> Hydraulic Fracturing

A technology under debate

acatech POSITION PAPER – Executive Summary and Recommendations

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NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

Hydraulic fracturing, commonly referred to as fracking, is a critically and controversially debated technology that divides opinion among both politicians and the general public. At the same time, hydraulic fracturing is a prerequisite for two applications significant in terms of economic and energy policy: the production of unconventional gas from shale formations (shale gas) and the utilisation of heat energy from petrothermal reservoirs deep underground. It is against this multi-layered background that acatech has elaborated this POSITION.

Addressing the various facets of fracking, the paper wishes to contribute to objectifying the debate. It aims at broadening the available information base by a comprehensive scientific and technical overview of the method and its risks and benefits. This will allow decision-makers from politics as well as interested members of the public to draw their own conclusions about hydraulic fracturing and to decide on the further use of the technology.

Fracking in the context of the energy transition and resource and climate policies

The German energy transition, European and international climate policies and the global availability of energy resources form the framework within which the exploitation of natural gas and deep geothermal energy must be addressed. The energy transition will remain one of the key challenges Germany will face over the coming decades. In this process, technological progress and competitiveness will play a crucial role. The requirements of the energy transition can only be met if the political echelons join forces with the industry, the scientific community and the public to find appropriate solutions and to set the right course.

There is no doubt that for the next decades, hydrocarbons will continue to play a significant role in Germany's energy supply system. Currently, natural gas covers around 22 percent of the country's primary energy demand. In 2012, domestically produced natural gas still accounted for 13 percent of this total. In about ten years' time, however, Germany's reserves of conventional gas will be exhausted. Without the production of unconventional shale gas, the country will then be totally dependent on natural gas imports. If, on the other hand, Germany were to use hydraulic fracturing to recover shale gas, it could sustain its domestic gas production at the current level for decades to come. Shale gas, incidentally the "cleanest" fossil energy source, could thus provide a bridging function.

The technology of deep geothermal energy seeks to recover the huge resources of heat energy locked deep underground for power and heat generation. Of all renewable energy sources, geothermal energy has the smallest ecological footprint. It can provide a sustainable, long-term supply with base-load power. Most of Germany's geothermal energy is stored in deep, hot rock, also known as petrothermal systems. Even with the current technology, these reservoirs could contribute substantially to covering Germany's demand of electric power and heat. An appropriate funding and development of the relevant technologies for the exploitation

At a glance

- Two energy sources significant in terms of economic and energy policy can be accessed by means of hydraulic fracturing: shale gas and geothermal heat.
- Possible environmental risks are a subject of controversy in politics and the public. Critical voices particularly fear contaminants infiltrating into the groundwater and fracking-induced micro-earthquakes.
- Pilot/test projects can provide the scientific community, the political echelons and the public with experiences with the fracking-technology, thus allowing for a better risk assessment.
- The use of the fracking-technology should be subject to strict safety standards and requires clear regulations and comprehensive monitoring.
- The responsible parties must ensure a comprehensive and transparent communication of the fracking project and involve the public in the planning process.

of petrothermal reservoirs by means of heat exchangers would largely enhance this potential. Deep geothermal energy could indeed become a major factor in the renewable energy portfolio that is to cover Germany's future energy demand.

Neither shale gas extraction nor the development of petrothermal systems are possible without hydraulic fracturing.

Hydraulic fracturing: processes and techniques

Hydraulic fracturing is a technology that uses water pressure to generate fractures in solid, low permeable rocks in the geologic subsurface. The method is carried out in deep wells and is usually applied through deliberately perforated sections of the cemented borehole casing. The objective of a fracking operation is to achieve a lasting improvement in the hydraulic permeability of the rock and to create highly conductive flowpaths for the transport of fluids (e.g. natural gas, oil and water). To this end, a so-called frac-fluid is pumped into the target rock. The injection of this fluid builds up sufficient pressure to either produce tensile fractures (hydraulic fracturing in the strict sense) or to trigger shear displacements along pre-existing faults or fissures in the rock (hydraulic stimulation). The shear fractures significantly enhance the hydraulic permeability of the rock. Hence, the frac-fluid usually used for conventional hydraulic stimulation in petrothermal reservoirs is water. If, however, hydraulic fracturing is employed to recover natural gas and oil reservoirs, the frac-fluid requires chemical additives as well as additional proppants like quartz sand or ceramic beads to keep the newly created tensile fractures open.

Typically, frac-fluids will contain 97.0 to 99.8 percent water and 0.2 to 3.0 percent additives. In Germany, the total number of chemical additives for tight gas extraction has already been reduced to around 30. Under current legislation, these 30 additives are not subject to any license restrictions. In the case of shale gas extraction, it appears possible to further reduce the number of additives to only two or three.

Seismic monitoring during fracking operations allows a permanent control of the fracprocess and ensures that the fractures do not extend beyond the target horizon of the reservoir. Whereas the horizontal extent of the fractures (length) ranges from a couple of ten to a few hundreds of metres, their height is generally much lower. The width of the fractures is often no more than a few millimetres and rarely exceeds one centimetre.

Hydraulic fracturing and the environment

Hydraulic fracturing is an established technology that has meanwhile been employed in over three million frac-operations worldwide. The technology was developed towards the end of the 1940s by the oil and gas industry in order to improve the productivity of conventional oil and gas deposits. Since then it has established itself as a key technology for the extraction of hydrocarbons from conventional deposits in low-permeable sandstones or carbonate rocks (tight gas/tight oil). In Germany, the fracking technology has been in use since 1961. In recent decades, it has primarily been employed to extract tight gas from deep reservoirs.

The outright opposition fracking is frequently met with can partly be attributed to media reports on incidents in connection with the production of shale gas in the United States. Such incidents occur in the context of the large-scale frac operations that have been carried out for over ten years in order to extract natural gas (and more recently also oil) from shale formations.

Whereas conventional gas and oil migrate through the Earth's upper crust and accumulate in geological structures acting as traps (conventional hydrocarbon deposits), shale gas is still stored in the rock where it was originally generated (source rock). These so-called unconventional hydrocarbon occurrences are widespread in some regions of the USA, but can also be found in other parts of the world – sometimes in quite substantial quantities. These resources, which usually have a large lateral extension, are accessed by deep boreholes that enter the deposit vertically before making a horizontal bend to run along the length of the shale formation.

There are several major environmental risks that are commonly attributed to fracking – particularly since reports on shale gas production in the United States fuelled the public debate. These risks include: contaminants infiltrating from the surface into drinking water horizons as a result of accidents or technical failures, toxic or environmentally hazardous substances and methane being released and ascending to the surface out of and along leaking boreholes as well as contaminants escaping from the fracked rock and rising up to the surface and emissions of methane into the atmosphere. Other concerns include the large land areas required for fracking, the significant amount of water used in the process, and, in particular, the phenomenon known as induced seismicity.

In Germany, groundwater protection is a particularly important issue in the debate on hydraulic fracturing. In this discussion, the terms "groundwater" and "drinking water" are often used as synonyms. However, once a depth of around 50 to a few hundred meters (depending on the regional geology) is surpassed, the naturally occurring groundwater is in fact undrinkable and unsuitable for economical utilisation. It frequently contains extremely high concentrations of salt (e.g. up to 30 percent or more in the North German Basin), high contents of trace metals and, occasionally, naturally occurring radioactive substances. Therefore, a clear distinction should be drawn between commercially viable shallow groundwater, medicinal water and formation water/deep saline brines without any potential for exploitation.

To date, there have been no reported environmental incidents caused by hydraulic fracturing in Germany. This is not least due to the high standards and comprehensive regulations that Germany has already introduced with regard to the design and monitoring of well sites/production facilities, the completion and casing of deep wells and the conduction of fracking operations. This position paper presents a number of recommendations and measures that could help to further improve safety, for instance in the field of site-specific risk assessments and well integrity management and monitoring.

The injection of fluids to create fractures in shale gas deposits or petrothermal reservoirs inevitably leads to the occurrence of induced (micro-) seismic events. However, these events are rarely perceptible at the Earth's surface. Their magnitude and frequency are particularly dependent on the respective geological and technical parameters. It is, therefore, important to employ "soft" fracking techniques based on local seismic hazard analyses. The aim must be to develop standards for the injection process that limit the magnitude of the microseismic activity perceptible at the surface while still significantly improving the permeability of the reservoir. Although research efforts have already yielded a variety of possible approaches and methods, further research in this field is still required.

Public perception and social debate

In an open society, the future use of hydraulic fracturing will require the consent of the groups and residents affected by the operations. It is therefore essential that planning approval procedures ensure full transparency, providing for a comprehensive communication of the necessary measures and offering active participation in the planning process to those directly concerned. Scientifically monitored pilot/test projects as proposed in Chapter 9 can contribute to this end by showing and explaining the technical procedures of a frac operation. Such experiences are important to create a basic confidence and appreciation of the economic and ecological potential hydraulic fracturing offers. At the same time, pilot/test projects can also serve to curb excessive expectations and foster a sound level of scepticism.

Conclusion

Scientific or technical facts do not justify a general ban on hydraulic fracturing. Its use should, however, be subject to strict safety standards and requires clear regulations and comprehensive monitoring. In Germany, high technical standards are already in place for the various different process steps involved in drilling, reservoir engineering and fracking. These standards would also have to be observed for potential shale gas production or the recovery of deep geothermal energy.

In the current situation, scientifically monitored pilot/test projects can play an important role for the development of shale gas extraction as well as the utilisation of deep petrothermal systems. Such pilot projects should be carried out under clearly set conditions and in accordance with pre-defined standards and should address any unresolved issues in terms of risk assessment. At the same time, the fact that the operations are being permanently monitored and that the public is informed and involved into the processes from an early stage could help to enhance public confidence in the fracking technology.

BEST PRACTICE: OPTIONS AND RECOMMENDATIONS FOR HYDRAULIC FRACTURING

acatech has drawn up a comprehensive list of best practice measures aimed at minimising any environmental risks that might arise in the context of hydraulic fracturing operations. These include:

- **Preparatory geological and geophysical studies and 3D-modelling of the subsurface:**
  Prior to every drilling operation, a 3D-image of the geological underground at the drilling site in question should be created. This can be achieved by combining all available geological data and information with the results of geophysical deep sounding methods and modelling techniques.

- **Site-specific risk assessment of the well site and drilling strategy:**
  Groundwater protection is to be guaranteed by designating water protection zones, identifying the boundary between drinking water/shallow groundwater and formation water/deep saline brines and establishing the overall hydrogeological situation, as well as by locating any geological barrier formations and tectonic fault zones. The risk of naturally occurring earthquakes must likewise be assessed.

- **Baseline measurements and long-term monitoring:**
  Regular monitoring of the near-surface groundwater (chemical composition and physico-chemical properties), the atmosphere (e.g. methane emissions) and natural seismicity (signal-to-noise ratios) is necessary both prior to and during pilot/test projects.

- **Frac-fluids:**
  All additives and relevant data pertaining to any frac-fluids intended for use are to be disclosed. Research and development efforts should be undertaken to reduce the number of additives and to replace potentially harmful substances with safe ones. Frac-fluids classified as toxic, hazardous or anything more than weakly water contaminating (Water Hazard Class 1) should not be used.

- **Flowback:**
  The so-called flowback fluids, discharged at the beginning of shale gas extraction immediately after a frac-operation, should be recycled and re-used. This measure substantially reduces the water consumption for fracking operations and largely avoids the necessity of fluid disposal.

- **Cluster drilling:**
  A significant reduction in land use can be achieved by exploiting shale gas deposits by clusters of 20 or more horizontally diverted boreholes issuing from a single drill site.

- **Induced seismicity/seismic monitoring:**
  Project-specific seismic monitoring should be carried out at the surface and, where possible, in adjacent observation wells, in order to provide a real-time record of fracture propagation during frac operations. Thus, accurate information is available at all times, allowing for immediate and appropriate measures to counteract any potential seismic hazards. A project-specific "traffic light system" should be developed to this end.

- **Well Integrity Management System:**
  A project-specific definition and establishment of minimum standards for a "Well Integrity Management System" is recommended. This should cover the entire life cycle of a deep well, from the planning and drilling stages to the exploration and exploitation of the resource and the plugging of the well once the project is finalised.

- **Well integrity monitoring:**
  The technical installations above ground (including the well site/production facility), the well integrity and the operations monitoring systems are to be regularly inspected.

- **Communication with the media and public:**
  It is important to engage in a transparent, dialogue-based information and communication process with the public and the media right from the earliest planning stages of any project that involves fracking.

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