent casing layer will preclude further flow between rock formation and wellbore. GW=groundwater

Badly cemented sections of a wellbore might occur, especially in highly deviated and horizontal sections. This is caused by bad casing centralization or the failure to rotate long strings, among others. In the case of a badly cemented section, which might allow fluids to migrate along the annulus, the next functional barrier is (a) the liner hanger seal which prevents fluid migration to the inside of the wellbore (Fig. 3) or (b) the cemented casing shoe next to the badly cemented section (Fig 4). Both barriers effectively stop unwanted fluids from continuing to flow.

The importance of a properly cemented casing shoe is also illustrated in Figure 5. In this figure, the cement of the production section has failed and back-flow or gas can enter the annulus between casing and rock formation. However, the cemented shoe of the prior intermediate casing stops the flow of further fluid. In this case, the only way fluids can continue to flow is across a leaking production liner hanger seal. Liquids and/or gas may then accumulate inside the wellbore, between the production liner and intermediate casing. Contamination of groundwater would not occur in this case as multiple barriers of steel tubes and cement are present in the upper parts of the well.

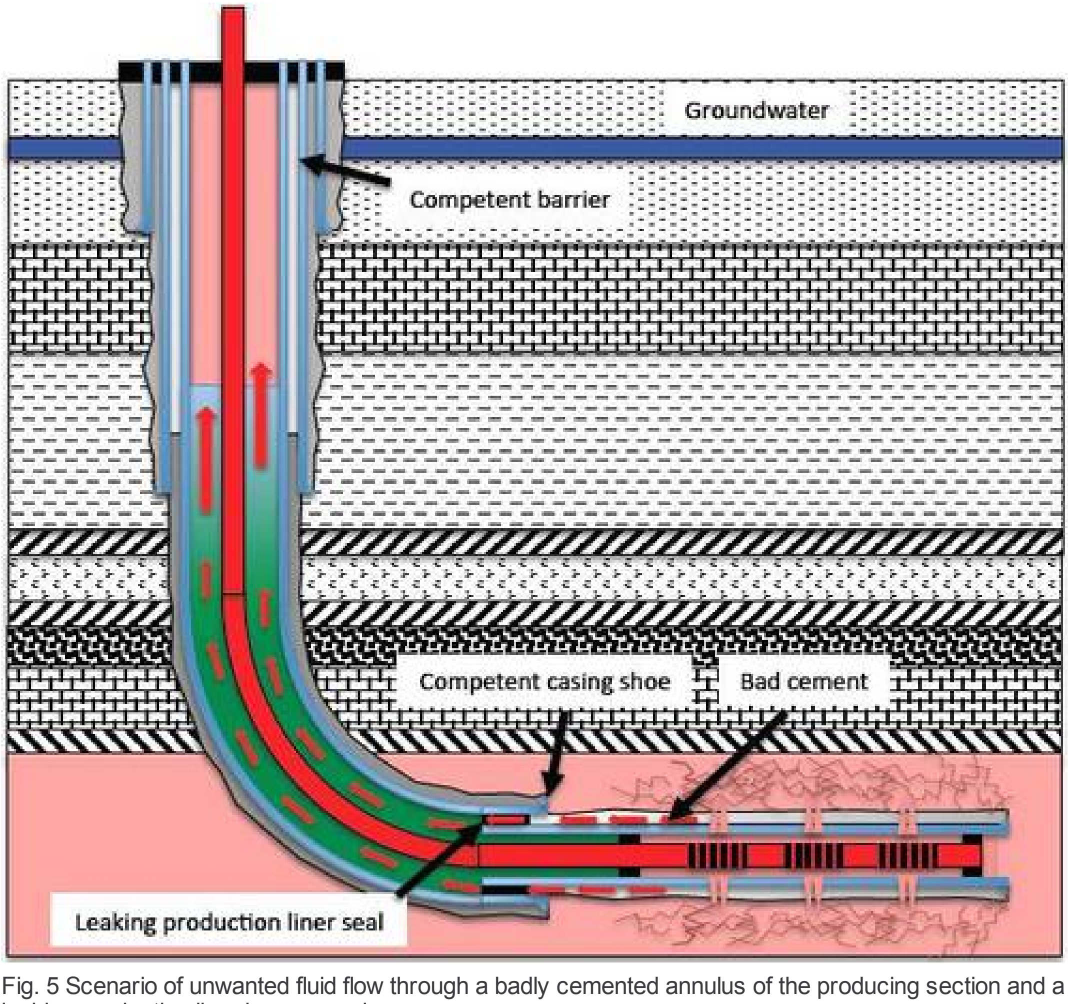

Fig. 5 Scenario of unwanted fluid flow through a badly cemented annulus of the producing section and a leaking production liner hanger seal.

A scenario in which fluids do enter the surrounding rocks is depicted in Figure 6. In this scenario the cement jobs of both the production section and the lower part of the intermediate casing have been badly carried out. Fluids can migrate along the annuli towards permeable rock formations (Fig. 6).

The worst case in these scenarios would be fluid migration along the annuli up to groundwater bearing formations. This would suggest

- that cementation is faulty all along the wellbore, from bottom to the top (Fig. 7)
- a lack of other lower pressure and permeable rock formations between the reservoir and the groundwater bearing zone.

If the latter were present, fluids would migrate into these formations and would not migrate further upwards. It has to be stated that loss of well integrity to this extent is hardly conceivable. A range of indicators for cement job quality exists which can be applied during or after individual cementing jobs of the different sections of a well. Careful consideration of these indicators accurately informs operators of the quality of the cementation between rock and steel pipes (see chapter 4). Incidents of integrity loss due to badly cemented well sections are often a result of neglecting due diligence and best practice during well construction.

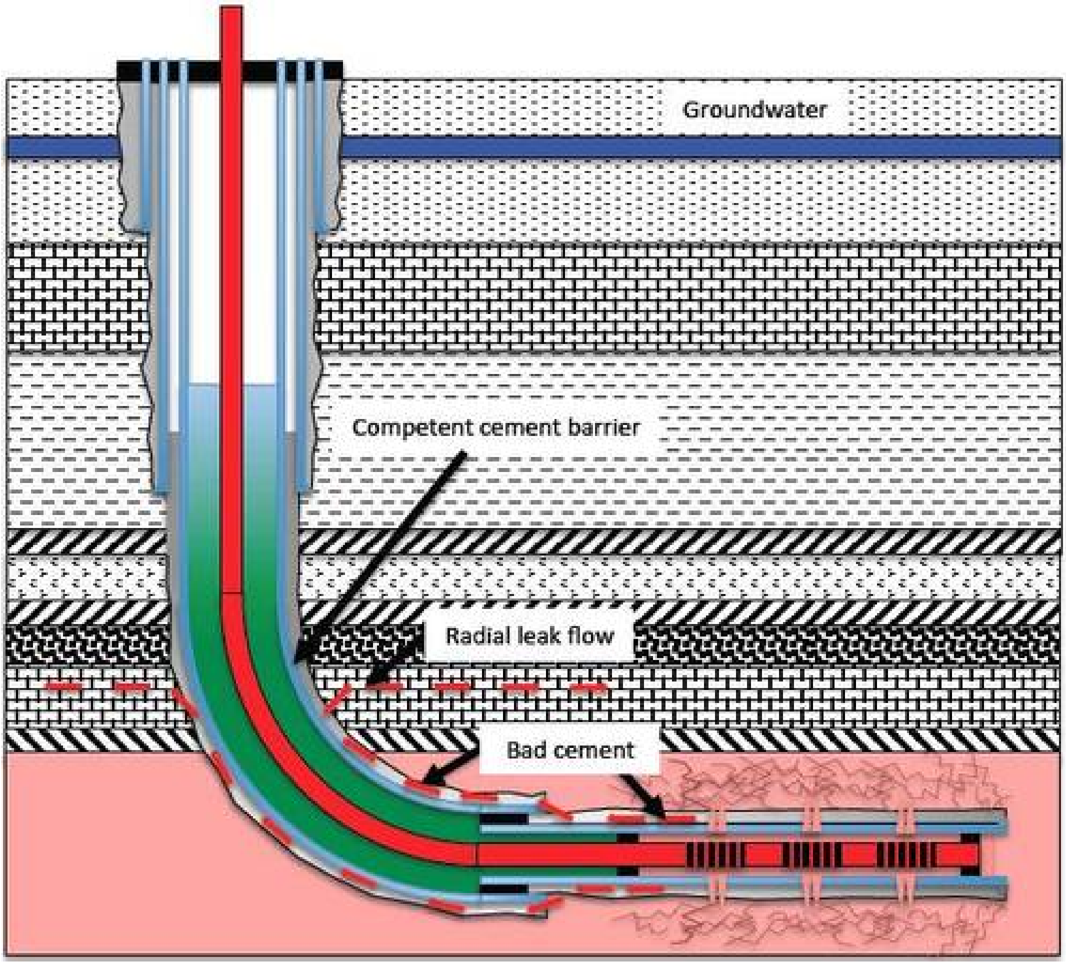

Fig. 6: Leak flow from annulus into rock formation.

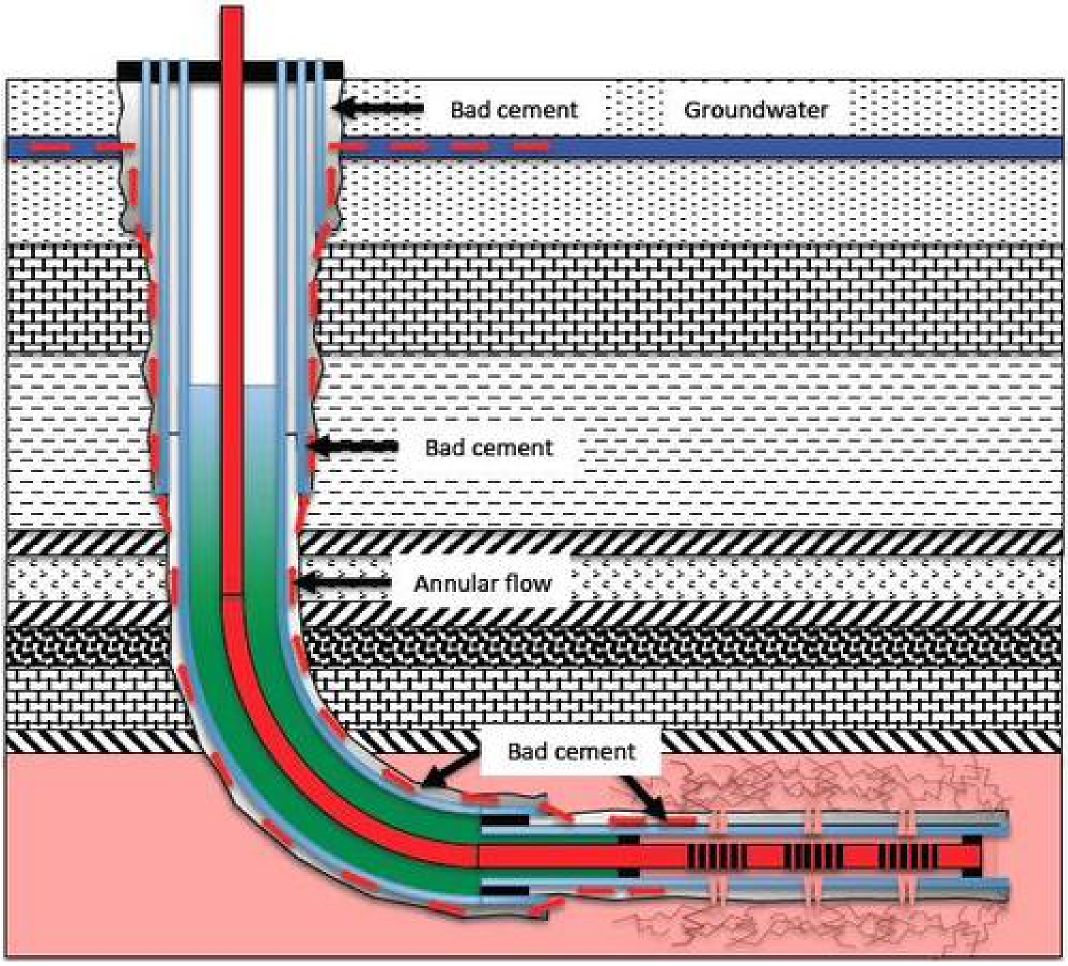

Fig. 7: Failure of all cement barriers.

Casing and Cementing Best Practices

The issue of proper wellbore casing and cementing has been widely discussed by industry and regulators for decades. Major best practices for zonal isolation are listed below, some of which are well known and some of which rely on new technical developments and experience. Many procedures specifically address groundwater protection. They apply to the cementation of all wellbore sections, although special attention must be paid to cementing the surface casing:

- Casing qualities and connections must follow minimum requirements as outlined in API Spec. 5CT.[5]
- During cementing, the best available mud displacement method to avoid mud channels must be chosen (centralize the casing, condition the borehole, reciprocate and rotate the casing and use spacers in turbulent flow).[6]
- The use of both top and bottom cementing plugs is highly recommended.[7] As the top plug is almost always used, the bottom plug is sometimes left. This is important, however, because it mechanically separates drilling mud from cement slurry inside the casing, minimizing the mixing of fluids during pumping.

- Provide thin and low permeable filter cake from the drilling fluid during the drilling phase and destroy thick filter cakes mechanically by scratchers during running of casing.[8] This will reduce the risk of later micro-annuli between cement/formation.

- Reduce cement slurry filtration (< 50ml/30min API fluid loss value) to avoid “bridging” during cement setting with the consequence of uncontrolled “take over” of hydrostatic pressure in the upper parts of the well.[9] This is of particular importance when isolating formations with higher pressure or areas with punctuated pressurized biogenic gas pockets in lower parts of the well.

- Reduce slurry chemical shrinkage to a minimum or even consider expanding cement systems to avoid micro annuli between casing/cement and improve the bonding.[10]

- Volumetric reductions of the slurry during the static transition time after cement pumping (time until the gel strength reaches 500 lb/100ft^2) could be filled in with gas, allowing subsequent bubble migration and the formation of micro channels. Slurries with low shrinkage and low filtration values, and high gel strength after pressure balance are recommended to limit bubble migration.[11]

- The use of right angle setting slurries reduces the amount of time in which gas can migrate within the unset cement.[12] Such systems are applied across high-pressure gas zones; they can develop sufficient strength to hinder gas percolation[13] (e.g. 500 lb/100ft^2) within a short period of time. Thus, gas migration stops within an acceptable distance above the gas entry point.

- The use of lightweight cements avoids cement losses in the case of weak (surface) formation.[14]Use lost circulation material if appropriate.

- The use of inflatable annular casing packers (ACP) can significantly enhance a standard cement job by providing specific points of isolation. The positioning of an ACP near a surface casing shoe would ensure a permanent pressure sea.[15]

- For surface casing applications, cement should always come to the surface, without exclusion. If cement does not appear at the surface during pumping, use parasitic pipe and cement through the annulus.[16]

- A cement bond log (CBL) should be run to determine the quality of a cement job and to plan a repair squeeze if required. Note that a sufficiently large compressive strength of cement needs to develop during a waiting time (WOC, wait on cement) before performing a CBL test and continuing with drilling operations. Typically WOC times can last up to several days. However, the general reliability of cement bond logs and a calculated cement bond index (BI) has been questioned throughout the literature since decades, e.g. Cement Bond Logging - A New Analysis to Improve Reliability, H. Gai and C. F. Lockyear, BP Research, SPE Advanced Technology Series, Vol. 2, No.1, 1994; Basic Cement Isolation Evaluation, George E. King, P.E., 18 November 2014

- The continuous bounded interval represents the length of continually good quality cement behind a casing. It depends on casing diameter and should follow recommendations[17] such as the 33 ft of continuous bounded interval for a 7-in. casing or 45 ft for a 9 5/8-in. casing (recommended by EPA, US Environmental Protection Agency).

- Once a section has been drilled, cased, and cemented, a pressure integrity test of the formation strength immediately below a casing shoe should be performed to ensure that there is an adequate seal at this location to prevent any fluid migration through the casing annulus.[18]

Risk Potential of Wellbore Integrity Failure vs. Depth

Shale formations occur at a wide range of depths throughout the world. Like in the US where Fayetteville produces from 1,200m and Haynesville from up to 4,500 m, in Europe targets occur from between 900 m and over 4,500 m. Thus, the distance between the shale gas pay zone and groundwater aquifers may vary by some hundreds of meters to several kilometers. Therefore it is necessary to distinguish between different risk potentials for the shallower and deeper cases. This is illustrated by conclusions of a study from the U.S. Department of Energy[19] where the risk of groundwater contamination resulting from zonal isolation problems after hydraulic fracturing was classified as low.

- There is often significant vertical separation between the fractured zone and groundwater zones, especially in the majority of deep shale gas plays.
- There are frequently permeable layers of rock between the fractured zone and groundwater that are capable of accepting fluid under pressure. This would lower the available fluid that could reach a groundwater zone.
- There are also frequently layers of rock between the fractured zone and groundwater zone through which vertical flow is restricted; thus serving as a hydraulic barrier to fluid migration.
- The use of advanced computer modeling in fracture design has increased the ability to predict the three dimensional geometry of fracturing; which lowers the likelihood of a fracture job extending into an unintended zone.

Usually shallow shale gas wells (900 - 1500 m) can be drilled using a minimum number of casing sections (e.g. surface, intermediate, horizontal production section). Thus, when considering wellbore integrity, the length of the cemented interval is small compared to deep wellbores and the theoretical risk of a continuous cement failure increases without a sufficient continuous bounded interval. For shallow shale gas wells, a second intermediate casing string would add another barrier to flowing fluids (compare Fig. 4 and Fig. 5).

Conclusions

1. Groundwater protection is the most important public concern among environmental issues related to shale gas field development. Therefore, the industry needs to invest further in environmentally acceptable shale gas production technologies, including the best available well construction techniques.
2. In several studies it was demonstrated that contamination of groundwater resulting from well integrity failure is very unlikely to happen when existing standards and current best practice are followed[1].

3. Contamination of groundwater resulting from well integrity failure may arise when best practices are not followed, mainly for cost reasons. However, the high risk of environmental damage and erosion of political and public acceptance is the price to pay in the mid and long term. Any groundwater accidents caused by bad well construction practices would clearly result in a heavy setback of shale gas activities and in the extreme, could lead to the abandonment of whole field development projects.

4. We suggest developing standardized guidelines for best practices during cementing jobs. Numerous individual technologies/best practices already exist, but not all are applied in a satisfactory way. Continuously updated and revised guidelines should also include an effective mechanism for monitoring compliance of operators.

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Water management options associated with the production of shale gas by hydraulic fracturing

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Published: March 14, 2012

Introduction

The grand challenge that natural gas producers must address is how to preserve the favorable economics of shale gas production while maintaining responsible stewardship of natural resources and protecting public health. The goals of the natural gas developers and the goals of those responsible for human and environmental health protection are intimately connected by water, including its use, management, and disposal.

Water Resources

The drilling and completion of wells require large quantities of water. Drilling of the vertical and horizontal components of a well may require 400 - 4000 m^3 of water for drilling fluids to maintain downhole hydrostatic pressure, cool the drillhead, and remove drill cuttings. Then, 7000 - 18,000 m^3 of water are needed for hydraulic fracturing of each well. These large volumes of water are typically obtained from nearby surface waters or pumped from a municipal source. In regions where local, natural water sources are scarce or dedicated to other uses, the limited availability of water may be a significant impediment to gas resource development.

Management of Flowback Water

TABLE 2 TYPICAL RANGE OF CONCENTRATIONS FOR SOME COMMON CONSTITUENTS OF FLOWBACK WATER FROM NATURAL GAS DEVELOPMENT IN THE MARCELLUS SHALE. THE DATA WERE OBTAINED FROM FLOWBACK WATER FROM SEVERAL PRODUCTION SITES IN WESTERN PENNSYLVANIA[1].

Constituent	Low[2] (mg/L)	Medium[2] (mg/L)	High[3] (mg/L)
Total dissolved solids	66,000	150,000	261,000
Total suspended solids	27	380	3200
Hardness (as $CaCO_3$)	9100	29,000	55,000
Alkalinity (as $CaCO_3$)	200	200	1100
Chloride	32,000	76,000	148,000
Sulfate	ND[5]	7	500
Sodium	18,000	33,000	44,000
Calcium, total[4]	3000	9800	31,000
Strontium, total	1400	2100	6800
Barium, total	2300	3300	4700
Bromide	720	1200	1600
Iron, total	25	48	55
Manganese, total	3	7	7
Oil and grease	10	18	260
Total radioactivity	ND[5]	ND	ND

1 Data compiled by Elise Barbot, University of Pittsburgh, and Juan Peng, Carnegie Mellon University

2 "Low" concentrations are from early flowback at one well. "Medium" concentrations are from late flowback at the same well for which the "low" concentrations are reported.

3 "High" concentrations are the highest concentrations observed in late flowback from several wells with similar reported TDS concentrations.

4 Total concentration = dissolved phase + suspended solid phase concentrations.

5 Not detected

Flowback of the fracturing fluid occurs over a few days to a few weeks following hydraulic fracturing, depending on the geology and geomechanics of the formation. The highest rate of flowback occurs on the first day, and the rate diminishes over time; the typical initial rate may be as high as 1000 m^3/d (GWPC and ALL Consulting 2009). The composition of the flowback water changes as a function of the time the water flowing out of the shale formation was in contact with the formation.
Minerals and organic constituents present in the formation dissolve into the fracturing water, creating

a brine solution that includes high concentrations of salts, metals, oils, greases, and soluble organic compounds, both volatile and semivolatile (Tab 2). The flowback water is typically impounded at the surface for subsequent disposal, treatment, or reuse. Due to the large water volume, the high concentration of dissolved solids, and the complex physicochemical composition of the flowback water, there is growing public concern about management of this water because of the potential for human health and environmental impacts associated with an accidental release of flowback water into the environment (Kargbo et al. 2010).

Treatment technologies and management strategies for flowback water are based on constraints established by governments, economics, technology performance, and the appropriateness of a technology for a particular water. Past experience with produced and flowback waters is used to guide developers towards treatment and management options in regions of new production (Kargbo et al. 2010). Flowback water management options for some shale plays, such as the Marcellus, are confounded by high concentrations of total dissolved solids in the flowback water, geography, geology, and a lack of physical infrastructure (Arthur et al. 2008; Kargbo et al. 2010).

Underground Injection

Most produced water from oil and gas production in the United States is disposed of through deep underground injection (Clark and Veil 2009). When underground injection is utilized, such operations are performed using Class II (disposal) underground injection control wells as defined by the U.S. Environmental Protection Agency (Veil et al. 2004).

However, the availability of adequate deep-well disposal capacity can be an important constraining factor for shale gas development. In Texas, there were over 11,000 Class II disposal wells in 2008, or slightly more than one disposal well per gas-producing well in the Barnett Shale (Tintera 2008). In contrast, the whole state of Pennsylvania has only seven Class II disposal wells available for receiving flowback water. The Marcellus Shale is a large resource that will eventually be exploited by a large number of producing wells.

Although the number of underground-injection disposal wells in Pennsylvania is expected to increase, shale gas development is currently occurring in many areas where insufficient disposal wells are available, and the construction of new disposal wells is complex, time consuming, and costly (Arthur et al. 2008). As a result, other solutions for flowback water management are necessary.

Discharge to Publicly Owned Treatment Works (POTWs) for Dilution Disposal

Although discharge and dilution of flowback water into publicly owned municipal wastewater treatment plants (POTWs) has been utilized (e.g. Penn Future 2010), this is not an adequate or sustainable approach for managing flowback water. The amount of high-TDS flowback water that can be accepted by POTWs is usually limited by regulation.

For example, in many POTWs in Pennsylvania, the amount of oil and gas wastewater must not exceed 1% of the average daily volume of waste handled by the POTW. In addition, discharge limits in Pennsylvania for TDS are set at 500 mg/L to insure the quality of the processed product. In general, the volume of flowback water that can be sent to POTWs is small compared to the volume of flowback water generated during rapid well drilling and well development.

Reverse Osmosis

Reverse osmosis (RO) is a well-known treatment method for producing drinking water and high-purity industrial water. In the RO process, water is passed through a semi-permeable membrane under pressure and a treated water of high quality is produced, along with a concentrate that requires disposal. This separation process removes material ranging from suspended particulates down to organic molecules and even monovalent ions of salt (Xu and Drewes 2006).

In trials of RO treatment of flowback water, the volume of concentrate for disposal has been reduced to as low as 20% of the initial volume of flowback water (ALL Consulting 2003). Driven by mechanical pressure, RO is energy intensive. Even with favorable energy prices, the treatment of flowback water using RO is considered to be economically infeasible for waters containing more than 40,000 mg/L TDS (Cline et al. 2009).

For high-TDS waters, vibratory shear-enhanced processing (VSEP) has been applied to membrane technologies (Jaffrin 2008). In VSEP, flat membranes are arranged as parallel discs separated by gaskets. Shear is created by vibrating a leaf element tangent to the membrane surface. The created shear lifts solids and fouling material off the membrane surface, thereby reducing colloidal fouling and polarization of the membrane (New Logic Research 2004). VSEP technology has been used successfully in the treatment of produced water from offshore oil production (Fakhru'l-Razi et al. 2009). However, the salt concentrations in offshore produced waters are far lower than those expected during shale gas extraction.

Thermal Distillation and Crystallization

The high concentrations of TDS in flowback water may limit the use of membrane technology, but such water is well suited to treatment by distillation and crystallization (Doran and Leong 2000). Distillation and crystallization are mature technologies that rely on evaporating the waste-water to separate the water from its dissolved constituents.

The vapor stream is passed through a heat exchanger to condense the gas and produce purified water. Distillation removes up to 99.5% of dissolved solids and has been estimated to reduce treatment and disposal costs by as much as 75% for produced water from shale oil development (ALL Consulting 2003). However, as with RO, distillation is an energy-intensive process.

Thermal distillation may treat flowback water containing up to, and in some cases even exceeding, 125,000 mg/L of TDS, but even the most modern technology is limited to low flow rates (300 m^3/d), necessitating the construction of large storage impoundments (Veil 2008). For example, flowback water from the Marcellus Shale gas sites can be produced at rates of 3000 m^3/d or higher.

Recent developments include using mechanical vapor-recompression systems to concentrate flowback water, which can be done at a fraction of the cost of conventional distillation because the heat of the compressed vapor is used to preheat the influent. Further water evaporation to create dry mineral crystals (i.e. crystallization) will improve water recovery and create salt products that might be reused as industrial feed stocks. Crystallization is a feasible approach for treating flowback water with TDS concentrations as high as 300,000 mg/L, but it has high energy requirements and large capital costs.

Other Treatment Options

Several other technologies have been or are being developed for treating flowback water, but each has its limitations. Falling into this category are ion exchange and capacitive deionization (Jurenka 2007), which are limited to the treatment of low-TDS water; freeze–thaw evaporation, which is restricted to cold climates; evaporation ponds, which are restricted to arid climates; and artificial wetlands and agricultural reuse (Veil et al. 2004), which are greatly limited by the salinity tolerance of plant and animal life.

On-Site Reuse for Hydraulic Fracturing

One of the most promising technologies for management of flowback water is its reuse in subsequent hydraulic fracturing operations. Flowback water is impounded at the surface and reused either directly or following dilution or pretreatment. Reuse is particularly attractive in regions where deep-well disposal options are limited or where the availability of make-up water for hydraulic fracturing is limited.

The reuse of flowback water has the benefit of minimizing the volume of such water that must be treated or disposed of and greatly reduces environmental risks while enhancing the economics of shale gas extraction. Potentially limiting factors for reuse are the chemical stability of the viscosity modifiers and other constituents of hydraulic fracture water in the brine solution and the potential for precipitation of divalent cations in the well-bore.

The effectiveness of friction reducers may be decreased at high TDS concentrations (Kamel and Shah 2009). The development of additives that retain their effectiveness in brine solutions are likely to expand the opportunity for reuse of flowback water for subsequent hydraulic fracturing. The divalent cations in the flowback water are solubilized from formation minerals and can form stable carbonate and sulfate precipitates in the wellbore if the flowback water is reinjected.

This may potentially reduce gas production from the well. In particular, barium and strontium form very low-solubility solids with sulfate, while high calcium concentrations may lead to calcite formation. Depending on the quality of the flowback water, pretreatment to reduce the divalent cation concentration by precipitation may be necessary.

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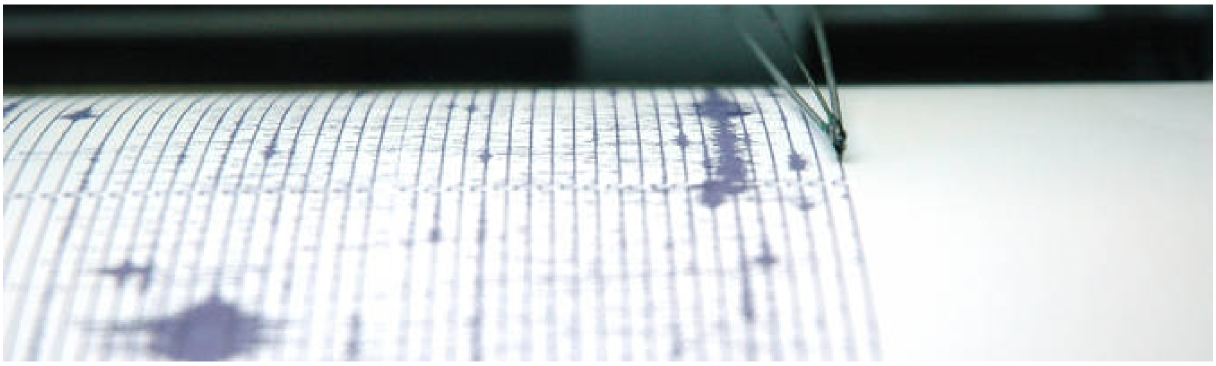
Induced Seismicity

SHIP Expert Articles



Induced seismicity once again primarily focused on disposal wells

Author: Horst Rüter

Published: October 13, 2014

The article "The 2001–Present Induced Earthquake Sequence in the Raton Basin of Northern New Mexico and Southern Colorado" (Weblink) published in October 2014 is not directly related to shale gas production but, instead, deals with seismicity created in connection with the disposal of reservoir water co-produced during coalbed methane production. However, it is of some interest here, because the origin of the disposed water does not really matter when considering seismicity in connection with disposal wells.

Disposal wells have been getting more and more attention when considering seismic risks ever since events in the Rocky Mountain Arsenal, in Denver, Colorado were reported in 1966 and experiments in the Rangley oil field in Colorado showed a clear correlation with the disposal rates. Other examples are: Prague, Oklahoma, 2011, M5.7; Youngstone, Colorado, 2011, M4.0; Paradox Valley, Colorado, M4.4; Guy-Greenbeer, Arkansas, M4.7. Research conducted in the Raton Basin adds to these already published reports.

Coal seam was produced in the Raton Basin on the border between Colorado and New Mexico, USA between 1862 and 2002. Between 2001 and today, coalbed methane (CBM) was produced, mostly from coal seams in the Raton, Vermejo and Trinidat formations at a depth of 200 to 800 meters. The production of coalbed methane always goes along with the production of a large amount of water (the article does not include the relation of the amount of gas and water), that needs to be disposed of.

In the Raton Basin, only small amounts of water can be disposed of without previous treatment (into discharge systems). Most of the water must be disposed of underground due to its chemical composition. In the Raton Basin, this is realized by means of a number of disposal wells (>20) into the Dakota formation, a conglomerate sandstone at a depth of 1,250 to 2,100 meters that is suitable for this purpose. Due to the underpressure in this formation disposal could mostly be carried out taking advantage of gravitation and without the need for additional pressure at the wellhead.

The Raton Basin does have a natural seismicity; however, only one earthquake is known to have occurred with a magnitude of >M3.8 before 2011. During the time water was disposed (2011 to today), on the other hand, there were 16 events >M3.8, the largest event on August 23, 2008, with a magnitude of M5.3. A similar increase applies for events of other orders of magnitude. The authors conduct a thorough analysis of the connection between the disposal of water and seismicity. They come to the conclusion that such a connection is hard to prove for an individual event. This would require more exact knowledge of the conditions within the seismic focus: the stress field, friction resistances, injection pressures, injection rates and injection volume as well as an exact localization of the events.

This is why the article concentrates on showing that the increase of the events as such is induced. Based on an estimated stress change of 4 kPa determined by means of a model calculation, the authors eliminate the possibility that events could already be triggered by the removal of water, because it is generally assumed that, to trigger such an event, at least 20 kPa would be necessary. It can therefore clearly be assumed that the disposal of water in the Dakota formation triggered most of the events that occurred between 2001 and today.

According to the data the authors present, the water that was disposed of and the disposal rates amount to 2 million barrels/ month (1 m^3 = 6.29 barrels). The data shows that the event rates of the earthquakes are temporally related to the disposal rates. A correlation between the magnitudes and the disposal rates or the cumulative volume of the disposed water cannot be found.

The localization of the events clearly allocates the events to the disposal wells, but also to the indicated fault systems. Here, it must be taken into account that the accuracy of the localization was initially very small (+- 15km) and only improved after a local network was put into place. For most events, a depth of 4-6 km was determined (i.e. in the bedrock). Where the depth could not be determined, a depth of 3.5 km was assumed, the disposal wells being less than 2 km deep. The authors state that there is no hydraulic connection between the Dakota formation and the bedrock, because there are several hydraulically restrictive layers in between. The authors do not see any connecting faults either, but it is obvious that the fault inventory is little known and that no information on the drilling activities of the companies was available. An explanation for if or how the events in the much deeper bedrock could be triggered by the injection of water into the sediment at the end of the slope without a hydraulic connection is not offered.

Conclusions

1. Similar to shale gas production, in coalbed methane production the disposal of co-produced water is the critical factor with regard to seismicity.
2. The event rate of the earthquakes is temporally related to the disposal rate of the water.
3. Event rates and magnitudes do not depend on the cumulative volume of the disposed water.
4. Disposal wells can also trigger events if no additional injection pressure was created.
5. With regard to the focal mechanism, it remains unclear how events in the bedrock kilometers below the formation into which water was injected can be triggered without an existing hydraulic connection.
6. In the US alone there are several thousand disposal wells in which induced seismicity did not occur. Therefore, the question why earthquakes could be triggered here over a duration of 13 years with a maximum magnitude of 5.3 without the water needing to be disposed of in a different way or a different location, remains unanswered.

Induced seismicity linked to wastewater injection is said to make up around 20% of total seismicity within the USA.

Author: Horst Rüter

Published: August 1, 2014

In an article that attracted a lot of press attention Keranen et al. (2014) take a closer look at the strong increase in seismicity in Oklahoma and therefore also in the central and eastern USA, something that has been talked about in publications for some time. The title alone [Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection] draws a connection between this increase with wastewater injection. The article describes disposal wells as ‘potentially responsible’. This also means that there is no direct link with fracking, i.e. with the stimulation of oil and gas deposits and no link with the extraction of gas and oil. Throughout the article the term ‘wastewater’ is used without stating whether this is wastewater from the oil/gas industry; however, it can be assumed that this is the case.

The authors regret that pressure data (of the injection pressures) are rarely accessible, even though only these would be able to establish a causal link between injections and seismicity. The authors use model calculations of possible spread of pressure as a substitute.

The observed quake swarms are very carefully researched and their statistical information presented. An astonishing result is that the many thousands of disposal wells in Oklahoma are almost exclusively aseismic, i.e. at least do not produce any noticeable events. Only the four wells with the highest injection rates are said to be responsible for causing 20% of the entire seismicity in the US in the years 2008 to 2014 and around 45% of seismicity (> M3) in the eastern states. The largest of these quakes (M 5,7) in 2011 near Prague, Oklahoma,is said to ‘probably’ be linked to these injections. Overall this means a 40times increase in annual seismicity compared with the years 1976 to 2007.

The article focuses on quake swarms near the town of Jones, which are therefore also called ‘Jones swarms’. For these, hydraulic model calculations are presented, with four of the main wells having 4 million barrels/month (250 l/sec) injected into them. The detailed localisation of the quake swarms shows that although these are in the neighbourhood (up to 35 km distance) of the injection wells, they are also linked to well-known fault systems like the Wilzetta Fault and the Nemaha Fault.

The reason why here in particular such extreme seismicity occurred is the coming together of high injection rates with the presence of active fault systems.Purely empirically (i.e. without considering a connection with rock mechanics) the occurrence of events is contrasted with modelled spread of pressure.This shows that even pressure increases of only 0.07 MPa (0.7 bar) can trigger an event. At least here events were localised in areas where the pressure modelling (no data were available) had exceeded this value.This value agrees well with the values mentioned elsewhere in the literature.

Summary and conclusions

1. The article does not establish a link between quakes and drilling, fracking or the extraction of unconventional gas. Given the hundreds of thousands of such activities we can continue to assume that they have little significance as the cause of induced seismicity.

2. A link between the extreme rise in seismicity in Oklahomawith wastewater injection (disposal wells) is regarded as likely.
3. Thousands of disposal wells do not cause noticeable events. The observed extreme rise in seismicity is merely due to 4 disposal wells.
4. These 4 disposal wells do not only have extremely high injection rates, they are also located in the immediate vicinity of known recently active fault systems.
5. Wastewater injection is thus generally possible without generating seismicity (many thousands of examples also in Oklahoma)
6. Disposallocations must be explored carefully paying particular attention to mapping fault systems and information about the stress field.
7. Injection tests must be conducted prior to the operational injection. Only locations with a high rate of injectivity are suitable.If these tests produce unfavourable results, the drilling must be abandoned.
8. Disposal locations must be seismologically monitored.
9. The injection must be stopped (response profile) if there is a sign of increased seismicity. The location will then be unsuitable, and the drilling has to be stopped.
10. It is difficult to see why the 4 injection wells in Oklahoma were used (or are still being used?) for so many years despite the observed extreme seismicity.

Can larger earthquakes be related to disposal wells?

Author: Horst Rüter

Published: June 19, 2014

This article by Sumy et al (2014) is particularly notable because it reports on the largest event to date related to gas extracted from the bedrock with a magnitude of M5.7. The team of authors looks at the M5.7 event in the context of a thousand other events registered during the injection phase (1993 - 2011). Of these, 110 were large enough to be evaluated in terms of hypocenter parameters and focal mechanism solutions.

The authors looked at the (temporally) neighboring events relative to the event just examined depending on when they had occurred (foreshocks or aftershocks). Within the 2011 Oklahoma sequence, the M5.7 event in November 2011 registered a foreshock of a size of M0.5 and an aftershock of a size of M5.0 in addition to many smaller events. The M5.0 foreshock, which (like all others) was located along the (200 km long) Wilzetta Fault, had previously been classified as being connected to several disposal wells operated since 1993.

The authors asked the question whether the M5.7 event could be a direct result of the M5.0 foreshock and whether this means that the classification as “induced” can also be transferred to the M5.7 event, which would make this event the largest known fluid-induced event to date. In this context, the authors examined the effect of the examined series’ earthquakes on the local stress field, which changes after each new event (coseismic stress changes). In order to be able to find out whether these stress changes could trigger a shear event, it was important to determine whether crack criteria (e.g. Coulomb criterion) were at least temporarily exceeded for a specific fault with a specified orientation. Here, the authors applied a value of 0.01 Mpa (0.1 bar) from literature sources as the sufficient additional stress value, a conservative assumption considering that the fault is critically stressed and, so to speak, “ready to go”. Relevant friction values in this context were varied in a larger range.

A very careful analysis of all events of the series that were suitable for evaluation leads to the conclusion that “M5.0 foreshocks **may** have triggered the cascading failure and thus the subsequent earthquakes along the Wilzetta Fault”.

Do induced earthquakes occur during hydraulic fracturing after all?

Author: Horst Rüter

Published: June 19, 2014

This article by Austin A. Holland (2013) is noteworthy for several reasons. It is also important for the discussion on induced seismicity in the context of the production of gas from shale gas reservoirs using hydraulic fracturing methods.

1. There are very few publications that are concerned with induced seismicity during hydraulic fracturing itself instead of with the events that occurred when disposing production water into permeable layers in the underground. The author states that "earthquakes related to hydraulic fracturing are usually very small events of magnitudes between M-1.0 and M-0.5". Larger events have only been reported once in the Bowland shale in the UK (2011). Previous cases from Oklahoma are not documented sufficiently to allow a differentiation between natural and induced events. The first case discussed there happened in Carter and Love Counties (1978), the second one again in Love County (1979). The author, considering the fact that the hydraulic fracturing technique has been applied to more than 100,000 wells in Oklahoma alone and only 3 cases in which possibly induced events were reported have occurred, summarizes: "**The percentage of hydraulically fractured wells that could trigger earthquakes is small**".
2. The small events (< M0.0) normally induced during hydraulic fracturing usually originate from the area of the cracks created during the fracturing process and are therefore also used for the mapping of crack formation. The events in South-Central Oklahoma (2011) of between M0.6 and M2.9 mentioned here occurred further away (2 km) from the well with 16 events being >M2. The earthquakes are thus not in direct mechanical contact with the created fractures that only extended to approximately 50m from the well, but can be classified as "triggered"[1]. The stress-diffusion caused by the injection of the additionally created pore pressure may very well extend this far, even within a timeframe of up to 40 hours as examined here.

There have been reports of a series of earthquakes in Oklahoma with 16 events > M2.0 that is directly related to hydraulic fracturing. It has been argued that this is because, on a timeline, the events correlate very closely with the hydraulic fracturing procedures and can also easily be classified in terms of location and depth. They are, however, not directly connected to the created hydraulic fracturing wells in terms of location. The impressed pressures of >400 bar have exceeded the 250 bar regarded sufficient for hydraulic fracturing in this area. This may be part of the reason why the pressure anomalies have extended far beyond the fractured area.

[1] Explanation concerning the terms "induced" or "triggered": Events that are not directly within the hydraulically fractured area are nowadays often described as "triggered". The term "induced" is also used as an umbrella-term and as a synonym for man-made.

Climate Impact

SHIP Expert Articles

Controversial studies on the impact of shale gas on climate

Author: Thorsten Warneke

Institute of Environmental Physics, University of Bremen

Published: October 23, 2014

Two recent articles (Howarth, R.W. (2014) and Heath et al (2014)) come to different conclusions regarding the impact of shale gas on climate. Natural gas is generally considered to be climate-friendlier than coal and oil. The reason is that natural gas emits less carbon dioxide than coal or oil. However, methane is a very potent greenhouse gas, and is the main constituent of natural gas; methane leakage during the life cycle of natural gas can potentially negate the climate benefits of natural gas compared to coal. It has been estimated that natural gas has a climate benefit compared to coal only if leakage rates are smaller than roughly 3% (Alvarez et al. estimated 3.2%, but this number has to be revised using the up-to-date global warming potentials of methane).

An article by Heath et al. harmonizes estimates of shale gas life cycle greenhouse gas emissions for electric power generation. Essentially they review existing literature on natural gas life-cycle greenhouse gas emissions and make the results comparable. Their main conclusions are that shale gas and conventionally produced natural gas have similar greenhouse gas emissions, which are approximately half of those from coal.
A second article by Howarth concludes that the life-cycle greenhouse gas emissions for natural gas are greater than those of coal or oil.

How is it that two studies with very different conclusions on the climate impact of natural gas have been published? The reason is that not enough data exist on natural gas life-cycle greenhouse gas emissions to make an ultimate conclusion. The study by Heath et al. mainly compiles estimates of greenhouse gas emissions from studies before 2012, which rely on the knowledge of greenhouse gas emissions during that time, whereas Howarth’s conclusion is based on recent studies that report large methane emissions from areas where natural gas is produced. These studies have not been considered by Heath et al. Neither of these recent studies provide sufficient evidence for a final conclusion for two reasons: either the emissions are given for large spatial areas where one cannot necessarily attribute the emissions uniquely to natural gas, or measurements are conducted on small spatial and temporal scales and it is uncertain to what extent these measurements can be extrapolated.

With an increasing number of measurements being taken over the next few years, a more robust estimate of lifecycle methane emissions from natural gas will be possible, but currently it is an open scientific question. One other point where the two studies differ is the time period considered for the warming potential. This is important because the shorter the time period, the higher the warming potential of methane compared to carbon dioxide. It would be better if future studies would consider several time scales, because of the importance for feedback in the climate system.

Measurements taken using aircraft point to high emissions during the drilling phase in the Marcellus shale formation

Author: Dr. Thorsten Warneke

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Published: May 23, 2014

The article “Towards a better understanding and quantification of methane emissions from shale gas development”, by Caulton et al., published in the Proceedings of the National Academy of Sciences in April, 2014, presents methane emission estimates deduced from measurements taken using aircraft. These measurements were conducted in southwestern Pennsylvania in the region of the Marcellus shale formation, known for its high number of shale gas exploration sites. The measurements were taken in June, 2012 over 2 days.

The authors derive a regional methane flux of 2 –14 g CH_4 s^{-1} km^{-2} over an area of 2800-km^2, which does not differ statistically from a bottom-up inventory. They found that only 1% of the wells account for 4 – 30% of the regional flux. In addition, they measured unexpected high emissions at sites that were in the drilling phase.

The conclusions of this article are based solely upon two measurement days. Due to this short time span the derived regional flux should be regarded as a snapshot and not as a representative value. The study supports the findings of previous studies, that a small number of sites are responsible for a large fraction of the flux. The new and interesting point of this study is the identification of high methane emissions from wells during the drilling phase, a period that has not up to now been known for high emissions. Emissions during this stage need to be quantified in future more comprehensive studies.

Official greenhouse gas inventories underestimate methane emissions.

Author: Dr. Thorsten Warneke

Institute of Environmental Physics, University of Bremen

Published: April 15, 2014

The article "Methane Leaks from North American Natural Gas Systems", published by Brandt et al. in the Policy Forum of the journal Science, compiles results on methane emissions from technical literature published over the last 20 years. This study represents an important piece of information in the current debate on the climate impact of natural gas. Natural gas emits less carbon dioxide during combustion than other fossil fuels, but its benefit to climate depends upon leakage rates over the well-to-consumer lifecycle. The leakage of natural gas is relevant to its impact on climate, because natural gas mainly consists of methane, a very potent greenhouse gas.

The study shows that measurements across years, scales and methods, find larger CH_4 emissions than those estimated by official inventories and that the natural gas and oil sectors are important contributors to these emissions. Among the inventories that underestimate CH_4 emissions is the greenhouse gas inventory by the U.S. Environmental Protection Agency (EPA). Measurements also suggest that a small number of sites are responsible for a large percentage of the emissions. The article states that the degree of natural gas leakage is unlikely to be large enough to negate the climate benefits of coal-to-natural gas substitution over a 100-year timescale. They say this is especially true for the power sector, but is uncertain for vehicle fuel.

The article by Brandt et al. strongly suggests that methane emission inventories have to be revised. The overall emissions from the natural gas sector are difficult to constrain by measurements however, since one cannot use the concept of a "representative" well-to-consumer lifecycle. Hence, there will be great uncertainties in any updated inventories. The uneven distribution of methane emissions from the sites lends itself to high mitigation potential through implementing better practices. Brandt et al. uses a 100-year timescale for evaluating the climate benefits of coal-to-natural gas substitution. The choice of this timescale is arbitrary and it has to be noted that for shorter timescales the climate benefit of coal-to-natural gas substitution will be smaller (or even negated), whereas for longer timescales it will be larger.

Methane emissions are underestimated by the U.S. Environmental Protection Agency (EPA)

Author: Thorsten Warneke

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Published: January 27, 2014

A recent paper by Miller et al. (2013), published in the Proceedings of the National Academy of Sciences, states that the emission of methane in the United States could be 50% higher than previously estimated. The results are based on a top-down method (see below), using an extensive set of atmospheric concentration measurements of methane for the years 2007 and 2008. The main findings of the study are:

- The U.S. Environmental Protection Agency (EPA) and the Emissions Database for Global Atmospheric Research (EDGAR) underestimate U.S. methane emissions by a factor of 1.5 and 1.7, respectively.
- Methane emissions from ruminants and manure are up to twice the magnitude of existing inventories.
- Methane emissions due to fossil fuel extraction and processing could be 4.9 ± 2.6 times larger than in the global methane inventory EDGAR.

CH_4 emissions* can be estimated from two fundamentally different methods; the “bottom-up” and the “top-down” method. The bottom up method uses various sources of information and extrapolates this information to get an emission estimate for a larger region. For example, information on emissions from natural gas wells is obtained by taking measurements from a couple of wells, and these emissions are then assumed to be representative for all wells in the country, giving a countrywide emission estimate. The top-down method uses the measurement of atmospheric concentrations to estimate the emissions from certain regions. This method provides data on cumulative emissions for relatively large regions, but does not give any information regarding the source of said emissions.

The study by Miller et al. (2013) uses the top-down method. Allowing for stated uncertainties it provides reliable estimates on regional emissions for the years 2007 and 2008. In principle the top-down method only allows for the determination of cumulative emissions from various sources over a certain region. However, the high level of regional emissions over the South Central United States area (Texas, Oklahoma, Kansas), a key region for fossil-fuel extraction and refining, would strongly suggest that these industries are responsible. This theory is also supported by measurement of propane levels. Propane is a tracer of fossil hydrocarbons and over Texas and Oklahoma good correlations with methane are observed.

Miller´s article was published just two months after a paper in PNAS by Allen et al. 2013 found that methane emissions during the pre-production and production stage of hydraulically fractured shale gas wells emitted less methane than previously. These results are not in conflict for the following two reasons: firstly Allen et al. only investigated a small part of the well-to-consumer lifecycle. Secondly there is a fundamental difference between their approaches.

Miller et al. determine the cumulative total emissions by a top-down approach. In contrast, Allen et al. use a bottom-up approach and measurements at just a few wells are used to calculate the total emissions. The bottom-up method used by Allen et al. only provides realistic emission estimates if the investigated wells are representative. If, however, a few facilities were to be responsible for a large fraction of the total emissions, this would only be captured by the top-down method (Miller et al.).

* Correctly “flux” should be used instead of “emission”. Flux includes uptake. Since uptake is not relevant in the context of natural gas production and the term “emission” is widely known, “emission” will be used in the following.

Lower methane emissions than expected at selected shale gas production sites in the U.S.

Author: Thorsten Warneke

Institute of Environmental Physics, University of Bremen

Published: October 15, 2013
Updated: October 24, 2013

Natural gas used for heat and power generation is generally regarded as climate friendlier than oil or coal. This is definitely true when only carbon dioxide emissions during the burning process are considered; but methane emissions during the complete well-to-consumer lifecycle, could potentially offset the climate benefit of natural gas. In order to fully assess the impact of natural gas on climate, a comprehensive set of measurements is needed, which does not currently exist. Ideally, the measurements would not only quantify the overall emissions, but would also identify the strength of the individual sources. The recent article by Allen et al. (2013) focuses on methane emissions during the pre-production and production stages of hydraulically fractured shale gas wells. It makes an important contribution towards a better understanding of methane emissions from natural gas, specifically for shale gas.

Methane emissions from natural gas in the U.S. and the contribution of the study by Allen et al.

The study was published in PNAS on 16 September, 2013.

According to the US Environmental Protection Agency (EPA, 2013), in 2011 natural gas systems represented the largest anthropogenic source category for methane emissions in the United States, responsible for emissions of 6893 Gg*. This amounts to about 25 % of total anthropogenic methane emissions in the US in 2011. Over the complete well-to-consumer lifecycle, the highest methane emissions from natural gas occur during the field production stage (EPA-estimate: 2545 Gg in 2011). This field production stage is targeted by Allen et al. (2013). Allen et al. (2013) mainly advance an understanding of methane emissions from completion flowbacks, equipment leaks, and pneumatic pumps and controllers. The main findings of Allen et al. (2013) are:

1. Methane emissions from well completion flowbacks are lower than expected. This is based on methane measurements from 27 events. The results show a high variability among these events, ranging from 0.01 to 17 Mg* per event, but all measurements are significantly lower than the estimate by the EPA (2013) of 81 Mg methane per event. The potential emissions from investigated wells range from 0.2 Mg to more than 1 Gg of methane. The measurements by Allen et al. showed that the actual methane emissions from all 27 completions were 98 % less than the potential emissions. This demonstrates that good practices can achieve low emissions from this important and potentially high source category.

2. The lower emissions from well completion flowbacks are partly counterbalanced by equipment leaks. In particular, the measurement of methane emissions from pneumatic devices show 60 % higher values than estimated by EPA (2013). This highlights a source

where emissions could be reduced in the future.

3. Overall the emissions measured in this study are low compared with other estimates. To compare with the EPA (2013), Allen et al. assumed that the emission factors from their work for completion flowbacks, equipment leaks, and pneumatic devices, were representative, and they calculated total annual emissions from these source categories to be 957 Gg/yr (uncertainty ±200 Gg/yr). This is slightly lower than the estimate by the EPA (2013).

Representativeness of the study and implications for the greenhouse gas balance of natural gas

The study by Allen et al. advances the understanding of methane emissions from natural gas production. It is an important contribution towards the better understanding of methane emissions from natural gas, but for an overall assessment of the greenhouse gas balance, additional studies are needed for the following reasons:

1. The source categories addressed by Allen et al. represent potentially very strong emissions sources in the shale gas production chain. The emissions from these sources are controversial and the measurements by Allen et al. provide the most comprehensive dataset that currently exists. To ascertain the overall climate balance, natural gas methane emissions from all stages in the well-to-consumer lifecycle need to be quantified. Despite their importance, however, the source categories addressed by Allen et al. make up roughly only 17 % of the total emissions from natural gas systems in the U.S. (EPA-estimate, EPA, 2013).
2. The U.S. natural gas system encompasses hundreds of thousands of wells (EPA, 2013). It is questionable if the measurements by Allen et al. can be regarded as representative for all these sites. The companies involved in this study were aware of the measurements and most likely applied good practices. Nevertheless, the measurements definitely show that emissions from the investigated source categories do not have to be high, if good practices are applied.

*Gg = Gigagram = 1000 tonne
*Mg = Megagram = 1 tonne

Note: Correction of the conflict of interest statement

About 3 weeks after publication of the article "Measurements of methane emissions at natural gas production sites in the United States" the authors corrected their conflict of interest statement. The new statement shows links between the authors and the gas industry. The correction of the conflict of interest statement is available here.

A documentation of studies on the greenhouse gas balance of shale gas

Author: Andreas Hübner

GFZ German Research Centre for Geosciences, Potsdam, Germany

Published: March 14, 2012
Updated: April 29, 2015

Introduction

Many studies have examined greenhouse gas (GHG) emissions from shale gas production and their possible impact on climate. The methodologies and assumptions of these studies differ, and have resulted in various conclusions on the potential emissions. Most studies explicitly state great uncertainty in some, or many, of their assumptions.

The GHG balance of shale gas has to take into account all GHG air emissions related to the production, transportation, and end-use of shale gas. GHG emissions related to end-use, i.e. electricity generation in gas-fired power plants, are reasonably well constrained and may be readily compared to other fossil fuels or renewables.

Production-related GHG emissions are much less well constrained and include: emissions from roads and well-pad construction; from diesel engines and compressors deployed during drilling and hydraulic fracturing; from well completion; and from venting/flaring during and after flowback. There is a strong variance in the quality of emission data on the production of shale gas, and also a variance in flow rate uncertainties and well lifetimes, and therefore in the eventual production volumes of individual shale gas plays.

2015

The impact of shale gas on the costs of climate policy

Kersting et al., 2015, report commissioned by German Federal Environment Agency

Abstract: "This report investigates the effects of an increased exploitation of shale gas reserves around the globe and the extent to which it can serve as a low-cost GHG mitigation option. We compare a scenario of global shale gas exploitation with a scenario in which shale gas use is very limited. Both scenarios are modelled with the global techno-economic POLES model and rely on a high regional disaggregation. The effects of shale gas production on the energy market and, consequently, on GHG emissions are analysed in a baseline case without additional climate policy and for mitigation targets compatible with the 2°C target. We find that shale gas should not be considered a cheap option to reduce global GHG emissions due to three reasons: the effects of global shale gas availability (a) are small in the short-term, (b) lead to higher baseline GHG emissions for most countries in the long-term due to lower energy prices and (c) result in higher costs of compliance with climate targets. Further, shale gas competes with renewable energy sources resulting in smaller cost reductions for renewable energy technologies. Lower energy prices also reduce the payoffs for energy efficiency measures, leading to shortened investment in such measures."

Allocating Methane Emissions to Natural Gas and Oil Production from Shale Formations
Zavala-Araiza et al., 2015

Abstract: "In this work, life cycle allocation methods have been used to assign methane emissions from production wells operating in shale formations to oil, condensate, and gas products from the wells. The emission allocations are based on a data set of 489 gas wells in routine operation and 19 well completion events. The methane emissions allocated to natural gas production are approximately 85% of total emissions (mass based allocation), but there is regional variability in the data and therefore this work demonstrates the need to track natural gas sources by both formation type and production region. Methane emissions allocated to salable natural gas production from shale formations, based on this work, are a factor of 2 to 7 lower than those reported in commonly used life cycle data sets."

2014

Methane leaks from North American natural gas systems
Brandt et al., 2014

From the abstract: "Natural gas (NG) is a potential “bridge fuel” during transition to a decarbonized energy system: It emits less carbon dioxide during combustion than other fossil fuels and can be used in many industries. However, because of the high global warming potential of methane (CH_4, the major component of NG), climate benefits from NG use depend on system leakage rates. Some recent estimates of leakage have challenged the benefits of switching from coal to NG, a large near-term greenhouse gas (GHG) reduction opportunity (1–3). Also, global atmospheric CH_4 concentrations are on the rise, with the causes still poorly understood (4). [....], we review 20 years of technical literature on natural gas emissions in the United States and Canada."

The authors conclude that "if natural gas is to be a “bridge” to a more sustainable energy future, it is a bridge that must be traversed carefully: Diligence will be required to ensure that leakage rates are low enough to achieve sustainability goals."

See **SHIP article**: "Official greenhouse gas inventories underestimate methane emissions" (Link)

Toward a better understanding and quantification of methane emissions from shale gas development
Caulton et al., 2014

From the abstract: "An instrumented aircraft platform was used to identify large sources of methane and quantify emission rates in southwestern PA in June 2012. A large regional flux, 2.0–14 g CH_4 s^{-1} km^{-2}, was quantified for a ∼2,800-km^2 area, which did not differ statistically from a bottom-up inventory, 2.3–4.6 g CH_4 s^{-1} km^{-2}. Large emissions averaging 34 g CH_4/s per well were observed from seven well pads determined to be in the drilling phase, 2 to 3 orders of magnitude greater than US Environmental Protection Agency estimates for this operational phase. The emissions from these well pads, representing ∼1% of the total number of wells, account for 4–30% of the observed regional flux. More work is needed to determine all of the sources of methane emissions from natural gas production, to ascertain why these emissions occur and to evaluate their climate and atmospheric chemistry impacts."

See **SHIP article** "Measurements taken using aircraft point to high emissions during the drilling phase in the Marcellus shale formation" (Link)

Harmonization of initial estimates of shale gas life cycle greenhouse gas emissions for electric power generation
Heath et al., 2014

From the abstract: "Through a meta-analytical procedure we call harmonization, we develop robust, analytically consistent, and updated comparisons of estimates of life cycle GHG emissions for electricity produced from shale gas, conventionally produced natural gas, and coal. On a per-unit electrical output basis, harmonization reveals that median estimates of GHG emissions from shale gas-generated electricity are similar to those for conventional natural gas, with both approximately half that of the central tendency of coal."

See **SHIP article** "Controversial studies on the impact of shale gas on climate" (Link)

Life cycle greenhouse gas emissions from Barnett shale gas used to generate electricity
Heath et al., 2014

From the abstract: "The data sources and approach used in this study differ significantly from previous efforts. The authors used inventories from the year 2009 tracking emissions of regulated air pollutants by the natural gas industry in the Barnett Shale play. [....] These data cover the characteristics and volatile organic compound (VOC) emissions of more than 16,000 individual sources in shale gas production and processing. Translating estimated emissions of VOCs into estimates of methane and carbon dioxide emissions was accomplished through the novel compilation of spatially heterogeneous gas composition analyses. Life cycle greenhouse gas emissions associated with electricity generated from Barnett Shale gas extracted in 2009 were found to be very similar to conventional natural gas and less than half those of coal-fired electricity generation."

Highlights (as presented on the article website):

- Central estimate for 2009 Barnett Shale life cycle GHG emissions is 440 g CO2e/kWh.
- Life cycle GHG emissions vary by well lifetime production, 420–510 g CO2e/kWh.
- The vast majority of GHG emissions are not affected by the type or origin of gas.
- Methane leakage comes mostly from potentially controllable sources.
- Gas composition variability can affect GHG estimation at fine spatial resolution.

A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas
Howarth, 2014

From the abstract: "The best data available now indicate that our estimates [Howarth et al., 2011] of methane emission from both shale gas and conventional natural gas were relatively robust. Using these new, best available data and a 20-year time period for comparing the warming potential of methane to carbon dioxide, the conclusion stands that both shale gas and conventional natural gas have a larger GHG than do coal or oil, for any possible use of natural gas and particularly for the primary uses of residential and commercial heating."

See **SHIP article** "Controversial studies on the impact of shale gas on climate". (Link)

Mitigation of climate impacts of possible future shale gas extraction in the EU: available technologies, best practices and options for policy makers

ICF, 2014, report for European Commission, DG Climate Action

From the Executive Summary: "The specific objectives of the study are to analyse international experiences in minimising onsite fugitive GHG emissions to identify lessons and best practices; to provide an overview of the most advanced technologies and practices that could be promoted or enforced for minimizing these emissions; to provide an overview of different policy options for a possible regulatory framework for minimizing these emissions and to analyse the climate, environmental and economic impacts of key policy options."

Implications of Shale Gas Development for Climate Change

Newell and Raimi, 2014

From the abstract: "Most evidence indicates that natural gas as a substitute for coal in electricity production, gasoline in transport, and electricity in buildings decreases greenhouse gases, although as an electricity substitute this depends on the electricity mix displaced. Modeling suggests that absent substantial policy changes, increased natural gas production slightly increases overall energy use, more substantially encourages fuel-switching, and that the combined effect slightly alters economy wide GHG emissions; whether the net effect is a slight decrease or increase depends on modeling assumptions including upstream methane emissions. Our main conclusions are that natural gas can help reduce GHG emissions, but in the absence of targeted climate policy measures, it will not substantially change the course of global GHG concentrations. Abundant natural gas can, however, help reduce the costs of achieving GHG reduction goals."

Life cycle environmental impacts of UK shale gas

Stamford and Azapagic, 2014

The authors make "a first attempt at quantifying a range of overall lifecycle impacts of shale gas production in the UK. The results suggest that the impacts range widely, depending on the assumptions. It is suggested that shale gas is comparable or superior to conventional gas and low-carbon technologies for depletion of abiotic resources, eutrophication, and freshwater, marine and human toxicities.

Conversely, it has a higher potential for creation of photochemical oxidants (smog) and terrestrial toxicity than any other option considered. For acidification, shale gas is a better option than coal power but an order of magnitude worse than the other options. The impact on ozone layer depletion is within the range found for conventional gas, but nuclear and wind power are better options still.

The results of this research highlight the need for tight regulation and further analysis once typical UK values of key parameters for shale gas are established, including its composition, recovery per well, fugitive emissions and disposal of drilling waste."

Westaway et al., 2015 Comment on 'Life cycle environmental impacts of UK shale gas' by L. Stamford and A. Azapagic. Applied Energy, 134, 506–518, 2014

Link to Final Draft of the article.

The authors conclude: "Overall, we consider that through their combination of tacitly assuming that dirty environmental practices that are already illegal in the EU and UK will nevertheless be followed there, and their emphasis on worst-case scenarios in which wells are assumed to yield unrealistically low amounts of shale gas, Stamford and Azapagic have seriously exaggerated the potential environmental impact of a future UK shale gas industry."

2013

Measurements of methane emissions at natural gas production sites in the United States
Allen et al., 2013

This article focuses on methane emissions during the pre-production and production stages of hydraulically fractured shale gas wells. A main finding is that methane emissions from well completion flowbacks are significantly lower than the estimate in a report from U.S. EPA (2013). Methane emissions from pneumatic devices, however, were 60 % higher than estimated by U.S. EPA (2013). The authors make an important contribution towards a better understanding of methane emissions from natural gas production, and specifically for shale gas operations, towards a more general assessment of the greenhouse gas balance of the natural gas sector. A comment on the study on the SHIP website points out that more data are needed and that the published data from this study are not representative. Additionally, the sampling policy for this study has been critizised.

See **SHIP article** "Lower methane emissions than expected at selected shale gas production sites in the U.S." (Link)

Methane emissions estimate from airborne measurements over a western United States natural gas field.
Karion et al., 2013

Full Text

Abstract: "Methane (CH_4) emissions from natural gas production are not well quantified and have the potential to offset the climate benefits of natural gas over other fossil fuels. We use atmospheric measurements in a mass balance approach to estimate CH_4 emissions of $55 \pm 15 \times 10^3$ kg h^{-1} from a natural gas and oil production field in Uintah County, Utah, on 1 day: 3 February 2012. This emission rate corresponds to 6.2%–11.7% (1σ) of average hourly natural gas production in Uintah County in the month of February. This study demonstrates the mass balance technique as a valuable tool for estimating emissions from oil and gas production regions and illustrates the need for further atmospheric measurements to determine the representativeness of our single-day estimate and to better assess inventories of CH_4 emissions."

Life cycle greenhouse gas emissions and freshwater consumption of Marcellus shale gas
Laurenzi and Jersey, 2013

Abstract: "We present results of a life cycle assessment (LCA) of Marcellus shale gas used for power generation. The analysis employs the most extensive data set of any LCA of shale gas to date, encompassing data from actual gas production and power generation operations. Results indicate that a typical Marcellus gas life cycle yields 466 kg CO2eq/MWh (80% confidence interval: 450–567 kg CO2eq/MWh) of greenhouse gas (GHG) emissions and 224 gal/MWh (80% CI: 185–305 gal/MWh) of freshwater consumption. Operations associated with hydraulic fracturing constitute only 1.2% of the life cycle GHG emissions, and 6.2% of the life cycle freshwater consumption. These results are influenced most strongly by the estimated ultimate recovery (EUR) of the well and the power plant efficiency: increase in either quantity will reduce both life cycle freshwater consumption and GHG emissions relative to power generated at the plant. We conclude by comparing the life cycle impacts of Marcellus gas and U.S. coal: The carbon footprint of Marcellus gas is 53% (80% CI: 44–61%) lower than coal, and its freshwater consumption is about 50% of coal. We conclude that substantial GHG reductions and freshwater savings may result from the replacement of coal-fired power generation with gas-fired power generation."

Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use

MacKay and Stone, 2013

This study gathers available evidence on the potential greenhouse gas emissions (GHG) from shale gas production and use in the UK and discusses the compatibility of shale gas production and use with UK and global climate change targets.

Main findings about the carbon footprint of shale gas are, among others: The carbon footprint (emissions intensity) of shale gas extraction and use is likely to be in a range which makes it comparable to gas extracted from conventional sources. When shale gas is used for electricity generation, its carbon footprint is likely to be significantly lower than the carbon footprint of coal.

Extraction and use of shale gas does produce emissions, and therefore the authors conclude that any increase in emissions associated with domestic shale gas operations would have to be offset by emissions cuts elsewhere in the economy, if UK's carbon budgets are binding constraints. With regard to global GHG emissions rates and cumulative emissions, the authors state that the production of shale gas could increase global cumulative GHG emissions if the fossil fuels displaced by shale gas are used elsewhere. The potential increase could be counteracted if equivalent and additional emissions-reduction measures are made. Recommendations given include the use of the best available technology, careful monitoring programs, and research into improved technologies.

Anthropogenic emissions of methane in the United States

Miller et al., 2013

From the abstract: "Existing state regulations in California and Massachusetts require ~15% greenhouse gas emissions reductions from current levels by 2020. However, government estimates for total US methane emissions may be biased by 50%, and estimates of individual source sectors are even more uncertain. This study uses atmospheric methane observations to reduce this level of uncertainty. We find greenhouse gas emissions from agriculture and fossil fuel extraction and processing (i.e., oil and/or natural gas) are likely a factor of two or greater than cited in existing studies. Effective national and state greenhouse gas reduction strategies may be difficult to develop without appropriate estimates of methane emissions from these source sectors."

See **SHIP article** "Methane emissions are underestimated by the U.S. Environmental Protection Agency (EPA)" (Link)

A Dilemma of Abundance: Governance Challenges of Reconciling Shale Gas Development and Climate Change Mitigation

Stephensons and Shaw, 2013

The authors argue that governance challenges are both more pressing and more profound as compared to the technical feasibility of reconciling shale gas development with climate action. It is pointed out that policy measures prove challenging, particularly in jurisdictions that stand to benefit economically from unconventional fuels. This dilemma is illustrated through a case study of shale gas development in British Columbia, Canada, a global leader on climate policy that is nonetheless struggling to manage gas development for mitigation.

Methane leaks erode green credentials of natural gas

Tollefson, 2013

This editorial in Nature magazine summarizes the current scientific debate on fugitive emissions of the natural gas industry. It includes reports on high methane leakage rates, measured at natural gas fields in the US, which were presented at an American Geophysical Union (AGU) meeting in December, 2012. “Whether the high leakage rates claimed in Colorado and Utah are typical across the US natural-gas industry remains unclear. The NOAA data represent a “small snapshot” of a much larger picture that the broader scientific community is now assembling”, says Steven Hamburg, chief scientist at the Environmental Defense Fund (EDF) in Boston, Massachusetts.

2012

Greater focus needed on methane leakage from natural gas infrastructure

Alvarez et al., 2012

This study addresses the potential climate implications of an increased use of natural gas (conventional and unconventional) in the U.S., instead of coal or oil in different sectors (e.g., electricity generation and transportation). Results show that using natural gas instead of coal in electric power plants can reduce radiative forcing immediately, and reducing CH_4 losses from the production and transportation of natural gas would produce even greater benefits.

The article includes a discussion on the upstream GHG emissions of shale gas. The authors explain that their "... conclusion that natural gas produces net climate benefits relative to certain types of coal reaches the opposite conclusion of Howarth et al. [2011] for three principal reasons. The main difference is that Howarth et al. [2011] assume much greater methane emissions than we do. As described above, we estimate that 2.1% of natural gas produced is lost annually between the well and the power plant (including the local distribution system, we estimate that the natural gas emitted is 2.4% of gross natural gas production). Howarth et al. [2011] used a range of 3.6–7.9% for shale gas and 1.7–6.0% for conventional gas (as a percentage of the CH_4 produced over the lifecycle of a well—also a different metric than we used)."

Has US Shale Gas Reduced CO_2 Emissions?

Broderick and Anderson, 2012

This report from the Tyndall Centre for Climate Change Research calls for a meaningful cap on global carbon emissions in order to take full advantage of the potential benefits from a coal-to-gas switch in power generation.

The authors examine the recent emissions savings in the US power sector, influenced by shale gas, and the concurrent trends in coal exports that may increase emissions in Europe and Asia.

“US CO_2 emissions from domestic energy have declined by 8.6% since a peak in 2005, the equivalent of 1.4% per year. Part of this decline is related to the switch from coal to gas in US power generation.

During this time, there has been a substantial increase in coal exports from the US (2008-2011) and globally, coal consumption has continued to rise. The calculations presented in the report suggest that more than half of the emissions avoided in the US power sector may have been exported as coal."

The report states that "... without a meaningful cap on global carbon emissions, the exploitation of shale gas reserves is likely to increase total emissions. For this not to be the case, consumption of displaced fuels must be reduced globally and remain suppressed indefinitely; in effect displaced coal must stay in the ground."

Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum.

Burnham et al., 2012

This study discusses the key sources of GHG emissions in conventional and shale gas, as well as in coal and petroleum, to estimate the level of GHG emissions and to understand the uncertainties involved in calculating their life-cycle GHG impacts. Current data gaps are identified and discussed. Life-Cycle Analysis results show "… that shale gas life-cycle emissions are 6% lower than conventional natural gas, 23% lower than gasoline, and 33% lower than coal." The sensitivity analysis shows that estimated ultimate recovery of gas wells contributes the most uncertainty to the shale gas model results.

Assessing the greenhouse impact of natural gas

Cathles, 2012

This study investigates the impact of a coal-to-gas switch on global warming and concludes that "the substitution of natural gas for coal and some oil would realize ~40% of the greenhouse benefits that could be had by replacing fossil fuels with low carbon energy sources such as wind, solar, and nuclear." This estimate however, will only be reached when methane leakage in natural gas production is further reduced in the future, below todays level.

Cathles discusses published leakage rates of natural gas production, as these are a major input parameter in his calculations. Especially he argues that the leakage rate estimated by Howarth et al. (2011) is about five times higher than published results, thereby challenging their conclusions that the climate impact of shale gas might be worse than that of coal.

A commentary on "The greenhouse-gas footprint of natural gas in shale formations" by R.W. Howarth, R. Santoro, and Anthony Ingraffea.

Cathles et al., 2012

These authors criticized the assumptions made by Howarth et al. 2011: "... they significantly overestimate the fugitive emissions associated with unconventional gas extraction, undervalue the contribution of "green technologies" to reducing those emissions to a level approaching that of conventional gas, base their comparison between gas and coal on heat rather than electricity generation (almost the sole use of coal), and assume a time interval over which to compute the relative climate impact of gas compared to coal that does not capture the contrast between the long residence time of CO_2 and the short residence time of methane in the atmosphere." These authors concluded that "Using more reasonable leakage rates and bases of comparison, shale gas has a GHG footprint that is half and perhaps a third that of coal."

Climate impact of potential shale gas production in the EU

Forster and Perks, 2012

Report for European Commission DG CLIMA

From the Executive Summary:

"A hypothetical analysis has been carried out of the potential lifecycle GHG [greenhouse gas] emissions that may arise from shale gas exploitation within Europe. In our base case, which does not represent a preferred scenario, we have estimated the GHG emissions per unit of electricity generated from shale gas to be around 4% to 8% higher than for electricity generated by conventional pipeline gas from within Europe."

"These additional emissions arise in the pre-combustion stage, predominantly in the well completion phase when the fracturing fluid is brought back to the surface together with released methane. If emissions from well completion are mitigated, through flaring or capture, and utilized then this difference is reduced to 1% to 5%. This finding is broadly in line with those of other U.S. studies which found that generation from shale gas had emissions about 2% to 3% higher than conventional pipeline gas generation."

The report also provides a review of the current legislative framework in the EU for the control of GHG emissions from shale gas operations. Additionally, the report examines the current GHG emissions reporting framework and explores the extent to which emissions from shale gas operations would be captured within the existing reporting requirements.

Venting and leaking of methane from shale gas development: response to Cathles et al.

Howarth et al., 2012

In a response to the above comment, Howarth et al. 2012 stood by their approach and findings: "… we conclude that for most uses, the GHG footprint of shale gas is greater than that of other fossil fuels on time scales of up to 100 years. When used to generate electricity, the shale-gas footprint is still significantly greater than that of coal at decadal time scales but is less at the century scale. We reiterate our conclusion from our April 2011 paper that shale gas is not a suitable bridge fuel for the 21st Century."

Effects of New Fossil Fuel Developments on the Possibilities of Meeting 2°C Scenarios

Meindertsma and Block, 2012

This report, commissioned by Greenpeace International, investigates the impact of new fossil fuel production on mankind´s ability to mitigate climate change. New fossil fuels include tar sands and shale gas, fossil fuels from remote locations, and fossil fuels with a very large increase in production in the near future.

The report concludes that "...in a scenario where the new fossil fuels are developed, we need to embark on a rapid emission reductions pathway at the latest in 2019 in order to meet the 50% probability carbon budget. Avoiding the development of new fossil fuels will give us until 2025 to start further rapid emission reductions."

Shale gas production: potential versus actual greenhouse gas emissions
O'Sullivan and Paltsev, 2012

The findings of this study reiterate what many recent studies have suggested; greenhouse gas (GHG) emissions of shale gas wells are slightly, and not extensively, higher than the emissions of conventional natural gas wells. The MIT - Massachusetts Institute of Technology authors calculate that the total fugitive GHG emissions from U.S. shale gas related hydraulic fracturing in 2010 represent 3.6% of the estimated fugitive emissions from all natural gas production-related sources in that year. They state that, "… the production of shale gas and specifically, the associated hydraulic fracturing operations, have not materially altered the total GHG emissions from the natural gas sector. At the same time the authors state that, "… fugitive emissions from the overall natural gas sector are a proper concern".

Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study
Pétron et al., 2012

The authors "... focus on describing and interpreting the measured variability in CH_4 and C3–5 alkanes observed in the Colorado Northern Front Range. We use data from daily air samples collected at a NOAA tall tower located in Weld County as well as continuous CH_4 observations and discrete targeted samples from an intensive mobile sampling campaign in the Colorado Northern Front Range."

The study suggests that methane emissions from natural gas production may be much higher than indicated by industry data and some of the recently published studies.

The paper by Pétron et al. was questioned and an alternative data interpretation was provided by**Levi, 2012**: Comment on "Hydrocarbon emissions characterization in the Colorado Front Range—A pilot study (Link to Final Draft of the paper)

Reply to Levis´ comment by **Pétron et al., 2013**: Reply to comment on "Hydrocarbon emissions characterization in the Colorado Front Range—A pilot study" by Michael A. Levi

Levi, 2013: Reply to "Reply to 'Comment on "Hydrocarbon emissions characterization in the Colorado Front Range – A Pilot Study"' by Michael A. Levi" by Gabrielle Pétron et al. (Link to Final Draft of the paper)

Air Sampling Reveals High Methane Emissions from Natural Gas Field.
Tollefson, 2012

This article briefly reviews the current debate on methane emissions as of February 2012 and features a new study from Pétron et al. (2012) (see above) which suggests that methane emissions from natural gas production may be much higher than indicated by industry data and some of the recently published studies.

Results are based on analyzed air samples from a region where hydraulic fracturing of gas wells is applied at large scale. According to Tollefson, the strength of the study by Pétron et al. is that it uses independent, original data and not data from industry reports or conceptual models. Interpretation of these data is, as usual, based on assumptions and models, however, and the authors readily point out substantial uncertainties in their calculations.

“Pétron says that more studies are needed using industry inventories and measurements of atmospheric concentrations. “We will never get the same numbers,” she says, “but if we can get close enough that our ranges overlap in a meaningful way, then we can say we understand the process.””

Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications
Weber and Clavin, 2012

These authors review several recent studies of the shale gas carbon footprint and provide a Monte Carlo uncertainty analysis of the footprint of both shale and conventional natural gas production. The results show that the most likely upstream carbon footprints of both types of gas production are largely similar.

The study also modeled an alternative scenario that provides for the use of RECs (Reduced Emissions Completions), as regulated for in future U.S. shale gas wells by the U.S. Environmental Protection Agency (EPA). This resulted in a substantial reduction of both the mean shale gas upstream carbon footprint and the uncertainty range.

The authors emphasize that the upstream carbon footprint represents less than 25% of the total carbon footprint of natural gas. When identifying emission reduction opportunities in the energy and transportation sector, it is of equal or greater importance that the efficiency of producing heat, electricity and other functions is considered.

2011

Methane and the greenhouse-gas footprint of natural gas from shale formations.
Howarth et al., 2011

This was the first study published on that topic in peer-reviewed literature. It gained a lot of public attention, partly due to its novelty, but foremost because it challenged the belief that natural gas is the cleanest of all fossil fuels in terms of GHG emissions. This had up until then been taken for granted. The authors argued that GHG emissions during shale gas production may be so high that the climate impact of natural gas from shale could be as bad, or even worse, than that of coal. The authors pointed out great uncertainties in some crucial model input data, however, and concluded that further studies with better input data would be needed.

The industry-sponsored ‘Energy-In-Depth’ group have in turn presented a critical appraisal, a collection of challenging reactions to this study, and documentation of subsequent studies with more positive conclusions on shale gas GHG balances. Howarth and his co-workers defend their positions with updated background information and FAQs here.

The greenhouse impact of unconventional gas for electricity generation.
Hultmann et al., 2011

Concerning methodology, the authors point out uncertainties due to the scarcity of reliable data on fugitive emissions from unconventional gas production and the lack of documentation of the equipment and practices most commonly used by these wells. They also elaborate on the selection criteria of Global Warming Potential time horizons and calculation factors and discuss the assumptions made by Howarth et al. 2011.

Taking into account the uncertainties, this study draws the conclusion “... that for electricity generation the GHG impacts of shale gas are 11% higher than those of conventional gas, and only 56% that of coal for standard assumptions."

The authors estimate that due to the future increased application of available and new technologies in shale gas development, the GHG balance of shale gas may be substantially improved and the difference between this and the impact of coal will continually widen. For this reason, the study recommends that “... any regulatory standard that classifies conventional gas as a source of ‘clean energy’ should therefore consider shale gas in this context; arguments that shale gas is more polluting than coal are largely unjustified.”

Life cycle greenhouse gas emissions of Marcellus shale gas.

Jiang et al., 2011

Looking specifically at Marcellus shale gas production, the authors identify emissions from well completion to be the largest source of GHG during gas production. This includes the natural gas associated with hydraulic fracturing flowback water, which is flared and/or vented. The authors point out that these emissions could be reduced significantly by using Reduced Emission Completions, which capture gas emissions.

Production-related emissions are not substantial contributors to the overall GHG balance, however, when looking at Life Cycle Analysis. This is dominated by the emissions of gas combustion. Overall, the authors find that natural gas from the Marcellus shale has 20–50% lower life cycle GHG emissions than coal for the production of electricity, depending upon plant efficiencies and natural gas emissions variability. According to this study, Marcellus shale gas adds only 3 % more emissions when used for electricity generation, as compared with the average from conventional gas.

Life Cycle Greenhouse Gas Inventory of Natural Gas Extraction, Delivery and Electricity Production

Skone et al., 2011

This study compared life-cycle GHG emissions for baseload power production with different types of natural gas and coal on different climate impact timescales. They found that “... using unconventional natural gas, from tight sands, shale and coal beds, and compared with a 20-year global warming potential (GWP), natural gas-fired electricity has 39 percent lower greenhouse gas emissions than coal per delivered megawatt-hour (MWh) using current technology."

”Additionally, “cradle to gate” GHG emission assessments (for raw material acquisition and transport) are modeled for different coal and natural gas types, including shale gas. These data are useful as input data when modeling life cycle analyses (LCAs) with end uses different from electricity generation in power plants.

An early draft version of Skone et al. 2011 was compared with Howarth et al. 2011 in a study by David Hughes 2011: Hughes critically examined the assumptions made by Skone et al. and supported the conclusions made by Howarth et al. 2011.

Modeling the Relative GHG Emissions of Conventional and Shale Gas Production.

Stephenson et al., 2011

With this modeling study, the authors compare GHG Life Cycle Analysis results for shale gas and conventional gas. They conclude “... that shale gas typically has a WtW [“well-to-wire”] emissions intensity about 1.8-2.4 % higher than conventional gas, arising mainly from higher methane releases upon well completion. Even using extreme assumptions, it was found that WtW emissions from shale gas need be no more than 15 % higher than conventional gas, if flaring or recovery measures are used. In all cases considered, the WtW emissions of shale gas power generation are significantly lower than those of coal."

Operations

SHIP Expert Articles

A critical look at US Shale Gas Projections

Author: Philipp M. Richter

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Published: February 21, 2014

This work is published as discussion paper: Richter, Philipp M. (2013). From Boom to Bust? A Critical Look at US Shale Gas Projections. DIW Discussion Paper No. 1338. DIW Berlin.

Highlights

- This paper provides a critical assessment of current optimistic projections of US shale gas production.
- Resource estimates are potentially overestimated due to extrapolation from non-representative production.
- Public acceptance and regulation can change due to an increase in the number of well drillings.
- Modeling low US shale gas production highlights redirected trade flows and lower than Base Case consumption in Europe and Asia.
- US Liquefied Natural Gas export capacity would only be required if US shale gas production continued its fast rise.

Executive Summary

In the last decade, the USA has seen an unexpected increase in natural gas production. Since 2005, annual production has increased by a third, reaching an all-time record in 2012. This rise in domestic production has been led almost entirely by a boom in shale gas extraction, as technological advances and the combined use of horizontal drilling and hydraulic fracturing have allowed for economic production of natural gas from shale formations. Moreover, this recent rise in US shale gas production is generally expected to continue, which has important implications for the US trade balance. Instead of largely relying on foreign natural gas supply, as envisaged less than a decade ago (e.g., EIA, 2005), the USA is now projected to become a significant exporter of Liquefied Natural Gas (LNG; e.g., IEA, 2012a or EIA, 2013a).

Although partly backed by realized production growth, it is in doubt whether the current shale gas boom can continue for three reasons. First, the amount of technically recoverable shale gas resources (TRR) is uncertain. Second, it is unclear to what extent US shale gas can continue to be produced economically. Third, public acceptance may drop, followed by a tightening of regulation.

Estimates of technically recoverable shale gas resources crucially rely upon assumptions on the potential area of shale production, on well-spacing and estimated ultimate recovery per well (EUR) –

all factors that are highly uncertain. In essence, historical production data is used to extrapolate the TRR. However, as current production is concentrated at the most productive shale formations, production histories at these sites may be non-representative for extrapolation and hence TRR are potentially overestimated.

Moreover, these estimates describe the technical potential, not the economically producible amounts of shale gas. Recently projected production levels are indeed covered by currently estimated resources, but are highly optimistic. The EIA (2013a) projects that roughly 60% of current shale TRR will be extracted up to 2040, or put differently, cumulative production will be almost three times larger than currently proved shale reserves. Given the global abundance of conventional reserves, it is yet to be determined to what extent US shale gas can compete on the international market. Moreover, the driving forces of the current high production level are of a short-term nature, such as the shift to the most productive shale gas deposits. Prices need to sufficiently increase to maintain large future shale gas production. Hence, US shale gas production may lose its comparative costs advantage to natural gas supply from conventional sources in other world regions.

Finally, even more wells need to be drilled, affecting a large area of land and being accompanied by adverse environmental effects. Applying the average EUR across all US shale gas deposits, up to 360 thousand wells is required over the next three decades to meet projected cumulative production. A fall in public acceptance and a tightening of regulation may impede this development, though. For instance, a reduction of the land area admissible for shale gas production or of permissible well density would directly lower future production possibilities. Regulatory changes obviously would have an increasing effect on the supply costs of shale gas production, and would tend to reduce resource availability. The IEA (2013b, p. 118) acknowledges as much by stating that "[a]ny adverse change in the generally favourable regulatory and operating environment in the United States could have a material impact on the outlook for unconventional gas production".

Hence, taking this critical assessment into account, this paper further provides two alternative scenarios that depart from the current optimistic projections for US shale gas production. One scenario is defined by a strong reduction in shale gas production as of 2015; the second scenario is derived from maintaining shale gas production at the level projected for 2015. These simulations particularly serve to investigate the implications of US shale gas production on the US market, on international trade of natural gas and subsequent infrastructure expansions. To this end the *Global Gas Model* (GGM) is used; a large-scale partial equilibrium model that allows the analysis of trade patterns and infrastructure expansions along the natural gas value chain.

A reduction in US shale gas production is partly compensated for by an increase in natural gas production outside the USA. It mainly leads to lower consumption of natural gas, however, in the USA but also in other countries. Instead of bearing the toll of total reduction in domestic production, US consumption stabilizes by attracting an increased amount of imports, while consumption in other countries will be lower than in the Base Case. LNG trade flows from South America and Africa will be redirected towards the USA, which competes with European and Asian countries for international supply. Existing US LNG import capacity will be utilized at higher rates and even extended to meet regional demand.

In conclusion, a critical evaluation is needed on several grounds, both of the estimated shale gas resource potential and projected future production levels. In particular the investment options of liquefaction and regasification facilities are heavily influenced by future US shale gas production. The current expansions of LNG export infrastructure will only be needed if US shale production continues to quickly increase; the licensing process should be adjusted in light of the discussed uncertainties. In contrast to the current debate on US export capacity needs, the US LNG import infrastructure in place will be utilized, and may even be extended if shale gas production cannot meet the hopes pinned on it.

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This work is carried out within the scientific project "RESOURCES: International Energy Resource Markets under Climate Constraints - Strategic Behavior and Carbon Leakage in Coal, Oil, and Natural Gas Markets" funded by the German Ministry of Education and Research.

The Importance of Shale Gas Exploration in Europe

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Published: February 20, 2014

The development of shale gas in the United States has shown that only with the consideration of a number of factors can the production rates of gas and/or liquids from unconventional reservoirs become economical. For this reason, and because of Europe's geopolitical situation and its energy strategy, a much more precise characterization of European shale gas/liquids plays is required for the meaningful evaluation of various development scenarios.

For a better understanding of Europe's shale gas reserves, specific exploration campaigns will be needed to answer three principal questions:

- What are the sizes of potential shale gas plays?
- What type of fluids can be expected?
- What will be the fluid deliverability?

The Chair of Drilling and Completion Engineering at the University of Leoben, Austria, in co-operation with industrial partners, is currently working to address exactly these issues by developing a unique environmentally friendly drilling and exploration system.

Future exploration wells will have to be drilled at strategic points to evaluate the potential of resources for further development. These wells will have the sole purpose of evaluating the formations and gathering information about them with state-of-the-art coring and logging technology.

This article aims to describe exactly the methods and technology needed for the exploration phase, to assess Europe's shale gas potential in a structured, efficient, and environmentally friendly way.

Why are Exploration Wells required?

As a study from the Centre of European Reform pointed out, there are 50 estimates from various literature sources. The estimates for technically recoverable shale gas resources in the EU are considered to be about 10%, and up to 35% of the gas in place[1], and as high as 17.6 and as low as 2.3 trillion m^3.[2] This shows a variance of almost one order of magnitude.

Some conclusions that can be drawn indicate the potential could be quite substantial and is definitely considerable for Europe, but the numbers also demonstrate uncertainty within these estimations. The uncertainty is firstly due to the inherent variance in shale rock properties, which can significantly vary from one well to another. Therefore production rates, as US experience also shows, may significantly vary from well to well. Secondly this high level of uncertainty can be attributed to insufficient areal coverage of about only one exploration well per 800km^2.[3]

Numerous properties typically evaluated for shale show tremendous variance, which affects the outcome of the volumetric predictions. That fact requires a scientific and disciplined approach for the best possible characterization in Europe.

Technology is the key

As already indicated above, various parameters have to be defined as part of unconventional resource exploration.
The first one is the geometric/volumetric extent of the shale layers. Two main sources of information can be used: logs of existing/conventional oil and gas wells; and seismic measurements in connection with geologic studies.

Logs deliver a continuous documentation of the whole profile in terms of physical properties, offer the advantage of correlating the shale layers to their exact depths and defining the precise thicknesses, and allow a well-to-well correlation, as in Figure 1. The drawback is that logs do not provide information on the parameters in between two wells. The latter problem can be solved with seismic measurements at the surface, which indicate the continuity and geologic complexity over a larger distance or area using 2D or 3D seismic measurements, respectively. Using just the existing information is not sufficient for reliable estimations as was also indicated above.

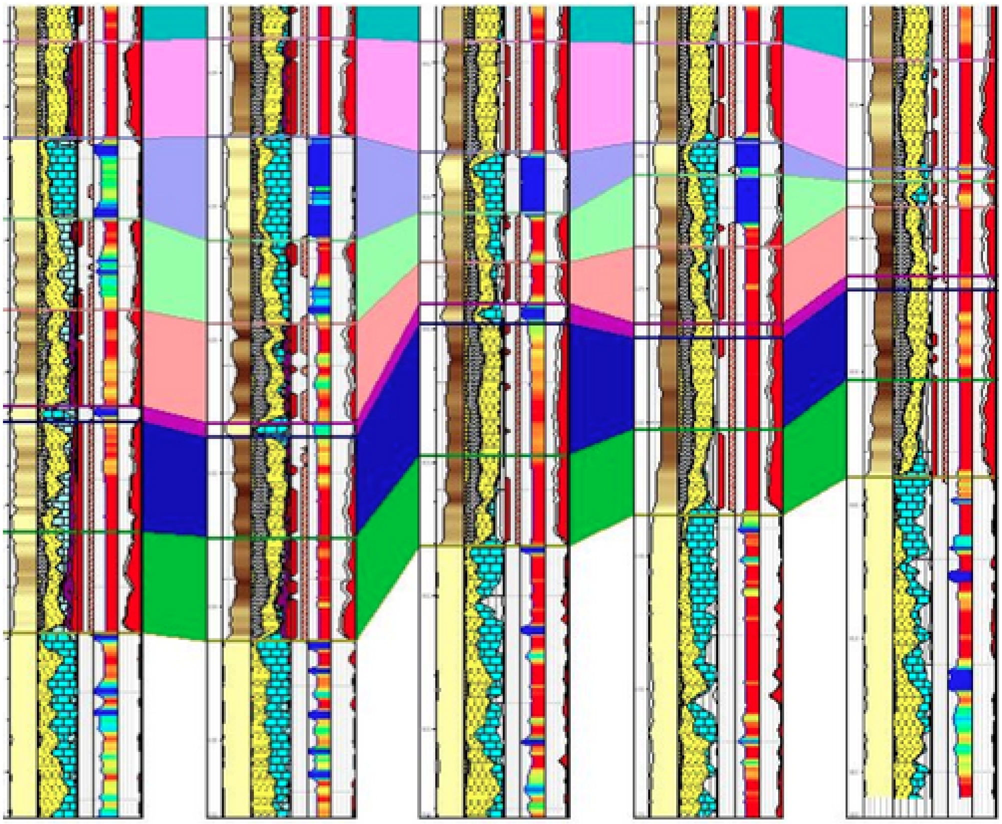

Figure 1: Exploration wells log correlation and cross-section of petrophysical properties. Track 1: Clay volume; Track 2: Mineralogy; Track 3: Pay indicator flag (red shading) and reservoir quality indicator (striped shading); Track 4: Water saturation; Track 5: Total porosity (black line), effective porosity, and gas-filled porosity (red shading).4

The next step is to estimate the gas in place and the gas production potential in these formations. In order to do that, wells have to be drilled and logged and/or cored subsequent to drilling operations. Logging implies lowering a tool equipped with special sensors and measurement devices into the wellbore and obtaining information about the rock around the wellbore – logs are an indirect type of information and must be transformed into reservoir properties. Sophisticated interpretation implements log and core data. Also for a better characterization of the mechanical rock properties and fluid flow behavior, which provide critical information for the completion of development wells, cores are required.

Logging

Logging oil and gas wells is a standard procedure in the oil and gas industry since its early beginnings. Logs of shale rocks however, have been more focused on potential well bore stability problems than on production potential. Due to the development of this type of unconventional resource, tools had to be tailored to focus exactly on specific shale properties. Some of the difficulties of a proper characterization are outlined below:

Conventional reservoirs often possess a less complex composition and structure in the rock components, as well as quite predictable properties. Shale layers in contrast are multi-component systems and show large variances in their composition and internal rock structure.[5] Figure 2 shows a typical shale system. In conventional sandstone reservoirs usually only inorganic matrix and inorganic pores are present, filled either with brine water, hydrocarbons, or any other gas such as CO_2.

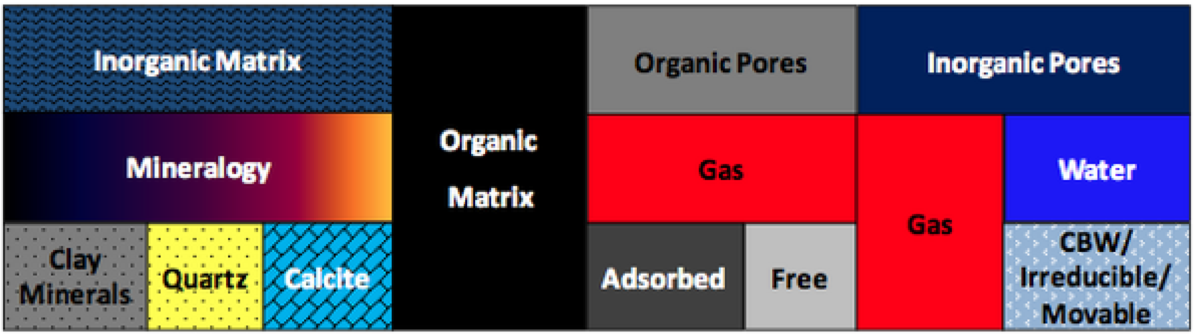

Figure 2: Petrophysical model of a shale rock.6

Shale rocks, on the other hand, have organic matrix and organic pores too. Now difficulties arise in the correct estimation of the components of the inorganic matrix, especially the composition of clay minerals, the estimation of the amount of organic matrix and the estimation of the porosity, which is contributing significantly to the total gas in place.

Due to the additional components and for the purpose of gas production, it is necessary to determine additional parameters: clay content, total organic carbon, brittleness index and other parameters can only be inferred approximately from logs of shale formations. The most accurate way to determine these parameters and other key properties such as the vitrinite reflectance, which gives an indication of the maturity of the rock, is to measure them directly at the core. Measurement of all these parameters has not been routinely provided for in existing conventional oil and gas wells in Europe and is the reason why logs alone cannot reliably be used for the determination of the actual hydrocarbon potential.

Even with state-of-the-art logging technology, however, some difficulties still exist, requiring rock samples to be brought to the surface for further testing.

Coring

Coring requires special equipment at the bottom of the drill pipe. First a coring bit is needed, which cuts the rock just at its circumference and has a circular hole in its center, as shown in Figure 3. Second, a bottom-hole assembly directly attached to the bit is used in order to retrieve the core, Figure 4, from the well.

Figure 3: Coring bit. 7

Figure 4: Typical shale core sample. 8

Previously, conventional coring methods usually required lowering the drill string into the hole, drilling the core, and pulling the entire drill string out again. This was time consuming and nowadays wireline coring is used to operate more efficiently. Instead of pulling the drill pipe out of the hole, a cable called the wireline is lowered into the hole and retrieves just the core barrel.

One requirement of the exploration phase is the finding of sweet spots, which are regions that have properties critical for high production potential, in the shale layers. One observation, according to the BGR study, is that the formation thicknesses in Germany are in the range from 10s to 100s of meters.[9] For a successful characterization, entire sections should be cored to identify zones of high potential zones.

Further, it is critical that these rock samples represent the downhole conditions. Time delays, core handling and transportation between the core drilling process and core evaluation can cause desiccation, changes in the fluid saturation, opening of cracks, mobilization of interstitial clays and alterations of other important properties, which affects the core quality as well as the core analysis results. Thus, it is recommended to perform an evaluation on-site immediately after retrieving the core from the well.

Exploration well characteristics and rig requirements

Coring and logging are technologies used to gather information in and around the borehole. As the lateral heterogeneity of the shale properties is rather large, numerous exploration wells would have to be drilled in a pattern-like arrangement for the best possible rock characterization and estimation of technically recoverable resources.
In practice, however, exploration well density is rather low. In the US densities of about one well per 400km^2 are reported.[10] For Europe, the numbers are currently even lower, as pointed out earlier in this article.

To keep environmental impact low, slim-hole or even micro-hole wells are valuable options compared to standard diameter wells. A small diameter well requires just minor amounts of drilling fluid (about 1:10) and also creates much less drill cutting and drilling waste (about 1:30) in comparison to standard diameter wells. Equipment, as well as rig requirements, can be decreased significantly, which decreases the energy requirements (about 1:4) and the surface footprint (about 1:4) of the operations.[11] Such an approach is designed to be highly cost effective to offset the costs for an intensified exploration program.

Utilizing the latest technology, exploration wells will have the following characteristics:

- Wells will be sparsely distributed over larger areas;
- Wells will be vertical only;
- No hydraulic fracturing operations will be required;
- Wells will be of small diameter to keep the environmental footprint low;
- They will be cost effective for an intense exploration program.

Conclusion

To define Europe’s shale gas potential, precise information about the rock is necessary. Although wells, logs, and cores already exist in most of the shale basins in Europe, their use for precise property estimations is limited. The density of available information is sparse. For more accurate downhole information, the drilling of exploration wells is indispensible. It is essential to utilize environmentally friendly and highly efficient technology that allows the collection of relevant exploration information at a large scale, to quantify Europe’s unconventional resource potential.

The proposed exploration wells will be different to US shale gas development wells insofar as no horizontal drilling and no high volume hydraulic fracturing operations are required to determine resource potential. Slim hole wells will be drilled to perform fast and efficient exploration drilling, to keep the environmental impact to a minimum.

The latest logging and continuous coring technology including on-site real-time core evaluation technology will be used to get the most accurate information defining Europe's true shale resource potential.

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Legislation

SHIP Expert Artikel

Polish unconventional resources: Implementation of European Energy Policy

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Published: June 30, 2015

European Energy Policy envisages the concerted action of the member states, aimed at providing them with secure, environmentally-friendly and competitive energy supplies. Since the establishment of the European Coal and Steel Community (1952) and Euratom (1957), the situation in the energy market has also changed as a result of geopolitical changes, technological progress as well as general civilization changes.

The cooperation of the member states in developing the energy landscape becomes more intensified due to growing global competition for access to natural resources, increase in energy prices and their diversification in relation to main competitors. Therefore, the European Union strives to become independent to the greatest extent possible on the issue of energy acquisition from unconventional sources from third countries. Still, the direction of the EU energy policy is determined by the following assumptions: combating climate change, reducing the EU's vulnerability to external factors resulting from the dependence on imported hydrocarbons, and promoting employment and economic growth. Poland plays a key role in this endeavour.

Recently, the hopes for achievement of the objectives set are associated not so much with the performance of shale gas any longer but of tight gas, another form of unconventional gas. Potential unconventional deposits and technological feasibility of extraction of this gas evoke discussion on replacing external supplies with domestic gas.

However, a method used for its extraction causes public concern about environmental pollution, in particular air and groundwater pollution. It should be emphasised that general EU legal regulations related to environmental protection were developed when hydraulic fracturing was not yet used in Europe and the use of this method was not fully justified, especially in terms of strategic planning, underground risk assessment, well integrity, baseline and operational monitoring, capturing methane emissions and disclosure of information on chemicals used on a well by well basis.

Moreover, the applicable law was not uniformly interpreted by individual member states with reference to the gas extraction from unconventional sources. That's why, after months of legal analysis, on 22 January 2014 the European Commission issued a recommendation on minimum principles for the exploration and production of hydrocarbons using high-volume hydraulic fracturing, thus defining basic rules that allow safe use of hydraulic fracturing for the EU member states. The most important principles include:

- obligation to prepare a strategic environmental assessment (based on the requirements of Directive 2001/42/EC) before granting licenses for exploration or production of hydrocarbons with hydraulicfracturing
- obligation to provide clear rules on possible restrictions of prospecting and production operations in protected, flood-prone or seismic-prone areas;

- obligation to define minimum distances between the prospecting or production operations carried out and residential and water-protection areas;
- obligation to establish minimum depth limitations between the area to be fractured and groundwater;
- obligation to make a relevant assessment of geological formations as for their suitability for gas extraction with the use of fracturing;
- obligation to make a risk assessment;
- obligation to determine the environmental status of the site subject to drilling so it is possible to monitor potential changes in the future;
- obligation to inform the public about chemicals used for fracturing of individual wells.

Pursuant to the recommendation, it should be implemented within six months of its publication. The commission will review the recommendation's effectiveness 18 months after its publication. The deadline is on 22 May 2015. Poland has not yet implemented these obligations in its legal system, nor has it drafted .However, legislative work is currently conducted on that matter.

Explorationand production of gas from unconventional sources in Poland is governed by the Act of 9 June 2011 – Geological and Mining Law. The most recent amendments of this act have become effective beginning of 2015.

The exploration and production sector as well as individual entrepreneurs hoped that the new regulations would, first of all, simplify procedures and shorten the waiting time for obtaining decisions from administrations. After critizism from the industry on the recent amendments, the following issues were taken into account:

- the establishment of the National Energy Minerals Operator (NOKE) and its participation in the licenses granted were abandoned;
- the scope of the proposed license for hydrocarbon exploration and production was extended to include hydrocarbon exploration;
- the possibility of carrying out geophysical surveys in order to investigate geological structures based on application, initiating hydrocarbon production and continuing at the same time the prospecting and exploration operations in the remaining area covered by the license was retained;
- a demand for documenting obligations arising from the license in an annual and not quarterly (as originally planned) schedule was accepted;
- marginal reservoirs were defined in respect of which no service charge is planned; the establishment of a new authority (GIOŚiNG - Chief Inspectorate for Environmental Protection and Geological Supervision) was abandoned.

In addition, comments aimed at ensuring greater clarity of some provisions of the Act were taken into account and transitional provisions were made more specific.

Still, the Recommendation of the European Commission has not yet been implemented to this day. In an official document submitted to the Commission on 31.12.2014, the so-called analysis of the Polish legal status in relation to the Recommendation of the European Commission of 22 January 2014 on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing (2014/70/EU) the Polish government pointed at four issues with still unclear legal status.

- Firstly, the current legislation lacks legal basis allowing the carrying out of strategic environmental assessment for shale gas prospecting, exploration and production since it is conducted for planning documents only.
- Secondly, the legislator has not introduced any minimum vertical separation distance between the zone to be fractured and groundwater.
- Thirdly, seismic-prone areas have not been referred to in the national regulations.
- Fourthly, the monitoring of hydrocarbon prospecting and production stages have not been legally regulated.

The Ministry of Environment explains that these issues will be regulated following the completion of a task requested by the Minister of Environment. This task aims to identify risks within the scope of impact of shale gas exploration operations on the environment in Polish conditions and defining optimum (from the perspective of legal provisions, geological conditions and technology) procedures for the management of such risks. It should be noted that both the amendment to the Geological and Mining Law and currently drafted special hydrocarbon act still do not address the aforementioned issues.

The Special Hydrocarbon Act

Additionally, it should be mentioned that currently legislative works are in progress on a bill on rules for preparing and executing investment projects within the scope of prospecting, exploration, production and transport of hydrocarbons (the so-called special hydrocarbon act). The main purpose of introducing new legislation is to simplify administrative and legal procedures and to increase their clarity. The bill is a nod to investors by bringing together in a single legal act provisions concerning the preparation and execution of hydrocarbon production, thus encouraging them to implement investment projects.

The special hydrocarbon act envisages speeding up the preparation and implementation of investments by shortening the waiting time for decisions on environmental conditions for the project implementation, decisions on reclassification of land as non-agricultural land, decisions on temporary reclassification of land as non-agricultural or non-forest land. Also, permits required under the Water Law Act shall be issued faster in the future. The regulation also aims to eliminate lengthy procedures relating toobtaining a legal title to real property for conducting the authorised operations. Still, the bill does not fully meet the expectations of the industry.

At the consultation stage the demands included, inter alia, the requests for including land for housing development to the activity related to prospecting, exploration and production of hydrocarbons and for allowing access to information data as well as geodetic and cartographic data related to the real property. In addition, the industry hoped that consideration would be given to comments regarding the limitation of the scope of application for the issuance of a decision on location and the removal of regulations related to environmental protection and fire regulations from the decision on location.

Providing local communities with active participation in legal procedures and with knowledge concerning such procedures as a tool for sustainable development of shale gas investments in Poland.

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Published: June 02, 2014

The implemented “Together about shale gas” ["A consensus on shale gas"] information campaign brought a number of opinions from the areas covered by this programme, concerning the social perception and social acceptance as well as signals of doubts within the scope of environmental or technological aspects and certain operations of companies holding licences in Poland. As a result of the programme, a need has been identified for providing real support in legal procedures.

Local communities were represented at meetings of Local Dialogue Committees by members of local associations and organisations from Pomorskie Province in the following licence areas: Wejherowo, Bytów, Kościerzyna and Kartuzy. Moreover, meetings were held outside the programme with representatives of associations from Lubelskie and Łódzkie Provinces as well as other provinces. The representatives of local communities involved in shale gas issues unequivocally expressed their wish to be provided with and be able to regularly update (monitor) the exact, substantive legal information in the form of permits and administrative decisions obtained by licence holding operators during the investment execution. The demands result from the lack of knowledge concerning individual investment stages and levels of environment and human health protection as well as from too general information so far provided by the authorities, local governments or investors themselves. Therefore, in their opinion such knowledge should be extended to include hard data from all the permits granted to operators whereas any further procedures undertaken should be carried out with the participation of local communities as provided by law.

What is the current perception of investments by social organisations (associations) of the local population and what the doubts are about?

The main areas of unresolved doubts and need for acquiring knowledge concerning actions taken by investors in respect of specific licences and lands come down to the following issues:

- **protection and safety of local water intakes and resources;**

Local communities have become sensitive to this issue as a result of the statement of Mr Gawłowski, Deputy Minister of the Environment that “water resources in Poland per capita are lower than those in the neighbouring countries and considerably lower than the European average. According to the data of the National Water Management Authority, there are about 1,580 cubic meters of water per capita per year on average in Poland whereas the average resources per capita in Europe amount to 4,560 cubic meters per year.”

- **conditions for obtaining and using a licence as well as further modifications to licences;**
- **programs of mining waste and sewage management and recycling methods;**
- **permits required by the Water Act Law for the specific use of waters, execution of water facilities; long-term decrease in the groundwater table level; drainage systems for structures or construction excavations and mining plants, introduction into sewage systems of industrial waste water containing substances particularly harmful to the water environment;**
- **industrial waste water containing substances particularly harmful to the water environment;**
- **conditions for the establishment of the mining usufruct and terms of use of private lands, including the issue of compensations;**
- **mine operations plan;**
- **fulfilment of the obligation to disclose geological documentation to local governments;**
- **requirement for obtaining an environmental permit;**
- **observance of all acts of the national and EU legislation regarding the gas & oil prospecting and extraction using the hydraulic fracturing technology and control;**
- **financial guarantee as security for potential damage to the environment**

Basically, most of the Member States have introduced a requirement for providing financial guarantee already before the works commencement. These legislative measures have resulted from the need to implement Directive 2004/35/EC on environmental liability with regard to the prevention and remedying of environmental damage. However, it should be noted that terms for granting such guarantee vary considerably, for example, with regard to their form, damage coverage, calculation methods or time frames.

- **environmental impact assessment or strategic environmental assessment**

Procedures related to making environmental impact assessments are one of the most diversified legal aspects in the legislation of individual Member States. It is best to show this diversity using specific examples.

In some Member States, it is obligatory to make an environmental impact assessment for projects related to the prospecting and extraction of unconventional hydrocarbons. In Bulgaria this requirement has been established since April 2012. In Denmark, it is also obligatory to make the impact assessment but only for projects of drillings involving hydraulic fracturing procedures. Lithuania has introduced still another regulation, namely projects relating to the prospecting of unconventional hydrocarbons must be preceded by the impact assessment but their extraction does not require such assessment.

In this context, it is also proper to mention the Polish legislation which provides for the need to make a prior project classification based on the provisions of the Regulation of the Council of Ministers of 9 November 2010 on Projects Likely to Have Significant Impact on the Environment. Currently, it is not required to make an impact assessment or to obtain an environmental permit if the operator conducts works related to the drilling of a well to the depth of 5,000 m outside the sensitive zones (specified in §3(43)(c) of the Regulation).

Also the aspect connected with a strategic environmental assessment should be discussed in a few words. As a general rule, the assessment does not have to be made in the Member States before the procedure for granting a licence for the prospecting and extracting of hydrocarbons is commenced. However, such obligation is stipulated in the provisions introduced in the United Kingdom and Lithuania.

- **distance from buildings and land development**

None of the Member States has introduced any regulation that would define a minimum distance from residential buildings – everything depends on planning conditions set by the relevant authorities. In the case of some countries the issues related to distance limits can be found with reference to drinking water and groundwater protection zones.

- **requirements connected with monitoring of individual environmental elements before work commencement**

The issues related to monitoring can be found in individual Member States, including Poland, in specific permits or decisions. In Denmark such monitoring is a part of licence obligations whereas, for example, in Spain the obligation to carry out such monitoring may be imposed within the environmental impact assessment procedure. In Poland, monitoring is not regulated in detail by law and is not a legal obligation of the licensee.

- **composition of the fracturing fluid**

Since the exploitation stage is the most complex one, it generates most inaccuracies and legal uncertainties. The protection of health and environment results mainly from the relevant directives and their implementation and application in individual Member States. The most problematic issues refer to the use of chemical substances in fracturing fluids, composition of those fluids as well as management of return fluids and storage of waste generated in connection with hydraulic fracturing.

The underground injection of fluids itself is subject to various regulations – some of the Member States consider it to be a procedure related to water management whereas other countries do not regulate this process at all as it is considered to be a part of a bigger project, namely the prospecting or extraction of specific resources. That is the case in Poland. Another important issue is that of solutions connected with the disclosure of the composition of fracturing fluids – basically, none of the Member States has introduced such a general disclosure requirement. In the United Kingdom, while granting permits involving groundwater the relevant authorities may require the disclosure of all the substances to be used during the works. A similar approach can be found in Spain – during the procedure of decision issuance by the Minister of the Environment the disclosure of such information may be requested.

The deposit exploitation stage involves also other reported problems, such as: problems connected with the sources of water (considerable quantities of which are used during fracturing), integrity of wells as well as gas burning and emission to air.

A way of meeting social expectations in legal procedures

There are detailed legal frameworks provided for all the aforementioned dubious issues, causing most questions and resistance and being of interest to residents. They also require investors to carry out a series of legal procedures. It means that the information related to those procedures and their results may be easily presented to representatives of local communities who may be also provided with a participation in some of such procedures. In Poland there are three legal instruments that may be used for offering specifics concerning particular well-drilling sites and for providing a real and not fictitious participation in making administrative decisions:

- obtaining public information as a result of an inquiry made by a local association in respect of already decided issues in order to discuss both rights and obligations of licensees in a given area;
- recognising as a party to proceedings in pending cases in order to provide with current participation in the administrative procedure, insofar as it is allowed by the Polish and European law;
- participation of a social or ecological organisation as a representative of a social group in legal procedures and reacting to situations not adequately clarified.

In order to ensure the real participation of local communities in making investment-related decisions and their influence on administrative decisions as well as to increase the social awareness and eliminate concerns, it is necessary to urgently develop a platform for monitoring permits and administrative decisions related to shale gas and a base for professional legal aid for local associations in the areas in which the licences have been granted.

The efficient organisation and broad information campaign in the form of local dialogue committees in the licence areas, education and regular monitoring of procedures as well as ensuring the participation of local communities in such procedures, combined with the integration of social groups, local authorities and investors, should soon result in the acceleration of administrative procedures, winning of social acceptance and understanding of difficult issues related to environmental protection and technology.

In practice, it means that the educational and information initiatives taken under the “Together about shale gas” ["A consensus on shale gas"] campaign should be continued and the programme should be also supplemented with a module of education concerning the locally determined legal situation of licensees, legal protection of local communities and ensuring the social monitoring of permits and licences as well as broad access to legal procedures in an organised and substantively organised manner.

How to apply European Commission Recommendations in real life: Stara Kiszewa case study

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As an expert for the "Together about shales" programme financed by the National Fund for Environmental Protection (NFEP), I have analyzed one of the first cases of a shale gas licence to which the recommendations of the European Commission should apply. With reference to a project concerning the prospecting and exploration of oil and natural gas in the 1/2011/p STARA KISZEWA licence area, the investor, PGNiG, has submitted the project's environmental impact assessment (EIA) to the Regional Director for Environmental Protection. Though individual minimum principles set out in the Recommendation of the European Commission have not yet been taken into account in the report, they will certainly be supplemented later.

Risk assessment and characterisation of the potential site

Pursuant to paragraph 5(1) of the Recommendation, operators should provide a competent authority with a risk assessment and characterisation of the potential site and surrounding surface and underground area.

With reference to risk assessment, the Recommendation specifies elements to be included in such assessment (paragraph 5(3) of the Recommendation). First, the operator should present a forecast of the changing behaviour of the target formation, geological layers separating the reservoir from groundwater and existing wells or other man-made structures exposed to the high injection pressures used in high volume hydraulic fracturing. Furthermore, the investor's risk assessment should respect a minimum vertical separation distance between the zone to be fractured and groundwater.

The EIA report prepared for the STARA KISZEWA licence area does not include a correctly and sufficiently carried out risk assessment in respect to the planned project. It should be pointed out that no standardised minimum vertical separation distances between the fracturing zone and groundwater have been established so far; in the EIA report however, the investor should indicate at least a potential distance in order to enable a competent authority to determine whether it is sufficient for the protection of the affected water-bearing and other geological layers.

Due to the fact that the areas with potential for wells (and consequently, the areas subject to hydraulic fracturing) are located in the territory of the Main Groundwater Reservoir no. 116 (Gołębiewo Intermoraine Reservoir) and in the territory of uniform bodies of underground water no. 30 (of good water quality), it is necessary to carry out a thorough analysis and risk assessment in relation to potential exposure during hydraulic fracturing operations.

Baseline study for the STARA KISZEWA area

Paragraph 6 of the Recommendation defines basic principles for requirements prior to the determination of the environmental status and before hydraulic fracturing.

The investor has partially determined a so-called “baseline” for the natural environment in the EIA report. It should be noted, however, that certain elements of the comprehensive assessment of this status have been omitted by the investor in the document, subject to analysis.

First of all, there is no description of the seismicity of the installation site, its surrounding surface and underground area. Due to the considerable scope of any project involving large-scale hydraulic fracturing, a prior description of the seismicity of the area is essential.

Moreover, the presence of methane and other volatile organic compounds in water, biodiversity, status of infrastructure and buildings as well as existing wells and abandoned structures have also not been exhaustively described.

Operational requirement

The requirements to be met in relation to operational works are set out in paragraph 9 of the Recommendation. Those requirements are defined for both competent administrative authorities and directly for operators conducting or planning to conduct operations.

First, the investor should present a water management plan for all project stages. Although the EIA report indicates water demand during individual project phases, it is not sufficient since the investor has not taken seasonal variations in water availability into account. This may result in the planned project having a negative impact caused by the short-term effects of water management in the investment area.

Second, it is necessary for the investor to develop a transport management plan. It seems insufficient to determine air emissions and describe the use of the existing public roads. The impact of motor vehicle traffic on the health of local communities and biodiversity should also be taken into consideration.

Third, the operational requirements set out in the Recommendation include the need to capture gases for subsequent use, minimise flaring and avoid venting. In the EIA report, subject to analysis, the investor has described proceedings related to the burning of the produced natural gas using so-called “flares.” No measures to limit the venting of fugitive emissions from the gas flare to air have been mentioned, however. It is worth noting that pursuant to paragraph 9(2)(c) of the Recommendation, venting of methane and other air pollutants should be limited, and only done in the most exceptional operational circumstances and for safety reasons.

In the EIA report the investor has also failed to specify the manner and scope of conducting integrity tests on individual wells. The results of integrity tests should be reviewed by an independent and qualified third party. In addition, such tests should be conducted at all stages of project development and after well closure.

Monitoring requirements

The EIA report presents proposals for monitoring of the impact of planned geological operations (Chapter 12). Still, the proposals do not include a number of elements for which such monitoring should be planned. All the monitoring requirements are specified in paragraph 11 of the Recommendation.

First of all, the operator should monitor:

- the precise composition of the fracturing fluid used for each well;
- the volume of water used for the fracturing of each well;
- the pressure applied during hydraulic fracturing;
- the fluids that emerge at the surface following high-volume hydraulic fracturing: return rate, volumes, characteristics, quantities re-used and/or treated for each well.

Monitoring of the aforementioned elements should be included also for the project planned in the case of the STARA KISZEWA licence. Moreover, monitoring should be planned in respect to the impact of hydraulic fracturing on the integrity of individual wells and the surrounding surface and underground area.

To sum up, it should be emphasised that taking the minimum principles set out in the Recommendation of the European Commission into consideration will contribute to the mitigation of potential risks and to both the authority involved in proceedings and the general public being adequately informed about the impact on individual environmental components, thereby achieving the high social and environmental standards proposed by the European Commission.

The legal consequences of European Commission recommendations on minimum principles for shale gas in Poland.

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Published: February 18, 2014

On 22 January, 2014 the European Commission published a recommendation specifying minimum principles for the exploration and production of hydrocarbons using high volume hydraulic fracturing[1]. The Recommendation is primarily the result of over two years of works and analyses related to the issues of human health and environmental protection, in connection with the growing development of prospection, exploration and production of unconventional hydrocarbons in European Union Member States. The works involved mainly public consultation[2] at European level, as well as relevant actions in the European Parliament and the Council.

What are the recommendations?

First, the legal nature of recommendations as a source of European legislation should be specified. They are adopted pursuant to Article 292 of the Treaty, on the Functioning of the European Union[3], and basically they form one of the non-binding secondary legislation acts that can also be adopted directly by the European Commission. Given their non-binding nature, there are no sanctions that could result in Member States being obliged to adopt and implement such recommendations. However, according to a decision of the Court of Justice, recommendations should be taken into consideration; one example would be the process of adjudication by national courts, in particular if the recommendations refer to the clarification of internal law provisions or supplement binding provisions of EU legislation. This position stems from the principle of solidarity valid in EU legislation[4]. Consequently, a Recommendation becomes a specific interpretation directive for courts and national administrative authorities involved in formal legal processes related to shale gas in our country (Poland).

Furthermore, it should be noted that the European Commission expects the minimum principles set out in the Recommendation to be implemented within six months of the publication date (i.e. the deadline expires on 22 July, 2014) and Member States are expected to inform the Commission annually of the implemented measures (starting from December, 2014). Based on the data collected, the European Commission will review the effectiveness of the measures put in place by Member States 18 months after the Recommendation's publication date. Failure to implement the minimum principles laid down therein may result in the Commission putting forward legislative proposals with legally-binding provisions on the exploration and production of hydrocarbons using high volume hydraulic fracturing.

Minimum principles

As for the minimum principles presented on 22 January in respect of processes related to hydraulic fracturing, it is worth noting that the European Commission has put an emphasis on the following issues: 1) the need for greater public participation in the decision making processes, 2) protection of groundwater, 3) seismicity, 4) the need for monitoring of the relevant environmental components potentially affected by high volume hydraulic fracturing, as well as 5) adequate control of chemical substances used and 5) rational use of water. Importantly, the Recommendation shows that the Commission aims to develop binding industry best practices and to promote the exchange of available information between authorities, business operators and representatives of the local communities concerned.

In order to protect groundwater against potential impact from hydraulic fracturing, Member States should establish minimum depth limitations between the area to be fractured and groundwater (paragraph 3(2) of the Recommendation) and implement the requirement of risk assessment before the commencement of any operations related to the exploration and production of hydrocarbons; thus anticipating geological layers separating the reservoir from groundwater (paragraph 5(3)(b) of the Recommendation) and respecting the aforementioned minimum vertical distance between the zone to be fractured and the groundwater (paragraph 5(3)(c) of the Recommendation).

The need to determine the status of existing fractures and individual geological layers before starting operations is particularly important since it helps with the evaluation of potential substance emissions during fracturing (e.g. geological layers with higher permeability will be taken into consideration, which in turn may affect the location of particular wells).

Analysis of seismicity and its constant monitoring (before, during and after fracturing operations) is one aspect of environmental protection so far omitted in the legislation of most Member States. It should be noted that the United Kingdom is the only state that has adopted regulation imposing an obligation on the operator to carry out seismic monitoring on a permanent basis. Its inclusion in the Recommendation’s minimum principles should be viewed positively (determining a baseline for seismicity - paragraph 6(2)(f) of the Recommendation; pressure control and adjustment during hydraulic fracturing operations – paragraph 9(2)(d) of the Recommendation; regular monitoring of the installation and the underground area before, during and after hydraulic fracturing – paragraph 11(1) of the Recommendation).

Moreover, requirements concerning comprehensive monitoring of relevant components of the environment on a current basis have been introduced. It has also been emphasised that such monitoring (carried out before, during and after fracturing operations) should include information on 1) the precise composition of the fracturing fluid used for each well, 2) the volume of water used for the fracturing of each well, 3) the pressure applied during fracturing, and 4) the return fluids as well as air emissions of methane and other volatile organic compounds. Results from monitoring should be reported each time to the relevant authorities.

One of the most controversial issues in relation to fracturing operations is the composition of the fracturing fluids used. Only a few Member States have implemented a requirement to disclose the components of these substances. In the Recommendation under consideration, the European Commission has emphasised again that manufacturers, importers and downstream users are obliged to comply with their obligations under the REACH[5] Regulation concerning the Registration, Evaluation, Authorisation and Restriction on Chemicals. Quite often operators conducting hydraulic fracturing operations ignore, for example, the requirement to verify whether the substance used by them has been properly registered. Additionally, relevant information on the chemical substances used should be publically disseminated – this obligation has been imposed directly on well operators but also indirectly on the relevant national authorities (paragraph 15 of the Recommendation).

The Recommendation also includes requirements concerning the need to determine a so called baseline. Interestingly, the Recommendation also provides guidelines that suggest well integrity tests (conducted at all stages of operations) should be reviewed and evaluated by an independent and qualified third party. Moreover, the Recommendation offers itself as a foundation for the development of an information database of best practices in the mining industry. It is worth noting that this solution is quite common in the Unites States of America where the mining industry provides and maintains so-called good practice databases.

Quick application of some recommendations

With reference to Poland, it should be noted that in the legislative sphere the Commission's proposals may soon be adopted, under a procedure of amendment to the Geological and Mining Law, conducted by the Minister for the Environment. As for the organisational suggestions, there are at least two tools available that, after certain modifications, could be used to adopt the Recommendation's provisions. First, the permanent monitoring of wells could be carried out, irrespective of licensees, by the Polish Geological Institute. Second, a public communication programme titled "Together about shales" has already been implemented, and after its extension to the area of all licences and introduction of the principle of full transparency of actions, taken by both operators and national authorities, this programme may meet the Recommendation's provisions. As a local platform for the exchange of knowledge, it would give organised groups of local communities a chance to participate in legal procedures.

To sum up, it should be emphasised that the European Commission has decided to take action in the form of non-binding legal acts, relating to the exploration and production of hydrocarbons using high volume hydraulic fracturing, thus casting new light on the interpretation of already existing provisions of law. This non-binding act does not mean that Member States need not actually adopt the minimum principles set out in the Recommendation. One gets the impression that the Commission has only postponed more restrictive legislative proposals concerning shale gas in Europe until it finds additional arguments for the need to develop detailed regulations for this industry. In Poland, people responsible for the execution of the shale project may now focus on working out measures to implement the Recommendation in a way that prevents the Commission from finding such arguments. What can be done to achieve this? It seems that the following may be of help:

- amendment of Geological and Mining Law;
- extension of well-monitoring with new locations under the programme implemented by the Polish Geological Institute;
- extension and modification of the public communication programme "Together about shales".

[1]the English version of the Recommendation is available;

[2]results of the public consultation are available in the report of the European Commission;

[3]Official Journal of the EU, 30.3.2010, C 83/47; Eur-lex/el;

[4]M. Kenig-Witkowska, Prawo instytucjonalne Unii Europejskiej, Warsaw 2011, pp. 191-192; judgment of the Court of Justice of 13.12.1989 – Case C-322/88 – Salvatore Grimaldi v. Fonds des maladies professionnelles, ECR 1989, p. 4407;

[5]Regulation (EC) No. 1907/2006 of the European Parliament and of the Council of 18 December 2006; Eur lex/el.

New developments in the debate about shale gas extraction using hydraulic fracturing - European Parliament demands mandatory Environmental Impact Assessment (EIA)

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Published: October 16, 2013

On Wednesday, October 9, 2013, the European Parliament examined the question of revising the Environmental Impact Assessment Directive (EIA) and formulated a request for a mandatory environmental impact assessment of so-called fracking procedures. This request is also part of the vote regarding the modification proposal of the European Commission for the Environmental Impact Assessment Directive for specific public and private projects (EIA directive 2011/92/EU) that was presented on October 26, 2012 (COM (2012) 628 final). Originally, the application of the procedure to all hydraulic fracturing projects was not intended. In fact, the proposal of the European Commission asked for existing regulations to remain in place. These regulations stipulate that the obligation to perform an environmental impact assessment depends on the amount of gas extracted. For the member states, this would have meant that either the EIA directive would not have been relevant per se for the planned hydraulic fracturing procedures or that all parties involved would have been uncertain about the legal situation and the directive's legal relevance.

The subject of the vote taken this week was the draft report of the Italian member of the parliament Andrea Zanoni from the liberal ALDE group that contains the proposal to make testing mandatory for both exploration – the exploration of raw material deposits in the earth's crust, that is – and exploitation wells with the new EIA directive. In a first reading, 322 delegates voted yes and 311 voted no.

The delegates proposed that in the future, hydraulic fracturing projects that have been heavily debated on a national level in the past should generally be subject to environmental impact assessments in Europe. They plan to make use of the political principle of environmental precaution which is to apply regardless of the quantity extracted in this context. Furthermore, this obligation is to apply both for the exploitation and exploration of possible shale gas deposits. EU delegates also suggested a higher transparency of information for the public regarding pending hydraulic fracturing projects. Moreover, precautions are to be taken to prevent conflicts of interest and to "define clear criteria for involving the public with the goal of achieving more acceptance" (Zanoni).

A binding EIA obligation in this sense has already been discussed on a national level several times as well in order to provide adequate protection of our groundwater and surface waters. In this context, it was always argued that the dangerous chemicals used during hydraulic fracturing pose a risk to water quality and our vital water supplies. Another issue regarded as problematic was the disposal of the contaminated waste water that results during hydraulic fracturing. Recent events in Colorado, where torrential rainfalls caused thousands of above-ground storage facilities of fracking waste water with unknown dangerous chemical additives from the production process to spill resulting in the possible long-term contamination of drinking water resources, had once more rekindled the debate in Germany.

What are the results of the parliament's request?

An environmental impact assessment as proposed would allow environmental protection issues and the possible impact of hydraulic fracturing on the population to be researched and observed adequately – there is no doubt about this for critics of fracking. Even if the request is a first step in this direction, it is not to be hastily equated with an already approved EIA obligation. In fact, it remains to be seen whether the European Parliament's request will be accepted by the Council of the European Union in the further proceedings. Clear results may not be available until after the second or even the third reading. This could still be some time. Should the parliament and council agree on a new EIA directive, responsibilities for the implementation of the measures included therein will be transferred to the member states at their discretion - a scenario that promises to be no less explosive. This has already been well documented by the month-long struggle of the (outgoing) coalition (CDU/CSU and FDP) to pass a German law regulating the controversial shale gas production which was finally deemed "failed" in June 2013.

Poland: New Draft Rules for Hydrocarbon Exploration and Production

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Published: May 14, 2013

On 15 February 2013 the Polish government published a Bill to amend the Act on Mining and Geological Law and other laws governing the process of mineral exploration and production (the "Bill"). The Bill introduces special solutions with respect to hydrocarbon exploration and production and hence is of particular importance for the shale gas industry.

Earlier, the Polish government actually considered preparing a special act concerning hydrocarbons only, but it is now believed this will not happen. Regulations concerning hydrocarbons will be introduced to already existing laws.

Key features of the Bill are presented below.

How will the new hydrocarbons licensing system be structured?

There will be material changes to hydrocarbons licensing. The new system will be structured as follows:

- No concession will be needed to prospect for hydrocarbons.
- There will be no need to obtain a special decision approving performance of geophysical surveys (except for offshore prospecting). Geophysical surveys are understood as geological works using geophysical methods combined with geological methods to investigate geological structures associated with the occurrence of hydrocarbons, with the exception of wells of depth greater than 100 meters and works using blasting agents. Removing the requirement for a special approval decision should allow greater flexibility and competition in the geophysical sector.

- There will be only one concession for both hydrocarbon exploration and production. The concession will be divided into two stages: exploration stage and production stage. The exploration stage will last a maximum 5 years, whereas the production stage will last about 25 years. Only minimal extension of these stages will be possible. An 'investment decision' will be required to move from the exploration to the production phase.
- Hydrocarbon exploration and production concessions will be issued in a 3-stage tender: (i) qualification, (ii) tender, (iii) compulsory signing of a cooperation agreement with the National Operator of Energy Fossil Fuels (Polish: Narodowy Operator Kopalin Energetycznych, "NOKE").
- The tender procedure may be initiated by a motion from an enterprise. The authority will be entitled to assess whether the motion is justified and to deny initiation of the tender procedure if it finds the motion unjustified.
- During the qualification procedure applicants will be assessed on qualification criteria concerning: knowledge and experience, technical capacity, financial capacity. It is particularly important that an applicant controlled by state authorities or nationals of third countries will have to prove it is independent from the controlling entity to an extent that assures public safety.
- Only qualifying applicants are eligible to take part in tenders. Tender criteria include: (i) management methods, system of organization and mode of operating, (ii) the scope and timing of the proposed exploratory and extracting works, and (iii) NOKE's share in the costs and profits of the works.
- NOKE and the tender winner then sign a cooperation agreement. The model cooperation agreement shall be contained in an executive regulation. An informal draft executive regulation has already been made public, but has not been subject to public consultation to date.
- NOKE is a state-owned company overseen by the Treasury Ministry, which will participate in shale gas projects and hold a share in concessions to "strengthen administrative oversight of proper execution of concession obligations and a safe secondary market of concessions". NOKE will receive profits from mining activity, but will bear only minimal costs (only up to 5% of the costs of the mining activity or the sum stated in the tender notice). It will be entitled to take decisions concerning the mining activity, but will be free of almost all related civil and public responsibility. Moreover, NOKE is not subject to liability insurance and will not participate in related costs.
- The concession is granted after the cooperation agreement is signed.

Will it be possible to team up with other enterprises?

Cooperation agreements will provide the only framework for inviting other enterprises to cooperate in shale gas activities. This means that NOKE will be involved. While every enterprise has to undergo the qualification process separately, a collective motion during the tender stage will be possible.

The possibility of teaming up for the purpose of activities under currently held concessions may be limited or even excluded.

Will concessions be automatically transferred following M&A transactions?

Contrary to the currently binding provisions, under the amended law concessions will not be automatically transferred after an M&A transaction such as: a division, merger or a business acquisition. A decision on transfer of the concession will be needed in each of these three situations. This will be time-consuming and risky, as the new concession-holder will have to go through the qualification procedure.

What will happen with concessions granted before the amended law enters in force?

The Bill contains a set of transition provisions addressing a range of cases. Most importantly, shale gas prospecting and exploration concessions granted before the entry into force of the amendment will remain valid until the expiry of the concession term. However, it will be possible to change the geological works project concerning such activity only once.

A shale gas prospecting and exploration concession granted before the amendment takes effect may be converted into a hydrocarbon exploration and production concession. To this end the concession-holder needs to file a motion within 2 years after the time the amendment took effect. In order to have the concession converted, the applicant will have to meet the qualification conditions (see above) and sign a cooperation agreement with NOKE. Conversion of the concession is an attractive option, as it enables the concession-holder to team up with other enterprises (under the amended law it will only be possible when a cooperation agreement has been signed). On the other hand, it will require the participation of NOKE.

The Bill also envisages a special procedure for granting a hydrocarbon production concession, if the applicant: (i) obtained a concession for prospecting or exploration of hydrocarbons prior to the effective date of the amendment, (ii) explored and documented a hydrocarbon deposit forming the mining ownership and drew up geological documentation to the level of accuracy required to obtain a concession to extract hydrocarbons, and (iii) meets the qualification criteria (see above). In such a case no fully-fledged tender procedure will be necessary.

Will anything change as regards EIA laws?

The Bill contains amendments to environmental impact assessment laws aimed in particular at facilitating shale gas projects. For example, according to the planned amendment the description of the natural elements in the EIA report will be limited to a radius of 500 meters from the outer boundary of the project. This will allow shale gas operators to reduce the scope of tests and costs of the EIA report.

After the amendment comes into force, the decision on environmental conditions will not have to be obtained upfront before the hydrocarbons prospecting and exploration concession is granted, but will be obligatory at a later stage i.e. before issuing the hydrocarbons exploration and production concession.

Furthermore, there will be no obligation to obtain the decision on environmental conditions for the hydrocarbons exploration drilling to a depth of 5000 m. Consequently, the decision on environmental conditions will have to be obtained only if the depth of hydrocarbons exploration drilling will exceed 5 000 m.There new draft law introduces also an amendment to EIA laws in respect to NGOs activity. The Bill contains the obligation for ecological organizations that want to take part in the proceedings to be registered by at least 1 year before the procedure pertaining issuing the decision on environmental conditions requiring public participation has started. This amendment aims at elimination of a risk of appealing against the decision on environmental conditions by NGOs formed on ad-hoc basis to block a specific investment.

What happens next?

The Bill undergoes public and intergovernmental consultations until 18 March 2013. Then, the government will have to consider the comments made and initiate the legislative procedure with parliament and the president. A binding law is not expected before September 2013.

It is worth mentioning in passing that a separate Bill amending the Tax Act saw light of day on 1 March 2013 and is subject to public consultation.

Overview of Environmental Issues and US Regulatory Framework Pertaining to US Shale Gas Development

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Published: May 1, 2012
Updated: September 17, 2012

I. Overview of the Controversy Associated with Shale Gas Development in the United States

The development of shale gas in the United States has been widely recognized as one of the most promising trends in U.S. both in terms of job creation and economic benefits as well as its resulting increase in the domestic supplies of natural gas.[1] Many people view natural gas as a cleaner-burning fossil fuel that could enhance energy independence, reduce emissions and serve as a bridge fuel to renewable energy.[2]

Though there are many proponents of shale gas, there are also many who oppose it because of the hydraulic fracturing technology necessary to produce it.[3] This opposition has intensified as hydraulic fracturing has become more commonplace in wells around the country and around the world.[4] For its part, the gas industry contends that hydraulic fracturing is safe, well-regulated, and has a proven track record having been used in the United States since the 1940s in drilling more than one million wells.[5]

In support of the safety of hydraulic fracturing, the industry often points to a 2004 EPA study that assessed the potential for contamination of underground sources of drinking water from the injection of hydraulic fracturing fluids into CBM wells.[6] In that study, the EPA concluded that the injection of hydraulic frac-turing fluids into these wells posed “little or no threat to [underground drinking water].”[7] After reviewing incidents of drinking water well contamination, the EPA found “no confirmed cases that are linked to fracturing fluid injection into coalbed methane wells or subsequent underground movement of fracturing fluids.”[8]

The industry also maintains that the continued use of hydraulic fracturing is critically important to producing the natural gas America will need in the future.[9] It is estimated that “[80%] of natural gas wells drilled in the next decade will require hydraulic fracturing”[10] and that without it, the United States could lose “[45%] of domestic natural gas production.”[11]

II. Environmental Issues Associated with Shale Gas Development in the United States

As discussed in more detail below, the US Environmental Protection Agency (EPA) is currently conducting a national study that should enhance the scientific knowledge of some of the water contamination concerns raised about shale gas extraction. Although the study is on-going, the EPA has already identified some of the potential impacts that shale gas development may have on the environment including:

1. Contamination of underground sources of drinking water and surface waters resulting from spills, faulty well construction, or by other means;
2. Stress on surface water and ground water supplies from the withdrawal of large volumes of water used in drilling and hydraulic fracturing (discussed in Section B below);
3. Adverse impacts from discharges into surface waters or from disposal into underground injection wells; and
4. Air pollution resulting from the release of volatile organic compounds, hazardous air pollutants, and greenhouse gases.[12]

For purposes of this initial article, the primary focus will be on water contamination and water quantity and flowback concerns (discussed in Sections A and B below) since these are the two primary concerns that have been raised by the public.

A. Water Contamination Concerns

Despite the industry's claims that hydraulic fracturing is a safe and proven technology, environmental organizations, public health groups, and local communities have expressed numerous concerns about the potential environmental impacts of the use of hydraulic fracturing around the country.[13] There have been many allegations that hydraulic fracturing has led to the contamination of drinking water in many communities.[14] This has led to increased calls for federal regulation of hydraulic fracturing under the Safe Drinking Water Act (SDWA), which would at least provide a minimum federal "floor" for drinking water protection in the states engaged in drilling shale gas.[15]

The nonprofit, investigative journalism or-ganization, ProPublica, has an extensive in-vestigation of hydraulic fracturing underway.[16] According to that investigation, numerous states have reported cases involving spills of hazardous materials or other occurrences of water contaminated by oil or gas operations.[17] There are also hundreds of cases of water contamination in drilling areas where hydraulic fracturing is used, including some pending lawsuits alleging contamination.[18]

ProPublica has also noted the difficulty scientists face in specifically determining "which aspect of drilling—the hydraulic fracturing, the waste water that accidentally flows into the ground, the leaky pits of drilling fluids or the spills from truckloads of chemicals transported to and from the site—causes [the reported] pollution."[19]

One challenge has been the refusal by the industry to make public the chemical makeup of the hydraulic fracturing fluid used on a particular well.[20] Without this information, "environmental officials say they cannot conclude with certainty when or how certain chemicals entered the water.[21]

B. Water Quantity and Flowback Concerns

Concerns have also been raised pertaining to the large volumes of water needed during the hydraulic fracturing process, and the disposal of the flowback or wastewater from fracturing operations. A recent U.S. Geological Survey (USGS) report noted these concerns in a report dealing with water resources and gas production in the Marcellus Shale.[22] According to the USGS report, "many regional and local water management agencies [in the Marcellus shale region] are concerned about where such large volumes of water will be obtained, and what the possible consequences might be for local water supplies."[23]

Chesapeake Energy Corp., one of the most active drillers in the Marcellus shale,[24] candidly admits water is an essential compo-nent of its deep shale gas development.[25] According to the company, “fracturing a typical Chesapeake Marcellus horizontal deep shale gas well requires an average of five and a half million gallons per well.”[26] Chesapeake also maintains that water resources are protected through stringent state, regional and local permitting processes and in comparison to other uses within the area, deep shale gas drilling and fracturing uses a small amount of water.[27]

Hydraulic fracturing also gives rise to concerns pertaining to the disposal of wastewater.[28] While some of the injected hydraulic fracturing fluids remain trapped under-ground, the majority—60–80% returns to the surface as “flowback.”[29] The USGS has noted that because the quantity of fluids is so large, the additives in a 3 million gallon job would yield about 15,000 gallons of chemicals in the flowback water.[30] Some states, such as West Virginia, have noted that wastewater disposal is “perhaps the greatest challenge” in hydraulic fracturing operations.

Other shale producing areas face the same challenges. In north Texas, increased water use stemming from a growing population, drought, and the Barnett Shale development has led to heightened concerns about water availability.[31] In January 2007, the Texas Water Development Board (TWDB) published a study of a nineteen-county area in North Texas that contains estimates of water used in the Barnett Shale development.[32] The TWDB report indicates that the fracturing of a horizontal well completion can use more than 3.5 million gallons (more than 83,000 barrels) of water.[33]

In addition, the wells may be re-fractured multiple times when the natural gas flow slows after being in production for several years.[34] However, the report estimates that the amount of water used for development has been a relatively small percentage of the total water use.[35] Although growing, the report calculated water used for the Barnett Shale accounted for only three percent of the total groundwater used.[36]

The TWDB report makes predictions of future water needs for the area, including Barnett Shale development.[37] These estimate an increase in the groundwater used from three percent in 2005 to seven to thirteen percent in 2025.[38]

III. Regulatory Framework for Shale Gas Development in the United States

As described above, hydraulic fracturing is a water intensive technology that raises many issues related to the environmental protection of U.S. water supplies. In the United States, the regulation of oil and gas exploration and production activities, including hydraulic fracturing and horizontal drilling, generally falls within the jurisdiction of the states.

However, there are also many federal laws that control certain aspects of oil and gas activities, which include the Safe Drinking Water Act (SDWA), Clean Water Act (CWA), Clean Air Act (CAA), and Resource Conservation and Recovery Act (RCRA). Over the past few years, there have been increasing calls for the Federal Government, through the EPA, to regulate hydraulic fracturing under the SDWA. So far, however, the US Congress has not passed legislation that would give EPA authority to do so.

In the US, there is constant and longstanding tension between the role of the federal government in regulating energy and the role of the states. That this tension exists in terms of shale gas development is not surprising or unique. The oil and gas industry has long maintained that state’s are in the best position to regulate shale gas development and that existing state regulations are adequate to protect water resources during the development of shale gas resources.[39] This view is also shared by the Ground Water Protection Council (GWPC), which represents state groundwater protection agencies and underground injection control (UIC) program administrators.[40]

However, there is a growing contingent of landowners, environmental groups and citizen groups calling for federal regulation and further investigation of hydraulic fracturing due to concerns about water usage and possible contamination.[41] Although a detailed discussion of the numerous state laws is beyond the scope of this article,[42] there are several important federal regulations that are relevant and discussed in detail below.

A. The Safe Drinking Water Act

The SDWA[43] is the primary federal law for protecting public water supplies from harmful contaminants.[44]Enacted in 1974,[45] and broadly amended in 1986 and 1996,[46] the SDWA is administered through a variety of programs that regulate contaminants in public water supplies, provide funding for infrastructure projects, protect underground sources of drinking water, and promote the capacity of water systems to comply with SDWA regulations.[47]

The EPA is the federal agency responsible for administering the SDWA[48] but a federal–state structure exists in which the EPA may delegate primary enforcement and implementation authority (primacy) for the drinking water program to states and tribes.[49] The state-administered Public Water Supply Supervision (PWSS) program remains the basic program for regulating public water systems,[50] and the EPA has delegated primacy for this program to all states, except Wyoming and the District of Columbia (which SDWA defines as a state).[51] The EPA has responsibility for implementing the PWSS program in these two jurisdictions and throughout most Indian lands.[52]

A second key component of the SDWA requires the EPA to regulate the underground injection of fluids to protect underground sources of drinking water. In terms of oil and gas drilling, the UIC program regulations specify siting, construction, operation, closure, financial responsibility, and other requirements for owners and operators of injection wells.[53] Thirty-three states (including West Virginia, Ohio, and Texas) have assumed primacy for the UIC program.[54] The EPA has lead implementation and enforcement authority in ten states, including New York and Pennsylvania, and authority is shared in the remainder of the states.[55]

Notwithstanding the SDWA's general mandate to control the underground injection of fluids to protect underground sources of drinking water, the law specifically states that EPA regulations for state UIC programs "may not prescribe requirements which interfere with or impede any underground injection for the secondary or tertiary recovery of oil or natural gas, unless such requirements are essential to assure that underground sources of drinking water will not be endangered by such injection."[56]

Consequently, the EPA has not regulated gas production wells, and historically had not considered hydraulic fracturing to fall within the regulatory definition of underground injection although it was a bit unclear under US law until the issuance of the Leaf v. EPA case.

Additional background information and insight from the U.S. Congressional Research Service CRS are presented in the paper "Hydraulic Fracturing and Safe Drinking Water Act Issues", published July 2012.

B. Leaf v. EPA

Until 1997, it was unclear whether hydraulic fracturing was regulated under the UIC programs.[57] In Leaf v. EPA, the U.S. Court of Appeals for the 11th Circuit ruled that the hydraulic fracturing of coal beds for coal bed methane (CBM) production constituted an underground injection that must be regulated.[58]However, since that decision was only applicable to states in the 11th Circuit, the only state actually required to revise its UIC program was Alabama.[59]

In response to the decision in Leaf v. EPA [60] and continuing citizen complaints about water contamination attributed to hydraulic fracturing used in CBM, the EPA began to study the impacts of hydraulic fracturing practices used in CBM production on drinking water sources in order to determine whether further federal regulation was needed.[61] In 2004, the EPA issued a final (phase I) report, based primarily on interviews and a review of the available literature, and concluded that the injection of hydraulic fracturing fluids into CBM wells posed little threat to underground sources of drinking water and required no further study.[62]

The EPA noted, however, that very little documented research had been done on the environmental impacts of injecting fracturing fluids.[63] It also noted that estimating the concentration of diesel fuel components and other fracturing fluids beyond the point of injection was beyond the scope of its study.[64]Some members of Congress and some EPA professional staff criticized the report, asserting that its findings were not scientifically founded.[65]

Subsequently, in the Energy Policy Act of 2005[66], the US Congress amended the SDWA Section 1421 to specify that the definition of "underground injection" excludes the injection of fluids or propping agents (other than diesel fuels) used in hydraulic fracturing operations related to oil, gas, or geothermal production activities.[67] This exclusionary language effec-tively removed the EPA's (previously unexer-cised) authority under the SDWA to regulate the underground injection of fluids for hydraulic fracturing purposes.[68] Environmentalists and others opposed to hydraulic fracturing commonly refer to this exclusionary language as "The Halliburton Loophole," based on a New York Times editorial of the same title.[69]

C. The FRAC Act

As shale gas development spread across the United States, so too did public concern about the safety and environmental impact of hydraulic fracturing. These concerns ultimately made their way to Congress where companion bills H.R. 2766 and S. 1215 were introduced in 2009 an effort to amend the SDWA to specifically include hydraulic fracturing.[70]

Representative Diana DeGette introduced H.R. 2766 on June 9, 2009 and Senator Robert Casey Jr. introduced S. 1215 as the "Fracturing Responsibility and Awareness of Chemicals Act"—or "FRAC Act").[71]The FRAC Act would amend the SDWA definition of "underground injection" to expressly include "the underground injection of fluids or propping agents" used for hydraulic fracturing in oil and gas operation and production activities.[72] The bills would also require public disclosure of the chemical constituents (but not the proprietary chemical formulas) used in the fracturing process.[73] As of October 23, 2010, H.R. 2766 had sixty-nine co-sponsors but ultimately the FRAC Act did not reach the house floor before the 111th Congress recessed.[74] The Act was re-introduced in the 112th Congress where it is still pending.[75]

IV. The US EPA Hydraulic Fracturing Study

In December 2009, six months after the introduction of the FRAC Act 2009, the U.S. House of Representatives Appropriation Conference Committee concluded a focused study analyzing the relationship between hydraulic fracturing and drinking water.[76] The committee believed the EPA should conduct this study.[77] The EPA agreed with Congress that a study was warranted due to the serious concerns from citizens raised about the potential impact on drinking resources, public health, and environmental impacts in the vicinity of shale gas production areas employing hydraulic fracturing technology.[78]

A. EPA Study Approach

In addition to examining the potential relationships between hydraulic fracturing and drinking water, a key goal of the EPA study is to generate data and information that can be used to assess risks and ultimately inform decision makers. The EPA has proposed four approaches to achieve this goal:[79]

1. Compile and analyze background data and information;
2. Characterize chemical constituents relevant to hydraulic fracturing;
3. Conduct case studies and computational modeling; and
4. Identify and evaluate technological solutions for risk mitigation and decision support.

In conducting its study, the EPA intends to follow a case study approach, which is often used in in-depth investigations of complex issues like hydraulic fracturing. The EPA admits that, "developing a single, national perspective on [hydraulic fracturing] is complex due to geographical variations in water resources, geologic formations, and hydrology."[80] Nonetheless, the EPA's intention is that "the types of data and information that are collected through case studies should provide enough detail to determine the extent to which conclusions can be generalized at local, regional, and national scales."[81]

The initial set of research questions proposed by the EPA includes:

1. What sampling strategies and analytical methods could be used to identify potential impacts on sources of drinking water, water supply wells, and receiving streams?
2. Are there vulnerable hydrogeologic settings where HF may impact the quality and availability of water supplies?
3. How does the proximity of HF to abandoned and/or poorly constructed wells, faults, and fractures alter expected impacts on drinking water resources and human health?
4. Is there evidence that pressurized methane or other gases, HF fluids, radionuclides, or other HF-associated contaminants can migrate into underground sources of drinking water? Under what conditions do these processes occur?

B. Recent Developments in the EPA Study

On November 2, 2011, EPA released details of its hydraulic fracturing study plan.[82] As set forth in the study, EPA will focus on the entire hydraulic fracturing water lifecycle, which includes water acquisition to wastewater treatment and disposal.

EPA will use a case study approach and has selected seven case studies that EPA believes will provide the most useful information about the potential impacts of hydraulic fracturing on drinking water resources under a variety of circumstances. Two sites are prospective case studies where EPA will monitor key aspects of the hydraulic fracturing process at future hydraulic fracturing sites.

Five sites are retrospective case studies, which will investigate reported drinking water contamination due to hydraulic fracturing operations at existing sites. The EPA is expected to issue its first report of findings in 2012 and its final report in 2014.

C. Other EPA Actions

While the EPA study is on going, there are a number of other activities underway by the EPA that could impact shale gas development going forward.

1. Effluent Guidelines for Shale Gas Extraction

In October 2011, EPA initiated a rulemaking to set discharge standards for wastewater from shale gas extraction.[83]

In terms of background, according to the EPA, and based on information provided by industry, up to one million gallons of shale gas wastewater or “flowback” or “produced water,” may be produced from a single well within the first 30 days following fracturing. These produced waters generally contain elevated salt content (often expressed as total dissolved solids, or TDS), many times higher than that contained in sea water, conventional pollutants, organics, metals, and NORM (naturally occurring radioactive material). Additional data show that flowback waters contain concentrations of some of the fracturing fluid additives.

While some of the shale gas wastewater is re-used or re-injected, a significant amount still requires disposal. Some shale gas wastewater is transported to public and private treatment plants, many of which are not properly equipped to treat this type of wastewater. As a result, pollutants are discharged into surface waters such as rivers, lakes or streams where they can directly impact aquatic life and drinking water sources.

The initiation of a rulemaking is the very start of the rulemaking process and EPA plans to reach out to affected stakeholders to collect relevant data and information. EPA also plans to collect financial data on the shale gas industry to determine the affordability of treatment options for produced water.

2. Guidance for Diesel Fuels

A key element of the SDWA UIC program is setting requirements for proper well siting, construction, and operation to minimize risks to underground sources of drinking water. The Energy Policy Act of 2005 excluded hydraulic fracturing, except when diesel fuels are used, for oil and gas production from permitting under the UIC Program. This was because of concern about the risks to drinking water from diesel fuels.

Over the past year, there has been some confusion over whether the industry must disclose the use of diesel fuel in hydraulic fracturing activities and if so, how and when. In response to the confusion, EPA has formulated draft guidelines for the use of diesel fuel in hydraulic fracturing.[84]

3. New US air standards for hydraulically fractured natural gas wells

The use of "reduced emissions completion (REC)", also known as “green completion”, has been prescribed for hydraulically fractured natural gas wells from Jan. 2015 onwards. This is part of the final rule on New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants[89], which was issued on April 17, 2012 by the U.S. Environmental Protection Agency (EPA).

V. Disclosure of Frac Fluid Chemicals

In addition to the FRAC Act and the EPA study, Congress has also separately request-ed information from the industry about the chemicals used in hydraulic fracturing.[85] On February 18, 2010, Henry A. Waxman, Chair-man of the Subcommittee on Energy and Environment, and Subcommittee Chairman Edward Markey sent letters to eight oil and gas companies that use hydraulic fracturing “requesting information on the chemicals used in fracturing fluids and the potential impact of the practice on the environment and human health.”[86]

On July 19, 2010, Congressmen Waxman and Markey sent another letter requesting additional information from companies involved in hydraulic fracturing, including a list of the total volume of flowback and produced water recovered from wells, how the water was disposed of and a variety of other well specific data to determine the chemical content of flowback and produced water.[87] The companies ultimately provided information to the US Congress on the chemicals being used in hydraulic fracturing operations.

More recently, there is a growing trend in the US towards requiring companies to disclose the chemicals used in hydraulic fracturing with a number of states now requiring this and more likely to come. Some states require or allow for the disclosure via FracFocus, which is a webbased national registry where companies can disclose the chemical additives used in the hydraulic fracturing process on a well-by-well basis.[88]

VI. Conclusion

The tremendous boom in shale gas production in the United States over the past five years has indeed been a game changer with potentially significant implications in terms of energy security and supply, climate change mitigation, and energy policy. While shale gas presents an enormous opportunity for the US and perhaps the world, there remain numerous legal, policy and environmental challenges that must be addressed before the full potential of shale gas can be realized.

In the United States, this analysis is currently underway with the on-going EPA investigation and a number of other studies assessing the environmental impact of shale gas development. While various studies are underway, some US state governments have begun to amend or enact state laws and regulations in an effort to pre-empt the need for further federal regulation of shale gas drilling operations. Some of the key actions taken by US States, such as the disclosure requirements for chemicals used in hydraulic fracturing, will be highlighted in other sections of the SHIP website.

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[3]See, e.g., Wes Deweese, Fracturing Misconceptions: A History of Effective State Regulation, Groundwater Protection, and the Ill-Conceived FRAC Act, 6 OKLA. J. L. & TECH. 49, 6 (2010).

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[5]AM. PETROLEUM INST., FREEING UP ENERGY, HYDRAULIC FRACTURING: UNLOCKING AMERICA'S NATURAL GAS RESOURCES 5 (2010),www.api.org/~/media/Files/Policy/Exploration/HYDRAULIC_FRACTURING_PRIMER.ashx

[6]See id.

[7]ENVTL. PROT. AGENCY, EVALUATION OF IMPACTS TO UNDERGROUND SOURCES OF DRINKING WATER BY HYDRAULIC FRACTURING OF COALBED METHANE RESERVOIRS STUDY, at 7-5 (2004) ,water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_coalbedmethanestudy.cfm. [hereinafter DRINKING WATER IMPACT STUDY].

[8]Id. at 7–6.

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[10]Id.

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[12]See generally ENVTL. PROT. AGENCY, NATIURAL GAS EXTRACTION – HYDRAULIC FRACTURING,www.epa.gov/hydraulicfracturing/.

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[14]Id.

[15]Id.

[16]See Buried Secrets: Gas Drilling's Environmental Threat, PROPUBLICA,www.propublica.org/series/buried-secrets-gas-drillings-environmental-threat (last visited May 1, 2012) (containing links to various investigative pieces concerning the environmental impact of gas drilling). In the Drilling Down series of articles, the New York Times is also examining the risks of shale gas drilling and efforts to regulate the rapidly growing industry. Drilling Down, N.Y. Times,topics.nytimes.com/top/news/us/series/drilling_down/index.html (last visited May 1, 2012).

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[27]Id.

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[29]Id.

[30]DANIEL J. SOEDER & WILLIAM M. KAPPEL, WATER RESOURCES AND NATURAL GAS PRODUCTION FROM THE MARCELLUS SHALE 3–4 (2009) pubs.usgs.gov/fs/2009/3032/pdf/FS2009-3032.pdf.

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[53]Id. (noting that requirements for Class II wells are found in 40 C.F.R. §§ 144–46).

[54]Id.

[55]See id. To receive primacy, a state must demonstrate to the EPA that its UIC program is at least as stringent as the federal standards. Id. For Class II wells, states must demonstrate that their programs are effective in preventing pollution of underground sources of drinking water. Id. at 37 n.77.

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France: Evolutions in the legal framework for shale oil and gas

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Published: March 14, 2012
Updated: November 20, 2015

Introduction

In March 2010, the French Government (hereafter referred to as the "Government") delivered the first research permits to explore shale oil and gas in France[1]. Afterwards French opponents of shale oil and gas operations focused their actions early in 2011 on hydraulic fracturing (hereafter referred to as "HF"). HF was already regulated by French and European laws before being used in shale oil and gas operations in France. Hydraulic fracturing had been applied twenty times in France under the existing legal framework, without any incidents being reported.

Following more than six months of major parliamentary debates in the French National Assembly and the Senate, Law n° 2011-835 was adopted on 13 July, 2011 and entered into force on 14 July, 2011. This law forbids "the exploration and exploitation of liquid or gaseous hydrocarbons through hydraulic fracturing" and enables the Government to abrogate "research permits which include projects using hydraulic fracturing." This law was then considered a political response to a public concern, which pushed the Parliament to ban HF to satisfy its opponents.

In our description of the French legal framework for shale oil and gas, we shall first look at the regulation of mining exploration and the steps required before exploiting a shale oil and gas field (Section 1.). Then we shall consider the technical regulations applicable to the exploitation of oil and gas (Section 2.). We shall also detail the changes brought about by the Law n° 2011-835 on shale oil and gas which entered into force on 14 July, 2011 (Section 3.).

Last, we shall review recent challenges to this law and consider France's role in the global discussion on shale gas and hydraulic fracturing.

Update November 2015: read the article "What´s to become of France´s troubled fracking commission?" (Weblink)

1. The public monitoring for mining exploration in France: activities are subject to authorisation

Two main steps are provided for in the mining law: first the allocation of an exclusive research permit (1.1) and then the declaration opening the research work (1.2).

1.1 The delivery of an exclusive research permit

In France, an operator wanting to explore a given area has to start by applying for an exclusive research permit. Shale oil and gas, being hydrocarbons, are subject to the Mining Code. The permit delivered under this code authorises the operator to explore the area and declare ownership of the operation for all resources found through his research. To obtain the permit, the operator must first submit a file to the Minister.

The file must include a technical study, the program of the contemplated works, cartographical documents, as well as an impact notice[2] which details the potential effects of the works on the environment, and how those effects are taken into account. The Minister then conveys the file to the Prefect of that particular area and the Prefect consults the directors of the relevant Regional Environment, Development, and Housing Agency (hereafter "DREAL"[3]). The Prefect has three months to report back to the Minister and give his opinion, along with the opinions of the DREAL's directors in question. The Minister makes a decision after taking the advice of the General Council of Mining. The permit can last up to five years and may be renewed twice.

1.2 The declaration of opening of works

Once the permit is granted, pursuant to article 83 of the Mining code, the opening of the research works is subject to a declaration from the operator to the Prefect supported by:

- a health and security document;
- a document detailing the consequences of the works on water;
- an impact notice (assessment).

The Prefect passes on the declaration and the file mentioned in 1.1 to the relevant services, which have one month to issue their opinion. The declaration is also handed to the mayors, whose territory is covered by the permit, to provide then with information. The mayors make this information publicly available by placing it on the bulletin board in front of the Town Hall. The mayors are not informed about the granting of research permits, they are informed only when the works are announced. The public has no information on the precise nature of those works as the declaration is the only document displayed. If the Prefect considers that the works might harm the environment, the office can impose special instructions onto the operator.

No mandatory environmental impact study is provided for. The Minister of the Environment may at his discretion request one if he considers it useful when delivering titles[4]. The main reason for such a request would be an expectation that the operations might trigger risks or important consequences on the environment or to public health. If the Minister orders the operator to carry out such a study, this study is eventually communicated to the public.

2. The public monitoring for mining exploration in France: activities are subject to technical regulations

Mining activities, including drilling activities (2.1) and environmental protection (2.2), are tightly regulated in France.

2.1 Drilling activities

The construction of oil and gas wells is subject to specific rules and procedures as defined by the General Regulation for Extractive Industries RGIE[5]. Each well is constructed in conformity with an official decision authorising it (permit or concession with a works authorisation) and casing and cementing programmes have to be approved by the DREAL.

Technically speaking, the well has to be drilled deeper than any groundwater-bearing formation used for water production and has to be sufficiently isolated to avoid leakage into freshwater aquifers. Moreover, the cementing and isolation of the well have to be designed specifically for each well and each environment. Otherwise, DREAL will not validate the drilling plan. Details of the RGIE are defined below:

To minimize the risk of groundwater pollution, the RGIE[6] applies article 26, which provides that the casing shall be designed according to the maximum loads. For HF, it implies the protection of the isolation through multiple layers of casing. Moreover, the casing must be checked on the day of their installation. DREAL oversees the monitoring and installation and must conduct regular tests to ensure its sealing.

A programme of tests taking into account the specificities of the environment and the corresponding fluid pressures must be presented by the operator to DREAL for the casing and cementing. The DREAL director may ask for complementary tests if warranted. The order of 22 March, 2000 details a further requirement for casing if the drilling takes place near groundwater that needs to be protected.

Article 22 of the applicable regulation further requires that the drilling plan be communicated to DREAL at least one month before the beginning of the research works and shall include, among other things:

- a provisional geological section of the formations to be cut through,
- a provisional technical section detailing the cementing and casing to be implemented, and the
- description of the operations to be conducted, including the nature and pressure of the fluids used, and measures to ensure the security of the environment.

The drilling plan must also detail the means provided to control the characteristics of the fluids and to identify early signs of a blowout, the characteristics of tools designed to seal the works in the event of a blowout, and the characteristics of the casing and cementing.

2.2 The protection of water and environment

Protection of water and the environment are covered by the relevant sections of the Mining Code and the Environmental code.

Pursuant to article L. 161-1 of the New Mining Code[7], as a general rule, companies must protect "natural resources", including water.

In addition to the aforementioned declaration, another declaration must be made for opening of the works (mentioned in 1.2). This filing must include a document indicating the effects of the works on water and, where necessary, the compensating measures to be considered as well as a statement of compatibility between the project and the guiding plan for the zoning and the management of water[8] mentioned in article L. 212-1 of the Environment Code.

The drilling plan (see 2.1 Drilling activities) sets out the fundamental measures to be implemented to protect groundwater from possible risks of pollution. Moreover, pursuant to article L. 214-3 of the Environment Code, every operation that may be dangerous to health or that may prevent the water from flowing freely, is subjected to a prior authorisation from DREAL.

More generally, the operator has to respect "environmental interests" that fall under the control of the Prefect, pursuant to article L. 173-2 of the Environment Code. Furthermore, the Prefect can order the operator to take certain measures to protect the environment. If the operator does not comply, the Prefect can himself carry out these measures and the operator has to pay the costs. The exclusive research license can even be cancelled by the Minister in certain cases, including where the operator demonstrates a lack of respect for the measures ordered by the Prefect, as detailed in article L. 173-5 of the Environment Code.

3. Changes brought about by law n° 2011-835

In order to properly understand the law n° 2011-835 of 14 July, 2011, it is also necessary to detail how it was passed (3.1) before analysing its provisions and its implementation (3.2).

3.1 Passing of the law n° 2011-835

In response to demonstrations all around the country, France´s Member of Parliament (MP) Christian Jacob, leader of the Union for a popular movement (UMP), submitted a bill to Parliament on 31 March, 2011, requesting the banning of all exploration and exploitation of shale gas using HF. His justification was based on the precautionary principle, which is indirectly enshrined in the French Constitution.[9]

The opposition had tabbed a bill on shale oil and gas in the Senate on 24 March, 2011 and another one in the National Assembly on 30 March, 2011. Their objective was to reinforce the HF ban with definitions (on HF and unconventional hydrocarbons) and to introduce new public participation regulations into the Environmental Code. The UMP bill was eventually adopted on 13 July, 2011 but the Government decided to use the fast-track procedure in order to satisfy public expectations. The bill was only passed after two votes in each assembly and the session of a joint committee. This exemplifies the intensity of the debate. It became Law n° 2011-835 but did not immediately nullify all the research permits as initially proposed to the Parliament.

The decision-making process of this bill was impacted by the context of upcoming senatorial and presidential elections. Members of Parliament chose to pass a bill specifically on HF while experts argued for amendments to the Mining Code in general, which also applies to shale oil and gas exploration and exploitation.

The Code, which dates back to 1956, imposes drilling standards that were adopted by decree over the years and have been proven to be suitable for the regulation of HF for the exploration and exploitation of resources other than shale oil and gas. However, experts argue changes would have been useful, to implement a procedure more in line with environmental law and giving more importance to public participation.

Additionally, law n° 2011-835 was adopted in advance of the publication of the final report from a group of experts from the CGIET[10] and the CGEDD[11], which were appointed in February, 2011 to help the Government make a decision on shale oil and gas. The group only published its provisional report in April, 2011. The report highlighted a number of issues, including the impossibility of making a rational choice without knowing the extent of the resources available in France. This report actually advised taking more time to improve the quality of the law based on a better knowledge of the subject.

The French Minister of the Environment commissioned a lawyer in April, 2011 to prepare another report on the reform of the Mining Code, present suggestions on how to update it, and in particular provide a mechanism for better public participation in decision-making. This report put forward several suggestions regarding further amendments to the Code, notably:

- a restructuring of the administrative organisation of the State and of the division of competences between the State and local authorities to better articulate mining law and environment law;
- an intensification of public participation in allocating mining permits;
- the creation of a High Council on Mining Resources, bringing together the State, local authorities, unions, non-governmental organisations and companies to improve the dialogue with civil society;
- the strengthening of the environmental evaluation of drilling projects;
- the development of education, research, and information of the public on mining debates.

The numerous public protests linked to shale gas were partly a result of the public having insufficient influence or knowledge on the legal process in the allocation of research permits. The aim of the reforms suggested by the lawyer is to use the notion of “ecological democracy” to bridge the gap between mining law and environmental law. The report, however, was delivered in October, 2011, three months after the law n° 2011-835 was adopted. In this way, a partial reform was put into effect instead of the suggested encompassing reform.

Such all-encompassing reform was also favoured by the two MPs appointed by the National Assembly (“rapporteurs”) to work on the bill that became law n° 2011-835. The issue was still politicised, as highlighted by the conclusion of this last information report on shale oil and gas. This report had two conclusions - one for each Author. This is extremely rare in France, especially for an information report, and highlights the partisan nature of the debate.

Despite the different experts’ and MPs’ reports favouring an evolution of the existing legal framework to adapt it to HF, the prohibition of HF was enacted but no definition of HF was provided. Please see below for further on this.

3.2 The content of law n° 2011-835 and its implementation

The law has only four articles. The first one provides for the prohibition of HF, the second one for the creation of a special commission, the third one for reports by the operators and the last for a yearly report to be submitted to the Parliament.

(a) Prohibition of HF

Article 1 prohibits the use of HF for the exploration and exploitation of shale oil and gas. It is the flagship provision of the law. The expression “hydraulic fracturing” is found throughout the text. Yet some observers noted that the law contained a loophole, as it did not provide any definition of the technique. The use of “hydraulic fracturing of rocks” for the exploration or exploitation of “liquid or gaseous hydrocarbons” is forbidden.

In this way, only the main use of HF is forbidden, but not HF itself. This lack of definition results from a compromise, which opens the possibility to implement experiments and scientific research under public supervision to define HF and evaluate its effect on the environment. However, the conditions for these experiments have not yet been approved or defined.

After the law was passed, several bills defining HF were tabbed by the French Socialist groups in the Senate and National Assembly. Indeed, they believed that the law passed in July did not go far enough because of the lack of definition of HF, leaving the door open for experiments and research on HF. One of the bills was rejected by the National Assembly, which enjoys a majority of MPs belonging to one party. The second one is still to be discussed by the Senate but has not yet been scheduled.

(b) Creation of a special Commission

Pursuant to article 2 of the law n° 2011-835, a commission shall deliver an opinion on the conditions of implementation of research-oriented experimentations, as provided for in article 4 of the law. This opinion will be made public. The order detailing the composition, mission and functioning of this National Commission on the Orientation, Monitoring and Assessment of the Exploration and Exploitation Techniques of Liquid and Gaseous Hydrocarbons (hereafter referred to as the “Commission”) has not yet been published.

The order must further detail the composition of the Commission. Currently, the law only provides limited provisions. The Commission is to be composed of one MP and one Senator and representatives of the State, local authorities, associations, employers and employees of the relevant industries. The respective weight of each of these members in the Commission could influence the opinions it will give.

The importance of this Commission is best understood in the context of the general forbidding of HF. Indeed, it is the only body that could allow an operator to use HF, for the sake of “scientific research”. Yet, “scientific research” could equally mean research on HF or research resulting from HF. The order will detail the scope of the authorisations the Commission can give, hence its crucial importance.

(c) Operators’ reports

Article 3 requires all the operators that have received a permit to submit a report to the Government stating which techniques are to be used for the exploration of liquid or gaseous hydrocarbons. Article 3 further provides that if such a report states the operator will or might use HF, the permit will be cancelled. 64 reports were sent, most of them covering exploration permits for conventional oil and gas.

On the basis of those reports, three research permits were cancelled by the Ministry for the Environment under law n° 2011-835. Two operators, namely Schuepbach Energy LLC and Total SA, failed to convince the Government that they would not use HF in their research. Consequently, their permits were cancelled. Schuepbach explicitly stated it would use HF while Total's report was deemed "not credible" by the French Minister of the Environment.

Schuepbach's CEO declared that the company would challenge the decision of the Ministry before the French Administrative Judge. There are two ways for the company to do so: going to court, which would probably trigger Government anger against a company that needs political support in France and abroad, or by asking the Minister for the Environment to reconsider his decision. These cancellations were the main direct effect of law n° 2011-835.

(d) Yearly report by the Commission

Pursuant to Article 4 of law n° 2011-835, an annual report is to be submitted by the Government to Parliament on:

- Developments in the techniques of exploration and exploitation of shale oil and gas;
- Changes in other countries' legal frameworks in order to adapt the French legal framework;
- the conditions of the experiments on HF that took place under public control.

The wording of this Article is important as it opened the door for subsequent changes to the law, in relation to developments with varying techniques. The law forbidding the use of HF leaves the door open to scientific research on this technique and a yearly review of it. In theory, it then provides the operators with the tools to challenge its relevance. This article discusses challenges to validity of this law in Section 4.

4. Challenges to the validity and constitutionality of law n° 2011-835

France is the first country in the world to officially ban the use of HF in exploration and mining research and projects. The implementation of law n°2011-835 and its ban on hydraulic fracturing was the source of much debate in 2012 and 2013. French authorities were separated on the issue of HF with opponents of the law recommending that more studies be conducted to conclusively identify the benefits and risks associated with HF. This is demonstrated by the July, 2013 report of a French parliamentary commission, which asserted that the exploration and use of shale gas could create 100,000 jobs and improve competition in the country. If deemed safe, the use of shale gas could not only help to reduce France's dependence on nuclear and other sources of energy but could also significantly boost its economy.

Proponents of the law, however, rejected the idea of relaxing a ban on HF on the basis that the environmental risks, such as seismicity and pollution of groundwater, remained unverified. French Minister of Ecology, Sustainable Development, and Energy Delphine Batho stated that due to the unknown threats that it posed to the environment, the ban should remain in place until substantial evidence disproves the existence of these and other potential risks. These debates were furthered heightened by litigation and concurrent European Parliament debates calling for further regulation of shale gas and oil and resulting in the rejection of a proposed ban on hydraulic fracturing.

4.1 Arguments presented before the Constitutional Court in opposition to the HF ban

Schuepbach, which had won two permits to explore shale gas in France prior to the implementation of law no°2011-835 openly protested the revocation of these permits. In response, the company formalized its objection to this action by filing an appeal before the Conseil d'Etat, France's highest administrative court. In its appeal, the company asserted that there was insufficient proof that HF could result in environmental dangers. Schuepbach further challenged the cancelation of its permits by asserting that law n° 2011-835 and the subsequent cancellations were contrary to the following four legal principles: (1) equal treatment; (2) freedom of enterprise; (3) right to property; and (4) Articles 5 and 6 of the Environment Charter[12].

After a preliminary review of the claim of Schuepback, the Counseil d'Etat referred the matter to the Cour Constitutionnel (Constitutional Court) after determining that the case involved some questions of law pertaining to the guarantee of rights granted under Articles 1 and 3 of the French Constitution. The Cour Constitutionnel rejected these four complaints presented by Schuepbach and held that the ban of HF and subsequent revocation of permits held by Schuepback are valid for following reasons:

- **Difference in treatment:** the Cour Constitutionnel noted that the intent of law n° 2011-835 is to prevent the dangers that research and exploitation of hydrocarbons may pose to the environment. According to the Court, this difference in treatment between HF and other forms of geothermal exploration is directly related to the purpose of the law, as the latter process has been determined to have no detrimental effects on the environment.
- **Infringement on Freedom of Enterprise:** law n° 2011-835 establishes an administrative and legal framework that prohibits HF for all research and exploitation of hydrocarbons. Moreover, the goal of this law is to ensure the general public interest of environmental protection. The law and its reporting requirements are proportionate in this regard and thereby do not constitute an infringement on freedom of enterprise.
- **Right to property:** the revocation or denial of permits is the direct consequence of the permit owner's explicit use of hydraulic fracturing or inability to meet reporting requirements. The Court held that this does not interfere with a legally acquired right to obtain and hold a permit. Furthermore, authorisations granted by an administrative authority cannot be treated as personal property.
- **Articles 5 and 6 of the Environmental Charter:** these issues were ruled as not raising constitutional questions and were therefore not addressed by the court on the basis of forum non conveniens.

4.2 France's role in the global debate on HF

Following the issuance of this decision, France's Minister for the Environment, Philippe Martin proclaimed the decision as an environmental and political victory, saying "with this decision the ban on hydraulic fracturing is absolute." While several oil and gas lobbying groups have criticized this decision as depriving France of the opportunity to benefit from nonconventional carbon resources, it is clear that the decision has been approved by the country's Executive. According to President Français Hollande, this ban will remain in place throughout his presidential term and beyond.

If implemented in the U.S., a similar decision would have had wide-scale economic implications. Shale gas has helped to reshape the domestic landscape for energy production in the country. This dramatic increase in production has also allowed the U.S. to redefine its role in international energy markets, as it is in line to shift the balance away from its dependence on external sources of natural gas by 2015. The country will also likely begin to export this product in the near future if production remains at its current levels.

Despite the fact that the long-term effects of HF are still largely undetermined, this procedure has now become the source of debate in the European Parliament as the legislative body seems hesitant to follow France’s lead. According to EU reports, total shale gas reserves in the EU exceed 56 thousand billion cubic metres (BCM) and more than 14 BCMs are deemed technically recoverable. Many of these reserves are located in France. France is joined by Bulgaria, however, who has also instituted a ban on hydraulic fracturing in an effort to further it environmental protection goals. Other countries, like Poland, fully endorse the implementation of a relaxed legal framework governing the research, exploration and exploitation of hydrocarbons.

In order to accommodate the differing approaches of each Member State, the European Parliament passed resolutions in September, 2012, granting each Member State the right to determine whether shale gas exploration will be allowed within its territory. The resolution further requires each Member State to create a strict and robust legal and regulatory framework where exploration is allowed. The court decision, upholding France’s ban, is therefore consistent with this.

4.3 Recent developments in the HF debate in France

Lately, a report (link) related to heptafluoropropan fracturing was published in April 2015. This report, composed in 2013 by Arnaud Montebourg, former “Ministre du Redressement productif ” (similar to minister for industry), describes how France could benefit in terms of growth, employment, industrial competitiveness, and energy independence from the development of this substitute to water-based HF.

Ségolène Royal, current minister of the Environment, immediately replied by expressing her opposition to shale gas, and assured that she will refuse all applications concerning shale gas drilling.

Moreover, a recent study published in April 2015 by the French Economic Observatory ("Can the US Shale Revolution be duplicated in Europe?") aims to contradict the fact that shale gas exploitation would be profitable in France.

In addition to this, a new national strategy for the ecological transition was adopted in February 2015 for the 2015-2020 period. This strategy reaffirms the current French opposition to shale gas exploitation.

5. Conclusion: a legal framework to be reformed and modernized

Although the French legal framework for shale oil and gas in general and HF in particular has been officially settled, debates continue within the European Union and internationally. Despite law n° 2011-835 enacting the banning of HF for the exploration and exploitation of shale oil and gas, much still remains to be decided since several important technical reports have not yet been finalized. One bill on shale oil and gas still remains to be considered by the Senate, even though it stands little chance of going through the National Assembly.

Further orders detailing and clarifying the law may have a crucial importance for the future of shale oil and gas in France. Moreover, the law n°2011-835, through its requirement for annual reports, opens the way for changes in the established legal framework following technical and regulatory developments. One could argue that the postponing of those questions has one benefit: it defers the debate, making room for better informed decision making.

Update November 2015: read the article "What´s to become of France´s troubled fracking commission?" (Weblink)

[1]In April 2011, Jean-Louis Borloo, who took back his position as a Member of Parliament, tabbed a bill aiming at cancelling all the permits delivered.

[2]An impact notice is more restrictive than an impact assessment.

[3]DREAL: direction régionale de l'environnement, de l'aménagement et du logement.

[4]The Minister of Environment has the possibility, according to the Environment Code, to ask for the completion of an environmental impact study. However, this has never been done by the Minister.

[5]The General Regulation for Extractive Industries ("réglement general des industries extractives", RGIE).

[6]The RGIE was completed by the order of 22 March 2000.

[7]The New Mining Code is a compilation of mining text that is still uncompleted. It should replace the actual Mining Code after its completion.

[8]SDAGE: "schéma directeur d'aménagement et de gestion des eaux".

[9]Pursuant to the preamble of the French Constitution, the Charter of Environment has a constitutional value and its article 5 provides for the precautionary principle, as well as article L 110-1 of the Environment Code.

[10]General Council on Industry, Energy and Technology, a public institution.

[11]General Council on Environment and Sustainable Development, a public institution.

[12]Article 5 calls for public authorities to monitor activities upon recognition that said activities may have an adverse affect on the environment and Article 6 establishes the promotion of sustainable development as an important public policy concern.

Germany: legal aspects of shale gas exploration and extraction

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Published: March 14, 2012

A. Introduction

Hydraulic fracturing (fracking) involves the injection of water, sand and a mixture of chemicals into rock formations at high pressure. This creates new fractures and opens existing fractures in the rock, allowing natural gas to migrate from the rock to the well and rise to the surface. This technology makes it possible to exploit gas dispersed in shale rock formations and allows drilling in areas that would not have been profitable 10 to 20 years ago. However, there are considerable environmental risks linked with this technology (for an overview cf. Lechtenboehmer et al., 2011, p. 17 ff.).

Apart from impacts associated with land consumption, damage to the environment and landscape, as well as air pollution and noise, another predominant concern is the potential for an adverse effect on water resources (The Widener School of Law's - Environmental & Natural Resources Law Clinic, 2010; Grün et al., 2011).

Hydraulic fracturing requires large quantities of water. Sand and chemicals are added to the water to facilitate the underground fracturing process. After the hydraulic fracturing process, the fracturing fluid is pumped out of the well, but dependent on underground pressure regimes, only a variable fraction of the fracturing fluid is recovered and stored in above-ground ponds to await removal by tanker.

This flowback water contains chemicals used for fracturing, as well as dissolved material that was released from the shale, including radioactivity generated through contact with slightly radioactive rocks that naturally occur underground, and therefore needs special treatment or disposal. The remaining water is left in the ground where it has the potential to contaminate shallow or deep groundwater aquifers (for potential impacts on water resources cf. The Tyndall Centre, 2011, p. 54 ff.; Umweltbundesamt, 2011, p. 13 ff.).

Some are suggesting that hydraulic fracturing may pollute shallow groundwater supplies with flammable methane (Osborn et al., 2011; Schon, 2011). Dependent on the technology used, the production of shale gas can emit significantly more greenhouse gases than the production of conventional natural gas. These higher emissions occur as methane escapes from flow back-return fluids and during drill-out following the fracturing (Howarth et al., 2011). Furthermore, shale gas operations can trigger small earthquakes (Majer et al., 2011).

All these potential threats to the environment have to be dealt with in the licensing procedure. This article investigates the legislation that applies to drilling and hydraulic fracturing for natural gas in German shale rock formations. It explores the main legal issues linked to the German mining law and the law on water management.

B. Tiered approval procedure in German Mining Law

Mining legislation in Germany consists of the Federal Mining Act from 1980[1] and a number of Mining Ordinances on technical and procedural issues, e.g. the Ordinance on the Environmental Impact Assessment of Mining Projects from 1990. These provisions are applicable to the exploration and exploitation of most mineral resources in Germany. The Federal Mining Act (article 3 par. 2 Federal Mining Act) differentiates between mineral resources that are part of landed property on the surface (grundeigen) and others that are not (bergfrei).

Most raw materials listed in the Act (e.g. metals, salts, hard coal and lignite, petroleum, fluorspar and barites) are not part of landed property. Furthermore, there are other raw materials, which are not covered by the Federal Mining Act (e.g. sand, gravel, natural stone, peat). These fall under the landowner’s property and thus the authorization procedure is determined by other laws, such as building laws, laws on nature protection and air pollution control etc. However, natural gas consists of hydrocarbons and, as such, is not affected by landed property rights on the surface, but instead falls under the scope of the Federal Mining Act, article 3 par. 3 sentence 1 group 2 of the Federal Mining Act.[2]

The German Mining Act provides for a tiered procedure in the approval of mining projects. First, it distinguishes between exploration and extraction. In both of these two stages it differentiates between the granting of a license and the approval of mining activities through operational plans. Fig. 1 gives an overview of the tiered approval procedure for mining projects in Germany.

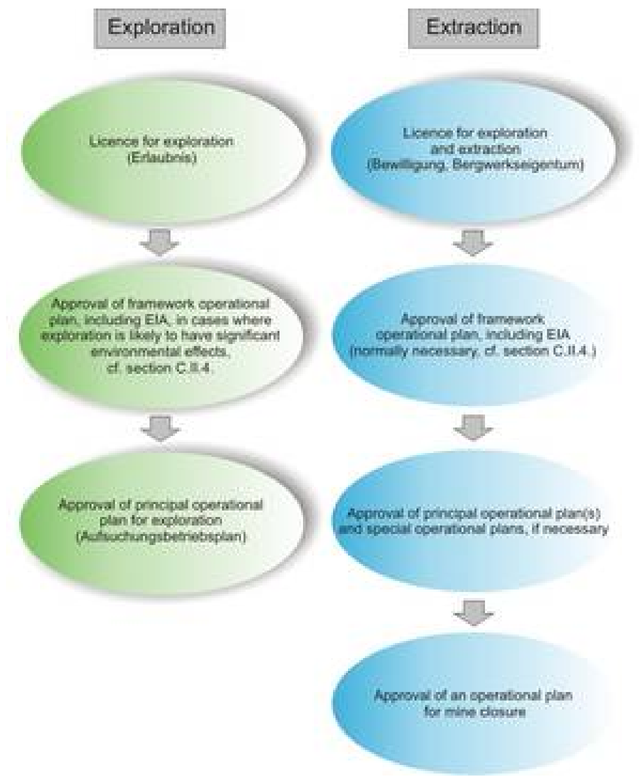

Fig. 1 Tiered approval procedure for mining projects in Germany.

C. Exploration

The exploration of hydrocarbons is subject to a two-step authorization procedure:

1. granting an exploration license that confers the exclusive right to explore the mineral resources specified in the license, and
2. the approval of (an) operational plan(s) for mining operations regarding exploration.

I. Exploration license

For shale gas drilling in Germany, the first step of the tiered approval procedure is to apply for an exploration license. The Federal Mining Act distinguishes between three types of license: a concession (Erlaubnis), which grants the right to explore (article 7 Federal Mining Act); a permission (Bewilligung), conferring the right to explore and to extract (article 8 Federal Mining Act); and a special form of permission (Bergwerkseigentum) which opens up the possibility to secure the right to explore and extract by making an entry into the land register.

Upon granting the license, the mining authority makes a binding decision. The license has to be conceded unless one or more of the conditions listed in article 11 of the Federal Mining Act are fulfilled. The provision does not mention environmental aspects explicitly, but these may be included in the decision via article 11 no. 10. According to this rule, the license has to be denied if predominant public interests preclude the exploration/extraction in the entire claim to be allocated.

The provision aims to avoid granting licenses when it is clear that these may never be used in the future. In principle, “predominant public interests” encompass all public issues recognized by the legal system, above all urban development, nature protection, landscape conservation, spatial planning and water protection etc. It is sufficient if the public interests are predominant in sum, hence it is not necessary for every single public issue to outweigh the mining interest.

In terms of predominant public interests, it is usually only strict prohibitions of legislation outside the mining law which come into consideration, particularly regulations which designate protected areas within the laws on nature conservation, water conservation or soil conservation.[3] These normally include exemptions. When granting a license, the mining authority has to check if the conditions for granting an exemption are present in the individual case. If an exemption cannot be conceded, the license has to be denied. In sum, it is only under exceptional circumstances that environmental issues and other public interests may prevent the granting of a license.

According to article 15 of the Federal Mining Act, the mining authority must consult the authorities safeguarding public interests before deciding on an application for an exploration license. This includes municipalities in as far as the interests of urban development are concerned (BVerwG, 1998). If a claim exceeds the frontiers of one municipality, all involved communities have to be consulted (other opinion Attendorn, 2011).[4]

However, it seems that public authorities and municipalities are not always consulted in practice. Cases were reported in which water authorities (Borchardt, 2011), or other authorities that should have been consulted according to article 15 of the Federal Mining Law (OVG Sachsen-Anhalt, 2003, Rn. 68), were not asked for an opinion, but only informed. In addition, neither the owner of the landed property on the surface, nor the public or environmental associations, has to be consulted even though the license confers a legal position which has implications for the authorization procedure regarding mining operations.

II. Approval of the operational plan(s) for exploration

For the execution of mining operations, the second step in the tiered authorization procedure, the operational plan developed by the mining company needs to be given approval by the mining authority (articles 51 ff. Federal Mining Act). The Federal Mining Act lists four types of operational plan: The principal operational plan (Hauptbetriebsplan, article 52 par. 1), the framework operational plan (articles 52 par. 2a and 52 par. 2 no. 1), the operational plan for special issues (Sonderbetriebsplan, article 52 par. 2 no. 2) and the operational plan for mine closure (Abschlussbetriebsplan, article 53).

1. Requirements under mining law

Every mining project needs the approval of a principal operational plan which forms the technical base for its installation and execution. Its validity is limited to a term of up to two years. A framework operational plan gives an overview of the entire project. It forms the basis and a brace for individual, principal operational plans and is approved for a term of 10 to 25 years. It only has a declaratory effect; the approval of a principal operational plan is needed for the execution of operations.

The Federal Mining Act distinguishes between the mandatory and the voluntary framework operational plan. A mandatory framework operational plan is necessary if the project is subject to an Environmental Impact Assessment (cf. section 4.). A voluntary framework operational plan only needs to be filed by the mining company if it is requested to do so by the mining authority.

Any part of the mining project which is not suitable for inclusion in the principle operational plan, which underlies special requirements in terms of time limitations and whose separate handling might be necessary in order to maintain clarity, may be subject to an operational plan for special issues. An operational plan for special issues may, for instance, cover an exploration borehole and its extension into a groundwater measuring point. An operational plan for mine closure secures the controlled closure of the mine and its suspension by the mining authority, including land restoration of the worked-out site. The latter is not relevant for exploration, only for extraction.

In the operational plan, the operator must describe the scope, the technical execution and the duration of the project. Based on this description, the mining authority will assess operational safety and the protection of workers, surface protection, prevention of public damage, environmental impacts and other issues regarding the project (article 55 and article 48 par. 2 of the Federal Mining Act). If all conditions mentioned in article 55 of the Federal Mining Act are fulfilled, and there are no other conflicting public interests (cf. next section), the mining authority has to approve the operational plan. The decision does not involve any discretion (in detail: Ludwig, 2012).

2. Other environmental permit requirements

Beyond the regulations of article 55 of the Federal Mining Law, article 48 par. 2 sentence 1 of the Federal Mining Law includes other public law requirements for the approval procedure of an operational plan.[5]This is particularly relevant for the law on spatial planning (BVerwG, 2006), the law on urban development (BVerwG, 1989), the law on air pollution control (BVerwG, 1986), the law on soil protection (BVerwG, 2005) as well as the law on environmental protection.

With respect to the latter, regulations in the law implementing the EU Habitats Directive in articles 31 ff. of the Federal Nature Protection Act (VG Koblenz, 2007; Ludwig, 2005, p. 77 ff.) and the provisions for environmental intervention, according to articles 13 ff. of the Federal Nature Protection Law, are notably applicable.[6] Provisions, which have to be applied in a special procedure scheduled by law, are considered to be within the competence of the respective authority (article 48 par. 1 sentence 1 of the Federal Mining Act).

This applies, e.g. for exemptions from ordinances, which establish protected areas through the laws on water conservation, soil preservation or environmental conservation, exemptions from the provisions protecting biotopes (article 30 of the Federal Nature Protection Act), exceptions from the law regarding the protection of species (article 38 of the Federal Nature Protection Act) and for approvals regarding the conversion of forests (article 9 of the Federal Forest Act).[7] In terms of spatial planning, there is an ongoing discussion about whether to extend the planning instruments that are applied to the coordination of different projects on the surface to areas below ground.

The reason for this is that recently there has been an increasing interest in the use of subterranean spaces for activities other than pure mining, e.g. geological carbon dioxide storage, geothermal energy production, subterranean pumped-storage hydropower plants or other forms of energy storage below ground. Conflicts between these different options for underground use need to be resolved; this could be done by applying spatial planning law below ground. But this is still being debated and has not yet been introduced in practice (cf. the analysis by Erbguth, 2011).

3. Requirements under the law on water protection

Besides the mining law, the law on water management is also relevant for shale gas exploration and extraction. According to article 8 ff. of the Federal Water Management Act, a permit (Erlaubnis) or approval (Bewilligung) is necessary for the use of a body of water. In the case of hydraulic fracturing, only a permit can be considered (cf. article 10 of the Federal Water Management Act). The mining authority decides whether to issue the permit based on article 19 par. 1 and 2 of the Federal Water Management Act.

This provision passes the competence from the water authorities to the mining authorities. If a permit for the use of the body of water is required, the mining authority has to instruct the mining company to file an application. There are different actions relating to the water body that may require a permit under article 9 of the Federal Water Management Act; the most important are described in the following sections (an overview of more actions is given in Grigo et al., 2011, p. 34 ff. and Lechtenboehmer et al., 2011, p. 25 ff.).

a) Water withdrawal authorization regime

Shale gas drilling and hydraulic fracturing requires large amounts of water. Under article 9 par. 1 no. 1 or 5 of the Federal Water Management Act, a mining company requires a permit for the withdrawal of water from surface water or groundwater.

b) Use of groundwater resources

Shale gas drilling and hydraulic fracturing pose a risk of groundwater pollution. Although shale gas in Germany is usually found beneath the shallow groundwater level, there are different reasons why hydraulic fracturing may lead to a pollution of groundwater resources. The most important are the following:

First, the borehole could pass the groundwater table.

Second, the fluids used in hydraulic fracturing operations may rise to the groundwater level through leakages in the cap rocks, or along the wellbore in cases of improper well construction or well failure. Third, a fraction of the fracturing fluid may return to the surface (flow back) where it becomes a potential hazard for the groundwater.

Article 9 of the Federal Water Management Act defines the term “use of a water body”. According to article 9 par. 1 no. 4 of the Federal Water Management Act, the first activity where the borehole passes the groundwater table may require a permit. Under this provision, “use” refers to an introduction and discharge of substances into the water body. In the drilling process, it is necessary to install a well casing to seal the well from surrounding formations and to stabilize the completed well.

Casing is typically a steel pipe lining the inside of the drilled hole and cemented into place (The Tyndall Centre, p. 16). This cement is a substance introduced into the groundwater table in the sense of article 9 par. 1 no. 4 of the Federal Water Management Act. According to article 48 par. 1 of the Federal Water Management Act, a permit may only be granted if harmful changes to the water quality are not to be expected.

This is subject to a scientific assessment by the competent authorities as part of the process of deciding and granting the permit for the particular case in question. Harmful changes to the water quality may be excluded if, for instance, the cement is coated with a steel tube and therefore might not come into contact with the aquiferous layers (Umweltbundesamt, 2011, p. 17 f.).

Measures likely to cause harmful changes in groundwater quality may need a permit, according to article 9 par. 2 no. 2 of the Federal Water Management Act. Harmful changes in water quality may be caused by fracturing fluids entering the groundwater. In this scenario it is more likely that fracturing fluid will end up in deep groundwater aquifers as opposed to in the shallow groundwater used for drinking water abstraction.

It remains uncertain as to whether deep groundwater aquifers are protected by article 9 par. 2 no. 2 of the Federal Water Management Act as they are highly mineralized and not used (Dietrich and Elgeti, 2011, p. 314; Seuser, 2012). However, according to the definition in article 3 no. 3, the Federal Water

Management Act does not distinguish between shallow groundwater and deep groundwater, and protects both, regardless of their chemical composition. The question has not yet been conclusively addressed. Nevertheless, at least in cases where interaction between deep groundwater and shallow groundwater, or surface waters, cannot be excluded definitely, a permit based on article 9 par. 2 no. 2 of the Federal Water Management Act is required (Umweltbundesamt, 2011, p. 18).

The shallow groundwater may be further contaminated if leaks from inadequately cemented wells occur (Lechtenboehmer et al., 2011, p. 25). Fracturing fluid rising to the shallow groundwater level through leakages in the cap rock, or fluid returning to the surface and threatening to seep into the groundwater, may also pose risks to the shallow groundwater. There is also the potential risk of the creation of linkages between different groundwater horizons through the drilling process (Töpfer and Butler, 2011, p. 79 for drillings in the context of the utilization of geothermal energy).

According to article 9 par. 2 no. 2 of the Federal Water Management Act, a permit is necessary for actions which are likely to cause harmful changes to water quality, either permanently or to an extent that is not merely inconsiderable. This provision is a catch clause, however, as it only applies if the conditions of article 9 par. 1 are not fulfilled. Whereas article 9 par. 1 targets measures that aim to use the water body, par. 2 also includes actions that do not have the purpose of affecting the water body (Berendes, 2010, § 9 marginal number 16).

Hydraulic fracturing involves injecting water, sand and a mixture of chemicals into rock formations at high pressure. Because shallow groundwater enjoys a high level of legal protection, a low degree of damage probability is sufficient to affirm the need for a permit, according to article par. 2 no. 2 of the Federal Water Management Act in cases of hydraulic fracturing (Umweltbundesamt, 2011, Seuser, 2012).

The permit has to be denied if harmful, unavoidable/non-compensable changes in the water body are likely to occur. The criterion “change” is linked to the functional assessment that the water quality has deteriorated in comparison to the previous water quality. The criterion “likely” is interpreted extensively. It is sufficient if tangible evidence exists for the aptitude of the measure to change water quality permanently, or not merely inconsiderably (Pape, 2011, § 9 marginal number 74 WHG).

A permit was denied, for example, in a case where a downhole heat exchanger was solicited to be authorized in a drinking water protection area beneath the groundwater level (VGH Wiesbaden, 2011). If in place, water protection ordinances of the Laender also have to be observed. If the authority should, after a scientific assessment in individual cases, come to the decision that a permit is not necessary, then the mining company’s obligation to announce activities according to article 49 par. 1 sentence 1 of the Federal Water Management Act comes into question.

c) Discharging fracturing flow back fluids and produced water into the groundwater or surface waters

The fracturing flow back fluid and produced water consists of water, different types of chemicals, as well as suspended and dissolved material from shale, including naturally-occurring radioactive material. It must be managed in an environmentally responsible manner. There are different options for disposal and treatment of the flow back and produced water (Abdalla et. al, 2011; Shale Gas Information Platform – Water Protection, The Basics), for instance, treatment in treatment facilities with subsequent discharge into surface waters or deep underground injection.

The latter may pose the potential risk of a discharge of substances into the groundwater.
According to article 9 par. 1 no. 4 of the Federal Water Management Act, the discharge of substances into a body of water requires a permit. In terms of discharge into surface waters, a permit may only be issued if the quantity and harmfulness of the wastewater are kept as low as possible, under observance of the possible processes and according to the best available technology (article 57 par.

1 no. 1 of the Federal Water Management Act). Beyond that, the discharge has to comply with the requirements for water quality and other legal prerequisites (article 57 par. 1 no. 2 of the Federal Water Management Act).

For discharge into the groundwater, under article 48 par. 1 of the Federal Water Management Act, the permit may only be granted if harmful changes to the water quality are not to be expected (cf. section above). However, in this context, article 82 par. 6 sentence 2 of the Federal Water Management Act, in conjunction with article 11 par. 3 lit. j of the Water Framework Directive, makes it possible to authorize discharges into the groundwater under certain circumstances, and specific conditions.

The competent authority will decide within its duty-bound discretion. The provision applies to the injection of water containing substances that result from operations involved in the exploration and extraction of hydrocarbons or mining activities. If this provision is applicable in cases of reinjection of fracturing fluid, flow back is doubtful (Umweltbundesamt, 2011, p. 19). The wording of article 11 par. 3 lit. j of the Water Framework Directive ("Such injections shall not contain substances other than those resulting from the above operations") supports the interpretation that the provision only applies to geogenic substances.

d) Other conditions for granting the permit

Beyond article 9 of the Federal Water Management Act, article 12 of the Federal Water Management Act also has to be considered for the granting of permits. According to article 12 par. 1 no. 1, the permit has to be denied if harmful (also by collateral clauses), unavoidable or non-compensable changes to the water quality are to be expected. "Harmful changes to water quality" are defined by article 3 no. 10 of the Federal Water Management Act as changes in the characteristics of the water body which affect public welfare, in particular the public water supply, or which do not comply with the requirements arising from the Federal Water Management Act, from ordinances adopted under this act or from other provisions of water protection law. Other provisions may be legally-binding quality objectives that are adopted in order to implement the EU Water Framework Directive.

According to article 12 par. 1 no. 2 of the Federal Water Management Act, the permit has to be denied if other requirements under public law are not fulfilled. These may follow from ordinances regarding the protection of water or, for instance, the law on environmental conservation. Otherwise, the competent authority grants the permit with in duty bound discretion. This duty provides a wide scope in the sense that it allows comprehensive discretion for allocation and management (Pape, 2011, article 12 marginal number 52).

Article 6 par. 1 of the Federal Water Management Act provides for some requirements so that this discretion can be exercised. Article 6 par. 1 contains general principles for water management, e.g. the maintenance or creation of existing or future opportunities of use, particularly for the public water supply. For the management of groundwater, article 47 and 48 of the Federal Water Management Act, in conjunction with article 4 of the Water Framework Directive, provide special requirements for exercising this discretion (Berendes, 2010, § 12 marginal number 9). According to article 47 par. 1 no. 1, the groundwater has to be managed in such a way that a deterioration of the quantitative and chemical status will be prevented.

For the management of surface waters, articles 27 ff. of the Federal Water Management Act have to be observed in exercising this discretion. For example, surface waters, as long as they do not qualify as an artificial or heavily modified water body (cf. definition in article 2 no. 9 of the Water Framework Directive), shall be managed in a way that avoids a deterioration of their ecological and chemical status, while maintaining or achieving a good ecological and chemical status (article 27 of the Federal Water Management Act, Art. 4 of the Water Framework Directive).

Here, different rules and regulations may have to be considered, for instance article 22 of the Federal Water Management Act, which opens up the possibility of compensation between different competing uses of a water body (Köck and Möckel, 2010, p. 1395). In any case, the decision has to take into account the fact that the discretion under article 12 par. 2 of the Federal Water Management Act aims to optimize the protection of water resources (Pape, 2011, § 12 marginal number 49).

4. Necessity of an Environmental Impact Assessment

The most pertinent question, in terms of approving the exploration and extraction of natural gas using hydraulic fracturing, is if an Environmental Impact Assessment (EIA) is necessary. The EU Directive on Environmental Impact Assessment (EIA Directive) was transposed into the German Mining Law in 1990.[8]

According to article 3 of the EIA Directive, the environmental impact assessment shall identify, describe and assess, in an appropriate manner, the direct and indirect effects of a project on the following factors: human beings, fauna and flora; soil, water, air, climate and the landscape; material assets and the cultural heritage, and the interaction between these factors. Projects which are subject to an EIA are listed in the Ordinance on the Environmental Impact Assessment of Mining Projects.

The list comprises, for instance, mining which covers a surface area of 10 ha, mining which involves lowering the groundwater table over a wide area or which involves the risk of significant subsidence. For the extraction of natural gas, an environmental impact assessment is only foreseen for a hauling capacity of more than 500,000 cubic meters a year and for the installation and operation of offshore production platforms (Annex I no. 14 of the EIA Directive, article 1 no. 2 of the Ordinance on the Environmental Impact Assessment of Mining Projects).

Beyond that, according to article 4 par. 2 in conjunction with annex II no. 2 d) EIA Directive, it is up to member states to decide whether an EIA shall be required for deep drillings. In particular, the provision mentions geothermal drilling, drilling for the storage of nuclear waste material and drilling for water supplies. Although drilling for natural gas using hydraulic fracturing is not listed explicitly, the enumerated forms of drilling are examples and the list is not exhaustive.

Moreover, for other forms of deep drilling, the member state may demand a case-by-case examination, as well as fix thresholds or criteria, to determine whether the project shall be made subject to an EIA. When doing this, the member state shall take the relevant selection criteria set out in Annex III of the EIA Directive into account (article 4 par. 3 of the EIA Directive).
In Germany, regarding deep drillings, the EIA Directive was transposed through article 1 no. 8 of the Ordinance on the Environmental Impact Assessment of Mining Projects.

An EIA is mandatory only for drillings of more than 1000m, in the context of the utilization of geothermal energy, in areas of nature protection and in areas protected in accordance with the EU Habitat Directive and the EU Birds Directive. For other forms of deep drilling, Germany did not prescribe a case-by-case examination or thresholds/criteria. However, when taking the selection criteria of Annex III of the EIA Directive into account, deep drillings using hydraulic fracturing need to be made subject to a mandatory EIA or at least to a case-by-case examination (Frenz, 2011).

The necessity of an EIA for an operation does not mean that the operation may not be permitted. The aim of an EIA is the identification, description and assessment of the dimensions, probability and frequency of the environmental impacts a project may have in cases where environmental impacts are likely (articles 1 and 3 of the EIA Directive). The potential environmental impacts are described at the beginning of the article.

There are several initiatives to amend the German Ordinance on the Environmental Impact Assessment of Mining Projects and to make every mining project using hydraulic fracturing subject to an EIA, or at least to a case-by-case examination (SPD Bundestag fraction, 2011; Land Nordrhein-Westfalen, 2011; Bezirksregierung Arnsberg, 2011; Grüne Bundestag Fraction, 2011; Dietrich and Elgeti, 2011, p. 315).

An EIA would be necessary due to the technology applied, regardless of the hauling capacity. Therefore, a framework operational plan including EIA would also be required for the exploration of shale gas in cases where the technology of hydraulic fracturing is applied.[9]
However, even without the amendment of the Ordinance on the Environmental Impact Assessment of Mining Projects, under the current legal situation an EIA may be required for mining projects that involve hydraulic fracturing, considering the jurisdiction of the European Court of Justice.

According to the European Court of Justice, the EIA Directive does not give a Member State the power to exclude certain classes of project which fall within Annex II of the Directive from the EIA procedure (including modifications to those projects), or to exempt a specific project from such a procedure, unless those classes of projects, or the specific project, could be regarded in their entirety, on the basis of a comprehensive assessment, as unlikely to have significant impacts on the environment (ECJ, 2009, n 42; ECJ, 1999, n 38).

Because of the direct effect of the EIA Directive (ECJ, 1995 - Großkrotzenburg), in the case of a transposition into national law that is not sufficient, the competent authority has to assess individual cases on a case-by-case basis to determine if an EIA is necessary (Otto, 2000; Staupe, 2000). The criteria of Annex III of the EIA Directive have to be observed.

When these criteria are applied, every deep drilling operation that uses hydraulic fracturing technology is subject to a case-by-case examination in line with article 4 par. 2 of the EIA Directive, according to the present legal situation (Frenz, 2011, p. 78; for a mandatory EIA for extraction Umweltbundesamt, 2011, p. 22). Depending on the result of this examination, an EIA may turn out to be necessary even for exploration. Nevertheless, the Ordinance on the Environmental Impact Assessment of Mining Projects should be amended in order to ensure the legal situation remains clear.

If an EIA is required, a mandatory framework operational plan (obligatorischer Rahmenbetriebsplan, article 52 par. 2a) has to be approved. A framework operational plan gives an overview of the entire project. It forms the basis and a brace for individual principal operational plans and is approved for a term of 10 to 25 years. It only has a declaratory effect; the approval of a principal operational plan is necessary for the execution of operations. The Federal Mining Act distinguishes between the mandatory and the voluntary framework operational plan, which the mining company only needs to file if requested to do so by the mining authority.

The approval of the mandatory framework operational plan is done by planning approval order and includes all possible parallel decisions (article 52 par. 2a of the Federal Mining Act in conjunction with article 75 of the German General Administrative Procedure Act). It also makes following other operational plans for the same project obligatory in terms of the questions concerned (for the exact wording cf. article 57 par. 5 of the Federal Mining Act).

5. Consultation with other authorities, stakeholders and the public

In terms of consultation, the legal situation is different for the approval of framework operational plans on the one hand, and alternative operational plans on the other.

a) Approval of framework operational plans

In order to guarantee the participation of the public, other authorities and stakeholders, the approval of a framework operational plan, including an EIA, is subject to a formal planning approval procedure in accordance with article 5 of the Federal Mining Act, and in conjunction with article 73 ff. of the German General Administrative Procedure Act. Other authorities have to be consulted by the competent mining authority.

There are also few provisions demanding the consent of another authority, for instance article 19 par. 3 of the Federal Water Management Act. Because of the potential that public consultation has to increase acceptance of a project, it has been proposed to conduct an EIA with comprehensive participation on a voluntary basis for every mining project that involves hydraulic fracturing (Dietrich and Elgeti, 2011, p. 315).

b) Approval of other operational plans

A consultation of stakeholders and the public is not prescribed for other operational plans. The only provision leading to the approval of other operational plans, regarding participation in the procedure, is in the Federal Mining Act article 54 par. 2. Pursuant to this article, other authorities, or the municipalities in their role as planning authorities, must be consulted.

There are some provisions in other acts which require the consent – and not only consultation - of other authorities, for instance article 19 par. 2 of the Federal Water Management Act for the decision on the permit regarding the use of the water body. However, in practice it has been reported that a permit regarding the use of the water body was not always considered to be necessary by the mining authorities (Scholle, 2011), and therefore the water authorities were not involved in the process.

Another example of making the consent of other authorities a requirement can be found in article 17 of the Federal Nature Protection Act in conjunction with the law of the Laender (e.g. article 10 par. 1 sentence 2 of the Saxon Nature Protection Act). Regarding consultation of the public and stakeholders, the German Federal Administrative Court held these existing rules to be unsatisfactory.

The Court therefore stated in its jurisdiction that the interests of certain stakeholders have to be observed in the decision on the approval of the operational plan, and that these parties must, therefore, be consulted in the administrative procedure. This includes persons affected by the indirect (in particular through air pollution) or direct effects of mining (i.e. through usage of the landed property or damages to the property).[10]

6. Announcement of drilling in accordance with article 4 of the Act on Natural Mineral Deposits

According to article 4 of the Act on Natural Mineral Deposits, the mining company has to announce the beginning of the drilling operation to the competent authority two weeks in advance. The competent authority has to be given access to the drilling site (article 5 of the Act on Natural Mineral Deposits).

D. Extraction

As with exploration, the extraction of hydrocarbons is also subject to a two-step authorization procedure:

1. granting an extraction license that confers the exclusive right to extract the mineral resources specified in the license, and
2. the approval of operational plans for mining operations regarding exploration.

I. The extraction licence

The right to extract is granted through permission (Bewilligung) and a special form of permission (Bergwerkseigentum). On granting permission, the mining authority makes a binding decision based on article 11 of the Federal Mining Act. According to article 15 of the Federal Mining Act, the mining authority must consult the authorities responsible for safeguarding public interests, including municipalities as far as the interests of urban development are concerned, before deciding to apply for an exploration license. A consultation with the public or other stakeholders is not foreseen in the Federal Mining Act.[11]

II. Approval of operational plans for extraction

Usually all four types of operational plan mentioned in the Federal Mining Act are relevant (cf. section C.II.1.) in terms of extraction. The mining company has to file a mandatory framework operational plan if an EIA is necessary (article 52 par. 2a of the Federal Mining Act). According to the law in force, an EIA for the extraction of natural gas is only envisaged for a hauling capacity of more than 500,000 cubic meters a year and for the installation and operation of offshore production platforms (article 1 no. 2 Ordinance on the Environmental Impact Assessment of Mining Projects). If this hauling capacity is not reached, a case-by-case examination as to whether an EIA needs to be conducted is necessary due to the direct effect of the EIA Directive (cf. section C.II.4.). Because of the potential environmental impacts of using hydraulic fracturing to extract natural gas, there are good reasons to assume that, in the case of extraction, an EIA is always required.

In addition to the approval of a mandatory framework operational plan, at least one principle operational plan is necessary for each mining project as the approval of the framework operational plan only has a declaratory effect. Beyond that, the mining company may elaborate on operational plans for special issues if necessary. An operational plan for mine closure is required for the controlled closure of a mine.

For the decision program on the approval of principle operational plans, operational plans for special issues, voluntary framework operational plans and operational plans for mine closure, cf. section C.II.1.-3. and 5. For the requirements outlined for the approval of mandatory framework operational plans, cf. section C.II.4. and 5.

E. Summary and conclusions

The German Mining Act distinguishes between the granting of a license and the approval of mining activities in both stages of a mining project: exploration and extraction. In Germany, current shale gas projects involving hydraulic fracturing are still in the exploration phase. In the majority of procedures, only a license for exploration has been granted; in some cases operational plans for exploration have been approved and exploration has already started (Grigo et al., 2011; Umweltbundesamt 2011, p. 6 f.). Licenses for extraction have not yet been issued.

The most pertinent question is whether an EIA is necessary for all mining projects involving hydraulic fracturing, including exploration. There is an initiative to introduce an EIA for all mining operations that use hydraulic fracturing. However, due to the direct effect of the EIA Directive, under the current legal situation a case-by-case examination as to whether an EIA is necessary has to be conducted for all deep drillings that apply hydraulic fracturing, including exploration.

If an EIA is necessary, a mandatory framework operational plan has to be approved which involves public consultation. Although a case-by-case examination needs to be conducted at the very least, even according to the present legal situation, the Ordinance on the Environmental Impact Assessment of Mining Projects should, nevertheless, be amended in order to ensure the legal situation remains clear.

Another critique of the present legal framework is that neither the public nor stakeholders (except for the authorities and the municipalities regarding aspects of urban development) need to be consulted in the procedure of granting a concession for exploration and/or extraction. The deficits of the German Federal Mining Act have been criticized for a long time, especially in terms of the participation and inclusion of environmental impacts (Hoppe, 1993; Beckmann, 1992).

Some aspects have been introduced under the jurisdiction of the German Federal Administrative Court. This has led to a legal situation that is not transparent and is – in a large number of sections - only fully understood by lawyers specialized in mining law. Therefore, considering the fact that German mining law is gaining new relevance with new technologies and new types of projects, it is time for a fundamental amendment to the German Federal Mining Act.

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[1]The cited Acts and Directives are listed in the 'List of legislation cited' at the end of the article.

[2]This also applies to coal bed methane, although article 3 par. 3 sentence 1 group 3 Federal Mining Law may suggests that this forms part of the concession regarding the exploration of coal, Franke, P., 2011, Rechtliche Rahmenbedingungen für die unkonventionelle Gasgewinnung in Nordrhein-Westfalen, in Frenz, W., and Preuße, A., eds., Chancen und Risiken von unkonventionellem Erdgas - 13. Aachener Altlasten- und Bergschadenskundliches Kolloquium, Volume 126: Clausthal-Zellerfeld, Schriftenreihe der Gesellschaft für Bergbau, Metallurgie, Rohstoff- und Umwelttechnik, p. 9-20, p. 11.

[3]The ordinances should be verified as to whether hydraulic fracturing should be prohibited explicitly in special zones, or in the entire area where the ordinance is applicable.

[4]Attendorn argues that article 15 of the Federal Mining Act refers to article 10 no. 11 of the Federal Mining Act. The wording of this article requires that predominant public interests preclude the exploration/extraction in the entire claim. However, this term is not to be taken literally by only referring to the surface area, otherwise it would be up to the mining company to bypass a protected area by stretching the territory of the solicitation beyond the frontiers of the aforementioned area. Therefore, the term is defined with a view to the quality of a public interest. The criterion is met if the space-related public interests are so important that they exclude the extraction in the entire claim (BVerwG, 1999).

[5]Provided, that there is no special procedure scheduled in the law for these issues.

[6]For more details cf. Ludwig, G., 2012, Umweltaspekte in Verfahren nach dem BBergG: ZUR, no. 3, p. forthcoming.

[7]For more details cf. Ibid.

[8]Gesetz zur Änderung des BBergG vom 12.02.1990, BGBl I, S. 215.

[9]Exploration of shale gas does not necessarily involve hydraulic fracturing. It may be sufficient to extract a drill core and use it for analysis.

[10]BVerwG, 04.07.1986 4 C 31/84 Altenberg, BVerwGE 74, 315 ff; BVerwG, 16.03.1989, 4 C 25/86, Moers-Kapellen, NVwZ 1989, 1162; BVerwG, 13.12.1991, 7 C 25/90, Gasspeicher, BVerwGE 89, 246; BVerwG, 29.06.2006, 7 C 11.05. In Detail Teßmer, D., 2009, Rechtsgutachten: Vorschläge zur Novellierung des deutschen Bergrechts, p. 85.

[11]For the whole cf. section C.I.

Relationship between state law set by the German federal government and potentially deviant legal positions of the federal states

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Published: May 22, 2012

Outlining the legal structures of the approval procedure concerning hydraulic fracturing (*fracing*) in the German State, several distinctions as well as positions of points have to be fulfilled. Concerning this matter, there has to be distinguished precisely between the requirements set under mining law on the one hand and under the law of water protection on the other hand. Additionally, other environmental permit requirements complete the complex national legal position of shale gas exploration and extraction.

Referring to the legal aspects accompanying with the innovative development of an unconventional field of gas resource the basal legal source, the German Mining Act, provides for a tiered procedure in the approval of mining projects. To this effect, the Act distinguishes between the granting of a license and the approval of mining activities in both stages of a mining project: *exploration* and *extraction*.

In Germany, current shale gas projects involving hydraulic fracturing are still in the exploration phase. In the majority of procedures, only a license for exploration has been granted; in some cases operational plans for exploration have been approved and exploration has already started whereas licenses for extraction have not yet been issued.

There are several isolated problems connected with the issue of introducing a mandatory EIA for all mining projects involving hydraulic fracturing - including exploration - by means of an amendment of the mining law. However, one of the most pertinent questions of the present legal framework concerning the domain of shale gas legislation is the relationship between state law set by the federal government and the states and their potentially deviant legal positions in matters of covering the subject of unconventional gas resources, in other words the demarcation of competences within the federal structure of the German state. Exemplary the lively discussion upon a *legal prohibition of the technology of hydraulic fracturing* to the full extent can be cited.

Inspecting the Basic Constitutional Law of the Federal Republic of Germany accurately it surfaces that, based upon article 74 para. 1 no.11, concurrent legislative powers shall extend to the subject of the law relating to economic affairs, such as mining. As far as a legal prohibition of *fracing*, for instance, concerns dangers specifically originating from mining, a veto in this vein might be drawn upon that rule of jurisdiction. With regard to potential dangers pertaining the use of a body of water, the relevant legal point of regard is article 74 para.1 no. 32, which treats the subject of the management of water resources.

As matters of the *current legislative powers* are affected in terms of art. 74 para. 1 no. 11 (mining), the several states are not entitled legally to ban *fracing* locally in contradiction to the federal legal source, the German Mining Law. As far as (scientifically based and proved) dangers related to the management of water resources are in the center of attention, the legal situation appears to be different at first sight – but de facto comes to the same result.

In that case art. 72 para. 3 no. 5 of the Basic Constitutional Law of the Federal Republic of Germany regulates that (although) “the Federation has made use of its power to legislate, the states may enact laws at variance with this legislation with respect to management of water resources (except for regulations related to materials or facilities)”. Thereby the states are given the opportunity of an*alternative legislation* in that range in order to compensate the abolition of the former art. 75 of the Basic Constitutional Law of the Federal Republic of Germany (framework legislation) in the course of the federalism reform 2006.

But – even with acceptance of that potential possibility on the part of the certain states – nevertheless*scientific based and proved expertises* of independent committees would be needed for evidence at first – and do not exist at the present time (cp. the commissioned expertise in North Rhine – Westphalia, which should be finished in fall 2012 as well as the expertise on behalf of the UBA concerning the matter of an amendment of the UmwRG-ÄndG). Moreover every “*regulation related to materials*” in the context of deviant state legislation referring to the management of water resources poses a variance-resistant regulation, which can be amended by a state in no case.

Finally the argument, that the federal legislator has exercised his competence depending upon art. 72 para.1 of the Basic Constitutional Law of the Federal Republic of Germany only fragmentary which empowers the states to enact complementary (but not deviant) rules does not pursue the problem to a solution, because even then the question “*whether*” as well as “*to what extent*” modification of that kind might be licit is perpetuated.

In other words there is no possibility to differ from federal law in that legal area at the disposal of the states. Therefore, considering the fact that German mining law is gaining new relevance with new technologies and new types of projects, it is time for a fundamental amendment to the German Federal Mining Act on the part of the federal legislator.

Poland: Legal aspects of shale gas exploration and production

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Published: March 14, 2012

1. Shale gas exploration and production in Poland

Poland is believed to have major shale gas deposits. The shale gas deposits are believed to be located in a zone stretching from the north-west to the south-east of Poland. About 100 prospecting/exploration concessions have been already granted by the Polish Ministry of Environment. Consequently, most of the area of potential interest is already undergoing prospecting/exploration works. The prospecting/exploration projects are at different stages of advancement. While some may still be at the survey stage, many have already entered the drilling stage.

2. Applicable law

Since the idea of shale gas prospecting/exploration and production is relatively new on the Polish market, legislation in place does not fully respond to the special circumstances of shale gas. Shale gas prospecting/exploration and production are covered by laws applicable to other hydrocarbons. Until 1 January 2012 shale gas prospecting/exploration and production was regulated under the Geological and Mining Law of 4 February 1994.[1]

On 1 January 2012 that law was replaced with the Geological and Mining Law of 9 June 2011 (‘GML2011’).[2] What is new about GML2011 is that it includes particular regulations dealing specifically with hydrocarbons. GML2011, like the formerly binding law, is accompanied by a set of executive regulations. Most of the new executive regulations have been already adopted with exception of the one concerning the tender for hydrocarbons concession (see point 4 below). GML2011 concerns only the geological and mining aspects of the mineral prospecting/exploration and production activities. It touches only marginally on environmental protection issues.

Under Polish law environmental protection is regulated in many dedicated Acts, a number of which give effect to European environmental law. The Environmental Protection Law of 27 April 2001 is the central piece of environmental legislation, containing basic provisions on environmental protection applicable inter alia to shale gas activities.[3] In addition to the Environmental Protection Law there are also many other Acts of a greater or lesser importance in terms of safeguarding environmental protection during shale gas prospecting/exploration and production, including, the Water Law, Environmental Impact Assessment Law, Waste Law, Extraction Waste Law and Environmental Damage Law.[4]

Currently, the possibility of enacting one piece of legislation dealing with all aspects of shale gas prospecting/exploration and production is under general political consideration, but no specific statements were made in this respect by the government. In my opinion it is rather probable that any new legislation will concern only particular issues such as geological, mining, organizational or fiscal aspects of shale gas prospecting/exploration and production.

Especially the intention to enact new regulations on shale gas tax was expressed by the government. So far the current government did not show any intention to adopt any law concerning specifically the environmental issues associated with shale gas activities. The Ministry of Environment is of an opinion that the existing environmental protection legal framework secures a reasonably sufficient level of environmental protection during shale gas activities.

Bearing in mind the extensive environmental protection laws, it seems that if shale gas prospecting/exploration or production impacts on the environment in a manner not regulated under the currently binding law, any such loophole will be addressed through amendments to the environmental laws currently in effect.

3. Impact of EU legislative developments on Polish law applicable to shale gas

Existing EU law does not specifically address the issue of shale gas prospecting/exploration or production. However, EU law impacts and influences two areas of Polish legislation which are of particular importance for shale gas prospecting/exploration and production, namely: (i) hydrocarbons prospecting/exploration and production, and (ii) environmental protection.

As regards the former, the EU adopted the Hydrocarbons Directive.[5] The Hydrocarbons Directive lays down general rules concerning granting authorization to prospect for or explore or produce hydrocarbons which should be followed in each Member State. These rules were transposed to Polish law in GML2011 and are applicable to shale gas activities.

EU law concerning environmental protection is extensive and, as mentioned under point 2 above, to a large extent has been implemented into Polish law and applies to shale gas prospecting/exploration and production.

4. Polish legal framework

The legal framework for shale gas prospecting/exploration and production is contained in GML2011 and the related executive regulations. Pursuant to GML2011, in order to perform mining activities investors have to sign an agreement with the State Treasury to establish a mining usufruct (authorizing the use of mining deposits) and obtain a concession from the Minister of the Environment (authorizing mining activities). A separate agreement and concession is required for the prospecting/exploration stage and later for the production phase.

Under GML2011 a concession for prospecting/exploration or production of hydrocarbons (including shale gas) has to be obtained through a public procurement procedure. The concession is granted to the winner of the tender. Subsequently, a mining usufruct agreement is signed with the concession-holder.

The obligation to put the concession out to tender is not compulsory. There is no need to hold a tender for a production concession if, among others, a business entity holds a priority right to sign a mining usufruct agreement for a given area. A priority right of this type is ascribed to an entity which explored a given area, prepared the local deposit management project and obtained a decision approving the geological documentation. The priority lasts for 5 years from the date of delivery of the approval decision.

In practice it means that entities which have already explored a given shale gas deposit under a prospecting/exploration concession (granted under the former law) and fulfilled other prescribed obligations, have a 5-year priority right to sign a mining usufruct agreement with respect to shale gas production. During this period no tender for granting production concession for the same deposit may be held by the authorities. This way the entity which prospected/explored a given shale gas deposit can feel relatively secure as to future production of any shale gas reserves discovered there.

An entity exploring a prospective shale gas deposit or producing shale gas has to pay: (i) a fee for establishment of a mining usufruct, and (ii) a royalty for shale gas prospecting/exploration or production.

Under GML2011 the enterprise running the mine usually bears liability for any mining-related damage. If mining damage occurs, the enterprise has to reinstate the former condition by providing substitute real estate, buildings, facilities, water and other similar goods. The enterprise may be required to pay damages to the aggravated party.

5. Environmental Impact Assessment Procedure

Under Polish law it is obligatory for some undertakings enumerated in the Environmental Impact Assessment Regulation (EIA Regulation) to obtain a decision on environmental conditions.[67] The decision on environmental conditions has to be obtained prior to obtaining, among others, a building permit, concession for prospecting/exploration and production of minerals or a water permit for constructing water facilities.

The undertakings enumerated in the EIA Regulation, for which a decision on environmental conditions has to be obtained, are divided into two groups: (i) undertakings for which an EIA procedure has to be performed each time during the procedure for granting the decision on environmental conditions, and (ii) undertakings for which an EIA procedure has to be performed only if the authority so requires.

The EIA procedure comprises the following stages: preparation and review of an environmental impact report, obtaining the opinions of other authorities and assuring public participation. Shale gas related activities are not explicitly enumerated in the EIA Regulation. However, some mineral prospecting/exploration and production activities are covered by the EIA Regulation (please see table below).

Stage	EIA group	Type of activity for which decision on environmental conditions is obligatory
Prospecting/Exploration of mineral deposits (including shale gas deposits)	Group (i)	n/a
	Group (ii)	• mineral deposits prospecting or exploration: (a) connected with geological works performed with use of explosives, (b) in the maritime territory of the Republic of Poland, (c) performed by drill-hole method at a depth greater than 1,000 m.
Production of minerals (including shale gas)	Group (i)	• production of natural gas and crude oil including its natural derivatives, in amounts exceeding 500 tonnes per day for petroleum and its derivatives and 500,000 cubic meters per day for natural gas; • production of crude oil including its natural derivatives and natural gas in the maritime territory of Poland; • installations for processing of minerals with annual processing capacity not less than 100,000 cubic meters
	Group (ii)	• production of minerals from deposits by using drilling methods in cases other than mentioned above; • production of minerals in the maritime territory of Poland in cases other than mentioned above or under the surface of inland waters; • installations for the surface storage of fossil fuels other than crude oil, or for surface storage of natural gas excluding liquid gas tanks with maximum capacity of 10 cubic meters, and oil tanks with maximum capacity of 3 cubic meters.

As can be seen, prospecting/exploration of shale gas deposits in most cases is covered with an obligation to obtain a decision on environmental conditions, however it will be dependent on the decision of the authority issuing the decision on environmental conditions as to whether an EIA has to be carried out.[8] For the production stage, too, a decision on environmental conditions has to be obtained. The EIA is obligatory only for the most intensive production activities, whereas for others it is only obligatory if the authority so requires.

6. Public Participation

Polish law provides for different levels of participation by parties other than the applicant for a given decision. During a procedure for issuing decision on environmental conditions, the following levels of participation are envisaged: (i) as a party to the procedure; (ii) as an entity holding such rights as the party; (iii) (interested) public participation.

A party to the procedure is a person whose legal interest or obligation the procedure concerns or who demands an action on the side of the authority on the basis of its (his/her) legal interest or obligation. Entities holding real estate which might be impacted by the planned undertaking are considered to be parties to the procedure for issuing a decision on environmental conditions. The same holds true for decisions on environmental conditions for shale gas activities.

Ecological organizations (i.e. social organizations having environmental protection as a statutory aim) may participate in the procedure for issuing a decision on environmental conditions on a similar basis as a party. An ecological organization may file an appeal against a decision, even if it did not participate in the first instance procedure. Moreover, the ecological organization may file a claim with the administrative court.

The rules on public participation provide wide public access to the procedure for issuing a decision on environmental conditions. Under Polish law everyone has a right to participate in the procedures requiring public participation. The right to participate includes an entitlement to access the files of the case as well as to file comments and proposals. In the procedure for issuing decision on environmental conditions, public participation is assured only when an EIA is performed (see point 5 above).

In the case of shale gas prospecting/exploration this means that public participation is obligatory only if the authority issuing a decision on environmental conditions decides to conduct an EIA. As regards shale gas production, public participation is obligatory with respect to large scale projects. For shale gas production on a smaller scale and other shale gas activities, public participation is obligatory only if the authority issuing the decision on environmental conditions decides to conduct an EIA.

If public participation is required in the procedure for issuing a decision on environmental conditions, the authority issuing the decision on environmental conditions makes available to the public information on, among others: the initiation of the EIA procedure, the course of the EIA procedure, the possibility to review the documents and file comments and proposals.[9] The minimum period for filing comments or proposals is 21 days. The justification for the decision on environmental conditions has to contain reference to the comments or proposals filed in a public participation procedure.

7. Possible impact on Natura 2000 sites

Two issues are of relevance regarding the impact of shale gas prospecting/exploration and production on Natura 2000 sites: (i) procedure for assessing possible impact on Natura 2000 sites, and (ii) procedure for obtaining approval for a project that might negatively impact a Natura 2000 site.

As a rule, assessment of the possible impact of a project on a Natura 2000 site is performed during the EIA procedure prior to the issuing of a decision on environmental conditions. However, with respect to undertakings which are not enumerated in the EIA Regulation and for which no decision on environmental condition is required, a separate Natura 2000 site impact assessment may be performed.

If the relevant permitting authority (issuing for example building permit, zoning permit, all water permits or permit to remove trees) determines that the given project needs a Natura 2000 assessment, it orders the applicant to initiate a separate procedure before the Regional Director of Environmental Protection, who decides whether to initiate a fully-fledged Natura 2000 site impact assessment.

This impact assessment involves a public consultation process. The Regional Director of Environmental Protection then issues a resolution approving the project or may impose conditions on implementation of the project. Undertakings which may have a material negative impact on the Natura 2000 protection sites may nevertheless be implemented under an approval of Regional Director of Environmental Protection if there is a public interest requirement, including social or economic interest requirements, and where there are no reasonable alternative solutions.

However, in such case the investor has to implement a nature compensation scheme to assure the integrity and proper functioning of the Natura 2000 site. If the negative impact concerns priority habitats and species, approval may be granted only in order to: protect human health and life, assure public safety, obtain other benefits for the natural environment or satisfy an aim of overriding public interest. This approval may be issued during the procedure of the Natura 2000 impact assessment as described above.

If a project which may materially negatively impact a Natura 2000 site is implemented without the required approval, the environmental authorities may bring the activity to a halt and demand the restitution of the previous environmental condition.

Importantly, even if no decision on environmental conditions is required for a given shale gas activity, a project may still need a Natura 2000 impact assessment if there is a risk of material impact on a Natura 2000 site in the vicinity. Implementation of shale gas activity may be prohibited if it is stated that it may materially negatively impact the said protection site and no special justification for its implementation occurs.

8. Water management

Shale gas prospecting/exploration and production consume large quantities of water for hydraulic fracturing and generate commensurate amounts of waste water. These issues are addressed in Polish law on a general basis without particular reference to shale gas activities.

Water for hydraulic fracturing can be sourced either (i) from the local water system under an agreement with a water provider, or (ii) through direct intake of surface or underground water. The former solution is simpler where technically feasible, but at times rarely available as the shale gas activities often take place outside the areas equipped with water system or, if the water system is available in the vicinity, the water taken has to be transported from the water systems to the shale gas site which also can be problematic.

Depending on the local conditions the latter solution may turn out to be more attractive even if a water permit and possibly engineering works are required in order to establish water intake. The water permit takes the form of an administrative decision. A special hydrological survey has to be attached to the water permit application. A water permit may only be issued if the planned activity will not contravene the local water plans or the requirements of human health, the environment and cultural goods.

A water permit is required, among others, for building water facilities (such as water intakes and reservoirs) and using surface or underground water intakes. A water permit for surface or underground water intake is not required if the water intake does not exceed 5 m^3 per day or if the intake is for the purpose of drilling or performing explosive boreholes with the use of water drilling mud for seismic tests.

The injection of hydraulic fracturing fluid (water mixed with proppants and chemicals) into the shale rock formation is not explicitly regulated under Polish law. No water permit is required for this action.

The water which eventually returns to the surface has to be either (i) cleaned and re-used for further hydraulic fracturing, or (ii) treated and disposed of. The former solution is not generally covered by law unless the process involves ponds, in which case a water permit is required. The chemical substances extracted from the return water during the cleaning process are classified as waste. In order to produce such waste the investor has to fulfill certain waste-related administrative obligations, depending on the type and volume of waste produced (among others, to obtain a permit to produce waste, see point 10 below). The waste has to be managed appropriately (i.e. by an entity collecting such waste and holding the necessary waste management permit).

As for the second solution, i.e. treatment and disposal of the waste water, two scenarios are possible: the waste water can be discharged to the local sewer system or directly into water or ground (soil). Discharge to the local sewers takes place under an agreement with the local sewer provider for a fee. However, if the waste water contains listed environmental pollutants, the waste water producer and the entity discharging the waste water into the sewer system have to obtain a special water permit for the discharges.

Alternatively, the waste water may be discharged into water or the ground (soil), which also requires a water permit.[10] Waste water discharged in this manner has to comply with the quality standards set forth in law. This may mean that pre-treatment is needed. If the waste water is stored prior to any actions being taken, a water permit may be required if the storage takes place at the areas of particularly high flood risk.

9. Chemical substances: Application of the REACH Regulation

Hydraulic fracturing fluids contain a mixture of sand and chemical substances. Obligations associated with the use of chemical substances derive mostly from the REACH Regulation, which is directly applicable in Poland.[11] Entities using mixtures of chemical substances for hydraulic fracturing of shales may be classified as downstream users.

Downstream user means any natural or legal person established within the European Union, other than the manufacturer or importer, which uses a substance, either on its own or in a mixture, in the course of industrial or professional activities. REACH Regulation requires the downstream user to identify and apply appropriate measures to adequately control the risks identified in safety data sheets received from their suppliers and follow the instructions contained therein or in the exposure scenarios.

Moreover, the downstream user is obliged to prepare a chemical safety report for any use outside the conditions described in an exposure scenario or if appropriate use and exposure category communicated to him in a safety data sheet or for any use his supplier advises against (subject to enumerated exceptions).

Additionally, the downstream user has to communicate up the supply chain, report to the relevant authorities, keep and update information. The downstream user has also the right to make the use known to the supplier. Polish law lays down penalties for breaches of downstream user obligations under REACH Regulation.[12]

10. Waste management

Shale gas activities may result in the creation of mining and other types of waste. Mining waste includes waste from prospecting/exploration, production, reworking and storing of minerals.[13] Before commencing mining activity, the future holder of mining waste is obliged to prepare a mining waste management program for filing with the respective authority.[14]

Approval for the said plan is given by way of an administrative decision. The holder of mining waste is obliged to hand over the waste to the nearest mining waste disposal plant.[15] If the holder runs the mining waste disposal plant itself, it needs a permit for running such plant as well as fulfill other environmental obligations.

With respect to other types of waste (unless more specific provisions apply), the producer of waste is obliged to obtain a waste production permit for annual waste quantities generated during the operation of the installation of (i) over 1 ton of hazardous waste or (ii) over 5,000 tons of non-hazardous waste.[16]

If waste is not generated in connection with operation of the installation, the waste producer must obtain a decision approving its hazardous waste management program, if it generates more than 0.1 tons of hazardous waste per year. If less than 0.1 tons of hazardous waste or over 5 tons of non-hazardous waste is produced per year, the waste producer is obliged to obtain to file information with the respective authority on the waste produced and the manner of waste management.

The waste produced has to be handed over to entities managing waste and holding respective permits; alternatively, the waste producer may recover or dispose of such waste itself.

11. Noise pollution

Maximum permissible noise levels are set forth in the executive regulation to the Environmental Protection Law.[17] Noise levels are determined for listed types of areas. Entities operating in the environment may not exceed the noise level in areas for which maximum permissible noise levels are laid down in the Regulation. This impacts on shale gas activities. If the environmental authority determines that there are excessive noise levels, it issues an administrative decision detailing the noise reduction measures to be taken.

12. Liability for environmental damage

Shale gas activities may result in environmental damage. Under Polish law an entity using the environment (i.e. the polluter) is obliged to immediately take preventive actions if the risk of environmental damage arises or to mitigating and remedial actions if real environmental damage occurs.[18] These rules apply to environmental damage to protected species, water or soil. The environmental authority has to be immediately notified about any environmental damage and any remedial actions have to be agreed.[19] If the polluter does not take preventive or remedial actions, it may be ordered to do so by the environmental authority in an administrative decision.

13. Summary

Polish law does not address in particular the issue of the environmental impact of shale gas prospecting/exploration or production. However, it does set out a comprehensive legal framework for environmental protection, derived in part from the transposition of European environmental law, and it is within this framework that shale gas activities have to operate. Shale gas companies have to comply with numerous administrative requirements before they can commence prospecting/exploration or production and can be subject to regulatory controls at any time thereafter.

[1] Act of 4 February 1994 Geological and Mining Law (J. o L. 2005 no. 228, item 1947, consolidated text, as amended).

[2] Act of 9 June 2011 Geological and Mining Law (J. o L. 2011 no. 163, item 981).

[3] Act of 27 April 2001 Environmental Protection Law (J. o L. 2008 no. 25, item 150, consolidated text, as amended).

[4] Act of 18 July 2001 Water Law (J. o L. 2005, consolidated text, as amended); Act of 3 October 2008 on making available information on environment and its protection, public participation in the environmental protection and on the environmental impact assessments (J. o L. 2008 no. 199, item 1227, as amended); Act of 27 April 2001 on waste (J. o L. 2010 no. 185, item 1243, consolidated text, as amended); Act of 10 July 2008 on extraction waste (J. o L. 2008 no. 138, item 865); Act of 13 April 2007 on environmental damage prevention and remediation (J. o L. 2007 no. 75, item 493, as amended).

[5] Directive 94/22/EEC of the European Parliament and of the Council of 30 May 1994 on the conditions for granting and using authorizations for the prospection, exploration and production of hydrocarbons (OJ L 164, 30.6.1994, p.3-8).

[6] Act of 3 October 2008 on disclosing information on the environment and protection thereof, public participation in environmental protection and environmental impact assessments (J. o L. 2008 no. 199, item 1227), which transposes Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (OJ L 175, 05/07/1985 p. 0004-0048).

[7] Regulation of Council of Ministers of 9 November 2010 on undertakings materially affecting the environment (J. o L. 2010 no. 213, item 1397).

[8] Under Polish law, decisions on environmental conditions are issued by different authorities, depending on the particular nature of a given undertaking. With respect to shale gas activities following authorities may be responsible for issuing decision on environmental conditions: Regional Director of Environmental Protection, starosta (i.e. head of the county) and wójt, burmistrz, prezydent miasta (i.e. head of the commune).

[9] See footnote 8.

[10] However, under Polish law, it is forbidden, among others, to (i) discharge sewage directly into underground water, (ii) discharge sewage into standing water (such as lakes and other reservoirs not connected directly with surface running waters), (iii) discharge sewage into lakes connected with surface running waters, if the time of such discharge is shorter than 24 hours, (iv) discharge sewage into ground (soil) if the extent of its purification or the thickness of the rock formation above the mirror of underground water do not secure the underground water from pollution.

[11] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/12/EC (OJ L 396, 30.12.2006, p.1) as amended.

[12] Act of 25 February 2011 on chemical substances and their mixtures (J. o L. 2011 No. 63, item 322).

[13] Act of 10 July 2008 on mining waste (J. o L. 2008 No. 138, item 865).

[14] Under Polish law, different authorities supervise mining waste administrative obligations, depending on the particular nature of a given undertaking. With respect to shale gas activities following authorities may be mentioned: Regional Director of Environmental Protection, Voivodship Marshall (i.e. head of the executive body in a Voivodship) and starosta (i.e. head of the county).

[15] Under Polish law, 'mining waste disposal plant' is defined as plant designated for disposal of mining waste, whether in a solid or liquid state or in solution or suspension, including dams, heaps and ponds.

[16] Under Polish law, 'installation' means (i) stationary technical equipment, (ii) set of technologically interrelated stationary technical equipments located within the same unit and held by the same operator, (iii) other buildings, which may cause emission.

[17] Executive regulation of the Minister of Environment of 14 June 2007 on permissible noise levels in the environment (J. o L. 2007 No. 120, item 826).

[18] Act of 13 April 2007 on the prevention and remediation of environmental damage (J. o L. 2007 No. 75, item 493, as amended).

[19] Under Polish law, the Regional Director of Environmental Protection deals with the environmental damage.

The Debate

SHIP Expert Articles

National positions, Statements, Public perception

Shale gas – an EU analysis

Elizabeth Shepherd, Eversheds

June 2012, updated December 2013

Introduction

Across the EU, there is awareness of the dramatic effect that shale gas has had in the US on energy prices, energy security and job creation. However, Member States continue to take very different positions on shale gas, driven by their own political agendas, and shaped by their individual energy policies and energy security concerns. Environmental issues continue to dominate headlines and influence the debate.

Scrutiny of the facts around shale gas has continued through 2013. As a result the European Commission now intends to deliver a Shale Gas Enabling Framework for the EU early in 2014 to manage risks, address regulatory shortcomings and provide maximum clarity and predictability across the EU.

This article considers the current status of regulation around shale gas activity in the EU, including the proposed EU Shale Gas Enabling Framework.

Current status in the EU

The European Commission’s proposed EU legal framework

The Commission Work Programme for 2013 included the initiative “Environmental, Climate and Energy Assessment Framework to Enable Safe and Secure Unconventional Hydrocarbon Extraction”. This initiative aims to deliver a framework on unconventional fossil fuels (through legislative and/or non-legislative measures) to manage risks, address regulatory shortcomings and provide maximum legal clarity and predictability to both market operators and citizens across the EU. The initiative is subject to an impact assessment. The impact assessment will look at options to prevent, reduce and manage surface and subsurface risks, to adapt monitoring, reporting and transparency requirements, and to clarify the EU regulatory framework with regard to both exploration and extraction activities.

The Commission’s Programme is in line with the European Council’s call of February 2011 to assess Europe’s potential for sustainable extraction and use of conventional and unconventional fossil fuels in order to enhance Europe’s security of supply. The Programme equally addresses the European Parliament’s call of November 2012 to introduce an EU-wide risk management framework for unconventional fossil fuels exploration and extraction, with a view to ensuring harmonised provisions for the protection of human health and the environment across all Member States.

Commission studies and assessments, a public consultation and European Parliament reports setting out its position are all informing the Commission’s work. The Commission is expected to adopt a binding legal framework which will produce a base level of European regulation. Whilst the Framework’s legislative form is still to be officially confirmed, it is increasingly expected to take the form of a specific Directive similar to those covering waste water and environmental impact assessments. In Brussels this framework is being referred to as the “Shale Gas Enabling Framework”.

Four general principles and measures have been developed for the Framework. These principles are creating a level playing field in Europe, tackling public acceptance through increased transparency and a focus on health and environmental risks, being clear and simple to understand and a degree of flexibility regarding specific local features. Ultimately the framework must also be compatible with the EU's long term strategy of a low carbon, resource-efficient economy. DG Environment has confirmed that rules will cover all potential environmental impacts of hydraulic fracturing.

The Commission is expected to make an announcement on the Shale Gas Enabling Framework in January 2014 which is likely to be too late to be acted on this parliamentary term. Due to the European Parliament elections in May 2014 and the appointment of the new Commission, to enter into office from 1 November 2013, it could take until 2015 to implement any legislation proposed (and depending on the Framework's form several more years for Member States to implement this legislation in their own national legal systems).

The Commission's public consultation "Unconventional fossil fuels (e.g. shale gas) in Europe"

As part of the Commission's broader initiative to involve the public in the Commission's on-going work an online public consultation was held between 20 December 2012 and 23 March 2013. The Commission also held a stakeholders' conference in Brussels on 7 June 2013. The results of this public consultation have long been considered to be a key determinant of future EU shale gas policy.

A detailed analysis of the results of the public consultation was released in October 2013. This followed high-level results which were presented at the stakeholders' conference. The detailed analysis was generally consistent with the high-level results. The detailed analysis concluded that the majority of respondents consider that the main challenge to the development of unconventional fossil fuels is a lack of transparency and supported disclosure of operational data (including volume of water and chemical additives). The majority of respondents also consider that the current legislative framework is not well adapted and favoured the development of comprehensive and specific EU legislation.

Commission studies

The Commission has released a number of studies as part of its consideration of whether new policy proposals for unconventional shale gas should be brought forward.

These studies include the January 2012 report produced by Brussels law firm Philippe & Partners which looked at experiences in four Member States (Poland, France, Sweden and Germany). In addition, three studies were released in September 2012 on the environmental and human health issues associated with hydraulic fracturing in Europe, the potential climate impact of shale gas production andunconventional gas's potential energy market impacts. The latest study, released in September 2013, considered the regulatory provisions applicable to unconventional gas in 8 Member States (Bulgaria, Denmark, Germany, Lithuania, Poland, Romania, Spain and United Kingdom).

The September 2013 study concluded that there are a number of potential regulatory gaps and legal uncertainties in national Member States legislation. This is in contrast to the January 2012 report which did not identify any significant gaps in the legislative framework, either at EU or national level, when it came to regulating shale gas activities.

European Parliament Reports

On 21 November 2012 the European Parliament (in plenary) adopted two reports by two European Parliament Committees , the ITRE (Industry, Energy and Research) Committee and the ENVI (Environment and Public Health) on different aspects of shale gas. The reports are non-legislative and their purpose was to enable the European Parliament to set out its political position on the issue ahead of any new regulation or policy being proposed by the Commission.

The report by the ITRE Committee on "Industrial, energy and other aspects of shale gas and oil", recognised the crucial role of worldwide shale gas production in ensuring energy security and diversity in the long term. This included the contribution which shale gas and oil can make to the EU's decarbonisation goals. The report reiterated that each Member State has the right to decide whether to exploit shale gas and oil. It also called for states to put in place a "robust regulatory regime" and ensure the necessary administrative and monitoring resources for the sustainable development of all shale gas-related activities.

The report by the ENVI Committee on "The environmental impacts of shale gas and shale oil extraction activities" confirmed that the risks are well-understood and could be effectively managed with existing technology and best practice. In particular, it stressed that wellbore integrity is key to preventing groundwater contamination. The report also called for a thorough analysis of EU legislation relating to shale gas production.

Disclosure of chemicals used in fracturing fluid is a key issue for both reports. Oil and gas producers responded by creating the natural gas from shale (NGS) Hydraulic Fracturing Fluid and Additive Component Transparency Service, managed by the International Association of Oil and Gas Producers (OGP). The primary purpose of the service is to provide factual information concerning hydraulic fracturing of NGS wells, and other issues including voluntary disclosure of chemical additives on a well-by-well basis in the EEA.

Climate Action

The EU is committed to reducing greenhouse gas emissions to 80 – 95% below 1990 levels by 2050 and to 20% below 1990 levels by 2020. The EU is therefore exploring the challenges of decarbonisation.

In March 2011 the Commission published its Roadmap for moving to a competitive low carbon economy in 2050. This Roadmap acknowledged that the EU needed to start working immediately on strategies to meet the 2050 target. It was used as a basis for the Commission's Energy Roadmap 2050 published in December 2011. Its aim is to develop a long-term European framework for energy supply which would complement, rather than replace national, regional and local efforts to modernise energy supply. It acknowledged the impossibility of forecasting the future so far as energy needs and sources of supply are concerned. It therefore presented various routes towards decarbonisation of the energy system, combining the four main carbonisation options – energy efficiency, renewable energy, nuclear and carbon capture and storage ("CCS").

The Commission confirmed that gas has a key role to play in the transition to decarbonisation, and that gas could become a low-carbon technology if CCS becomes commercially available on a large scale basis. It noted that shale gas and other unconventional gas sources have become potential important new sources of supply in or around Europe which could potentially lessen the EU's import dependency. The issue is however whether or not shale gas in Europe will prove viable, and if so when. This is currently not clear, due to the early stage of exploration in all Member States.

In order to meet the long-term 2050 targets an energy and climate-change strategy to 2030 is being established. In addition, a binding international climate agreement is expected to be entered into in 2015 and implemented from 2020. The EU's 2030 energy and climate change strategy is also being adopted to ensure that the EU will be able to meet this international agreement.

In March 2013 the Commission adopted a Green Paper for consultation on the 2030 strategy. This strategy is also being developed to ensure that the EU will be able to meet any international agreements on climate mitigation expected to be adopted in 2015 and implemented from 2020. The Green Paper highlights that the developments relating to unconventional gas and oil, and concerns over the affordability of energy and competitiveness must be taken into account in the 2030 strategy.

At the same time as the Green paper, the Commission published a consultative communication on "The future of CCS in Europe", aimed at initiating a debate on the options available to ensure the timely development of CCS. This communication acknowledges the benefits of gas in that it has half the greenhouse gas emissions of coal and can be used to complement renewable energy sources. Responses to this communication will feed into the Commission's work on the 2030 strategy. It has been suggested that this strategy could be released at the same time as the Shale Gas Enabling Framework in early 2014.

REACH Regulation (EC 1907/2006)

The Commission is also looking closely at the application of the stringent REACH Regulation to ensure that shale gas activities are dealt with appropriately. This is in the context of a wider concern by ECHA (the European Chemicals Agency), regarding the completeness of registration dossiers, in particular the adequacy of the use descriptors for particular substances which are submitted as part of the registration process.

REACH requires manufacturers or importers of substances in the EU to register those substances withECHA within timescales which depend upon the toxicity of the substance and the volume manufactured or imported by each registrant per year. The final registration deadline is 31 May 2018 for substances manufactured or imported in quantities of 1 tonne or more. In addition, a chemical safety assessment (with exposure scenarios) is required where a substance is manufactured or imported in quantities of 10 tonnes or more per year.

The aim of REACH is to ensure that the risks of substances are properly understood and managed appropriately. In 2011, DG Environment expressed concern that chemicals used in hydraulic fracturing were not registered for that use under REACH. However, based on current levels of shale gas activity in the EU, it is likely that the tonnages necessary to trigger registration under REACH will not have been reached. In addition, the use descriptors which have to be submitted as part of the registration process do not require details of the precise use of the substance, simply that it is sufficient to allow adequate risk management measures. This means that use descriptors do not have to be specific to shale gas.

In September 2013 the Joint Research Centre's Institute for Health & Consumer Protection commissioned by DG Environment released its report on the use of certain substances in hydraulic fracturing of shale gas reservoirs under REACH. This report concludes that consideration be given to increasing available information on use, exposure and risk management for substances used in fracturing fluid and makes some suggestions. The report does not suggest that to date industry has acted in a non-compliant way. Careful legal and technical analysis of the recommendations is required to ensure that a disproportionate burden (bearing in mind the aim of REACH to ensure that the risks of substances are properly understood and managed) is not placed on industry.

It is important to frame the debate regarding chemicals used to extract shale gas in the wider context of REACH and its specific rules regarding when exposure scenarios must be prepared. Outside of unconventional gas, all REACH registrants and downstream users are struggling with chemical safety assessments and exposure scenarios. For this reason the European Commission's REACH Review identified that this was an area for improvement.

Over the past two years recognition has grown that REACH (covering substances rather than additives) is not the mechanism to address public disclosure concerns regarding the chemical constituents of hydraulic fracturing fluid. Industry has responded to this concern by developing the NGS Hydraulic Fracturing Fluid and Additive Component Transparency Service.

Environmental Impact Directive

In October 2013 the European Parliament adopted proposed amendments to the Environmental Impact Directive 2011/92/EU by a narrow majority. These amendments included an automatic requirement for an Environmental Impact Assessment (EIA) for the exploration or extraction of shale gas involving hydraulic fracturing. (Currently an EIA is only required when the extraction of natural gas exceeds 500,000 m^3/day). The proposed amendments now require the agreement of the European Council. Member States remain divided, however, the Council is expected to adopt a decision in January 2014.

Member States' positions

As confirmed in the Lisbon Treaty (2009) and re-iterated in recent Commission communications, each Member State has "the right to determine the conditions for exploiting its energy sources, its choice between different energy sources and the general structure of its energy supply" (Art. 194).

Due to political, historical and geographical differences between the Member States they have very different energy supply structures. Due to these differences Member States have also adopted very different positions on shale gas. At their most extreme, reactions range from Poland's enthusiasm for shale gas, where it is seen as an opportunity for independence from Russia, to France's continued reluctance even to allow exploration, despite potentially significant shale gas reserves.

Elsewhere across the EU, shale gas continues to rise up the political and social agenda. Member States demonstrate sharp differences between public opinion and political opinion. Political support for shale gas is not yet reflected in activity and even in countries where there is strong political support development has been slow.

UK

The UK is arguably the best informed Member State in that it was the first to carry out a detailed study which concluded that there is no direct risk to water aquifers, so long as the well-casing is intact. Concerns were however raised following seismic activity near Cuadrilla's drilling site in Blackpool, in the North West of England in April/May 2011 which led to a temporary moratorium.

2013 has been an important year for shale gas producers in the UK following the lifting of the temporary moratorium in December 2012. The lifting of the moratorium was subject to new controls to mitigate the risks of seismic activity. These new controls include a traffic light system to categorise seismic activity and direct appropriate responses. The Government's decision followed analysis of detailed studies and advice from leading experts. At the same time the Government announced that there would be a consultation on how the current licensing regime could be modified to support the particular characteristics of shale gas developments and that a tax regime specific to the shale gas industry would be developed.

Since December 2012 the Government has continued to demonstrate its support for shale gas. In June 2013 the UK Government announced that the 14th onshore licensing round would be launched in 2014 (this is the competitive process by which the UK allocates permits to explore for and extract petroleum).

In July 2013 the Government published a consultation paper on proposals for a tax regime for shale gas. In this consultation the Government recognised the potential for shale gas to increase energy security, create jobs and generate substantial tax revenue. The proposals in the consultation aim to unlock early investment and support industry development.

At the end of July draft technical guidance for onshore oil and gas exploratory operations was released for public consultation. The Government has also produced guidance on how shale gas (and other onshore oil and gas) developments should proceed through England's planning system.

The Chancellor , in his Autumn Statement on 5 December 2013, announced a new tax allowance to kick start the exploitation of onshore oil and gas (including shale gas). The allowance makes the effective tax rate for shale gas projects lower than that in the US and the most competitive in Europe. Legislation to implement the allowance is expected to be included in the Finance Bill 2014.

The United Kingdom Onshore Operators Group (UKOOG) (the representative body for UK onshore oil and gas companies including exploration, production and storage) has also published industry guidelines covering best practise for shale well operations in the UK. The Department for Energy and Climate Change (DECC), the Health and Safety Executive (HSE), the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA) provided input into these guidelines. The guidelines also provide a template for the public disclosure of hydraulic fracturing fluid composition.

UKOOG has also entered into a Memorandum of Understanding with Water UK (which represents the UK water industry) to ensure their respective members co-operate through the shale gas exploration and extraction process. The memorandum's key aim is to give the public greater confidence and reassurance that everything will be done to minimise hydraulic fracturing's effects on water resources and the environment.

Overall the UK government remains positive and whilst the legal framework is being clarified the overall approach of the UK appears to be that it does not see the need for further EU legislation on shale gas activity, it simply wants the freedom to explore and understand the extent of its shale gas opportunity. In spite of this political support the rate of exploration has been slow and no further hydraulic fracturing activities have been undertaken in the UK since the moratorium was lifted. Public debate regarding onshore hydrocarbon production (both conventional and unconventional) has increased and there have been high profile protests highlighting public concern regarding hydraulic fracturing.

Poland

Poland is recognised as another EU frontrunner in shale gas development. This is due to the combination of political will and in the case of Poland, potentially favourable geology. Poland is currently dependant on Russia for its crude oil and natural gas. Development of shale gas is considered by the Polish authorities as a key component of its strategy to diversify Poland's energy mix and improve its energy security.

The Polish Geological Institute released a report in June 2012 which suggested shale gas reserves could be up to 1.9 trillion cubic meters. More recent reports have suggested these reserves may be less favourable with the US's Energy Information Administration reducing its previous estimate for Poland's reserves by 20%. The Polish Geological Institute is expected to publish a new report on the country's shale gas reserves in 2014.

Politically Poland remains supportive of shale gas development with the Deputy Environment Minister announcing Poland would commence commercial shale gas production in 2014. However, the terms of and delays in the enactment of new legislation to regulate the licensing and tax system have led to industry criticisms. This new legislation is now not expected to be enacted until after the end of 2013 and key terms are still disputed.

Germany

Prior to the Federal Elections in September 2013 progress was made to develop draft legislation to regulate hydraulic fracturing. The draft legislation clarified that hydraulic fracturing was in principle permitted in Germany other than in areas which are or are planned to become water protection areas. An attempt to implement the legislation stalled in June 2013 when the coalition government withdrew the draft legislation due to internal opposition (see SHIP article).

The Federal Elections have resulted in changes to the Federal Parliament and a new coalition government. It is expected that any legislation proposed by the new coalition will be less favourable to hydraulic fracturing than that proposed by the previous coalition.

The Christian Democratic Union and the Social Democratic Party have reached agreement for a new coalition. The agreement is unclear over whether the new coalition will establish a formal moratorium (although it has been widely reported that a moratorium has been agreed) on the use of hydraulic fracturing until the risks to health and the environment (particularly water) can be fully assessed. The use of eco-toxic substances and the disposal/injection of flow-back water are raised as particular concerns. The coalition is recommending that the German States, together with the scientific community and industry, work together to gain a better understanding and close knowledge gaps around hydraulic fracturing.

It is expected that the coalition will propose legislation to improve the protection of groundwater, require an EIA for the exploration and extraction of unconventional resources through HF and a restriction/prohibition on the use of ecotoxic chemicals in HF operations. The approach to regulation is likely to be informed by two comprehensive studies by experts into the environmental impact of hydraulic fracturing which were commissioned by the Federal Ministry for the Environment and the State of North Rhine-Westphalia.

France

In France, shale gas activity was suspended in July 2011, with a ban on the exploration and exploitation of hydrocarbons by hydraulic fracturing and the cancellation of exploration permits which had been granted. It has since been confirmed that this decision will apply throughout President Hollande's 5 year term in office. However, it has been stressed that if other techniques for shale gas extraction were developed this decision could be reassesse (see report).

Despite politicians, experts and industry continuing to debate the merits of shale gas and a number of pro-shale reports (including reports produced by the French Parliamentary Office for Scientific and Technological Choices and the Academy of Sciences), France is no further forward in promoting its shale gas potential. At the beginning of October 2013 the French Constitutional Court rejected a challenge to the exploration ban imposed in 2011. The Court noted that in the current state of scientific knowledge, the ban was not disproportionate.

Romania

Since coming to power the current Prime Minister has declared his Government's support for unconventional gas and the government programme for 2013 – 2016 specifically refers to the exploration and exploitation of unconventional resources as a priority activity. The moratorium imposed in May 2012 has been lifted and Chevron has been granted the permits necessary to commence exploration. The Prime Minister has confirmed that it will be up to the government in power beyond 2019 (when exploration is expected to complete) to determine whether shale gas exploration will progress into exploitation.

The Prime Minister has assured the public that hydraulic fracturing will not be used to exploit shale gas in Romania for the next 4-5 years and that a final decision on shale gas will be taken once the country's resources are confirmed. Confirmation of Romania's unconventional gas resources is expected to take about 5 years. Chevron's country manager has since explained that hydraulic fracturing may be used in the final stages of its exploration operations (2-3 years time).

A new royalties system is expected to enter into force in 2015 which will impose different requirements for unconventional, conventional and offshore hydrocarbons.

What about the economics?

The economic significance of shale gas cannot be underestimated. Domestic gas production in the EU is falling, and there is increasing reliance on imports from outside the EU. France currently imports gas from Algeria, the Netherlands, Russia and Norway, the UK from Norway and the Netherlands and LNG from Qatar.

In the meantime, thanks to shale gas, the US may well become a LNG exporter and there are several LNG terminals, originally built to import gas, which are now looking to start exporting from the US, possibly to Asia and the Middle East where the margins are better. This is bound to have a huge impact on international gas flows and, by extension, gas prices, which already look set to continue to rise. Certainly in the US shale gas has had a dramatic effect on gas prices which have come down by 85% from an all-time high in 2005. In addition, there are estimates that shale gas in the US has created around 600,000 direct and indirect jobs in the last few years, this is predicted to increase to 800,000 by 2015 and 1.6 million by 2035.

But can shale gas be produced on an economically viable scale in the EU? It is one thing finding shale gas, and another generating commercially viable production from it, as Poland is finding. For example, geological factors may make shale gas in the EU more expensive to produce, and there are also infrastructure challenges. Other challenges include greater urbanisation in the EU, and different land ownership rights from those in the US.

Pipeline infrastructure is variable across the EU, and less well developed in eastern Europe. Significant investment may be required in some countries to upgrade the network to cope with increased gas flows. Investment has already started in Poland to expand its domestic and transit infrastructure with EU support. In September 2011, a gas interconnector was opened between Poland and the Czech Republic, which could form part of an enhanced north-south gas corridor which may be required if Poland's shale gas production supports exports.

Another concern is the limited supply of suitable drilling rigs in the EU. Many new drilling rigs will either have to be built or brought into Europe to drill the types and numbers of wells that commercial-scale shale gas production would require. However commentators make the point that where there is demand, supply will follow, and this was certainly the experience in the US.

Conclusion

Whilst energy prices and security of supply continue to dominate the headlines, the reality is that shale gas cannot be ignored without potentially damaging consequences to European energy security and prosperity.

There is no doubt that shale gas will influence the global energy market, which in turn will impact on the EU. Outside the EU, China is very keen to take advantage of its recently announced large shale gas resources. China has potentially the world's largest shale gas resources. China has offered subsidies to Chinese operators, introduced a gas floor price and Chinese companies have entered into agreements with international shale gas operators to bring the necessary technology to China and set up joint ventures to exploit reserves.

Whether the EU will be left behind depends on how it engages in the debate. Much rides on the proposed EU Shale Gas Enabling Framework. The EU and Member States need to allow shale gas exploration to advance, at least to understand the scale of the opportunity. There must be a concern that unless the EU is able to provide a favourable environment (including regulatory stability) for that exploration, US companies which have the technical expertise to help will look to easier targets, such as China and Australia.

Public acceptance is of course key. Despite the potential benefits of shale gas exploitation, exploration of this resource has not yet gained widespread public acceptance in the EU. It is essential for there to be open and transparent debate, based on sound, peer reviewed, scientific analysis which examines the opportunities and the issues. Only if the public, as well as the regulators, can be satisfied that shale gas can be produced safely can there be any hope of replicating across the EU the job-creating, economy transforming effect which shale gas has had in the US.

Shale gas in Germany – the current status

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October 2012, updated April 2015

Shale gas exploration and production is a controversial topic in Germany, although activity in this energy sector remains very limited. Estimates on the amount of shale gas reserves in Germany vary and contain great uncertainties. The latest estimate of the amount of technically recoverable shale gas is 25-81 Tcf or 700-2268 billion m^3. This is about 2-7 times the German natural gas reserves from conventional reservoirs.

Background

Germany imports around 70 % of its energy resources. Main imports are hard coal* (approx. 81 %), petroleum** (approx. 98 %), natural gas** (approx. 90 %), and uranium* for nuclear energy (100 %). Only one quarter of Germany's energy supply is produced within the country (this includes renewable energy) (*data from 2012, BMWi; **data from 2014, LBEG).

Shortly after the disaster of Fukushima in 2011 (Tohoku-oki earthquake), the Federal Government of Germany initiated an energy transition process [Energiewende] for the entire country. Hence, all nuclear power plants in Germany will be shut down until 2022. This plan has dramatic implications for Germany's energy mix. All electricity generated by nuclear power plants (22% of the entire gross electric energy output) has to be replaced. Natural gas is often regarded as an important transition energy source and could replace part of the energy from nuclear power plants. In the future, natural gas as an energy source will be perceived as more important, because it is available even when the wind isn't blowing and the sun isn't shining, according to the Federal Environment Minister Barbara Hendricks, speaking in Berlin at theZEIT Conference on Natural Gas and Climate Protection in October, 2014.

Merely 10 % of Germany's natural gas consumption originates from domestic natural gas production. In addition, the annual domestic natural gas production is decreasing due to depletion of conventional reservoirs (conventional and tight gas) (annual report LBEG, 2013).
Germany's unconventional gas deposits are mainly made up of shale gas, which may play a central role in improving the security of supply from a domestic energy source.

Public debate of shale gas production

For about 4 years now, the topic of hydraulic fracturing has been present in the media, in public discussions, and among experts. The focus of the public debates is on the possible environmental impactof the fracking-technique such as contamination of groundwater, earthquakes, elevated greenhouse gas emissions, enormous water consumption, and risks due to improper disposal of flowback water.

Several citizens' initiatives against shale gas production were founded, especially in the German States of North Rhine-Westphalia and Lower Saxony. These two states are the most promising regions for shale gas exploration to date. Aside from the citizen's initiatives "Bundesverband Bürgerinitiativen Umweltschutz e.V.", (BBU, Germany's national association of citizens' environmental protection initiatives) and "No Moor Fracking" the website "Gegen Gasbohren" (against gas drilling) is the joint communication platform of many German citizens' initiatives against shale gas development in Germany. German beer brewers and the environmental protection officers of the Protestant churches in Germany (EKD) also publicly object to the shale gas extraction technique.

In Germany, the hydraulic fracturing technique has been applied for conventional and tight gas reservoirs since the 1950s to increase production rates. Since then, more than 300 frac jobs were successfully conducted in depths of sometimes more than 5000 m (annual report 2010, LBEG). According to the annual LBEG report from 2012 "there has been no known environmental damage during all these years". However, the technique of hydraulic fracturing for shale gas production is still new territory for Germany, as the geological formations with the interesting shale formations are at shallower depths and the frac volumes are considerably greater than with conventional reservoirs (annual report 2012, LBEG). Citizen's initiatives point to the lack of monitoring or systematic investigations of environmental impacts of the hydraulic fracturing activities carried out to date.

To this date, one test drilling using the hydraulic fracturing technology in shale rock was conducted in Germany in 2008 (Damme 3, Lower Saxony). ExxonMobile also published the chemical composition of the frac fluids used in the 3 frac treatments. The test drilling was conducted to achieve an estimate of the production potential of the existing shale rock formations. However, there are no final results as of now (annual report, LBEG, 2012).

There is, however, a general consensus among all parties involved (citizens, public authorities, environmental associations, the science community and also the industry) that intensive research on all aspects of the topic of shale gas is required.

Political context

Following the decision in June, 2013 not to introduce the Bill on regulation of ‚fracking technology' within the last parliamentary term, the Federal Environment Ministry and the Federal Economics Ministry presented a combined framework document in July, 2014. The main points (see SHIP News) included the strongest regulations that have ever been seen in this area; the document intended there would be no commercial production for financial purposes in the foreseeable future. Only scientifically supported testing measures were deemed possible. The framework document was as much commended by fracking opponents, who have called for a total ban on the technology, as it was heavily criticised by fracking proponents, who deem it as amounting to a total ban. In September, 2014 ExxonMobil launched an advertising campaign regarding the extraction of shale gas through ‚fracking', under the title, „Let's talk about fracking". In an open letter ExxonMobil claims that it has „succeeded in fulfilling a key political and public demand: our fracking will only use two non-toxic and easily biodegradable additives [Cholinchlorid und Butoxyethoxyethanol]." Hereby industry has directly addressed a point raised within the framework document [„(...) Test measures to research effects on the environment and sub-surface may be possible, providing the deployed fracking fluid is not hazardous to water."]. Previously in April, 2014 ExxonMobil published the development of a minimum reduced additive, framed by the 3rd status report on the implementation of the Neutral Expert Group recommendations [see SHIP News]. At the same time Federal Environment Minister Barbara Hendricks was presented with 660,000 signatures from fracking opponents.

In September, 2014, with an open letter (the Copenhagen Declaration), the European Geological Surveys of the North Atlantic Area criticised the lack of utilisation of their specialist authority in research of the geological sub-surface (see SHIP News). The Directors of the Surveys (including BGR-President Prof. Dr. Hans-Joachim Kümpel) are concerned about misleading media reporting, regarding the exploration and exploitation of minerals and energy commodities, in particular the exploitation of shale gas. They feel that often scientific results and conclusions are ignored. „Often dangers are evoked that simply do not exist. The use of fracking for natural gas production arouses widespread fear amongst the population, fear that from a geological perspective is largely unfounded,“ claims BGR-President Prof. Dr. Hans-Joachim Kümpel.

Surprisingly in November, 2014 a revised version of the original framework document was released. It included the addition that „exceptions can be made following successful test measures and commercial fracking may be permitted, provided an independent expert commission votes positively with respect to environmental impact and earthquake security; the relevant German federal state authorities must additionally approve these activities. The vote of the expert commission is not binding for German federal state authorities.“

On 1st April 2015 the German Bundeskabinett (Germany´s government) introduced a bill regulating hydraulic fracturing in Germany (for details see SHIP News). The bill will be discussed in the German Bundestag (Germany´s parliament) and may experience amendments before final approval.

Scientific reports and positions

ExxonMobil study on the risks of hydraulic fracturing

In early 2011, ExxonMobil Production Deutschland GmbH (EMPG) initiated an information and dialog process on the potential risks and environmental impact of unconventional gas production, as a response to widespread public opposition to its exploration activities in North-Western Germany. An extended summary version of the "Risikostudie Fracking" (study of fracking risks) was presented during the final conference on April 25, 2012, in Osnabrück, Germany.

At the heart of the information and dialog process was a panel of eight leading experts from German research organizations who worked on a broad spectrum of questions, in particular regarding the environmental risks and health risks of hydraulic fracturing. The experts were selected very carefully; besides excellent scientific expertise, requirements included independence from the natural gas industry and from ExxonMobil.

The main conclusions of the scientists are:

- Compared with conventional gas production, hydraulic fracturing in unconventional reservoirs bears a new range of risks, stemming from an increased number of wells and a related increase in water consumption, the use of chemical substances, and increased traffic. Additionally, many potential gas shales are present at shallower depths than is the case for conventional reservoirs in Germany.
- The assessment of the risks has shown that a slow and cautious development of hydraulic fracturing in unconventional reservoirs should be possible – there is no factual reason for a ban of the technology.

EMPG and the scientists pointed out that the experts did their research without prejudice and were not influenced by EMPG. In this respect, EMPG's willingness to implement all recommendations in future hydraulic fracturing projects in Germany, is remarkable [see SHIP News].

Risk study Federal Ministry for the Environment

In August 2012, the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Environmental Agency (UBA) presented a study on the environmental impact of shale gas development [see SHIP News]. An environmental impact assessment is required for any shale gas activity that includes hydraulic fracturing. Another requirement is the availability of a wide range of information and the participation of the public. Shale gas exploration should not be allowed in areas with unfavorable geological conditions and in drinking water protection areas. It is recommended that environment and safety related approvals and monitoring shall be administered by the environmental authorities.

The study recommends that hydraulic fracturing should not be banned, but its application should only be allowed with strict regulation in place and should be accompanied by intensive administrative and scientific supervision.

In July, 2014 the National Environment Agency introduced a second report on the environmental impact of using fracking for the exploration and extraction of natural gas, in particular for shale gas deposits (seeSHIP News). It is recommended in this study „(…), that scientifically supported tests are carried out, as without such tests, our scientific knowledge of the risks and opportunities of fracking technology will remain limited."

Risk study by the Ministry of Environment and the Ministry of Economy of North Rhine-Westphalia

In September 2012, the Ministry of Environment and the Ministry of Economy of North Rhine-Westphalia presented a study about the impact of hydraulic fracturing on the environment. The study emphasizes that the risks related to shale gas development cannot conclusively be evaluated at present and calls for more research. Moreover, it recommends that hydraulic fracturing should be prohibited in drinking water protection areas.

This study recommends suspending shale gas exploration with hydraulic fracturing in North Rhine-Westphalia, until less harmful additives for the fracturing fluids are available and the waste disposal is regulated to an acceptable extent. The state government implemented the recommendations immediately and stopped hydraulic fracturing until further notice, that is until more information on the risks of this technology is available.

Administrative regulation of the State Office for Mining, Energy and Geology (LBEG)

In late October 2012 the LBEG issued a new circular regarding the "Minimum requirements for operating plans, inspection criteria and approval processes for hydraulic well stimulation in crude oil and natural gas deposits in Lower Saxony". The administrative regulation refers to conventional and tight gas deposits in which hydraulic fracturing is applied. The requirements and processes for hydraulic fracturing in crude oil and natural gas deposits stipulated by the circular are intended to ensure an official assessment and evaluation. The LBEG thus defines a basis for future applications that is comprehensible for both companies and the public. The circular does not apply for geothermal energy and shale gas reservoirs.

Joint statement of the Geological Surveys of the German States (SGD) and the Federal Institute for Geosciences and Natural Resources (BGR)

In March 2013, the BGR and the SGD published a joint statement on the studies on hydraulic fracturing published in 2012 (studies by the UBA, the state of North Rhine-Westphalia and the risk study of the ExxonMobile dialog process). The statement was drawn up on behalf of the federal/state soil research committee. The examination of these studies resulted in harsh criticism of the presentation and assessment of the geoscientific facts. "The highlighted geoscientific deficits of the studies may result in a one-dimensional perception and accordingly in a general overestimation of the uncertainties when assessing geoscientific-based dangers and risks of hydraulic fracturing technology. (…) It should be emphasized that many of the recommendations with geoscientific relevance are already common practice." The statement also notes that it is not accurate to say that there is not enough data for regional evaluations of the geological underground.

Statement of the German Advisory Council on the Environment (SRU)

The SRU statement issued in May 2013 advocates a sober assessment of the chances and risks of hydraulic fracturing. The SRU states that shale gas production in Germany is dispensable under current conditions. In its report, the SRU points out that, in accordance with current scientific knowledge, there are still important questions that remain unanswered with regard to the risks associated with hydraulic fracturing. The committee recommends to clarify these questions one by one and to only issue permits for pilot projects until then.

"Hanover Declaration" of the Institute for Geosciences and Natural Resources (BGR), the Helmholtz Centre Potsdam – German Research Center for Geosciences (GFZ) and the Helmholtz Center for Environmental Research (UFZ)

The three institutes for geology and environment, BGR, GFZ and UFZ, published their joint statements on the topic of "Environmentally Compatible Hydraulic Fracturing" for the extraction of shale gas in August 2013. The "Hanover Declaration" is the result of a two-day conference with national and international experts on scientific and technical aspects.

The main conclusions are:

1. Natural gas is an indispensable resource for Germany. Recovery of shale gas could contribute to a stabilization of resources caused by dwindling domestic natural gas extraction.
2. If the fracking technology is to be applied for shale gas extraction in Germany, this requires environmentally-friendly procedures (e. g. the use of environmentally-friendly frac fluids). Furthermore, the existing legal framework for the exploration and production of natural gas will need to be developed further. The protection of drinking water must be a top priority.
3. To assess whether fracking can be conducted in an environmentally-friendly manner, proposed procedures should be first checked against local geological conditions in each individual case, and accompanied by appropriate monitoring measures. For this an environmental impact assessment based on the corresponding mining regulations must be carried out. Furthermore, it must be ensured to involve the environmental administration, in particular the water authorities, in the process.
4. The operation and development of technology for shale gas extraction in Germany requires a transparent and step-by-step approach.

Therefore

- first projects should be carried out as demonstration projects and all parties involved (public, industry, scientific community and environmental organizations) should be included from the start;
- individual measures and results should be published and accompanied and evaluated by a comprehensive scientific program;
- the main focus should be on research regarding the possible impact on groundwater quality of hydraulic fracturing measures.

Unique so far in the development of the "Hanover Declaration" was the fact that all parties involved were able to access the draft online and contribute to its creation.

The German Academy of Technical Science (acatech)

The German Academy of Technical Science, wishes to take a position regarding the basis of technical facts at the end of 2014. It aims to address the theme of hydraulic fracturing with its many facets including the ecological, legal, economic and political implications, as well as communications and community acceptance. It will provide an integrative assessment of all risks and opportunities. In addition to clarifying the technical and scientific aspects, the publication will spread light on the ecological, economic, legal and socio-political dimensions of fracking technology. Focus will be on the distinction of fracking in the context of deep geothermal energy and the extraction of shale gas.

Research on shale gas in Germany

GASH- Gas Shales in Europe

The GASH project was the first major European shale gas initiative and carried out a broad variety of shale gas research. Nine leading European research organizations are involved in this project, along with national geological services and industry partners.

The companies involved in GASH do not only act as sponsors; both the companies and scientific partners support GASH by delivering access to core data material, and by providing and applying their own analytical facilities.

One of the main problems in European shale gas exploration research is caused by a lack of access to shale gas relevant data from promising stratigraphic horizons crossing national borders. To overcome this issue, a web-serviced GIS database is being developed (European Black Shale Data Base, EBSD).

GeoEn

Basic research on German gas shales was conducted within the GeoEn project. GeoEn is an interdisciplinary national energy research program funded by the German Ministry for Education and Research. The program concentrates on four core topics of relevance to fossil and renewable geo-resource energy production. These are: shale gas, CO_2 capture, CO_2 storage and geothermal energy. Results will be used to offer safe and environmentally-friendly solutions to the growing energy demand of the future. GeoEn was the sponsor of the Shale Gas Information Platform SHIP.

NiKo

The Federal Institute for Geosciences and Natural Resources (BGR) started the project NiKo in 2011, in close collaboration with the United States Geological Survey USGS. The project will run for four years until 2015. NiKo investigates the shale gas potential for Germany, with a first report published in May 2012 (in German). The report suggests a large German shale gas potential of 700-2268 billion m^3.

The conclusion of the study on environmental concerns is this: "From a geoscientific point of view, environmentally-friendly application of the technology is possible, as long as the law is observed, the necessary technical measures are taken and local baseline studies and pilot surveys are carried out. Hydraulic fracturing is compatible with the protection of freshwater reservoirs."

In a second step, the potential of shale oil in Germany will be studied within the NiKo initiative as well.

Polish shale gas exploration: the way forward

Andrzej Rudnicki, Polish Geological Institute – National Research Institute PGI

July 2015

The withdrawal of U.S. major ConocoPhillips from shale gas exploration in Poland has definitely deflated the hopes for a shale gas El Dorado in Poland. Early in June 2015 the U.S. oil company announced its decision to relinquish three unconventional oil and gas exploration concessions held in Poland. Conoco drilled 7 wells and performed hydraulic fracture stimulation in Poland. According to company managers, commercial volumes of natural gas were not found (see here).

Most probably, a slump in oil and, consequently, gas prices are additional adverse factors with serious impacts on the viability of unconventional oil and gas exploration in Poland. Oil price stood at over USD 100 per barrel in the beginning of exploration boom in Poland in 2011, while as of mid-June 2015 it was less than USD 70. There are two Polish oil companies remaining in shale gas exploration: Orlen Upstream and PGNiG.

How much shale gas in Poland?

High expectations during the last years for a shale gas boom were based on optimistic but simplified resource assessments based on a comparison of the Polish and U.S. shales. However, since the start of the shale gas project Polish geologists have warned that the 2011 estimates by U.S. Energy Information Agency might be overly optimistic. The Agency's report estimated recoverable shale gas resources at as much as 5.5 Tcm.

An in-depth analysis of available pre-existing data, samples stored at the Central Geological Archives of the Polish Geological Institute and of geophysical data led to a more detailed estimate published by PGI in 2012: recoverable shale gas resources are not expected to exceed 768 Bcm (weblink to report). However, this does not mean that Poland should give up exploration and potential production.

So far, about 70 shale gas exploration wells have been drilled across Poland (Table 1, Figure 1).

Based on data available from existing wells, PGI-NRI geologists are to prepare a new report on recoverable shale gas resources by the end of 2015. Both Orlen and PGNiG plan to drill additional wells in 2015. PGNiG has just started drilling one of the new wells (Wysin-2H) in Pomerania. However, at least 100 more wells are needed to enable a more accurate estimate of these resources.

It is known that the gas occurs in the so-called shale belt stretching from Pomerania in the north to the Lublin region in the southeast of Poland. The belt is not uniform in terms of gas content. Polish geologists have long established that very large fields capable of competing with the U.S. or Chinese ones cannot be found in Poland.Polish shale gas reservoirs are located deeper (3 to 5 km) than, for example, the ones in the United States. Moreover, they are highly diverse. Some of them are rich in organic matter, which may suggest a high content of gas, but comprise clay minerals that tend to swell on contact with water and complicate the fracture stimulation operations. On the other hand, some of the shales are more brittle but contain less gas. Interview with Prof. Gregory Penkovsky, a geologist, deputy director of the Polish Geological Institute (in Polish).

Table 1. Completed shale gas exploration wells and downhole operations in the wells (01 July 2015). DFIT - Diagnostic Fracture Injection Test. Compiled by: Ireneusz Dyrka PGI-NRI, 2015

Type of downhole operations	No. of vertical wells	No. of directional/horizontal wells	Total
Fracture stimulation	13	12	25
DFIT only	4	0	4
No fracture stimulation	37	4	41
Total	54	16	70

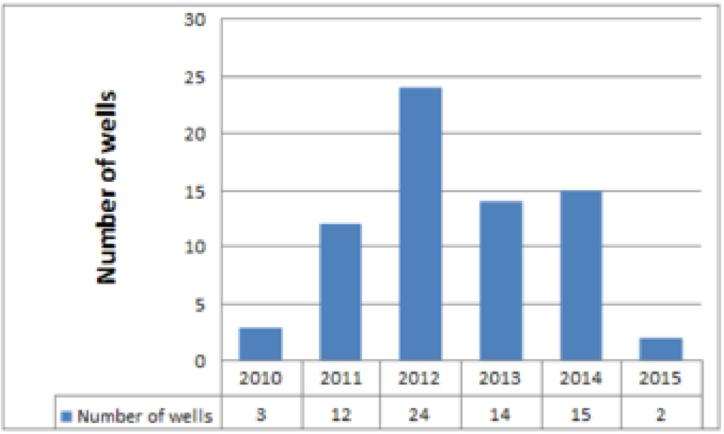


Figure 1. Shale gas wells drilled in Poland. Compiled by: Ireneusz Dyrka PGI-NRI, 2015

Impact on the environment

Importantly, any potential shale gas production in Poland will not pose a risk to the environment. In March 2015, Polish Geological Survey published a report on environmental risks from shale gas exploration and production. The report (Press release and report in Polish, English translation of report) is based on a thorough analysis carried out by PGI specialists in collaboration with scientists from AGH University of Science and Technology and from Gdańsk University of Technology under the supervision by the Polish General Directorate for Environmental Protection.

Data concerning the quality of surface and ground water, ambient air, soil, migration of fluids and gas and other environmental aspects have been collected for several years. Monitoring started before the wells were spud-in and ended two years after the stage of drilling. No damage to the environment was found.

High demand of natural gas

There are still prospects for development of Polish shales. As Professor Grzegorz Pieńkowski of PGI-NRI noted, should estimates by Polish Geological Survey (resources in the order 346 to 768 Bcm) prove to be correct, it would be possible to produce several billions of cubic metres of gas per year. A production volume in the order of 4-5 Bcm would satisfy approx. 30% of the domestic demand for gas and enhance Poland's energy security. Poland currently imports almost 12 Bcm of natural gas: 9 Bcm from eastern countries and almost 3 Bcm from the European Union (Table 2).

Gas imports have been growing for many years (Figure 2) to meet a steadily increasing demand. Currently, Poland consumes almost 15 Bcm natural gas per year (Figure 3). On the other hand, according to the latest "Poland's reserves of mineral resources", as prepared by Polish Geological Institute – National Research Institute, domestic natural gas production reached 5.258 Bcm in 2014. Domestic gas production is growing at a rate lower than the demand for gas is growing (Figure 3). Accordingly, should shale gas production prove to be viable, Poland would satisfy as much as 60% of its current consumption from domestic sources with significant changes in the national gas supply structure.

Projects aiming at diversification of natural gas supply sources are being implemented alongside the studies on the potential of unconventional gas resources. These projects include the construction of a liquefied gas terminal at the port of Świnoujście. Its initial regasification capacity will be 5 Bcm per year and, on expansion, will reach as much as 7.5 Bcm per year. The terminal is to be commissioned in summer of 2015.

Table 2. Poland's gas imports in 2013. Source: Polish Ministry of the Economy

Gas export country	Mcm of gas
Russia, Azerbaijan, Central Asia countries	9114.73
Germany	2149.96
Czech Republic	553.41

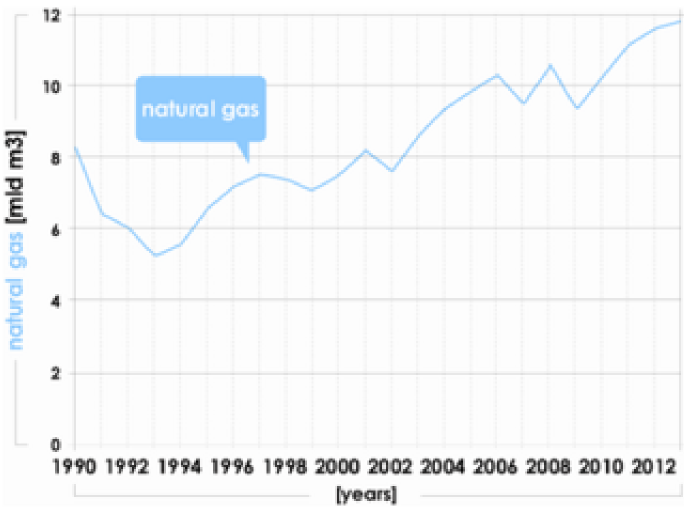


Figure 2. Poland's gas imports from 1990 to 2013

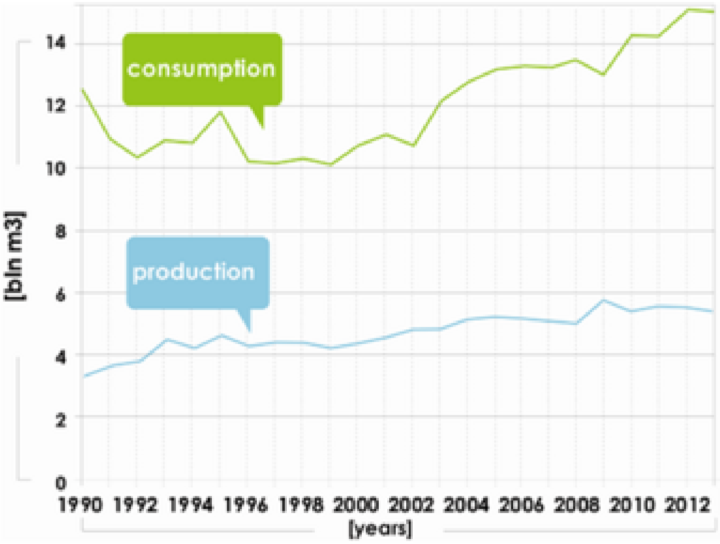


Figure 3. Poland's natural gas consumption and production from 1990 through 2013

Shale Gas in Poland

Mirosław Rutkowski, Polish Geological Institute – National Research Institute PGI

May 2013

Poland is carrying out the most intensive program of exploration and prospecting for unconventional hydrocarbons in Europe. The major target of the exploration is the Lower Paleozoic gas shales, but Permian Rotliegend tight gas sandstones and Carboniferous coalbed methane are also being considered as unconventional resources.

The concession areas of exploration cover 37,000 sq km, which constitutes 11% of the country's territory and extends as a wide belt from Pomerania (northeastern Poland), through Mazowsze and Podlasie (central Poland), to Lubelszczyna (southeastern Poland). According to a report published by the Polish Geological Institute in March, 2012, estimated technically recoverable shale-gas resources are probably in the range of 346 to 768 bcm.

The prospect of increased natural gas production creates new hope for rationalization of the Polish energy mix, which is currently based mainly on coal. Alongside other supply projects it would allow the diversification of Poland's energy sources, and this is considered an important element of the country's energy security. Because of this, shale gas production as a new branch of the national economy is supported by all the main Polish political parties and has major public acceptance.

"*We are looking for the ways and meantools to get into the barrel of honey, but still we don't know if there is honey inside or it's just the smell of it*."

Hubert Kiersnowski, Polish Geological Institute – NRI

Resources

The first shale gas resource estimates in the Polish Lower Paleozoic strata (Ordovician and Silurian) were made by private consulting agencies, using a limited quantity of available public geological data provided by the Polish Geological Institute. These data were collected during a deep-drilling program that took place in Poland between 1960 and 1980.

In 2009 the Wood Mackenzie agency estimated recoverable resources of Lower Paleozoic shale gas in Poland to be of a volume of 1400 bcm. In the same year Advanced Resources Int. estimated the resources to be 3000 bcm, whilst Rystad Energy published information on potential resources calculated to be 1000 bcm. These estimates, compared with the volume of officially documented conventional natural gas resources (145.15 bcm), led to very optimistic conclusions.

In 2011, super-optimistic visions describing Poland as a "second Norway" started to dominate public discussion, following a publication from the U.S. Energy Information Administration in 2011. The EIA predicted geological shale gas resources to be about 20,000 bcm, with a volume of 5,300 bcm possibly recoverable.

A Polish Geological Institute report published in 2012 dampened everyone's zeal. Scientists from PGI hold the view, based on archival geological and geophysical data, that recoverable shale gas resources are only in the range of 346 to 768 bcm, whereas, in comparison, maximum level of recoverable natural gas is 1,920 bcm. Recoverable resources of shale oil were also calculated for the

Silurian and Ordovician strata and they represent a volume of 215 to 268 MMtons with a maximum prediction of 535 MMtons. It is believed shale oil should be found at the eastern side of the gas shale belt.

This huge decrease in the estimate of resource volumes was an unpleasant surprise. It should be noted, however, that even these lower calculations constitute volumes 2 to 5 times larger than those documented in conventional gas reservoirs in Poland, and so can still fulfill Polish gas demand for up to 65 years in an optimistic scenario.

The PGI report was prepared in co-operation with specialists from the U.S. Geological Survey. The USGS provided natural gas production data from the American shale gas plays, from which a few were chosen, as they show similar geological features to the Polish shale plays; by analogy possible production rates were estimated. The PGI report did not take into account data from wells drilled recently in Poland. The next report will be published after drilling 100 new wells in Poland, probably in the first half of 2014.

Concessions and perspectives on exploitation

In the Polish public administration structure, responsibility for preparing for shale gas exploitation lies with the Minister for the Environment, supported by the Deputy Minister for the Environment, and the Chief National Geologist. The procedure for issuing concessions for unconventional hydrocarbon exploration is dealt with by the Department of Geology and Geological Concessions, at the Ministry of the Environment.

Under actual Polish law for the issuing of concessions for exploration, any legally operating Polish or foreign entrepreneur may apply, subject to the submission of a Project of Geological Work, listed in accordance with the provisions of Geological and Mining Law. The concession is issued for a period of three to five years and commits the concessionaire, among others things, to drill up to three exploratory wells in a defined area.

Exploration concessions do not entitle the holder to mineral deposit exploitation. This condition is the subject of dispute with the European Commission, which wishes to introduce more effective protection of the interests of exploration companies. Currently, despite investing significant funds into drilling, they have no guarantee of running any of the following exploitation. The Ministry of the Environment controls the progress of geological work specified in the concession agreement, the production of investor annual reports, information on the development of each additional kind of work and the final results of exploration. Up to now, the Environment Office has issued 109 concessions for exploration and identification of unconventional gas deposits. These concessions have 19 capital groups. The largest share has been allocated to the Polish Oil and Gas Company (PGNiG).

The location of concessions and company data are regularly published on the Ministry of the Environment website. It is planned to dig 309 exploration wells up to the year 2021 (128 for certain, an optional 181 in addition, depending on the capabilities and results of the work). According to the Ministry of the Environment, work on most of the concessions is going too slowly. In half of the areas, concession investors have not begun any activity.

Up to 31 December, 2012, investors had made 33 exploration wells. Hydraulic fracturing was performed in 11 wells. Eight treatments performed in vertical section wells can be described as pilot works. The full program of research, including fracturing in horizontal sections at a length up to 1 km, has been carried out in three cases. The results disclosed by some companies are promising but far below expectation. Low results from technological tests was one of the reasons the Exxon Mobile company gave for withdrawing from exploration in Poland.

According to Mikołaj Budzanowski, former Minister for the Treasury, commercial gas production will start in 2014, most probably at the “Wejherowo” concession. Analysts say that this is possible but 2015 or 2016 is more likely. Full development of the deposits, depending on the results of exploration work, will need several decades. In many areas exploitation will never proceed because of environmental and infrastructural constraints.

Economic and social aspects

Poland consumes about 14.5 billion m^3 of natural gas annually. Almost 70 % of natural gas is imported, the rest is produced from domestic resources. In the national energy balance - strongly dominated by coal - the role of natural gas is minuscule. Natural gas is a key raw material for the chemical industry however, and an important element in the municipal infrastructure.

In light of the EU’s energy mix climate policy for Poland, specialist debates concerning optimum gas usage levels, carried out long before the shale gas boom, indicate that natural gas should play a greater role in Poland, as a more environmentally friendly fuel, and in an effort to reduce the absolute dominance of coal. Realization of the possibility of increasing domestic production of natural gas, through the development of unconventional deposits, strengthens this conviction.

Public opinion deems the chance to reduce dependence on gas imports from an eastern direction to be very important. An agreement with Gazprom is effective until the year 2037 and is seen as a treaty that is not only economic but also political. This agreement has already been used to try to apply political pressure, and history suggests that this may happen again in the future.

The necessity of importing gas from a monopolist provider makes it possible for that monopoly to dictate deposit prices, which are now among the highest in Europe, even after the renegotiation agreement. This reduces the competitiveness of industry, and inhibits the gasification process of the municipal economy. We have even observed the return of previous gas recipients, to the use of cheaper coal. In wintertime stifling smog from coal becomes a huge problem, especially in the large cities in the southern part of the country.

Extreme dependence on coal and the unfavorable structure in place for gas import make the Polish situation unique among the countries of the European Community. Awareness of these conditions raises high hopes for shale gas exploitation. This helps to explain why the development of new energy resources has such a high acceptance level within Poland. According to a survey by the Public Opinion Research Center, CBOS, of September, 2011, 73 % of Polish citizens are in favor of shale gas exploitation, despite doubts about hydraulic fracturing and its potentially harmful effect on the environment. 4 % of the population are definitely opposed.

Groups protesting against hydraulic fracturing are few and local in character. One of the most active is theAssociation Niesiołowice – Węsiory “Kamienne Kręgi”, directed by Hieronim Wiącek. Paradoxically, a group of opponents to fracturing through their activities have had a positive impact on companies looking for gas, they must now carefully observe the norms of environmental and mining laws and work in an exemplary fashion with local communities. A few attempts to disregard public opinion ended negatively for oil companies, who were even forced to give up on troublesome locations.

Political aspects

As noted before, all the main Polish political parties support the idea of the development of potential unconventional gas resources. The first 11 exploration concessions were granted by the Prawo i

Sprawiedliwość political party at the end of their term. The Platforma Obywatelska political party, which has formed the government since 2007, strengthened support for exploration work on Polish shale gas – the Ministry of the Environment granted more than 100 exploration concessions, which practically exhausted the possibility of acquiring more prospective areas.

The approach to shale gas by the two main political parties in Poland (Platforma Obywatelska and Prawo i Sprawiedliwość) differs only in the way that the predicted tax revenue should be invested, and the way in which oil and gas companies should be supervised by the government.

Support for the governmental exploration and exploitation program is declared also by the current coalition partner Polskie Stronnictwo Ludowe, and the opposition party Sojusz Lewicy Demokratycznej. The only parties that run an active campaign against shale gas are the Ruch Palikota, a parliamentary party, and the Zieloni 2004 party, which is not represented in the parliament.

Prime Minister Mr. Donald Tusk (Platforma Obywatelska), during his last and current term in office, has emphasized that shale gas exploitation is one of the government's priorities.
Those most involved in implementation of the government's shale gas program are the Ministry of the Treasury, the Ministry of the Environment and the Ministry of Foreign Affairs. A high degree of interest in the field is also shown by the Ministry of Economy, the Ministry of Finance and the Ministry of Science and Higher Education.

The government's announcement in November, 2012, of project objectives in the so-called Hydrocarbon Act, was an important step on the way to organizing legal and financial issues concerning this new branch of business. It introduced a new tax structure for the oil and gas sector and set the government's supervision over oil and gas companies in the form of a national agency called National Energy Minerals Operator (NOKE).

NOKE will also have the right of first refusal on the secondary trade in licenses, on market terms. One of the most important elements of the new act is that higher tax revenues will go towards municipal government budgets. Details are being discussed with the participation of the opposition parties, the organization of entrepreneurs and local communities.

On the initiative of the former Treasury Minister, Mr. Mikołaj Budzanowski, in mid-2012, five firms, PGNiG, ENEA, KGHM, PGE, and TAURON Polska Energia, signed an agreement that will see them accelerate the development and exploration of shale gas in Poland.

Another important government initiative was the idea of support for the development of new technology for shale gas exploitation. An agreement between the Polish Agency for Enterprise Development, the Centre for Research and Development and the Ministry of Science and Higher Education, was signed in July, 2012. The first competition for funding research projects was announced in August, 2012. The total budget for the project is quite high and accounts for 1 bln PLN. Half of the budget will come from national budgetary means, the rest will be sponsored by companies interested in the new technology results.

In regions that are likely to be among the first to participate in the exploitation of shale gas, local authorities have set up agencies. Their task is to represent the interests of local communities to investors and to mediate on approaches to possible conflict resolution. Such agency positions have been set up by the Marshals of Pomerania, Warmia-Mazury, Kuyavian-Pomeranian, Lublin and Mazovia voivodeships.

Concerns are raised by unfavorable opinions on the exploitation of shale gas that seem to prevail in most European countries. Particularly puzzling is the attitude of politicians in countries that have never performed hydraulic fracturing, or sometimes even deep-drilling on a larger scale. To make matters worse, in our point of view an aversion to new and little-known technology is present within the European Parliament, which in the future may result in an exacerbation of the EU policy.

Gas market analysts believe that increasing the environmental requirements of shale gas production will extend the authorization procedures for operations and may call into question the fragile economy of the new drilling industry. Polish members of the European Parliament, regardless of party affiliation, are trying to cool an emotional debate in the Parliament, presenting arguments based on existing Polish research and experiences. The most active include Boguslaw Sonik (floor manager of the Environment Committee report, September 2012), Lena Kolarska - Bobińska, Tadeusz Cymański, Konrad Szymanski and Jerzy Buzek.

Environmental issues

In the years 2010–2012, several local protests were recorded against attempts at shale gas exploration, mainly in Pomerania and around Zamość. The safety of hydraulic fracturing was disputed and requests made for more open information on the policies of the oil companies.

To test rumors about the dangers of hydraulic fracturing, the Ministry of the Environment has performed environmental research in the area of the Łebień LE-2H borehole in Pomerania, where in mid-2011 the Lane Energy company carried out the first full-scale hydraulic fracturing in a horizontal section in Poland.

A research report (so called “Report of Łebień”) published by the Polish Geological Institute in March, 2012, is the first, and apparently the only, fully scientific publication concerning the effects of fracturing on the environment in Europe.

The co-ordinator was the Polish Geological Institute. The research involved geologists and hydrogeologists from the Institute and included specialists from the Institute of Geophysics, the Polish Academy of Sciences, the Provincial Inspectorate of Environmental Protection, the Department of Biology at the Faculty of Environmental Engineering at Warsaw University of Technology, and the Oil and Gas Institute in Cracow. Over 30 experts were involved in the field works, and about 20 in the laboratory. The research included all elements of the environment, whose condition was monitored before, during and after the fracturing.

Researchers assessed the state of the atmosphere, soils, groundwater, seismic activity and noise level. They researched the radiation levels and searched for traces of increased concentrations of methane and radon in soil, air and surface water. They checked the management of waste on the drilling rig, the quality of fluid return purification and the increased impact of water abstraction on groundwater resources.

The research did not identify any deviations from the norm, except for sound levels which slightly exceeded the permissible level during fracturing fluid injection into the borehole. It was recommended that groundwater quality monitoring be continued, to exclude the possibility of emergence of contaminants in the long term. So far, monitoring in the control boreholes has shown no change. The results of the report were published on the website of PGI.

The General Directorate for Environmental Protection, in co-operation with the Ministry of the Environment, began in May, 2012 the development of a two-year program of comprehensive evaluation of the impact of hydraulic fracturing on the environment. Research will include five boreholes selected according to the geographical criteria reported by the oil companies, which are voluntarily participating in the program. The Polish Geological Institute performs the geological and hydrogeological part of the program.

Contact person at PGI-NRI: Andrzej Rudnicki

Gaining public trust: monitoring shale gas

Mike Stephenson, British Geological Survey

January 2014

Monitoring and regulation are vital for orderly and sustainable energy development - and public and investor confidence. In the case of shale gas, public confidence is particularly important. At the moment, public confidence in shale gas in Europe is rather low with the result that most activity prompts protests. These are dismissed as 'nimbyism' by companies and supporters of shale gas, but they are still enough to slow development down and maybe enough to stop it entirely.

Two months ago I visited oil sands and shale gas operations in Alberta, Canada. Alberta is sitting on enormous resources but there is a big challenge in selling their sustainability to Canadians because both oil sands and shale gas extraction have impacts on atmosphere, wildlife and water. The new 'Alberta Environmental Monitoring Agency' will monitor environmental effects in detail providing real time data that is scientifically credible, accessible, open and independent from companies. It's hoped that this flow of data will reassure the public that resource management is within sustainability limits and will immediately show if something has gone wrong.

In Europe there are serious questions about whether we should be taking up another fossil fuel like shale gas in a big way but many experts think that shale gas could have a role in the next few years as a bridge to low carbon, especially if it displaces coal-fired electricity. But to allow it to go ahead, Britain and Europe should consider a more comprehensive monitoring system so that subsurface usage can be managed to the satisfaction of the public. The monitoring system should go beyond the immediate site of the drilling, looking at the wider geological basin, particularly in the case of dense activity in the subsurface.

The monitoring should include subsurface sensors - not just microseismics but also sensors for groundwater and rock properties. It should also go above ground to look at fugitive emissions and surface behaviour through INSAR for example. Such a large scale monitoring system might go a long way to reassuring the public that we can manage the subsurface sustainably and safely. Monitoring of this type will also be pertinent to other energy activities that depend on geological containment or understanding of deep flows, for example carbon capture and storage (CCS), underground gas storage, geothermal and radioactive waste disposal.

In the UK and Europe we already have bits of the network in place. In the UK, for example, the BGS national seismic monitoring network and the BGS methane groundwater survey are measuring the all-important natural baselines that will help us to establish whether changes have happened following drilling. Many geological surveys in Europe also carry out these roles but we should increase the density of monitoring, and expand to include other aspects of concern to the public – for example fugitive emissions and ground subsidence - and learn to present this data more freely, openly and transparently.

At the British Geological Survey we are planning a project called the '**Energy Test Bed**' which will be a new national monitoring network distributed in five key regions of Britain with the aim of creating regional-sized subsurface natural laboratories. Each region would be chosen for its particular energy challenge and subsurface geology type. For example the northwest of England could be chosen to monitor possible shale gas drilling including high density seismic monitoring, electrical resistance tomography monitoring of shallow aquifers, satellite surveying and downhole geodynamic monitoring. Other areas with different challenges may warrant a different suite of sensors; however the full 5 natural laboratories would cover a representative range of geological and energy-related conditions for UK development.

A monitoring network of this kind would greatly improve our knowledge of Britain's subsurface and contribute to increased efficiency and environmental sustainability. We'll have to make the data completely open and transparent, display it and encourage the public to understand what it means.

A real-time national monitoring system, the science results of which are communicated transparently and effectively, might go a long way to reassuring the public that shale gas drilling and other subsurface activities can be done safely and sustainably.

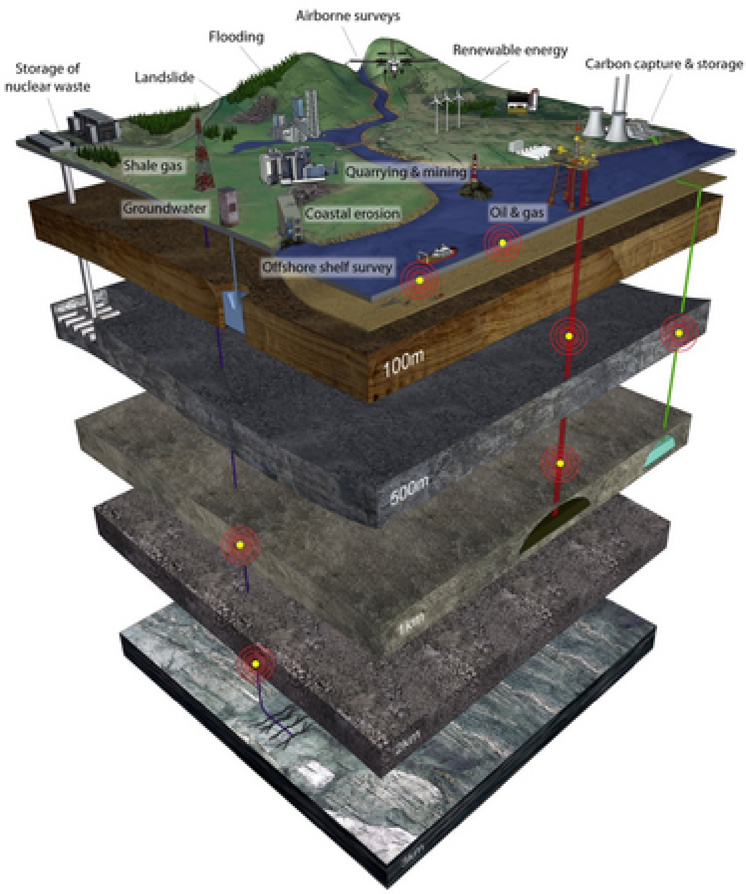


Fig. 1. A national monitoring network for the subsurface

Shale gas activities in Britain: results of a BGS-DECC study on the Bowland and Hodder shales in the North of England

Mike Stephenson, British Geological Survey

January 2014

On 27th June 2013 the results of a study on the Bowland and Hodder shales in the North of England were released by BGS (British Geological Survey) and DECC (Department of Energy and Climate Change) scientists in the presence of Ed Davey (UK Secretary of State for Energy and Climate Change) and Michael Fallon (Business and Energy Minister). The study considered resource (gas-in-place) of shale gas in an area between Wrexham and Blackpool in the west, and Nottingham and Scarborough in the east (Fig. 1). The estimate is in the form of a range to reflect geological uncertainty. The lower limit of the range is 822 trillion cubic feet and the upper limit is 2281 tcf, with a central estimate of 1329 tcf. This estimate is a resource figure (gas-in-place) and so represents the gas that we think is present, but not the gas that might be possible to extract. The proportion of gas that is possible to extract is unknown at present. It will depend on the economic, geological and social factors at each operating location.

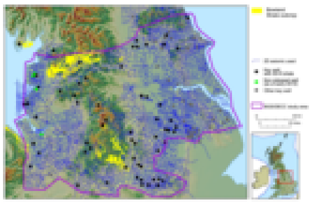


Fig. 1. Area and key data for the BGS-DECC shale gas resource estimate.

Details of how the estimate was made are in the report but in brief the key to the estimate was to calculate the volume of shale in the chosen area. To get this BGS built a 3D static model using 64 key wells and 15000 miles of seismic, as well as years of data from shale outcrops. In the report the main lower Carboniferous shale unit (known as the 'Bowland-Hodder unit') was shown to be up to 5000 m thick in basin depocentres (e.g. the Bowland, Blacon, Gainsborough, Widmerpool, Edale and Cleveland basins; Fig. 2) and to contain quite high total organic carbon (TOC) levels (1-3%, but can reach 8%). The unit is known to be capable of generating gas because there are conventional gas fields in and around most of the basins, and offshore.

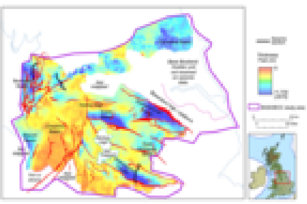


Fig. 2. Thickness of the Bowland-Hodder unit

The Bowland-Hodder unit was deposited in rifting basins across central Britain during the Visean and Namurian. Some of the shales were deposited syn-rift, others post-rift. The upper post-rift part of the Bowland-Hodder unit is laterally continuous, with organic-rich, condensed zones that can be mapped, even over the platform highs (Fig. 3). There is also a lower underlying syn-rift unit, expanding to thousands of metres thick in fault-bounded basins, where the shale is interbedded with mass flow clastic sediments and re-deposited carbonates.

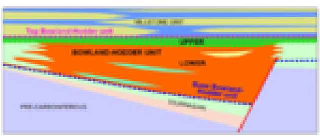


Fig. 3. Schematic of the upper and lower parts of the Bowland-Hodder unit

Following a calculation of the volume in cubic metres of the two components of the Bowland-Hodder unit we had to multiply by an estimate for the amount of gas that a typical cubic meter might contain. This and a Monte Carlo simulation gave us an in-place gas resource for the upper Bowland-Hodder unit of 164 to 447 tcf and a range of 658 to 1834 tcf for the lower thicker unit. The map below (Fig. 4) shows the prospective parts of the lower and upper Bowland-Hodder unit superimposed.

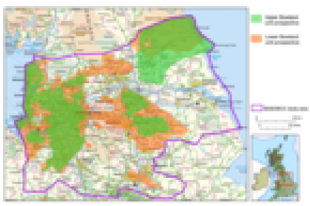


Fig. 4. The prospective areas.

Developments in British shale gas

Mike Stephenson, British Geological Survey

January 2013

On 13 December 2012 Edward Davey, Energy and Climate Change Secretary announced that exploratory hydraulic fracturing (fracking) for shale gas can resume in the UK, subject to new controls to mitigate the risks of seismic activity (details here). Fracking was suspended in May 2011 following two small seismic tremors near the country's only fracking operations in Lancashire in the northwest of England. Following the May ban, intensive study of fracking in the area was commissioned by the UK Department of Energy and Climate Change (DECC) carried out by an independent panel of experts in seismology, induced seismicity and hydraulic fracturing (Dr Brian Baptie, BGS; Professor Peter Styles, Keele University and Dr Christopher A. Green, GFRAC). The report can be downloaded here.

Amongst the recommendations were that: (1) hydraulic fracturing should invariably include a smaller pre-injection and monitoring stage before the main injection; (2) hydraulic fracture growth and direction should be monitored during operations; (3) future hydraulic fracturing operations in Lancashire should be subject to an effective monitoring system that can provide automatic locations and magnitudes of any seismic events in near real-time.

Perhaps most important, the report recommended that operations should be halted and remedial action instituted, if seismic events of magnitude 0.5 ML or above are detected. This has become known as a traffic light system.

A wide expert consultation also resulted in a report by the Royal Society and Royal Academy of Engineering (download report). Amongst the recommendations of this report were that national baseline surveys of methane and other contaminants in groundwater, as well as seismicity and residual stress, should be conducted. The report supported realtime monitoring as well as traffic light controls.

Following these consultations and reports the UK Government has concluded that the seismic risks associated with fracking can be managed effectively with controls which include:

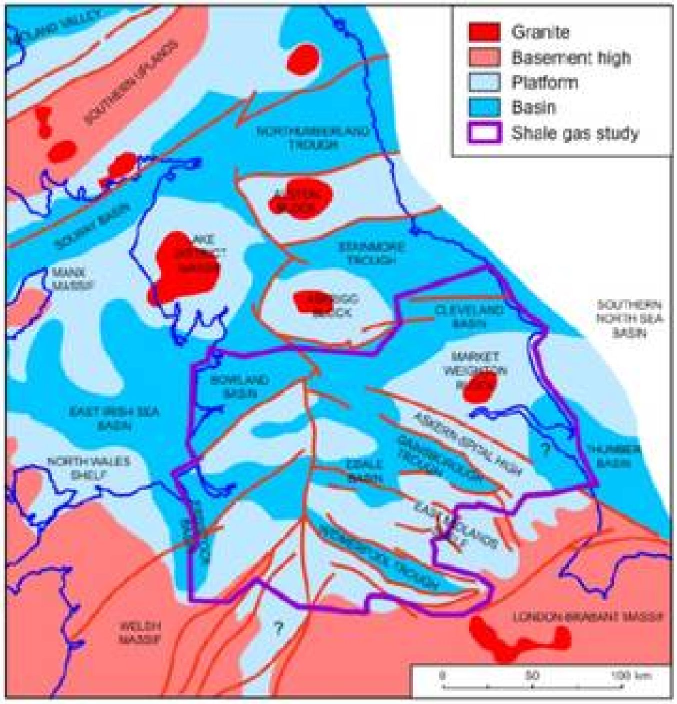
1. A prior review before fracking begins to assess seismic risk and the existence of faults;
2. A fracking plan to be submitted to DECC showing how seismic risks will be addressed;
3. Seismic monitoring carried out before, during and after fracking; and
4. A new traffic light system to categorise seismic activity and direct appropriate responses. A trigger mechanism will stop fracking operations in certain conditions.

The other main development in Britain will be the release early in 2013 of the Bowland Shale Mapping and Resource Estimation. The work is being done by the British Geological Survey for DECC. This will be a very important milestone in British shale gas because it will provide a state-of-the-art figure for Gas in Place and reduce the uncertainty that has surrounded the question of the country's potential in the last two years.

In 2010 DECC (BGS) estimated potential shale gas production from the Upper Bowland Shale in the north of England at 4.7 tcf using a basic comparison with the Barnett Shale of Texas. This was close to a reserve estimate though not carried out in the conventional way. In 2011 Cuadrilla produced an estimate of 200 tcf Gas in Place for a smaller area, with stacked shales. The two figures were widely misunderstood and misreported in the British press and considered by many to be a discrepancy. Despite attempts by scientists to explain the difference between reserve and resource estimates, the misconception has persisted, rather undermining public and investor confidence.

The new estimate will be an independent Gas in Place estimate for the north of England carried out by BGS geologists. The maps below indicate the area of interest.

British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL



Shale gas in Britain – the pros and cons

Mike Stephenson, British Geological Survey

March 2012

Methane natural gas is an important part of Britain's energy mix and will continue to be so in the future. As old coal and nuclear power stations shut down, gas could provide flexible and reliable backup supplies of electricity to complement increased renewable energy. Gas is the primary fuel to heat homes in Britain, and will likely remain so until well into the 2020s. Gas is also a relatively clean fuel whether used for heating or by power stations, and could be very clean when used in association with carbon capture and storage technology.

But we have to get the gas. 2011 was a landmark year for Britain because for the first time the country imported more methane natural gas – whether piped from Norway or shipped from Qatar – than was pumped from Britain's offshore gas fields. Importing gas is fine if you have the amount you need, and a steady supply helps to keep prices stable. But supply can be affected by unforeseen international events. So it makes sense to have 'home-grown' gas.

This is why Britain is waking up to the idea of shale gas for power and fuel into the future. Shale is the most common sedimentary rock, and Britain has a lot of it in northern England, the Midlands, Wales and southern England. Shale is soft so often isn't seen at the surface, but shale of various ages underlies much of the country.

The British Geological Survey's (BGS) first area-based assessment[1] of the amount of shale gas that might be present in these areas came up with a fairly large figure of 150 billion cubic metres (BCM), which is about half of Britain's estimated reserves of conventional natural gas and about one and a half year's worth of gas at present rates of usage. However other unpublished estimates for parts of the country are much larger.[2] To reduce uncertainty, BGS (commissioned by the UK Department of Energy and Climate Change) is working on a new volumetric-based estimate which may be available within the year.

The problem is, however, how to get the gas out. Britain is a crowded island full of people who are fond of their surroundings and concerned for the quality and care of the environment. The key extraction technology, hydraulic fracturing ('fracking'), has had a very bad press in the last year, and has been blamed for causing earthquakes. The public also worry about contamination of groundwater by methane and/or chemicals from fracturing fluids.

As any shale gas engineer will tell you, you need to crack the shale to release the gas. A simple well without hydraulic fracturing will not release much gas. The shale itself is very rich in organic matter but the gas which is generated from the organic matter, can't move easily in the rock because it is fine grained and impermeable. So hydraulic fracturing is generally essential.

Some of the public's worries are no doubt justified. Badly managed hydraulic fracturing (though not related to shale gas) has recently been shown to have contaminated water wells in Wyoming.[3] One of the problems is that it's very difficult to get reliable independent information, and there are lots of vested interests. So peer-reviewed science has a role in deciding what the real risks are.

Most geologists think that methane or fracturing fluid contamination of aquifers is unlikely because of the great difference between the depths at which hydraulic fracturing activities are usually carried out and the aquifers from which we get our water. Put simply, there's a lot of hard, impermeable rock between the rocks being hydraulically fractured and the aquifer. However there are relatively few peer-reviewed studies of methane contamination during shale gas hydraulic fracturing, and rather problematically, there are few baseline studies of amounts of background biogenic or thermogenic methane in groundwater.

Biogenic methane is usually generated by bacteria, and isn't usually associated with deep shale. Thermogenic methane, generated by heat acting on the organic matter in shale, is usually deep but sometimes occurs naturally in shallow aquifers. Showing that methane in a water well is thermogenic (when the $\delta^{13}C$ of the C in the CH_4 is above about -50 ‰) might be one way of telling if a deep hydraulic fracturing operation is leaking, but you have to know what the baseline natural levels of methane are as well.

It's a little known fact that many of our aquifers in Britain contain methane – biogenic and thermogenic.[4]Knowing how much is natural – so that you can distinguish it from possible leaked methane – is only possible if you've measured baseline levels. This is why the BGS is working on a baseline survey at the moment.

It's well known that hydraulic fracturing causes earthquakes - usually infinitesimally small - because they are used by geologists to track the progress of a fracturing operation. However the two earthquakes caused by hydraulic fracturing in Blackpool recently (of magnitudes 1.5 and 2.3) were larger than the operating company expected. Some areas of Britain are quite used to natural earthquakes of this size, or earthquakes caused by old mine workings, but they came as a shock to the people of Blackpool.

The larger quake on the 1st April 2011 was felt by more than 50 people, but the energy released was quite inconsistent with the damage that was claimed for the earthquake. The seismology, including the matching seismological traces, told BGS seismologists that the two earthquakes were generated in the same area underground, and in the same way.[5] The coincidence in time between the earthquakes and the hydraulic fracturing operations suggests they resulted from high pressure water finding its way into small pre-stressed faults which then moved slightly.

Earthquakes can be monitored during hydraulic fracturing in quite a sophisticated way. For risk mitigation, a 'traffic light ' system can be used. The operator would monitor seismicity, and if any of the myriad small tremors exceeded a threshold magnitude the 'red light' would come on and the operations would be stopped immediately to avoid causing a larger earthquake which would be felt by the local population. The operator would also have to avoid hydraulic fracturing close to known active faults. Proposed mitigation options are detailled in the "Geomechanical Study of Bowland Shale Seismicity".[6]

Because the technology to construct wells and manage subsurface operations is mature there is little reason to believe that shale gas extraction involves greater risks than in conventional hydrocarbons extraction. Reassurance can be gained by monitoring seismic activity during hydraulic fracturing and through long-term monitoring of the condition of nearby aquifers.

The British Geological Service Shale Gas Project website provides more information on shale gas in the UK.[7]

[1] https://www.og.decc.gov.uk/UKpromote/onshore_paper/UK_onshore_shalegas.pdf

[2] www.guardian.co.uk/environment/damian-carrington-blog/2011/sep/23/cuadrilla-shale-gas-uk-energy

[3] www2.epa.gov/region8/pavillion

[4] Gooddy, Daren; Darling, George. 2005 The potential for methane emissions from groundwaters of the UK. Science of the Total Environment, 339. 117-126. http://www.sciencedirect.com/science/article/pii/S0048969704005467

[5] earthquakes.bgs.ac.uk/research/events/BlackpoolMay2011.html

[6] www.cuadrillaresources.com/wp-content/uploads/2012/02/Final_Report_Bowland_Seismicity_02-11-11.pdf

[7] www.bgs.ac.uk/shalegas/

Shale gas in the Netherlands

Yvonne Schavemaker, Netherlands Organization for Applied Scientific Research TNO

May 2012, updated July 2015

The Netherlands has been a large producer and consumer of natural gas since the development of the Groningen gas field in the 1960s, the largest natural gas field in continental Western Europe. Current forecasts show that production from conventional onshore and offshore fields will decline noticeably in the next decades, but the Netherlands still has the ambition to sustain its prominent role in the northwest European gas market and aims to be able to meet future demand. Energie Beheer Nederland (EBN), the Dutch state participant in energy projects, has stated the ambition to achieve 30 BCM production of gas in 2030 from small fields. This will require large investment into under-explored areas, new technologies and also, most probably, the development of challenging reservoirs such as shale gas.

Role of TNO

The Netherlands Organization for Applied Scientific Research, TNO, is an independent research organization, which aims to enable a robust transition to sustainable energy supply. TNO invests in environmentally friendly alternatives to fossil fuels, but also looks to find the most optimal and clean uses of fossil fuels, during the transition to more sustainable solutions. Of these transition fuels, natural gas is expected to play the largest role, being a relatively clean fossil fuel.

As a research institute and geological survey for the Netherlands, TNO has a broad knowledge of the Dutch subsurface; it governs the database containing all data and information on the subsurface of the Netherlands. By using existing data from this database, a first evaluation from TNO in 2009, commissioned by Energie Beheer Nederland (EBN), confirmed strong potential for shale gas in the Netherlands, although these high estimates were presented with large uncertainties. Due to these large uncertainties in gas-in-place estimates, there are many views on the potential of shale gas resources in the Netherlands.

TNO currently works on refining shale gas estimates based on additional data collection and an integrated multidisciplinary approach. Investigations focus on Jurassic Posidonia shale formation and the deeper Namurian shales. Besides reserve estimations, TNO researches methods and technologies relevant to possible future shale gas exploitation. This includes research into the minimization of surface footprint, monitoring and simulating of hydraulic fracturing, and looking at alternatives to stimulation. Well integrity and wastewater treatment options are further fields of research. These studies often take place in close co-operation with other research organizations, universities, or with industry.

Also, TNO has taken the lead in the European Energy Research Alliance (EERA) Joint Program on Shale Gas. Together with over 24 research institutes and universities, we create a transparent and independent knowledge platform on shale gas and provide a research-based understanding of technology and methods, which addresses the concerns that are raised regarding shale gas development.

Recently the M4ShaleGas consortium, a consortium of EERA JP Shale Gas members, got a European project awarded under the 2014-2015 H2020 LCE16 call. The M4ShaleGas stands for “Measuring, monitoring, mitigating & managing the environmental impact of shale gas”. The general objective of the M4ShaleGas program is to provide scientific recommendations for minimizing the environmental footprint of shale gas exploration and exploitation in Europe, a website will be available in Q3 2015.

Public debate

Exploration and the expected production of shale gas in the Netherlands has given rise to public resistance [e.g. Haaren, Boxtel]. TNO provides data and information on shale gas development. Recently, TNO has initiated the development of an “Argument Map” for shale gas exploitation in EU member states, available in four languages. This map shows in a concise and clear way, the arguments of all stakeholders (operators, water companies, NGOs, research institutes, etc.) and it can be used as guidance for further discussion.

In reaction to the shale gas discussion, the Dutch Ministry of Economic Affairs set out a study in 2011, on the possible risks and effects of exploration and exploitation of shale gas, which was carried out byWitteveen and Bos, Arcadis and Fugro. The resulting advice, published in 2013, was that additional research is necessary to determine the local effects on people and nature, and that environment location-specific investigations are needed, for instance in the form of an environmental impact assessment.

In reaction to this study, the Ministry of Economic Affairs and Infrastructure and Environment decided to develop a "Structural Vision Shalegas”. This vision will be an integral part of the structure vision of the spatial use of the subsurface “Structural Vision Subsurface”, which is currently under development. The "Structural Vision Shalegas” will give the government information on whether shale gas in the Netherlands could be developed and how and in what areas on national level this could take place. In July 2015 three studies that are part of this initiative were published (weblink):

1. PlanMER (Environmental impact assessment),
2. Inventory of innovative technologies to minimize environmental impact of shalegas development and
3. Exploration of societal effects.

The final Structural Vision is planned to be finished end of this year. Based on these studies the Minister announced there will be no commercial shale gas development in the next 5 years. The Energy Report 2015, which is in development, will indicate whether or not it is desirable to exclude development of shale gas in the Netherlands on the longer term. The Energy report is a report of the Ministry which gives an integral vision on the energy supply in the Netherlands, taking into account topics and dilemmas relevant for a sustainable energy supply towards 2050.

Licenses

Oil and gas licenses can all be found in the database of the Dutch Ministry of Economic Affairs and are specifically for oil and gas exploration and production purposes. The list of license applications and withdrawals is regularly updated. The database does not differentiate between conventional or unconventional resource licenses.

Currently no new licenses will be awarded for shale gas exploration and old licenses will not be prolonged.

The map indicates the license applications and approvals that are most likely to be for the exploration of unconventional gas.

The public debate in France

Helen Etchanchu, ESSEC Business School in Cergy, France

December 2014

The public debate in France is highly contested and mediatized. France is one of the only countries to have issued a legal ban on the hydraulic fracturing technique, the so-called Jacob Law; and it did so very early in the debate. Generally speaking, France does not have an extractive culture. Around 75% of its produced electricity stems from nuclear power. The following describes the public debate in France, based on media articles, political developments and government reports. It clusters the main dynamics into three periods between 2011 and 2014.

Social movements and the Jacob law prohibiting fracking, 2011

The shale gas debate was strongly politicized very early on in France, due to strong local civil movements. The first public information meeting on shale gas was organized by José Bové on December 20th, 2010 in Saint-Jean-du-Bruel in the Larzac region. José Bové, a European deputy for the green party coalition EELV, and a well known French politician and militant, was a key person who leveraged his popularity in the media and helped local citizens to organize events and build citizen collectives opposing shale gas development. Very quickly citizen collectives were created in different regions, starting in the Larzac, and then spilling over into Ardèche - those areas that were included in the exploration permits that were issued in 2010. Three permits for the research of shale gas in the South (Montélimar, Villeneuve de Berg and Nant) had been granted to 1) Schuepbach Energy, then associated with GDF-Suez, 2) Total E&P France and 3) Devon Energie Montélimar SAS. These permits were granted by Jean-Louis Borloo, who was environmental minister at the time. Local politicians started to join the mobilization against shale gas, some of them complaining that they had not been previously informed and had only heard about the issuance of the permits from the media. This is possible because in France the property rights of underground resources remain with the State (i.e. in contrast to landowners' property rights in the US) and are approved by the national environmental ministry.A political opportunity also helped to increase the movements' strength, as regional elections were to be held in March, 2011. On January 11th José Bové launched a petition to the government to ban fracking, called "Gaz de schiste non merci", alluding to the same slogan movements had used to fight GMOs in the country. Three months later 100,000 people had signed. The main points mentioned in the petition were that:

- government had granted permits without previously informing local stakeholders;
- environmental destruction due to fracking can be observed in the US;
- shale gas exploitation plays counter to French engagements in lowering carbon emissions;
- the petition signers thus asked government to immediately issue a moratorium on any exploration activity of shale oil and gas, and that permits be cancelled.

On February 11th, 2011 Nathalie Kosciusko-Morizet, then Minister for the Environment, indeed suspended all permits and exploratory research activities on shale gas in France. Later the Prime

Minister extended this moratorium by by several months. This did not reassure citizens however, who organized a first manifestation opposing shale gas in Villeneuve de Berg, on February 26th, with 10-20,000 participants. The main concerns with shale gas development remained that it may potentially contaminate drinking water and harm local tourism and agrarian activities.

One of the strongest mobilizing citizen collectives remains the collectif 07 from the Ardèche region. This citizen collective helped create other anti-fracking collectives nationally and internationally. Arguably, one of the key factors that led to the strong initial mobilization was the screening of the movie "Gasland", and notably the fear that drinking water becomes contaminated. The well-known image of a local resident next to a fracking site setting the water from his faucet on fire quickly spread internationally [see SHIP article]. In France, virtually every information session on fracking referenced at least parts of the Gasland movie. While the movie triggered initial contestation, the loosely structured but well-connected citizen collectives could quickly leverage arguments against shale gas, based upon American experiences. They brought forward example cases from the US (which have been generally refuted by industry), where fracking caused environmental damage.

During the temporary moratorium, in February, 2011, jointly with the economics ministry, the environmental ministry launched a study to inform the government on economic, technical, legal, social and environmental issues associated with potential shale gas and oil development in France. This study was conducted by the public institutes of the respective ministries: the CGIET (Conseil général de l'industrie, de l'énergie et des technologies) and CGEDD (Conseil Général de l'Environnement et du Développement Durable). The initial report was provided to government on April 21st, 2011.

Its main conclusions were the following:

- The economic potential remains unsure as long as no exploratory drilling is conducted, but estimates are around 100 million m³ for shale oil and 5000 billion m³ for shale gas, which makes France one of the most promising countries in Europe;
- The hydraulic fracturing technique can still be much improved in terms of efficiency and environmental protection;
- It should only be conducted under strict control and for scientific research purposes so as to determine the potential;
- It would be detrimental to the economy and job creation not to estimate the potential of this resource;
- A necessary mining code reform should require public consultation meetings before permits are granted;
- The regulation of techniques to extract hydrocarbons should be adapted and could include suggestions for best practices (e.g. limiting the number of additives used);
- The tax law should be adapted so as to cater to the interests of local communities;
- After 2-3 years of scientific research a rational decision on whether or not to exploit this resource in France may be taken.

In parallel, the National Assembly, specifically its Sustainability Commission, ordered an information study on shale gas and oil conducted by the deputies Francois-Michel Gonnot, and Philippe Martin (the latter was to become environmental minister in 2013). This report was published on June 8th,

2011. It seeks to provide objective information on technical, economic, environmental and legal aspects of shale gas development, as well as the international dynamics.The deputies underline that France will be impacted by the international consequences of decisions from other countries.

In the end it envisaged three scenarios:

1. Exploit shale gas: if scientists judge environmental risks to be controllable this could favor economic development;
2. Exploit shale gas at a later point in time: this could provide France with a competitive edge if no alternative energy sources have emerged;
3. Do not exploit shale gas: this could favor the development of renewables, but this would also need to be accompanied by strict import constraints on fossil fuels.

On March 31st, a law proposition was filed by Christian Jacob, deputy of the UMP party, and 124 deputies from the majority signed the Jacob law proposal. At this time nearly 90,000 people had signed the anti-shale gas petition. In April, 2011 dissent was at its peak, with the National Assembly voting on this law proposal prohibiting fracking scheduled for May 11th, 2011. Industrialists also tried to weigh in on the regulatory process. Specifically the professional association of drillers wrote several open letters to the government. Their initiatives were, however, hardly mentioned in the media. And one of the very few articles regarding the letter of April 11th, 2011 was illustratively entitled: “Shale gas: the drillers want to be heard”.

Eventually the Jacob law was published in the national register on July 14th, 2011 (for a summary of the legal procedure see the senate’s website). The law focuses on the prohibition of the hydraulic fracturing technique used for unconventional shale oil and gas extraction. The law also establishes two dispositions, however, which aim to advance research and information gathering on the issue: 1. exploratory research for scientific purposes is allowed, and 2. a multiparty commission is to be created that should establish public recommendations for the forms in which research on shale gas could be conducted. A report was to be given to the government one year after the promulgation of this law. In itscomplementary report the CGIET and CGEDD mention that this commission would soon be created. To this day, however, the commission foreseen in the Jacob law does not exist. This is one of the things that industry and favorable politicians lament.

The three permits mentioned previously, Villeneuve de Berg, Nant and Montélimar, were not the only ones, but generated the most contestation. They were officially cancelled in October, 2011. Schuepbach Energy filed a “priority question of constitutionality” (QPC) to question the constitutionality of the Jacob law, which went to the French constitutional court (conseil constitutionnel) but was eventually rejected on October 13th, 2013.

Energy transition debates and research for alternative techniques to fracking 2012/13

After the presidential elections in Spring, 2012, the new president Francois Hollande organized a nationwide large-scale citizen deliberation effort on the French vision of its energy transition. The main objective of this national debate on the energy transition was to engage citizens and inform the government’s law project on the energy transition. This energy transition law was one of the main points of Hollande’s election manifesto that includes the decrease down to 50% of French electricity derived from nuclear energy by 2025 and the strong development of renewables. He launched an environmental conference in September, 2012 that prepared the ground for the deliberation during the following months.

On this occasion 22 industry leaders wrote a joint letter to the government asking to reopen the debate on the evaluation of French shale gas potential on September 27th, 2012. They asked for a nationwide debate on shale gas that would integrate “all concerned stakeholders, citizens, NGOs, industrialists and researchers”. They highlight that France has a “duty to explore its resources” and that shale gas could be a step towards the increased economic competitivity of the country. Similarly, the economic competitivity report ordered by the new government, the so called “Gallois” report, issued on November 5th, 2012, mentioned shale gas favorably as a potential opportunity for economic development.

The OPECST (Office parlementaire d'évaluation des choix scientifiques et technologiques) was mandated with a study to search for alternative technologies to hydraulic fracturing. This mission of the parliamentary office was conducted by the deputy Christian Bataille and Senator Jean-Claude Lenoir. The OPECST report confirmed that fracking is the only viable technology to date to extract unconventional hydrocarbons. A preliminary report was published on June 5th, 2013 so that its recommendations could inform the national energy transition debate that was coming to an end. The final version was adopted by OPECST on November 26th, 2013. These reports generated much controversy and debate. The main propositions were the following:

- Explore France’s shale gas and oil resources;
- Conduct research on alternative technologies to keep improving existing solutions;
- Use shale resources to finance the energy transition;
- Reform the mining code to align shale gas development with local interests.

On June 25th, Delphine Batho, then environmental minister, officially cancelled one of the non-conventional permits originally granted to Hexagon Gas in 2010. She was discharged of her functions on July 2nd, 2013. She was dismissed on the very same day she had publicly criticized the budget cuts of the environmental ministry. She later attributed her aggressive discharge to industry lobbying by Vallourec, a French MNC who is the leading drilling tube producer internationally, and increased its activities thanks to shale gas development in the US. This accusation was widely diffused by the media and naturally found much criticism from industrialists as well as agreement from environmentalists.

As mentioned before, industry was barely participating in the public debate in the media during the initial social movement period, but towards the end of the energy transition debates in Summer 2013, industrial associations such as Ufip (Union française des industries pétrolières) and MEDEF (Mouvement des entreprises de France) were increasingly heard. The MEDEF published its propositions for the national debate on the energy transition. Their priorities for the sake of economic competitivity were the maintenance of nuclear energy and the development of shale gas. Similar arguments were put forward by Ufip.

Two extraordinary shale gas related meetings were held during the end of the national energy transition debate: the first on June 27th, 2013, giving an outlook of energy prices and the impact that shale gas has on world markets; the second one specifically on shale gas on July 3rd, with six intervening experts. The experts could barely find common ground and during the question and answers session key figures and hypothesis on which certain pro and contra arguments were based were heavily debated. When the official conclusions of the energy transition debate were published on July 18th, 2013, the industry association MEDEF did not accept these conclusions that penalized nuclear and discarded shale gas.

While these dynamics show that certain voices in favor of shale gas may grow louder, and even the economic competition Minister Arnaud Montebourg expressed himself in favor of shale gas in the media, President Hollande confirmed repeatedly that shale gas will not be exploited nor explored during his presidency. While the final OPECST report, favorable of shale gas, was published in November, 2013, Government continuously signals its opposition, for example an additional seven pending permits on shale oil have been officially cancelled.

Political developments in 2014

On January 22nd, 2014 the European Commission released its recommendation on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing. This announcement renewed favorable statements on shale gas in the press by Arnaud Montebourg. The Crimean crisis raises questions and fears of energy security at a European level. In March, US president Obama urged the EU to decrease its energy dependence and the European Parliament voted in favor of an exemption of shale gas from an environmental impact assessment. These international dynamics also infiltrate the French debate. For example, references in the French press to the European Union, Commission, and Parliament have significantly increased in 2014.

Finally, former President, Nicolas Sarkozy, announced his candidacy for the presidency of his party (first step towards French presidential elections) in September, 2014. In his first public meeting after this announcement on September 25th, he mentioned shale gas favorably; he pointed to the American example and stated that he “cannot accept that the US became energy independent thanks to shale gas and that France cannot benefit from this new energy at a time when our territory and families are plagued by unemployment, that’s unacceptable”[1]. This is interesting to point out, particularly as it was under his presidency that the Jacob law was put into effect. Nathalie Kosciusko-Morizet, ex-environmental minister and in office when the social movements took off, distanced herself from Nicolas Sarkozy on this point. And Ségolène Royal, who is the current environmental minister (the 4th since Hollande took office), confirmed clearly, in response to Sarkozy’s statement, the governments’ opposition to shale gas, and that there will be neither shale gas exploitation nor exploration: “All public and private means shall be focused on the development of renewable energies”[2]. Royal later presented the law project on the energy transition that was voted upon by the National Assembly on October 14th. The main aspects of this law that was allocated €10 billion include:

- 100% of buildings will be low-consumption by 2050 by means of legal obligation of energy renovation with the help of fiscal, and other financial support (particular aid for low income households);
- reduce the part of nuclear energy in electricity production down to 50% by 2025 and further develop renewables by means of an increased dedicated investment fund;
- increase electric vehicle usage through the installment of charging stations and financial incentives;
- reduce waste by 50% including the prohibition of one-time usage plastic bags and disposable dishes.

This law project shows the French governments’ intention to push for an energy transition that does not include shale gas and strongly decreases nuclear energy usage. Questions on economic competitivity, energy security, and decreasing energy dependence specifically on Russian gas, present strong motivating factors at a European level, however. As the UK and Poland are going ahead with exploration and Germany is still discussing the regulatory constraints under which fracking may or may not be allowed in Germany, it remains to be seen whether France’s position is going to become more open to shale gas extraction or whether it continues its strong opposition. Opponents and proponents alike are already thinking ahead to the next presidential election in 2017 that may bring new impulses in one direction or the other.

1 Translated by author. Original quote: "Je ne peux pas accepter que les Etats-Unis soient devenus du point de vue de l'énergie indépendants grâce au gaz de schiste et que la France ne puisse pas profiter de cette nouvelle énergie alors que le chômage ravage tant de nos territoires et tant de nos familles, c'est inacceptable."

2 Translated by author. Original quote: "Tous nos moyens publics et privés doivent être sur les économies d'énergie et les énergies renouvelables"

Extraction of non-conventional natural gas - Concerns about water management

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September 2013

The German Alliance of Public Water Management (AöW) is concerned about groundwater protection. This is due to the fact that there are currently no known measures for reliable protection of groundwater from the chemicals and formation waters* that occur during hydraulic fracturing. What is meant here, are the high safety standards that are generally required in Germany for the most important resource humanity needs to survive - water.

Water is the basis of life

Germany and Europe have established a complex system for the careful and sustainable use of water that covers ecological, economical and social aspects of the water cycle and is legally based on the European Water Framework Directive (2000/60/EC) and the German Federal Water Act.

Hydraulic fracturing involves high pressure. Even previously very dense rock layers below the groundwater reservoir may exhibit cracks after hydraulic fracturing through which the problematic substances could rise all the way up to the groundwater (Myers, 2012; Davies *et al* 2012). The underground is not a rigid construct the structure of which is known. It is constantly moving and aquifers form large-scale underground storage facilities that cannot be sealed reliably.

In a survey published by the German Federal Environmental Agency (UBA, Umweltbundesamt) in August 2012 regarding the environmental effects of hydraulic fracturing it became clear that an uncontrolled rise through the drill pipes during the gas extraction phase cannot be excluded. The post-operational phase was also regarded as important because some of the fracking fluids remain in the ground and cannot be retrieved. This is a permanent risk that can cause harmful substances to enter the groundwater and surface waters. It would pose a long-term risk to the drinking water supplies of large parts of the population in Germany.

A recently published US American study by Jacksen *et al* 2013 reports on the results of the analysis of 141 water wells in the area of Pennsylvania. In samples taken from a radius of one kilometer from hydraulic fracturing facilities methane concentrations were 6 times higher than average; ethane concentrations were 23 times higher and even propane was detected in 10 wells. Possible causes for the contamination could be the proximity to hydraulic fracturing facilities, valley bottoms and the structure of the region.

Precautionary principles must be observed

Hydraulic fracturing requires considerably more drilling than conventional gas extraction. Fracking fluids with toxic substances and substances that are hazardous to environment and health, irritants, corrosive substances, substances that are hazardous to water and substances that are severely hazardous to water are pressed through these drill pipes. If these substances leak into the groundwater, contamination results. This is a risk, which is contrary to the precautionary principle.

According to this principle, risks to human health have to be averted even before they become clearly visible - in particular if these risks would cause long-term, severe or irreversible damage. This is the background for the duty of care principle of § 48 of the Water Resources Act. According to this article, use of groundwater may only be permitted if there is no reason to believe that there will be a detrimental change in the quality of the water.

Furthermore, there are considerable deficits in the determination of the additives used, the composition and the concentration of the fracking fluids. The only information so far that was also available to the scientists who carried out the risk survey for the Federal Environmental Agency, was the data and the safety data sheets published by the companies. Chemicals that are only slightly or not at all hazardous to water are also used; however, this does not mean that the risk of the other chemicals is less worrisome. In addition, to date there was simply not enough information to examine the interaction of different substances in the "fracking cocktail".

Formation water contains heavy metals

Even hydraulic fracturing with non-hazardous additives does not solve the problem that the formation waters with the heavy metals contained therein could rise and contaminate the groundwater.

Together with the extracted gas, what is commonly referred to as flowback (part of the compressed water, sand, fracking fluid and formation water) reaches the surface. Part of this flowback is compressed again. The rest must be disposed of. These are very large amounts. In the United States they are often stored in open basins, which can overflow if it rains. If similar plans exist for Germany, this would result in hundreds of dangerous flowback “lakes” in the drilling areas.

Even storage in closed containers is a problem where chemicals and heavy metals are concerned. Considering the large quantities that must be deposited of with tank trucks, accidents are inevitable. Another difficult question is where to deposit them to. The highly contaminated flowback water cannot simply be injected back into the ground somewhere else, discharged into other bodies of water or disposed of via sewage treatment plants. The sewage plants are not even equipped for this purpose. The question of disposal remains entirely unclear. This is a problem that is still being underestimated.

Basic conditions and required action

The German Alliance of Public Water Management ("Allianz der öffentlichen Wasserwirtschaft e.V.") demands that the protection of groundwater and groundwater supplies for future generations must be given priority over other interests.

Involvement of local authorities, water suppliers and the public

It must be obligatory for the affected municipalities and the corresponding water suppliers that operate near areas of hydraulic fracturing to be included in the approval procedures as early as possible. This should already take place when the question whether there is a permission requirement arises.

Even prior to approval of an exploration permit in accordance with § 11 No. 10 of the Federal Mining Act it should be checked whether there are overriding public interests that prevent exploration. An early involvement of the local authorities and water suppliers can help recognize and consider such interest. In addition to that, we demand a mandatory environmental impact assessment and a modification of the Mining Act to provide for this.

In water protection areas deep drilling for finding or extracting natural gas, oil or geothermal energy, during which rocks are fractured under hydraulic pressure, must be excluded. We furthermore demand a ban for protected areas that are not designated as such that are catchment areas for drinking water production and in priority areas for drinking water production. This is necessary because there are also risks for surface waters from which drinking water is obtained. Hydraulic fracturing should therefore also be prohibited in catchments areas of rivers and lakes that are sources of drinking water. The ban should also include a safety distance from the sensitive areas mentioned here, including the soil "under" these areas to exclude in particular water pollution caused by horizontal drilling and geological fault.

The modification drafts presented by the Federal Environment Ministry regarding changes for the Water Resources Act and the environmental impact assessment for mining projects were not accepted for debate by the German Parliament. Neither were the propositions of the individual federal states in the Federal Council, unfortunately. The current situation is therefore legally unsatisfactory and the existing laws are, in our opinion, not sufficient. While the legal modifications discussed so far may protect drinking water supplies in water protection areas for now and allow the public to participate in environmental protection issues thanks to environmental impact assessments in the context of regulated procedures, there are still unsolved research issues as the risk study has shown.

Preserving water resources for generations

Germany is a densely populated area. We possess large quantities of water resources, most of which have a good quality, and we cannot endanger these based on a short-term natural gas boom. We need clean water to survive - for personal hygiene, for farming, etc. The gas will be used up quickly, but groundwater contaminated with pollutants will take generations to regenerate and the consequences of a groundwater remediation, that may become necessary, will be paid for by the general public, whereas profits made from gas extraction will go to private investors.

*Formation water is water within a rock unit regardless of the origin of the fluid. These waters may be of meteoritic origin, i.e. surface water which infiltrated into the soil (e.g. rain, sea water) or which was trapped in the pores of a rock during its formation. Formation waters from deep underground often have a high salinity (so-called brines with >100 g/L total dissolved solids) and may contain large amounts of heavy metals.

Alliance of Public Water Management e.V. (AöW)
The AöW is the representation of interests of public water management in Germany. The purpose of the organization is the promotion of public water management by bundling interests and competences of municipal and organized water management.

AöW members are water supply and waste water disposal facilities and companies that provide services themselves or by means of autonomous facilities and are fully publicly owned. In the same way, water and soil organizations and water management associations are organized in the AöW. Members are also persons who support the purpose and goal of the AöW.

Shale gas and responsible innovation

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May 2014

Shale gas exploration and exploitation suffers from public acceptance issues in large parts of Europe. It is seen as a challenge to extract shale gas and to benefit from its economic potential while preserving responsible stewardship of the environment and public health (Gregory et al., 2012). The 2010 report of the International Energy Agency argued that industry needed to earn a *social license to operate* (IEA, 2010).

Yet, public resistance in some European states has increased since the publication of this 2010 IEA report. This raises the question whether such public acceptance is possible to achieve. What should a license to operate incorporate? Is it possible to formulate conditions under which shale gas exploration becomes publically acceptable? Is industry able to live up to such requirements? Is the public trust of companies and governments sufficient that they can believe their conditions will be adhered to? All these questions should be addressed when discussing socially responsible shale gas exploration.

In our research we believe that public acceptance will originate from the differences in values that are important to different stakeholders (Correljé et al., 2015). In this approach the identification of values forms the key to addressing public acceptance and to engaging in socially responsible innovation.

In this approach the values of the different stakeholders need to be identified. The values of a specific stakeholder are important in determining the lens through which they view the world and developments in the world. Their values determine the norms of this stakeholder and what new world developments should entail. For example, discussion of a technological design that includes and respects the values of a stakeholder will provide input that can help to formulate more widely supported options (Van de Poel, 2013).

In order for such an approach to work, an open discussion between stakeholders is essential. To achieve such an environment it is important that public resistance is taken seriously. Public resistance is often seen as something to overcome; as a barrier that hinders a project from proceeding. When public resistance is approached in this way, however, the goal becomes to guide the perceptions and actions of stakeholders. At the same time emotions can form a manifestation of ethical insight and as such should be taken seriously (Roeser, 2011).

In the search for choices, it is crucial to keep all options open. In this respect it is important not to pay attention solely to the technological possibilities, but also to include the views of all relevant stakeholders and the institutional design that accompanies a new technology. Each of these three aspects are essential for engagement in responsible innovation (Taebi et al, 2014).

Technological design can help to accommodate societal concerns. Sometimes such a solution can be clear and immediate. For example, the recycling of water from fracking fluid processing reduces the need for fresh water. Technical adaptations can also create trade-offs between different societal concerns. For example, the use of drinking water instead of surface water can eliminate the need for biocine in the fracking fluid to eliminate bacteria. Such a measure addresses the tension between two aspects that create societal concern: the use of large quantities of fresh water and the use of chemicals (BIO Intelligence Service, 2013).

The second issue is the involvement of the relevant stakeholders, including local citizens, municipalities, industry, and NGOs. It is important to gain understanding of the relevant social values and the value conflicts between stakeholders. For example, by analyzing arguments that are put forward in public discussion, insight can be gained into the values that are important to the different stakeholders (Correljé et al, forthcoming).

It is also important to provide insight into the dynamics of the debate between the stakeholders, both in respect of the nature of the arguments put forward, as well as the (dis)appearance of arguments. Attention should be paid to how procedures for participation are put in place, ensuring they create an atmosphere that facilitates constructive dialogue. Ideally, such a dialogue should start early in the design process, before contestation has arisen and parties have become locked into their arguments.

Such stakeholder dialog should be open to any outcome. Nevertheless, the interpretation of 'facts' and the scope of the dialog will differ among various stakeholders. One the one hand, it is preferable to reach agreement on such issues, for example through a procedure of joint fact-finding. On the other hand, it cannot be assumed that agreement will always be reached, in which case, possibly, a trade-off can be achieved between different values and preferences.

The third issue is incorporating the relevant institutions into the design process. Institutions such as legal, standard, and regulatory bodies, as well as customs, traditional and routine institutions, are often geared towards the support of existing habits and practices. They should adapt to adequately accommodate the characteristics of innovation. To adequately cover new aspects of shale gas exploration, the relevant institutions should be (re)designed in accordance with the values of the stakeholders. These adapted institutions should also include procedural aspects such as reliability, transparency, and accountability. Obviously, stakeholders should be certain that these rules and regulations are executed with integrity.

Socially responsible innovation requires the participation of stakeholders and the accommodation of their values. In the participatory process, it is important not to consider public resistance as something to be overcome. The process should aim to create procedures, institutions and a technological design that generates societal support. An important starting point is to identify the values that matter.

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Insights from ‘Frack Off’ to ‘Frackademia’ – Public Perceptions of Shale Gas in the German Context

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May 2014

Shale gas extraction via fracking is covered more and more in the German media, as it is in many other countries. Big headlines and strong images represent the complex socio-political context in which this potential energy source is discussed, often with a focus on reaching independence from difficult or problematic gas providers in unsure political situations. In order to gain insight into these discussions and to better understand the arguments used on the different sides, we analyze how different types of media cover this topic and how these are reviewed and assessed by readers. For this, our main sources of information are articles on fracking from online versions of newspapers and magazines, as well as the accompanying readers’ comments.

Other sources that offer a different approach to the topic include videos on fracking shared and discussed on YouTube, as well as discussions in online communities and social networking services. With these sources at hand, we conduct a qualitative media analysis with a special focus on what kinds of arguments are frequently used against or in favor of fracking, how lay people respond to them and what additional arguments and perspectives they share in their discussion contributions. While we concentrated on the public discussion in Germany, some of our sources are international and show the public perception of fracking in other European or North American countries. We see this as a first step towards learning more about what public or stakeholder discourse is out there, how these connect to other controversies and what (if any) conditions should be for a social license to operate.

All in all, fracking seems to hit a nerve. Its opponents see the method as a vital attack on mother earth, our hunger for energy means we drill deeper and deeper into the ground without any acknowledgement of potential risks. This extreme critique can be found in Josh Fox’s controversial film ‘Gasland’ (2010). This film is of special interest as it raises the question of how this sort of strong presentation can impact its audience, and how perceptions or awareness of risk can be changed. Supporters of shale gas extraction stress the importance of energy independence and emphasize long-term experience with drilling methods and manageable risks.

In our analysis, we find different kinds of arguments that include: the economic, scientific and political aspects of fracking; the representation of lay people’s opinions in the media; fracking and energy policy; and the emotional aspects of the topic. Yet often, it is difficult to differentiate between the arguments made; they are intertwined, influence each other and are raised by diverse groups at different times. In the following we would like to focus on what we have termed the ‘normative aspects of fracking’, as we feel they are an important aid to grasping the issues being raised and they shape the discourse substantially.

Normative Aspects of Fracking

There are considerable ‘emotional’ or normative aspects in the discussion of fracking that shouldn’t be overlooked when studying public perceptions of this technology. In fact, we would argue that understanding these is essential to mapping and analyzing the complexity of the debates. It is important to note that even if there are extensive ‘emotional’ aspects involved in the public perception of fracking, this doesn’t mean that citizens’ opinions on this technology should be dismissed as purely emotional reactions that are unfounded or irrational.

Unfortunately, this is often exactly what happens in the case of fracking; the reasonable arguments and opinions of lay people are often dismissed by experts as purely emotional responses. This can be seen in various articles arguing in favor of fracking, when authors claim that “in Europe however, shale gas has been demonized”[1] or that „it would be wrong, to dismiss shale gas extraction on purely emotional grounds.”[2] Yet, these emotional or normative arguments have legitimacy as they reflect basic societal or individual values that tell us a lot about the ethical frameworks behind them. Instead of a deficit model approach, in which conflict around technologies is supposedly resolved by providing more information to the uninformed and therefore opposed public, the ‘emotional’ arguments based on values should be looked at more carefully.

A striking example of how an emotional approach to the topic can have significant impact on the perception of fracking can be seen in Josh Fox’s very successful documentary ‘Gasland’. As a first step to better understanding the impact, we therefore present a short analysis of this film. To better understand the connections between visual arguments and how they influence public perception, further in-depth research focused on perception and opinion-forming in the context of these (strong) visual imageries would be necessary.

‘Gasland’ tells the story of Josh Fox, the director of this non-fiction movie, who was offered 100,000 dollars for his family’s land by a drilling company. In order to understand the consequences of this offer, he interviewed several people whose land had been drilled for gas, but also people representing governmental institutions and the oil and gas industry. In the course of the documentary the viewers are presented with how producing shale gas contaminates groundwater and negatively affects the health of humans and animals. The famous shot from Gasland where a farmer lights his tap water on fire went viral globally and instigated an even greater fear of fracking than before. When looking at public perceptions of fracking the question is: how is it possible that this movie had such a large impact on people’s perception of shale gas?

Industry and scientists are prone to respond to the movie in a rational way,stating that the presented information in Gasland is incomplete or even incorrect. The effect of this attempt to ‘rationalize’ the presented images, however, seems to have little effect. The answer to this phenomenon can be found in the word ‘image’. Josh Fox is a master at creating the right image, framing a shot by using the right filters, camera-angles, props, music and so on. A medium such as film or television is all about transferring information.

When we transfer information it is very important to understand how information is perceived. It is also very important to know who the audience will be. Where Industry and scientists try to transfer knowledge about the production process and the precautions taken, Josh Fox wanted to project a completely different message, namely: “shale gas is dangerous for you and your environment”. In order to make sure this message comes across the *right* way, he puts a lot of effort into the way he presents it. To the people affected by drilling, he introduces himself as a friend in the same boat. During the filming, he varies between professional dynamic and static or handheld ‘home video’ camera usage, depending upon the information and feeling he wants to communicate. He adds music to the imagesthat he knows will be recognized and liked by his target group. In short, Gasland was made with the intention of communicating a certain message, and it succeeded to a certain degree.

To better understand the degree to which it was successful, it would be necessary to further investigate how viewers perceive and judge Gasland and other documentaries on fracking. By analyzing the images used, we can get deeper insights into the analogies and arguments made by critics of fracking, and potentially better understand the complex interfaces and discourses; often these cannot be explained solely by offering more ‘sound information’ on the technicalities of fracking, or by dismissing normative arguments as too emotional or irrational.

A further important ‘emotional’ context can be found in the broad opposition to nuclear energy found in Germany, which eventually lead to a complete withdrawing from nuclear power. Two aspects of this opposition to nuclear energy might bear some relevance to opinions on fracking. The first aspect concerns the impact of emotional engagement with nuclear energy on public perception. In the Eighties, lots of books aimed at teenagers were published that dealt with the effects of nuclear disasters in a very detailed manner.

These books were discussed in the majority of schools and might therefore have had a big impact on the perception of nuclear energy amongst this generation of students.[3] It would be interesting to discover if similar literature appeared in other countries, and if not, if this kind of emotionally charged literature could be part of the explanation into why Germany was the only country that decided to withdraw from nuclear power after the Fukushima incident. This might furthermore show that the emotional aspect concerning a technology such as nuclear energy or fracking should not be underestimated, and that emotional approaches to a technology such as fracking can be quite powerful tools for shaping public perception.

In the case of Germany, where there already is a strong emotional opposition to nuclear energy, the population may be even more susceptible to films such as ‘Gasland’ and other negative portrayals of fracking. Emotional approaches can be used by both opponents and proponents of fracking, however. There are articles that try to shape public perception by igniting fears of job loss and economic instability were Germany not to use fracking.[4]

This strategy doesn’t seem to work, however, as people commenting on one particular article accuse the author and the magazine of being lobbyists, manipulating the numbers and concealing the dangers of this technology, citing counter-arguments such as water pollution, the population density of Germany in comparison with the USA, and the risk of possible earthquakes. Other comments are more emotional and show that in the discussion of fracking, certain values such as sustainability, care for the environment and worries about future generations play a distinctive role. Proponents of fracking are perceived as having the “wrong” kind of values, cherishing money over people and the environment. There are even comments that reference the above mentioned film ‘Gasland’. This shows that the film, although only available in English and dealing with the situation in the USA, does play a role in the perception and ergo the discussion of fracking amongst the German public.

Future Research

Using our qualitative approach to analyze different types of media on the perception of fracking, we were able to identify key aspects of this topic, as well as a variety of different opinions and argument patterns both for and against fracking, which play a distinctive role in the public assessment.

As our main sources consisted of relatively anonymous commentaries to videos and online articles, however, we have no concrete data on age, gender, political orientation or social background of the commenters in question. A next step could then be to conduct a quantitative survey to verify our findings and gain more insight on how certain parameters such as age or gender influence the perception of fracking. Setting up focus groups might be another way to get the necessary representative data and to test if the argument patterns found in our qualitative analysis repeat themselves in this setting.

We also regard a cross-country (Germany, other European states and the USA) analysis and comparison as important to better identify the specific values expressed in the ‘emotional’ arguments.

These might differ within and between different countries. An in-depth analysis of how perceptions around fracking are shaped would offer further important insights. In this context it could be helpful to look at the way the arguments are related to or even based upon other controversial technologies.

Opponents of fracking often contextualize their arguments according to highly debated technologies such as nuclear power. In the German context, critics can find it beneficial to frame fracking using similar arguments that have proven to work in the past against nuclear energy. Perceptions of course are in constant flow. As political situations become more tense and gas supplies more uncertain, societal and political discussions will potentially re-evaluate what was once clear; for example, through consideration of a moratorium. Therefore, the challenge for further research is to keep these developments on the agenda and to try to understand the discourses and arguments.

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3 For an interesting commentary on this topic, see: “Pädagogische Horrorshow”, by Judith Liere, published on www.spiegel.de