SRU German Advisory Council on the Environment

Fracking for Shale Gas Production

A contribution to its appraisal in the context of energy and environment policy

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1 Introduction

1. Production of shale gas using the so-called fracking technology is currently the subject of a heated energy and environmental policy debate. Legal decisions on appropriate precautions against environmental risks arising from fracking will shortly have to be taken at both national and European level. Hydraulic fracturing, or fracking for short, is a technique that makes it possible to extract natural gas that is trapped in rocks (cf. Chapter 2).

2. Advocates of the technology stress its opportunities for the energy system in particular. For example, they claim that shale gas production in the USA has brought a significant reduction in the price of natural gas and has strengthened the competitive position of US industry. The Federal Institute for Geosciences and Natural Resources (BGR) estimates that the potential volume of shale gas is significant in Germany too (BGR 2012). Advocates also cite various energy policy advantages of shale gas, such as its contribution to security of supply, its function as a technology for bridging the transition of the energy system towards renewable energy sources (the "*German Energiewende*"), or the relatively favourable green house gas balance of natural gas (European Parliament 2012c). They consider the environmental risks of fracking to be basically manageable.

Critics point to the environmental risks, which they consider to be substantial, unclarified or possibly uncontrollable. In this context they also frequently cite reports from the USA about releases of dangerous substances involving serious environmental impacts (Deutscher Bundestag 2012, p. 26297 ff.).

3. In Germany many of the federal states (*Länder)* are politically in favour of a moratorium. In a unanimous decision by the federal and Land levels, the Conference of Environmental Ministers stresses that *"in view of the current scientific data situation it is not justifiable at this point in time to approve projects for the exploration and production of shale gas using fracking technology with the aid of chemicals that are toxic to the environment"* (UMK 2012, TOP 41/42/43). It was in this spirit that the Bundesrat, on 14 December 2012, adopted a resolution and submitted a proposal for an ordinance which would make fracking projects subject to compulsory EIA (environmental impact assessment). Such decisions also have to be seen in the light of growing acceptance problems: To date, 25 citizens' initiatives have joined to form an alliance "Against drilling for gas", which is calling for a ban on unconventional natural gas production (Gegen Gasbohren 2012, p. 8).

4. In the meantime numerous studies have been published or commissioned in the EU and Germany on the environmental risks and the energy economics or legal aspects of fracking, and their findings are also the subject of controversial discussion (European Parliament 2012a; BROOMFIELD 2012; FORSTER and PERKS 2012; PEARSON et al. 2012; MEINERS et al. 2012; EWEN et al. 2012; BGR 2012; Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen 2012).

5. Conflicting positions can also be observed at European level: for example, some European states (Bulgaria, France, Czech Republic) have imposed a ban or moratorium on fracking projects. However, in the light of the expected benefits for the energy industry, the United Kingdom and Romania have given up their moratorium (EurActiv 2012a; SAVU 2013; THEURER 2013). Poland is planning substantial investment in the development of shale gas projects. Following contradictory initial positions by its environmental and industrial committees, the European Parliament has adopted a fairly positive stance, provided a number of important conditions are satisfied, e.g. better enforcement of relevant European legal provisions and the harmonisation of provisions on the protection of human health and the avoidance of environmental risks (European Parliament 2012a). In December 2012 the European Commission held consultations to start a process which could also lead to European environmental legislation in the years ahead (European Commission – DG Environment 2012).

6. Legislative changes are already under discussion at federal level as well. Since 25 February 2013 proposals have been tabled by the responsible ministries for amendments to the Ordinance on the Environmental Impacts of Mining Projects *(Verordnung über die Umweltverträglichkeitsprüfung bergbaulicher Vorhaben – UVP-V Bergbau)* and the Federal Water Act *(Wasserhaushaltsgesetz – WHG)* (BMWi and BMU 2013), which was supposed to serve as a basis for a Cabinet decision (cf. Item 88).

7. The German Advisory Council on the Environment (SRU) believes it is important to consider the broad overall picture that not only considers energy policy aspects, but also takes account of environmental risks. The Council bases this report on the existing studies, but also raises further questions. For example, it undertakes a critical assessment from the point of view of energy policy. In view of the great energy policy hopes attached to the production of shale gas, it is first important to establish whether and under what conditions shale gas can in fact make a positive contribution to the *German Energiewende* or may run counter to its objectives.

Table 1

Fuels that are or could be produced in Germany using fracking techniques

	Conventional gas	**Unconventional gas Coal bed methane**	**Unconv. gas Tight gas**	**Unconv. gas Shale gas**	**Oil**	**Petrothermal geothermal energy**
Occurrence (depth)	3,000 –5,000 m[f]	700 – 2,000 m[a]	3,500 – 5,000 m[a]	1,000 – 5,000 m[b]	1,000 -2,500 m[f]	up to 5,000 m[c]
Proppants added	Yes[i]	Unclear[h]	Yes	Yes	n. k.	In exceptional cases[g]
Chemicals added	n. k.	Unclear[h]	Yes	Yes	n. k.	In some cases (acid)[c]
In use for	> 50 years	Test wells in 1990s[j]	30 years[d]	Test wells[e]	> 150 years	> 20 years
Horizontal drilling	Yes	n. k.	Yes[f]	Yes[e]	Yes[k]	Yes

n. k. – not known

Source: [a] ExxonMobil 2012b; [b] BGR 2012; [c] BMU 2007; [d] 2012; [e] ROSENWINKEL et al. 2012b; [f] WEG 2008; [g] GtV 2012; [h] EWEN et al. 2012; [i] RWE Dea 2012; [j] THIELEMANN 2008; [k] Wintershall (no date)

There are however various other questions about the justifiability of fracking which need to be clarified before any commercial production of shale gas. The SRU regards fracking as a case for applying the precautionary principle (for the precautionary principle see SRU 2011a). The precautionary principle justifies state action to avoid risks even if there is only abstract reason for concern about the possible occurrence of damage. Furthermore, risk assessment is also a process of weighing the potential benefits of a technology for society against its risks. In the case of shale gas production in Germany, the latter include risks for important legally protected goods in particular: water, human health, soil, biological diversity and climate. The conservation of drinking water and groundwater deserve special attention in this context.

2 Basic information on fracking

8. To permit a better assessment of fracking technology, this chapter provides some basic information about its areas of use and the characteristics of natural gas production from conventional and unconventional sources. Fracking technology is used to tap natural gas, oil and deep heat reservoirs (petrothermal geothermal energy) (Table 1). This technology basically increases the permeability of the deep rock by injecting fluid under high pressure. The fuels can then be extracted through the fissures that are thereby created or enlarged (EWEN et al. 2012). The various techniques differ among other things in the depth of the wells (700 – 5,000 m), the use of horizontal drilling and the use of various proppants and chemicals.

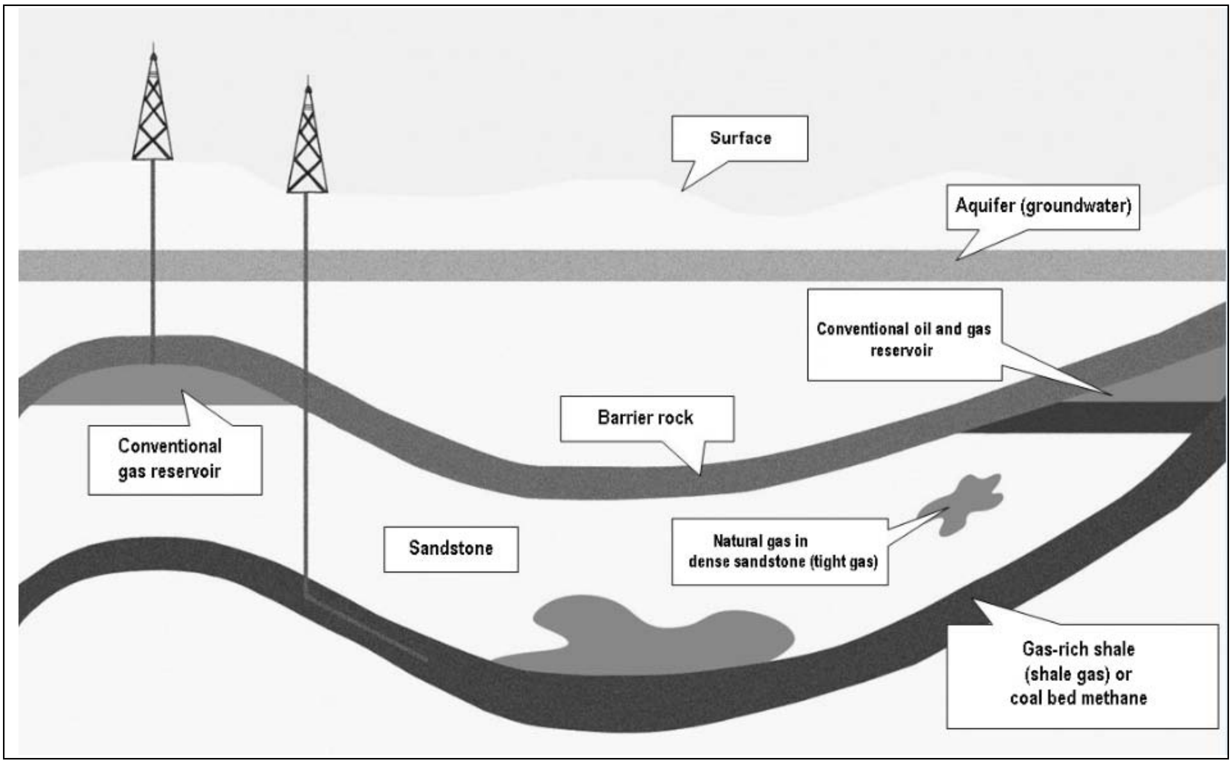
2.1 Natural gas

9. Natural gas essentially consists of methane, smaller amounts of other hydrocarbons, plus molecular nitrogen (N_2), hydrogen sulfide (H_2S) and carbon dioxide (CO_2). From the point of view of their formation, a distinction is made between thermogenic and biogenic methane. Whereas thermogenic methane is formed from organic material at high temperatures and pressures in deep sedimentary horizons, biogenic methane forms close to the surface as a result of microbial degradation (Arbeitsgruppe Gasführung im Untergrund 2002). The thermogenic methane trapped in conventional and unconventional reservoirs is important for energy production.

Natural gas in conventional reservoirs migrates – depending on porosity conditions – from the target rock along partings and pressure gradients into overlying reservoir rock (see Fig. 1). Where this formation is covered by a gas-tight caprock, gas reservoirs form. Conventional production extracts natural gas from such sources with the aid of deep wells (as a rule deeper than 500 m). Germany's conventional natural gas deposits are located mainly in the North German Basin, at depths of between 3,000 and 5,000 m in the Zechstein and Rotliegendes formations (BGR 2012; WEG 2008).

Figure 1

Oil deposits and conventional and unconventional gas reservoirs



Source: UBA 2011

10. Unconventional natural gas is the collective term for thermogenic natural gas which is still partially bound in the target rock or in dense reservoir rock. A distinction is made between tight gas (resources in Germany 0.1 trillion m³), shale gas (resources in Germany 1.3 trillion m³) and coal bed methane (resources in Germany 0.5 trillion m³) (ANDRULEIT et al. 2012, Table 14). [N.B. European readers should note that the word “trillion” is used in this statement in the US/UK sense of 1,000,000,000,000. Similarly, one billion is 1,000,000,000]. Tight gas is trapped in dense strata such as sandstone, limestone and clay minerals. In Germany it normally occurs in strata at a depth of 3,500 to 5,000 m. Shale gas occurs in carbon-rich sediments such as argillaceous shales and oil shales, mostly at depths of 1,000 to 5,000 m (BGR 2012). Coal bed methane occurs in conjunction with (hard) coal at depths between 700 and 2,000 m (BORCHARDT 2011).

Of the unconventional types of natural gas, shale gas offers the greatest resources. The following remarks therefore focus on shale gas. The greatest shale gas potential within Germany is located in North-Rhine/Westphalia and Lower Saxony.

2.2 Production of conventional natural gas

11. Before natural gas can be produced from conventional deposits, the geological, hydrogeological and seismic characteristics of the region have to be determined. To produce gas it is necessary to develop the regions with a transport infrastructure, establish well sites, drill wells into the reservoir rocks, and construct production facilities. Once gas production ceases, the production facilities have to be dismantled, and the wells sealed and tested for integrity.

In the first drilling stage, deep wells are drilled by ramming or scavenging until an impervious or almost impervious clay stratum is reached. Drilling then continues using clayey mud (BGR 2012). Geological data on the borehole are collected to document the number and thickness of barriers and aquifers and the characteristics of the reservoir rocks (mineral composition, porosity). Known or assumed disorders of the barrier functions of caprocks are determined to permit assessment of possible gas production. Deep wells are drilled unavoidably through aquifers and cause at least localised damage to layers impervious to water. For this reason the well is sealed in sections by means of steel casing, sometimes taking the form of two or more concentric pipes. The space between the wall of the borehole and the casing or between the pipes is sealed with cement (BGR 2012). If the assessment is positive, the well site is developed for further production.

12. The natural gas reaching the surface is accompanied by formation water. Depending on the geological conditions (pressure, temperature, rock), this may be contaminated with salts, metals and hydrocarbons, and also other pollutants. In that case it has to be classified as problematic in terms of human and environmental toxicology (see Chapter 4.1). In Germany, formation water is usually disposed of by injecting it into disposal wells with a depth of between 500 m and several 1,000 m (ROSENWINKEL et al. 2012b). When the gas production volume falls off because of the diminishing gas pressure in the reservoirs, it is possible to use hydraulic fracturing, or fracking for short (see also Table 1).

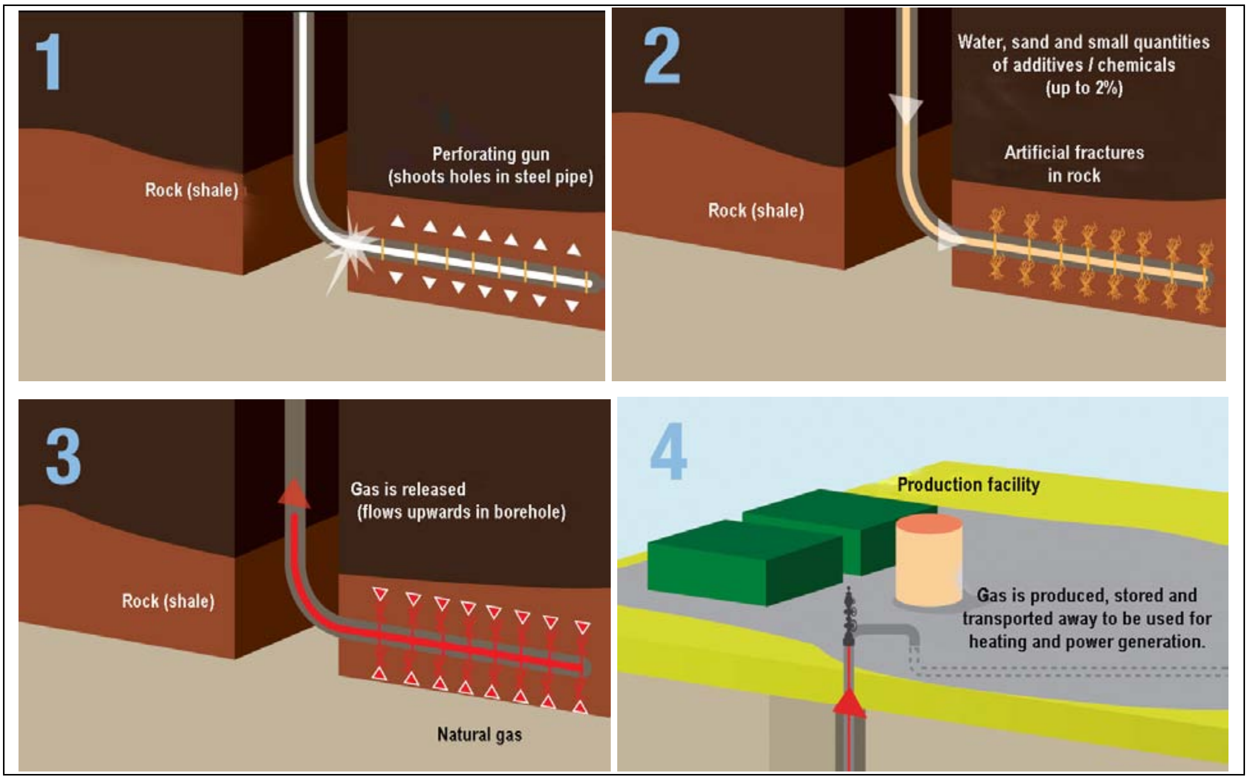
2.3 Production of shale gas

13. In the past, production of shale gas in Germany has not been technically or economically viable. It is only as a result of the ongoing development of specialised drilling techniques with horizontal drilling from a vertical borehole in combination with fracking that these deposits have become accessible at reasonable cost. The unconventional aspects of this gas production are the special properties of the reservoir rock (very low permeability, rapid decrease in pore pressure during production) and the use of a modified fracking method (see Fig. 2). A deep borehole is drilled into the gas-bearing rock strata and continued into the reservoir rock by horizontal drilling. In the horizontal drill holes, perforating guns are used to create holes in the steel casing by mechanical means. Then a fracking fluid (a mixture of water and additives) is pumped into the ground (at a pressure of up to 1,000 bar (EWEN et al. 2012)) to create further fissures and keep them open.

As well as sand or ceramic particles (proppants to keep the fissures open), various chemicals are added to the water (Table 2; Section 4.1.2). The precise composition of the fracking fluids depends on the individual geological conditions. The fracking fluid recipes used for the first fracking tests for shale gas extraction in Germany (Damme 3, Lower Saxony) have been published (ExxonMobil, no date).

Figure 2

Fracking methods



Source: EurActiv.de 2012

Table 2

Purposes of the additives used in fracking fluids

Additive	**Purpose**
Proppant	Keeps open the rock fissures created by fracking
Scale inhibitor	Prevents deposition of precipitates which are not readily soluble, such as carbonates and sulfates
Biocide	Prevents bacterial growth, prevents biofilms, prevents formation of hydrogen sulfate by sulfate-reducing bacteria
Iron control	Prevents iron oxide precipitation
Gelling agent	Improves proppant transport
Temperature stabilizer	Prevents premature decomposition of the gel at high temperatures in the target horizon
Breaker	Reduces viscosity of fracking fluids containing gel to permit deposition of proppant
Corrosion inhibitor	Protects equipment from corrosion
Solvent	Improves solubility of additives
pH control	Adjusts pH of fracking fluid
Crosslinker	Increases viscosity at high temperatures to improve proppant transport
Friction reducer	Reduces friction with fracking fluids
Acids	Pretreats and cleans cement and drilling mud from perforated sections of drill hole; dissolves acid-soluble minerals
Foam	Supports proppant transport
H_2S scavenger	Removes toxic hydrogen sulfide to protect equipment from corrosion
Surfactants	Reduces surface tension of fluids
Clay stabilizer	Reduces swelling and displacement of clay minerals

Source: BMU (2012), p. 11

The process of fracturing the reservoir rock takes a few hours. When the pressure is released, the flowback, consisting of fracking fluid and formation water, comes to the surface. As time goes on, the quantity of flowback becomes constant, but the ratio of fracking fluid to formation water decreases. The quantity depends on the reservoir and the geological conditions. Part of the fracking fluids remains permanently in the soil. During the production phase the gas released flows up the well to the surface, where it is captured. It contains moisture which has to be condensed above ground and disposed of as part of the flowback. The flowback can either be injected into the ground elsewhere, or processed and reused. In most cases the formation water which also occurs in conventional gas production is currently discharged into disposal wells or injected into old production sites. (ROSENWINKEL et al. 2012b). Fracking is a prerequisite for producing shale gas. It is not merely a supporting measure for maintaining economic production rates, as in a conventional gas reservoir.

3 Shale gas in the context of the *German Energiewende*

14. The issue of shale gas extraction in Germany is the subject of controversial discussion in the context of long-term climate objectives and the task of transforming the energy system towards renewable energy sources (the *German Energiewende*). Developments in the USA have given rise to hopes that shale gas could be the key to falling gas prices in Europe and Germany as well, and that natural gas could serve as a technology for bridging the transition to an energy supply system largely based on renewable energy sources. Gas-fired power plants are regarded as a good supplement to renewable energy sources, since they have a shorter payback period than power stations using other fossil fuels or nuclear power, and their operating technology is more flexible. What is more, natural gas has a better climate balance than other fossil fuels, though this has yet to be conclusively investigated in the case of shale gas (see also Chapter 4.5). However, the profitability of both existing and new gas-fired power plants is at risk because of higher fuel costs and falling spot market prices (for electricity) in Germany, and many gas-fired power plants are faced with the prospect of closure (MATTHES 2012, p. 3). Power generation from coal, by contrast, is on the increase (SETTON 2013).

Thus shale gas production – if it results in falling gas prices – could support the objectives of the *German Energiewende*. The assumed price effects must however be subjected to critical scrutiny. First of all, a realistic estimate of the potential – at global, European and of course German level – is needed to make it possible to assess the relevance of the resources. It is also necessary to take a globally and regionally differentiated look at other factors which determine the potential influence of shale gas on fuel prices. In the first instance, the market for fossil fuels is governed by world market developments (see Item 19; Chapter 3.2); the extent to which prices can be influenced by European or national shale gas production is a central issue.

It is also necessary to distinguish between short-term and longer-term trends. In energy policy discussions, short-term price trends are often cited to cast doubt on policy decisions that are based on longer-term considerations. For example, low gas prices in the USA are currently being used as an argument in favour of revising climate and energy objectives at national and European level (cf. Item 22; Chapter 3.3). The time factor in the development of shale gas production is also relevant in that although the use of natural gas will continue to play an important role over the next ten to twenty years, consumption of this fuel in both Germany and the rest of Europe is likely to drop considerably in the long term as renewable energy expands (NITSCH et al. 2012; European Commission 2011b).

Only against the background of this differentiated approach is it possible to assess the political need for action regarding the development of shale gas to support European and German energy and climate policy.

15. Germany consumed some 84 billion m³ of natural gas in 2011 (ANDRULEIT et al. 2012). Natural gas currently accounts for 21% of primary energy consumption in Germany. After oil and coal it is the most important fuel in the energy mix (BMWi 2013). According to the Lead Study (Leitstudie 2012) performed for the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), on which the structure of the objectives of the *German Energiewende* is based, consumption of natural gas in Germany could fall slightly by 2030 to 87% of the figure for 2010. However, by 2050 the quantity of natural gas used is likely to drop to about half the 2010 figure (NITSCH et al. 2012, p. 102). According to this scenario, demand for natural gas in Germany would show a substantial drop from the status quo over the coming decades. Even lower demand for gas is expected in the various scenarios for power supply based entirely on renewable energy or on more ambitious climate objectives for 2050 (SRU 2011b, Chapter 3.2).

Only about 14% of Germany's natural gas consumption is currently met by domestic (conventional) production, and the trend is downward (BGR 2012). In 2010 the largest shares of gas imports into Germany came from Russia, Norway and the Netherlands (ZITTEL 2012). Thus the gas market is not a German market, and it does not make sense to confine the focus to German shale gas when assessing price effects.

3.1 Shale gas resources – global distribution and uncertainties

16. A central factor for estimating the resources of natural gas is the production rate of the gas in place (GIP). The literature assumes a production rate of 80% of GIP for conventional gas, but this varies from 20% to over 90% depending on geological conditions. Experience in the USA indicates that the production rate for unconventional gas is distinctly lower, at only 5 to 30% of GIP (European Parliament – DG Internal Policies 2011, p. 65). Conclusive findings about the extent to which these figures can be applied to Europe, and to Germany in particular, have yet to be obtained. There are many indications in the literature that the production rate is site-specific (ANDRULEIT et al. 2012) and that it would consequently show considerable variations for different potential production sites in Europe and Germany. The individual character of the production sites makes it basically impossible to undertake a precise assessment of resources without extensive exploration drilling. However, in the great majority of countries exploration is only just beginning or has yet to start. In addition to the lack of a common standard for potential assessment and data presentation, not to mention the definitions used, this is one reason for the great differences in the estimates of resources found in the literature. In cumulative compilations for entire regions or continents, some sources do not include certain countries owing to lack of data (PEARSON et al. 2012, p. 30 ff.; ANDRULEIT et al. 2012, p. 19 and 22).

In 2011 the BGR estimated worldwide natural gas resources (natural gas in conventional and unconventional reservoirs) at around 785 trillion m³. The estimate puts the share of resources in unconventional reservoirs at around 60% (ANDRULEIT et al. 2012, p. 20). In a study for the European Commission the Joint Research Center, PEARSON et al. (2012, p. 31) – on the basis of a comprehensive evaluation of the literature – estimates that shale gas accounts for between 18 and 26% of total natural gas resources currently regarded as technically recoverable. In their most optimistic scenario, the contribution of shale gas to global primary energy supply is estimated at up to 30% in 2025 and 35% in 2040 (PEARSON et al. 2012, p. 230).

However, not only ANDRULEIT et al. (2012) and PEARSON et al. (2012), but also the authors of other sources cited in this text point out that the available data are subject to considerable uncertainties and can only be verified by exploration. Figure 3 documents the massive variations in the estimates of resources in the various publications.

An indication of the fact that past estimates have been distinctly on the high side is provided by Figure 4, which is taken from a BGR publication and is also based on a number of data sources. The figure shows that the U.S. Energy Information Administration (EIA) made a drastic downward correction to its estimates of technically recoverable US shale gas resources for 2011 compared with 2009 (to 13.64 trillion m^3) (EIA 2012a, p. 58). Compared with the estimates compiled by PEARSON et al., this figure is in the middle of the range (2012, p. 230). The data shown for Poland in Figure 4 show extreme variations from year to year. Whereas in 2010 the EIA estimates Poland's technically recoverable shale gas resources at over 5 trillion m^3, in 2011 the Polish Geological Institute (PGI) puts shale gas resources at 560 billion m^3, and in 2012 the US Geological Survey (USGS) puts the figure as low as 38 billion m^3. In all cases the figures are the mean of the available estimates (PEARSON et al. 2012; ANDRULEIT et al. 2012, p. 22 f.; WYCISZKIEWICZ 2011, p. 46; GAUTIER et al. 2012).

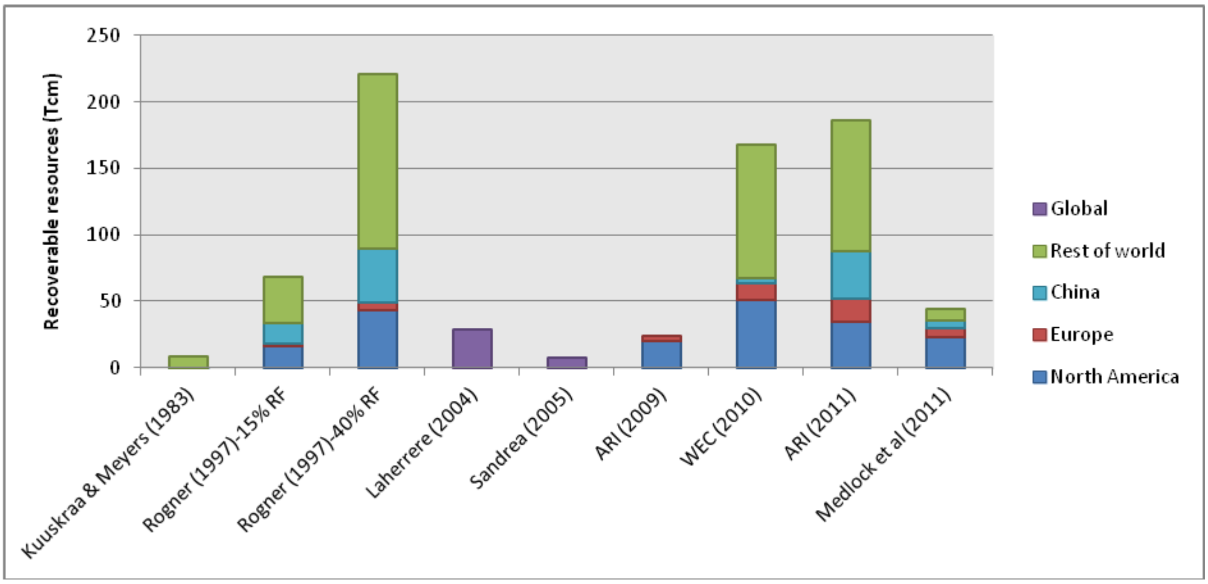
However uncertain the data situation may be, it is nevertheless clear that the potential quantity of shale gas varies greatly from one region or country to another, and hence also the possible effects of individual shale gas production on natural gas prices (see Chapter 3.2). The largest technically recoverable shale gas deposits are currently thought to be in the USA (25%) and China (20%). However, no analyses of potential are yet available for many other countries. According to the estimates available to date, Europe accounts for less than 10% of the technically recoverable shale gas thought to exist worldwide (PEARSON et al. 2012, p. 30 ff.).

A study by the BGR (2012, p. 31) and information from the EIA (2011b, p. 1–5, Table 1.3) indicate that the main occurrences of shale gas in Europe are to be found in Poland, France, Norway and Sweden. However, there are grounds for assuming that shifts in these figures will take place as a result of ongoing corrections arising from better information (cf. Poland). The BGR estimates Germany's recoverable resources of shale gas at an average of around 1.3 trillion m^3. It bases this on shale gas in place of between 6.8 and 22.6 trillion m^3 and assumes a production rate of 10%. According to these estimates, Germany's shale gas resources are considerably larger than its conventional gas resources (0.02 trillion m^3 excluding tight gas), and also larger than the Polish resources, for example (ANDRULEIT et al. 2012). The authors stress, however, that these figures for shale gas resources in Germany are provisional, and that the necessary geological and geochemical data were still incomplete at the time of publication (op. cit., p. 19 ff.).

The concept of static lifetime, which assumes constant consumption and total extraction, is frequently used to illustrate relative quantities. The estimated technically recoverable shale gas resources of between 0.7 and 2.3 trillion m^3 would have a static lifetime of 8 to 27 years.

Figure 3

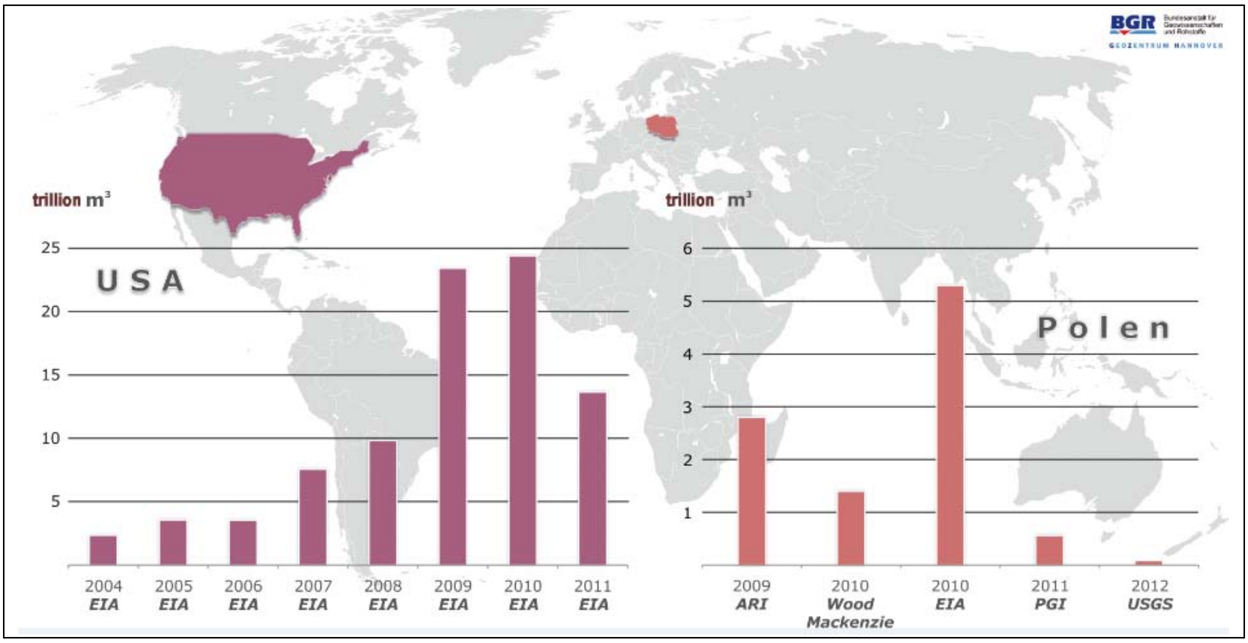
Estimates of technically recoverable shale gas resources (in trillion cubic metres)



Source: Pearson et al. 2012, p. 27

Figure 4

Comparison of shale gas resource estimates for USA and Poland (recoverable using state-of-the-art technology)



EIA – U.S. Energy Information Administration; ARI – Advanced Resources International Inc. USA;
PGI – Polish Geological Institute; USGS – U.S. Geological Survey

Source: ANDRULEIT et al. 2012, p. 22

As already explained, all existing estimates of potential are subject to great uncertainties. Moreover, a realistic assessment of shale gas resources would have to take account of environmental requirements and excluded areas (see Chapter 4.3), whereas the existing estimates do not. This represents a substantial information deficit, which will have to be remedied for the continuing debate. The quantities of unconventional natural gas that are recoverable while satisfying environmental restrictions and other spatial demands are probably considerably lower than the potential determined on the basis of existing criteria. Another aspect which is likely to place considerable restrictions on the market potential of shale gas is the economics of production, if – as would undoubtedly be the case in Germany – production is only permitted subject to strict environmental requirements.

3.2 Market and price effects of shale gas production

17. As explained in Item 14, any consideration of the price and market effects of shale gas production is most meaningful if broken down by global and regional production and also in terms of short-term and long-term effects, because the actors' adaptation mechanisms change in the course of time. Furthermore, it is important to examine not only potential impacts on the natural gas market, but also effects on the prices of other energy sources, because the markets are (at least partially) interdependent.

3.2.1 Global production of shale gas

Short-term effects on fuel prices in Germany

18. At present, it is only in North America that shale gas is produced on a considerable scale, which means that global price effects of shale gas production primarily emanate from the activities in this region. Production of shale gas in the USA was stepped up by 48% per annum between 2006 and 2010 (EIA 2011a, p. 37). In 2012 shale gas production accounted for about 32% of all natural gas produced in the USA (ARTUS 2013, p. 2), which in turn accounted for 30% of the country's primary energy requirements. The substantial increase in gas production is supported by a restrictive export policy with regard to natural gas (that is a very restrictive practice regarding permits for the construction of export infrastructure). As a result, there is keen competition between suppliers in the USA, with limited sales opportunities. The consequence is a veritable drop in the price of natural gas. The EIA estimates that the low price level in the USA will persist for a limited time, but not indefinitely (PEARSON et al. 2012, p. 2 ff.; EIA 2013, p. 5). The energy market in the USA has responded by substituting natural gas for coal, especially in power generation. This has resulted in large quantities of coal becoming available for export, which has already led to a downward trend in coal prices in Europe (BRODERICK and ANDERSON

2012; VIHMA 2013, p. 5 ff.). Thus the price effect of global shale gas production on fuel prices in Europe has so far tended to be indirect; in Germany it currently means a reduction in coal prices and hence a further deterioration in the competitive position of natural gas compared with coal. In other words the effect of shale gas has – at least to date – proved to be the opposite of what was hoped.

Medium and long-term effects on fuel prices in Germany

19. In view of high transport costs over long distances, trade in natural gas has to date been very largely restricted to regional markets (PEARSON et al. 2012, p. 163). Imports of gas into Germany have largely taken place by pipeline, and in view of the high factor-specific costs they are governed by long-term agreements. In these agreements the price of gas has been linked, after a time lag, to the price of oil ("gas-oil price link") (ANDRULEIT et al. 2012, p. 21; PEARSON et al. 2012).

However, various recent publications describe or at least forecast greater global integration of the gas market and, partly as a result of this, a relaxation of the oil price link. The rapid growth of shale gas production in the USA and the simultaneous drop in demand for natural gas as a result of the economic crisis are cited as major drivers for the interlinking of the markets, as are the expansion of the infrastructure and the increasing trade in liquefied natural gas (LNG) (PEARSON et al. 2012, p. 164; ANDRULEIT et al. 2012, p. 21). The development of costs for LNG also plays an important part in the future interdependences and price relationships between the markets. Falling transport costs for LNG would make it economically more attractive to trade in natural gas even over large distances between the formerly regional markets (PEARSON et al. 2012, p. 171 ff.). If greater globalisation of the natural gas market did indeed come about, the surplus supply due to global shale gas production could theoretically make itself felt in Europe as well in the form of falling natural gas prices (op. cit., p. 230). Thus in the medium and long term a direct effect on natural gas prices in Europe is also a possibility, in addition to the indirect price effects observed to date.

However, the scale of such effects also depends on the policy decisions taken by the shale gas producing countries (for example, the USA's current export policy restricts the growth of natural gas exports), and also on the consumption trends in other demand regions, e.g. Asia. In the course of 2010 imports of LNG into Asia increased by 18%, and the trend continued in 2011 as a result of the Fukushima disaster in Japan (PEARSON et al. 2012, p. 179). Thus it is perfectly possible that North American natural gas exports may not reach Europe in the future either, because of preference being given to supplying the Japanese market, where natural gas prices are even higher (IEA 2012a, p. 17). China too is a major player in the interaction of natural gas supply and demand, because of the rapid growth in demand for natural gas. In recent years it has considerably increased imports of LNG (EIA 2012b), and according to the current Five Year Plan the natural gas share of the energy mix is to be stepped up considerably. To this end it is expanding its LNG import capacity, and Chinese companies are securing shale gas resources in North America (IEA 2012a). Moreover, through cooperation with international companies they are acquiring know-how for domestic production of shale gas. It is clear that the additional supply of natural gas has to be seen in relation to increased demand in other regions of the world than Europe. The fact that global demand is increasing, including in regions where selling prices are high or which are not very distant from the important (potential) production locations, suggests that global shale gas production will at best slow down further price increases in Germany, but not result in any fall in natural gas prices.

One precondition that, if satisfied, might make it at least a theoretically economic proposition to export natural gas (as LNG because of the distance) from regions rich in shale gas (North America, China) to Europe, and hence give rise to price pressure on the German market, would be continuing/long lasting large price differences between the markets. The greater the price difference, the greater the volume of exports (EIA 2011a, p. 40; 2012a).

However, neither the EIA nor HUGHES (2013) consider it likely that prices in the USA will remain at the present low level in the medium and long term, even if the studies are based on different assessments of shale gas production trends in the USA. In the American Energy Outlook (AEO) 2011, the EIA (2011a, p. 37) expects production of shale gas in the USA to almost triple between 2009 and 2035. In its AEO 2013, the institution also expects to see further increases in production, but at the same time it forecasts a significant rise in natural gas prices from 2018 onwards (EIA 2013, p. 5). The reason given by the EIA is growing demand for natural gas in the USA, whereas conventional production of natural gas is on the decline. The EIA also expects shale gas production costs to rise, because the most productive sites are increasingly becoming exploited. HUGHES (2013), by contrast, expects the diminishing productivity will in the medium term lead to a fall in total shale gas production in the USA. His arguments are also based on the fact that the "sweet spots" (i.e. the most productive reservoirs) are already exhausted (see also GÉNY 2010, p. 43). According to his analysis, constant or rising production would only be possible by increasing the number of wells, which would be very capital intensive and not economically sustainable at present prices. To substantiate this, he cites the fact that the value of the shale gas produced in the USA in 2012 amounts to 35.5 billion US dollars, whereas the production costs needed to maintain this volume in the future must be estimated at 42 billion US dollars per annum (HUGHES 2013,

p. 50). The International Energy Agency (IEA) also confirms that the surplus of gas has led to prices falling below production costs (IEA 2012b, p. 129).

As a result there is reason to expect an adjustment in production and a market shakeout (SCHMID and MARK 2013). HUGHES (2013, p. 50) expects total production in the USA to fall once projects in progress (well drilled, production not yet started) are completed. In the case of shale gas one can even see signs of a "hog cycle" (WESTPHAL 2013), which is symptomatic for commodity markets (KALECKI 1977, p. 43 f.): Adjustments to production quantities always follow the price and scarcity signals with a certain time lag, thereby reinforcing the upward and downward price swings (cf. Fig. 5). It can therefore be assumed that the fall in gas prices in the past two years in the USA to the level of earlier record lows is only temporary.

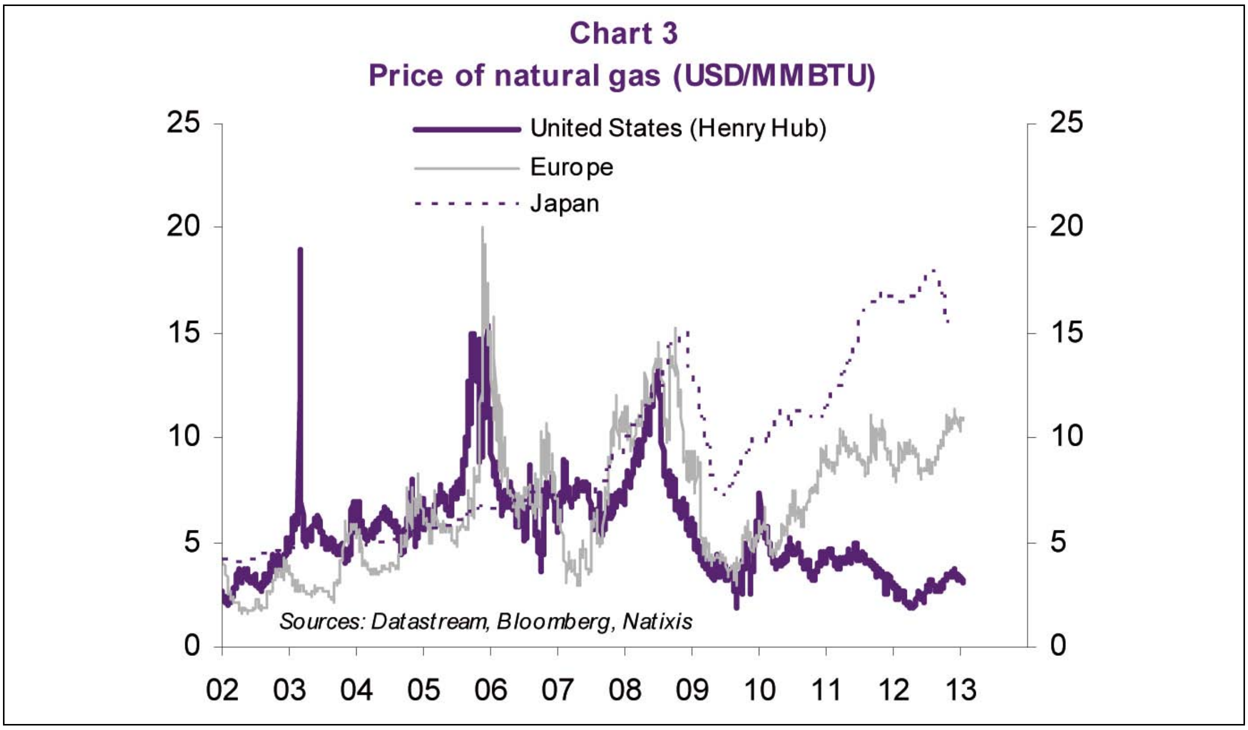
GÉNY (2010) also observes a number of factors driving up the costs of shale gas production in the USA, especially rising leases due to the keen competition for land within the production industry, inefficient use of technology and persistently high rates for abortive wells. Also, the current relatively low level of production costs is attributed to the exemption from the general national environmental regulations which was enacted in 2005. The introduction of dangerous substances during fracking was exempted from the "Save Drinking Water Act" (GÉNY 2010, p. 36; IEA 2012a, p. 104), though in some cases the individual states have different environmental provisions (BOERSMA and JOHNSON 2013). The pressure to regulate the extraction of shale gas by means of effective environmental legislation is high, even if there is uncertainty about whether and when this will once again be the case at federal level. At present the U.S. Environmental Protection Agency (U.S. EPA) is preparing a comprehensive study (EPA 2013) which could form the basis for environmental re-regulation in the course of 2014 (WYCISZKIEWICZ 2011). This too is a potential factor for cost increases and hence for falling production or rising prices.

Taken together, these factors suggest that the low prices in the USA are only temporary. The IEA expects to see an upward trend in gas prices in the USA (IEA 2012a, p. 107; 2012b, pp. 41 and 43). Thus the medium and long-term price effects in Europe are also likely to prove even weaker than the short-term effects, even if they cannot be ruled out completely.

Overall, an inexpensive additional supply of shale gas has a price-cushioning effect on fossil fuels compared with a reference scenario without shale gas. This could lead to an increase in demand (PEARSON et al. 2012, p. 154; BRODERICK et al. 2011). In the absence of supporting measures, this will have a retarding effect on climate action, renewable energy expansion or energy efficiency measures.

Figure 5

Gas price trends in the USA



Source: ARTUS 2013, p. 3

3.2.2 Regional shale gas production – Germany and Europe

Short-term effects on fuel prices in Germany

20. It can be said with relative certainty that at least in the short term, shale gas production in Germany and Europe will not take place on a scale that will influence fuel prices. This is basically indicated by the estimates of potential, but also a number of other factors.

As set out in Chapter 3.1, the potential quantities of shale gas in Germany are small on a global comparison, especially if the potential area is further restricted by the exclusion criteria currently under discussion (Chapter 4.3). Consequently, shale gas production in Germany would not have a major influence on the quantities available on the European market and would therefore not influence natural gas prices. In 2011 a statutory ban on shale gas production was imposed in France (e.g. The Economist 2013), and in Poland the potential estimates have been repeatedly adjusted downwards (see Fig. 4). While the Polish Institute for International Relations made fairly optimistic comments on the first test wells for shale gas in 2011, it also made it clear that the industry was a long way from producing on a large scale (WYCISZKIEWICZ 2011). Recent press reports indicate uncertainty and in some cases disillusionment about the economic exploitation of Poland’s shale gas. ExxonMobil, for instance, has already withdrawn from shale gas production in Poland because of insufficient production rates from the reservoirs tested (KENAROV 2013). On the whole, the latest findings and political developments are tending to put a damper on expectations regarding commercial shale gas production in Europe.

Other obstacles include the relatively high production costs to date in Europe, which are roughly two to three times the level in the USA. GÉNY (2010, p. 88) estimates the breakeven prices for shale gas production in Poland or Germany at between 20 and 40 EUR per MWh. There are indications that present gas prices in Germany and Europe are too low for shale gas production to develop on a large scale on the European market (GÉNY 2010, p. 84 ff.; ZEW 2013).

As far as large-scale commercial production is concerned, the development of the shale gas industry in Germany and Europe is still in its infancy. This also applies to its resources of technical equipment, skilled personnel and infrastructure. In many cases there is also a lack of data on site-specific geological and geochemical conditions. The task of obtaining and evaluating the relevant information will probably take several years. Experience in the USA suggests that several more years will then be needed for the next stage – expanding production volume to the target production level (GÉNY 2010). Thus in view of the necessary production lead times, shale gas in Europe cannot make any substantial contribution to energy supply in the short run.

Long-term effects on fuel prices in Germany

21. In the long-term too, current estimates indicate that the influence of German and European shale gas on fuel prices will tend to be very limited in view of the relatively small quantities on a global comparison, even if production levels could be higher in the medium and long term than in the short term. For this to happen, however, the economic framework conditions would have to develop very favourably for shale gas production (GÉNY 2010, p. 96 ff.). Although rising natural gas prices are forecast for Europe and technical advances will probably result in falling production costs, neither of these factors – as far as one can tell at present – will be sufficient to make large-scale production economically attractive. Increasing globalisation of the energy markets, as outlined in Item 19, will probably further weaken the impact of European shale gas on prices. Moreover, shale gas production has to compete with other natural gas supply options for the European market. A study by the IEA in 2009 suggests that European shale gas projects would mostly be much more expensive than new conventional natural gas projects (GÉNY 2010, p. 88). This leads to the conclusion that the future supply of gas and hence its price in Europe are more likely to be dictated by new gas projects in Russia and LNG projects in North Africa and Qatar than by European shale gas (op. cit., p. 89).

Table 3 summarises the estimates described in Chapter 3 regarding the effects of shale gas production on fuel prices in Europe.

Table 3

Matrix of price effects of shale gas production

	Potential effects of shale gas production on fuel prices **in Europe**	
Potential production	**Global**	**Regional (in Germany, in Europe)**
Short term (up to 2020)	Marked, but currently due rather to indirect price effects (coal getting cheaper)	Very slight
Medium and long term	Direct (gas) and indirect (coal) effects possible, but uncertain, and likely to be less marked than in the short term	Uncertain

SRU/Statement No. 18–2013/Table 3

3.3 Consequences for energy and climate policy

22. The importance of shale gas for energy and climate policy is currently the subject of controversial discussion. As well as hopes of falling gas prices, there are increasing calls, mainly from various sectors of industry, the European Commission and politicians, to undertake a fundamental review of the climate and energy policies of the EU and the German government in the light of the shale gas situation. A major argument cited is the reindustrialisation of the USA driven by low energy costs due to shale gas. Cheap energy is said to be raising the pressure of competition and increasing the readiness of energy-intensive industries to relocate from Europe to the USA. What is more, shale gas is claimed to lower the cost of fossil fuels so much that European climate policy and the transformation into a energy system based primarily on renewable energy will become too expensive and therefore need to be corrected (ARTUS 2012; 2013; RILEY 2013; EIA 2013, p. 2; WESTPHAL 2013, p. 3; OETTINGER 2012; EurActiv 2013; 2012b; NEUBACHER et al. 2013; Frankfurter Allgemeine Zeitung 2013; LOUVEN 2013; “High prices for industrial power in Germany put strain on competitive position”, press release by VIK dated 17 January 2013). At the same time hopes are being raised that the shale gas finds, especially in Poland and the USA, could lead to fundamental changes in these countries’ blockade stance with regard to climate policy if the more climate-friendly gas is used there instead of coal (HELM 2011; SCHRAG 2012).

23. However, a critical analysis of these arguments is necessary. The potential analysis set out above and the assessment of possible market and price effects of shale gas suggest that it would be a mistake to take current short-term price cycles as a reason for fundamentally revising a long-term political programme. There are still great uncertainties about medium-term trends. In fact, there may rather be a need for supporting action to correct the effects of short-term market developments in the interests of the energy and climate policy targets set for 2050.

Shale gas revolution does not explain reindustrialisation in the USA

24. Since 2009 there has been a remarkable increase of over 30 percentage points in industrial production in the USA, whereas the figure for the Euro zone has tended to stagnate (ARTUS 2013, p. 3). In particular, the automobile industry and a number of energy-intensive industries, for example the chemical industry, have profited from this upswing. Associations and policy advisers generally attribute the reindustrialisation of the USA entirely to the shale gas boom and the associated fall in gas prices. They argue that US gas prices are well below one quarter of European prices (op. cit.). In autumn 2012 the European Commission, in the light of the reindustrialisation of the USA, put forward the industrial policy target of restoring the industrial share of gross domestic product (GDP) to 20% by 2020 from the 16% it fell to in the economic crisis (EurActiv 2012b; 2013; OETTINGER 2012; European Commission 2012, p. 4).

25. However, there are doubts about such a single-cause explanation of the reindustrialisation of the USA. It is also questionable how permanent the fall in gas prices in the USA will be (see Item 19). First of all, the reindustrialisation of the USA cannot be largely attributed to energy costs. Even if current gas market prices reached a low in 2012 and are having an impact on other energy markets, it must be borne in mind that the gas market is only part of the overall US energy market (accounting for a share of nearly 30%) (ARTUS 2013). Furthermore, as in Germany, energy costs – even in energy-intensive industries – represent only a fraction of total production costs, so a drop in prices is only really relevant for the competitive position of very few specialised segments (Roland Berger Strategy Consultants 2011; REHBOCK 2013, p. 2). The crucial factor for reindustrialisation is more likely to be the fact that the dollar, on a weighted average of all trading currencies, has been devalued by more than 30 percentage points since 2002 (ARTUS 2013, Chart 11B, p. 6; Fig. 6). This makes imports correspondingly more expensive and exports correspondingly cheaper.

The US President's Economic Council also stresses that the economic programme from 2009 to 2012 with a total volume of 767 billion US dollars (approx. 5.5% of GDP) has had a significant impact on economic growth and employment in recent years (Council of Economic Advisers 2013).

As outlined in Chapter 3.2 (Item 19), there are also indications that the drop in gas prices over the last two years is only of a temporary nature and that in the medium term gas prices could rise again in the USA as well. However, long-term investment decisions by capital-intensive enterprises are not made on the basis of short-term price cycles, but take account of medium-term risks. Thus other investment motives (especially proximity to the market, growth potential) are probably of greater significance for direct investments in the USA by a number of European industries than gas prices which, although currently low, are likely to rise again in the medium term.

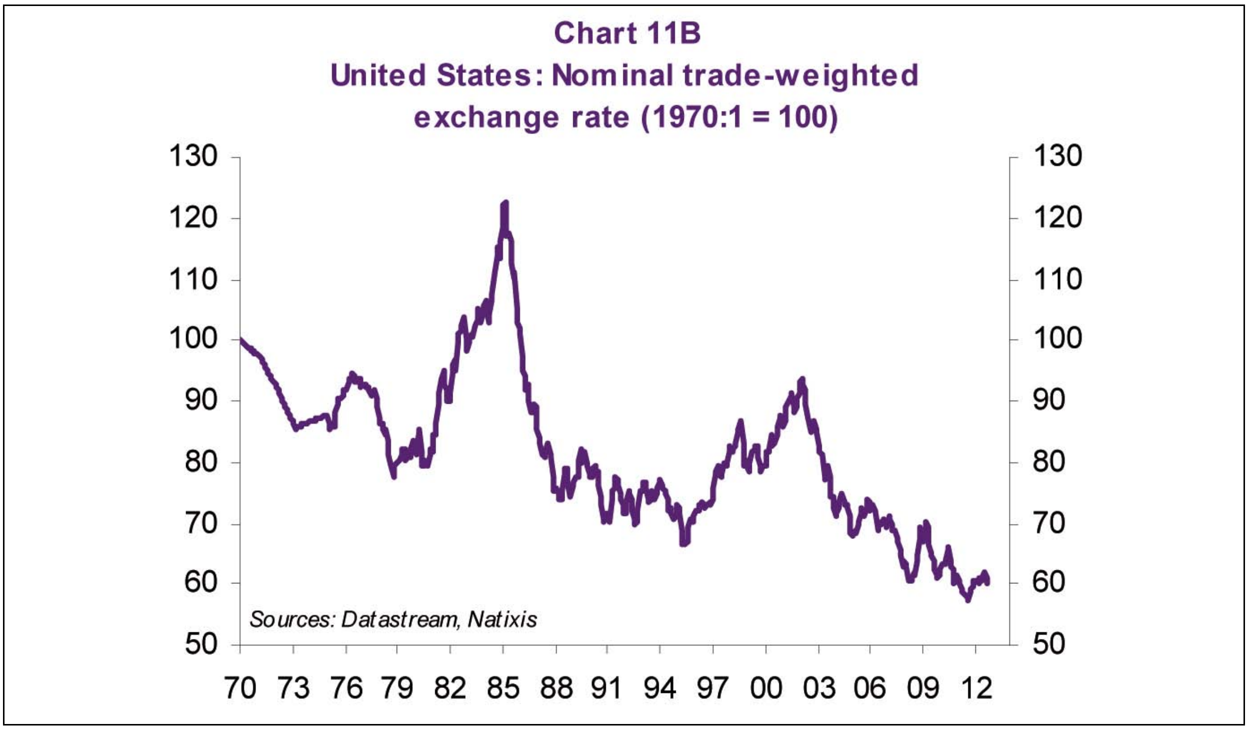
Long-term price trends do not suggest a need to revise energy and climate policy

26. For the pioneering climate policy role of Germany and the EU there are numerous industrial, economic and environmental policy arguments which the SRU and other authors have cited in various expert reports and statements against an undue focus on short-term cost considerations (SRU 2005; 2008a; 2008b; JÄNICKE 2012; SCHREURS 2012). One of the supporting arguments in favour of transforming the energy system is that the transition to renewable energy sources will in the long term contribute to cheaper energy supplies. Depending on expectations about fossil fuel prices, this reversal effect is predicted to take place in the 2030s, or at the latest in the 2040s (SRU 2011b; NITSCH et al. 2012; SUTTON et al. 2011). Industrial representatives and individual research institutes are now voicing the opinion that this argument is obsolete following the discovery of shale gas (Frankfurter Allgemeine Zeitung 2013; FISCHER 2013). This would make investments in energy efficiency or fuel switching to renewable energy relatively more expensive and hence unprofitable.

Additional fossil reserves can have price-restraining effects on the world market prices of fossil fuels. As explained in Chapter 3.2, it can be assumed that the effects will be much weaker in the long term than in the short term (TEUSCH 2012; GÉNY 2010; WESTPHAL 2012; 2013; WYCISZKIEWICZ 2011, p. 18). It is thus very doubtful whether shale gas will result in fossil energy remaining cheaper in the long term than renewable energy sources. This applies to Europe in particular.

Figure 6

Weighted exchange rate trends for the USA compared with other trading currencies



Source: ARTUS 2013, p. 6

It should also be noted that the EU is relatively poor in fossil fuels. This makes the EU vulnerable to sharp fluctuations in prices. Another argument used to justify the European energy and climate policy and the transformation of the energy system has been security of supply and safeguards against such price fluctuations. In its standard scenario the IEA's World Energy Report 2012, which already takes account of the latest optimistic forecasts for shale gas, nevertheless expects a decrease in the self-sufficiency of the EU (IEA 2012b; cf. Fig. 7). Thus shale gas will not bring about any fundamental change in Europe's fossil energy dependence (Chapter 3.1).

The IEA is forecasting that the EU's annual import costs for fossil fuels will triple or even quadruple to over 600 billion US dollars between 2000 and 2035. A large proportion of this rise in costs has already taken place in the last decade. And a further rise in import costs by over 100 billion US dollars (or around 20%) is forecast between 2011 and 2035 (IEA 2012b, p. 73). Moreover, energy price shocks associated with fossil fuels are a factor that should not be underestimated behind the recession of 2008 (SPENCER et al. 2012; Oxford Economics 2011; RIFKIN 2011). They thus present a similar risk for the future, because they mean a massive withdrawal of purchasing power and can significantly affect the trade balance in states which import a large proportion of fossil fuels.

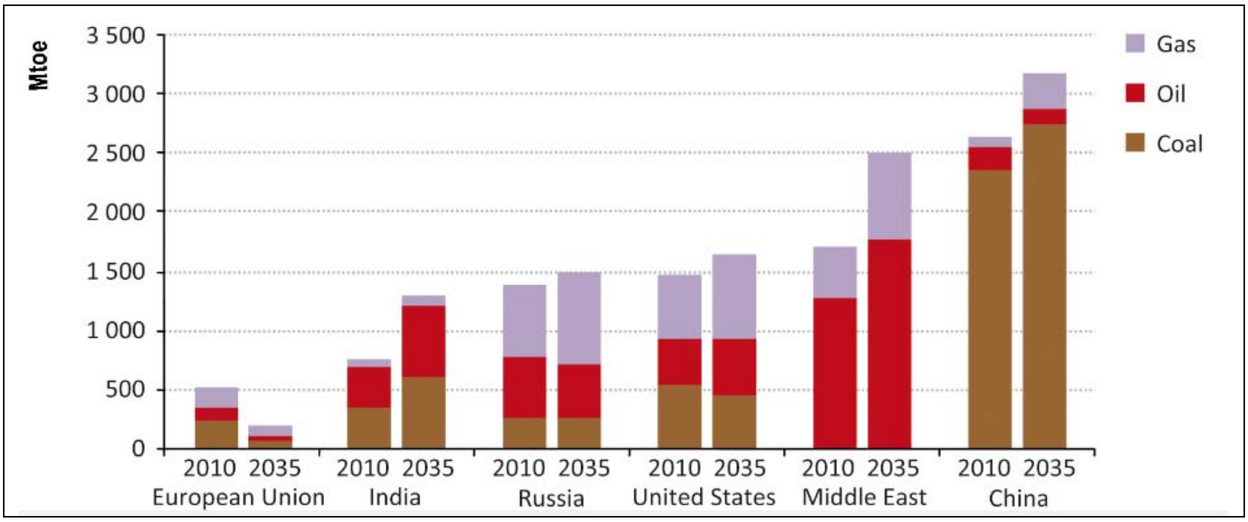
No change expected in the climate policy of "laggard states"

27. There are hopes in some quarters that the availability of shale gas could significantly improve the greenhouse gas balance of a number of countries that have so far played a "laggard" role in international and European climate policy (European Parliament 2012c; 2012b; SCHRAG 2012). Such hopes are based in the first instance on the assumption that shale gas would significantly reduce the use of coal and that the climate balance of shale gas would be substantially better than that of coal (SCHRAG 2012; HELM 2011). Although there is evidence of a reduction in the use of coal in the USA (MILDNER et al. 2012), the climate balance of shale gas (Chapter 4.5) is disputed, uncertain and highly dependent on the technology. Methane emissions from shale gas production are currently the subject of a critical environmental policy discussion in the USA (DRAJEM 2013). Since the justification for the use of shale gas is primarily economic, one cannot exclude the possibility that it will be continued even if the climate balance of shale gas turns out to be less favourable than present knowledge suggests.

In the USA, officially reported CO_2 emissions admittedly showed a marked drop between 2005 and 2011, particularly in the wake of the 2008 recession, but also as a result of the switch of fuels towards gas and renewable energy sources. However, the official energy forecast merely expects to see a stabilisation of energy-induced CO_2 emissions by 2040 with a slight increase (EIA 2013, p. 3; BIANCO et al. 2013, p. 11). Although gas is expected to partially replace coal as a major fuel for power generation (EIA 2013, p. 6), the overall impact would seem to be moderate. Recent political analyses suggest rather that "climate protection remains a minor consideration for the USA" (MILDNER et al. 2012). So it is hardly to be expected that it will seriously get to grips with the problem shift resulting from cheap coal exports (BOERSMA and JOHNSON 2013).

Figure 7

Declining production of fossil fuels in the EU – an international comparison



Source: IEA 2012b, p. 65

And on closer scrutiny, hopes that the unconventional gas deposits in Poland might transform Europe's energy policy in general and the Polish attitude to climate policy in particular (KLUZ 2012; EurActiv 2011; CHMAL 2011; MATTERN 2012), would also seem to be exaggerated. Poland is especially relevant because its veto stance against a high ambition level in European climate policy has given it a leading role among the EU states that take a sceptical attitude to climate protection (FISCHER and GEDEN 2013). Shale gas production enjoys widespread political and public support in Poland, especially with regard to security of supply and ensuring independence from Russia (WYCISZKIEWICZ 2011). However, in the course of 2012 it proved necessary to revise the original estimates of shale gas reserves downwards by a factor of 10 to 100 (see Chapter 3.1). In view of these downward corrections in Poland's shale gas potential, there would seem to be doubt about any substantial fuel shift from coal to gas in the Polish power generation sector. At any rate it would not mean any improvement in energy independence. Thus it is not plausible to expect a fundamental repositioning of Poland's climate policy as a result of the shale gas finds.

Need for supporting action in the event of short-term price shifts

28. In the short term there is a noticeable shift in price relationships between the various energy sources. At present this applies particularly to the drop in prices of imported coal. However, there is unlikely to be a long-term fall in gas prices in Europe (Chapter 3.2). The sections below nevertheless seek to identify the need for action that would arise in the individual sectors in the event of a sharp drop in gas or coal prices.

29. Two different aspects are relevant in the power sector: on the one hand the competitive position of gas and steam turbine (combined cycle) power plants compared with coal-fired power plants, and on the other hand the direct and indirect consequences for the expansion of renewable energy.

Sharply falling gas prices could provide a certain counterweight to the current profitability problems of combined-cycle power stations, the flexibility of which makes them particularly suitable for supplementing the supply of power from renewable energy sources with its rapid and substantial fluctuations. There are, however, more fundamental reasons for these profitability problems. Power plants with high variable costs, such as gas-fired power plants, are being pushed off the market because of falling electricity prices in particular. As the SRU will point out in its statement on energy market design planned for autumn 2013, the main reasons for this are the current surplus of coal-fired base load, the very low price of CO_2 and the rapid growth of renewable energy sources (NICOLOSI 2012, pp. 10 and 13; KRANNER and SHARMA 2013).

Low gas prices do not endanger the further expansion of renewable energy sources as long as the payment model of the Renewable Energy Sources Act *(Erneuerbare-Energien-Gesetz – EEG)* and the in-feed priority for power from renewable energy continue in force. This also applies to other EU countries that have introduced a similar support system (RAGWITZ et al. 2012). However, falling prices for fossil fuel reduce the price of electricity. Falling market prices for electricity automatically increase the EEG surcharge, which is used to refinance the difference in costs between the fixed payment for renewable energy and the market price. Although it is an indicator that can easily be misinterpreted (WEBER et al. 2012, p. 4), the size of this surcharge is currently seen as an indicator of the cost of renewable energy. Thus a falling gas price may indirectly contribute to political measures that curb the expansion of renewable energy in response to the argument of minimising costs.

30. In the mobility sector, falling gas prices could give rise to an increase in the percentage of gas-powered vehicles. An incentive which would reinforce this trend is the EU requirements for reducing the CO_2 emissions of cars and light commercial vehicles, and in future probably heavy goods vehicles as well. Various technical options are available for achieving this goal, for example the use of gas to replace gasoline and diesel fuels (SKINNER et al. 2010; RUMPKE et al. 2011). The CO_2 reduction potential of gas-powered vehicles is limited, however. Sizeable investments in a gas-powered fleet of vehicles could thus prevent alternative investments with greater greenhouse gas reduction potential.

31. The heating market in Germany is already predominantly a natural gas market, which means there is reason to fear that falling gas prices would have a strong direct impact. Falling natural gas prices would be an obstacle to energy efficiency measures (FISCHER 2013). Since thermal insulation leads to rising basic rents, any measures going beyond what can be recovered relatively quickly through reducing running costs easily come up against acceptance barriers. In the event of falling gas prices, the realisable energy cost savings due to extensive energy-saving refurbishment would fall considerably – which in view of fixed public budgets and the resistance outlined above could mean a fall in the refurbishment rate. Thus falling gas prices would endanger the German government's efficiency targets in the heating sector.

32. Thus if the global shale gas situation should result in permanently lower prices for gas or coal, consideration should be given to supporting instruments that avoid negative impacts on the reduction of greenhouse gas emissions and the renewable energy expansion path. In the power sector it is of great importance to avoid linking cost reduction strategies to the level of the EEG surcharge, since a reduction in the market price of electricity would automatically increase the surcharge and thereby slow down the expansion of renewable energy. Another important supporting measure is a distinct CO_2 price signal by the European emissions trading scheme or other instruments. This will only succeed on a sustainable basis with more ambitious EU climate targets for 2020 and 2030.

Negative impacts on innovation and the spread of efficiency measures, e.g. in the heating sector, can only be counteracted by strengthening the existing promotion instruments and the statutory requirements. Suspending or reducing these in the event of falling gas prices would postpone necessary investment in replacements and thereby endanger the achievement of the German government's climate objectives.

33. On the whole, a pro-cyclic response by energy policy to possible price reductions for coal and gas, such as reducing efficiency measures or slowing the pace of renewable energy expansion, would be wrong. Instead consideration should if necessary be given to anti-cyclic supporting measures that further stabilise the transformation of the energy system.

3.4 Synopsis and open questions on shale gas production in the context of the *German Energiewende*

34. On the basis of present knowledge, German shale gas production cannot be expected to have any major influence on natural gas prices in the next few years, since the potential production quantities are small on a global scale and it is also doubtful whether large-scale commercial exploitation is economic in any case. Thus domestic shale gas cannot be expected to have any positive effect on the competitive position of natural gas compared with other fossil fuels. Instead, price effects of global shale gas production (to date mainly in North America) give cause to fear that the transformation of the energy system may slow down. However, many of the assumptions made to date are highly speculative, because a number of questions still remain unanswered. These include:

- How great is the real shale gas potential in Germany and Europe that can be economically exploited subject to strict environmental requirements and given precautionary observance of excluded areas? How long would it take to establish commercial production of shale gas in Europe? The longer the lead times, the less suitable shale gas is for playing a bridging role in the transformation of the energy system.
- How will production rates, production costs and total production of shale gas in the USA and other regions with large suspected reserves (e.g. China) on the one hand and global demand on the other hand develop, and what impact will they have as a result on natural gas prices? There are wide variations in the relevant estimates. What export policy decisions will these (future) producing countries take?
- How will conventional production of natural gas, e.g. in Russia, Norway and Poland, and the transport and infrastructure costs for LNG develop, and how will this influence natural gas prices?
- What empirical assessment can be made of the connection between the expected production of shale gas and the development of gas prices? There is a conflict between the condition for realising shale gas production in Germany – distinctly higher natural gas prices – and the effects it is hoped this will bring, namely falling natural gas prices and consequently competitive advantages for this transitional technology.

The fear that the "shale gas revolution" in the USA will seriously alter the competitive position of the European economy does not stand up to closer examination. The shale gas boom in the USA does not provide any valid reasons for a revision of the European climate and energy policy. Published statements frequently fail to communicate adequately the very great uncertainties about future market developments, and often focus only on the highly optimistic variants. Ultimately there is a risk that misguided policy decisions might be taken on the basis of such biased interpretations.

The central conclusion of this analysis to date is that German shale gas will not bring any benefits for the transformation of the energy system, and that society can therefore have no overriding interest in promoting this source of energy. Even if no large-scale production becomes established in Germany, the SRU recommends regular reviews and ongoing development of supporting measures to minimise the risk that global exploitation of shale gas as an additional resource could lead to an increase in total emissions. It is also necessary to prevent a situation where falling fossil fuel prices as a result of shale gas production slow down the expansion of renewable energy or the implementation of energy efficiency measures.

4 Environmental impacts and risks

35. Exploration and extraction of energy sources always represent an encroachment on nature and the environment. Shale gas production involves environmental pressures and risks both in the immediate vicinity of the production facilities and underground. The process begins with exploration of the reservoir by means of deep boreholes. If the results are promising, this is followed by the erection of the production equipment. After the end of production, the technical facilities are dismantled. The construction of well sites requires development of the site (roads and infrastructure) and involves surface sealing. This inevitably involves land use and encroachments on nature and landscape. Operation of the gas production facilities gives rise to noise and pollutant emissions. There is also the risk of contamination of soil and groundwater resulting from formation water and the use of hazardous chemicals (for fundamental aspects, see Chapter 2).

On the way to the gas-bearing rock strata, the deep wells necessary for shale gas production pass through the subsurface groundwater strata, saline aquifers and the barrier layers separating them. Before gas production, the wells are sealed in accordance with codes of practice laid down in the *Länder* ordinances for deep drilling, among other things to avoid hydraulic short-circuits. In shale gas exploration and production, the sedimentary strata of the gas reservoirs have to be broken up over large areas to create artificial flow routes for the gas. This measure is non-reversible. It requires the use of fracking fluids, which can have unintentional negative effects both at the surface and underground. The shale gas produced is accompanied by formation water, which depending on the hydrogeological conditions may contain large concentrations of salts, heavy metals, volatile components and radioactive substances. These substances are toxic to humans and the environment and must therefore not be allowed to enter the groundwater, surface water or the soil.

In addition to its main component, methane, the shale gas produced contains other volatile hydrocarbons. In conventional production of natural gas, diffuse gas losses from the production facilities are reduced by technical precautions, and these must similarly be used in unconventional production.

Figure 8 provides an overview of the individual process steps in the production of shale gas and possible environmental impacts; the latter may show great variations in probability of occurrence, intensity and duration.

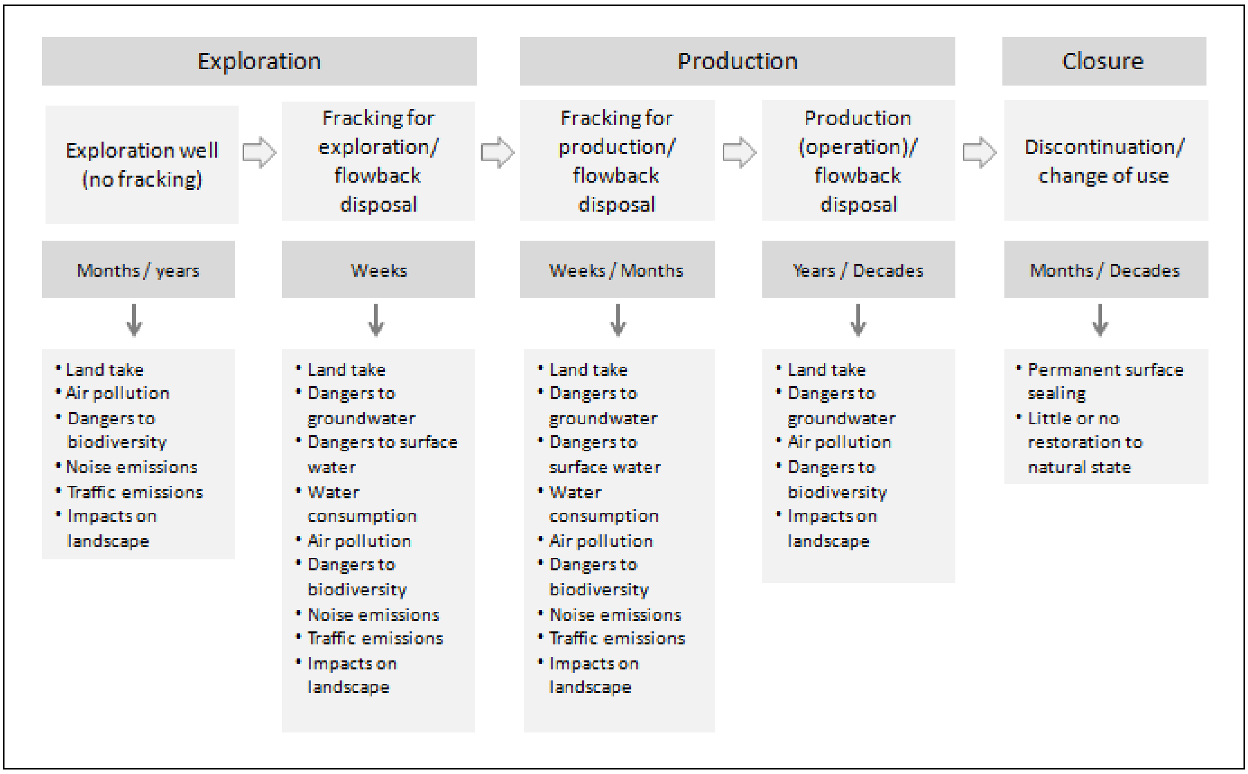
As a guide to assessing the impacts of unconventional shale gas production on nature and the environment and the risks involved, we look below at the possible adverse effects on the various legally protected goods: water and health, air, soil, biodiversity and climate.

4.1 Water and health

36. The present debate about unconventional shale gas production in Germany centres round fears about the risks to health and the environment. On the one hand, formation water with a high brine content is transported to the surface from the rock, and hydrocarbons are released. On the other hand, unconventional production involves injecting chemicals into the rock formation as a technical auxiliary. The public is concerned in particular about the risk of adverse effects on groundwater near the surface. Groundwater conservation is of special importance, because near-surface groundwater may be used for producing drinking water. At the same time it

Figure 8

Impacts and risks of shale gas production on nature and the environment



SRU/Statement No. 18–2013/Fig. 8

is closely connected with terrestrial ecosystems and surface waters. And it also constitutes a habitat in its own right. Contamination due to substance inputs is very difficult – if not impossible – to remedy. Application of the precautionary principle is therefore of special importance when it comes to protecting the groundwater (BARTEL et al. 2010; SRU 1998).

The following section first looks at aspects of fracking that relate to water conservation. These include on the one hand the water consumption for fracking and on the other hand the impacts of possible inputs of critical substances into the soil or groundwater (EWEN et al. 2012; MEINERS et al. 2012). The contamination paths on or below the surface are directly related to health and the environment and can be observed and documented by monitoring. The processes in deep horizons are more difficult to register and assess, but in view of their depth they are better protected by geological barriers.

4.1.1 Water consumption

37. In general, fracking processes for shale gas production involve using large quantities of water. The water is needed to break up the rock formation and create artificial flow routes for the gas. Over a period of several hours, the water quantities needed for fracking are drawn from surface waters, process water wells or the local drinking water system, mixed with proppants and chemicals to form fracking fluids, and injected into the rock formation through the horizontal well. From every well site it is possible to drill several main wells into the gas-bearing sedimentary rocks. From each of these it is possible to drill several horizontal wells, which may be up to 1.5 km long (Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen 2012; EWEN et al. 2012).

EWEN et al. (2012) put the fracking fluid requirements per well with ten fracking processes at 1,600 m^3 each. However, the quantity of fracking fluid used is highly dependent on regional conditions, for example the depth of the gas deposit and the material properties of the rock formation (EPA 2011a). In argillaceous shales it may be necessary to use up to 5,000 m^3 per fracking process to extract shale gas (BGR 2012). In the USA, shale gas production uses an average fluid volume of 11,400 m^3 for a horizontal well (EPA 2011a).

Compared with the total amount of water available in Germany, the quantities needed for fracking are very small. However, since these are always local operations with very large local water requirements over a short period, it is necessary to investigate the consequences of such water extraction at each individual site. For this purpose it will be necessary to assess the regional conditions for water use and the groundwater recharge and to identify the aquifers that are in contact with the surface. This information must be included in the authorities' decision on the planned water extraction.

4.1.2 Near-surface contamination

38. Contamination of bodies of water near the surface may take place during handling of fracking fluids if accidents occur when delivering component concentrates or mixing fracking fluids ready for use. Near-surface leaks in the well casing can also cause contamination. Releases of flowback during collection and transport may also contaminate the soil, near-surface groundwater strata or surface waters. Other contamination routes involve subsurface pathways (Section 4.1.3).

Although fracking fluids consist primarily of water (> 95%), the large volume of fluid needed in shale gas production can result in several 100 m^3 of chemicals being injected into the rock formation (EPA 2011a; EWEN et al. 2012). Depending on the geological properties of the target rock, the chemicals added may serve as friction reducers, gelling agents, thickeners, clay stabilizers, biocides, solubilizers, breakers, surfactants, pH adjusters, crosslinkers or crosslinking inhibitors, and as foam retardants (see Table 2). Some of these substances possess properties which present problems for health and the environment. For many components, however, the relevant information is not available.

39. Flowback (formation water containing fracking fluid components) is collected at the surface with the natural gas. As a rule it is heavily contaminated with dissolved salts, heavy metals and arsenic, and natural radioactive substances and hydrocarbons. The hydrocarbons are natural components of the fuel, but as volatile organic compounds (VOC) they are mobile and also find their way into the air. Flowback is generally problematic in terms of human and environmental toxicology. It is common practice in oil and gas production to transport formation water in overland pipelines. However, cases of leaks and soil contamination are not unknown here. In the Völkersen gas field in Lower Saxony, an elevated concentration of benzene was detected in the soil around a formation water pipeline in December 2011. The drinking water in the region was not affected, however, and no contamination was found in samples from private wells either. Benzene contamination was nevertheless found in near-surface groundwater (RWE Dea 2013). Benzene has also been identified as the relevant soil contaminant in other cases of faulty production water pipelines (e.g. Nienhagen oil field, Steyerberg, Wardböhmen) ("Lagerstättenwasserleitungen – LBEG schließt Überprüfung von Eignungsnachweisen ab", LBEG press release of 7 May 2012). It is therefore necessary to ensure continuous surveillance of pipeline integrity by means of adequate monitoring.

Health protection

40. The great importance of human health as a protected asset is reflected in the intensity of the debate about drinking water contamination by fracking fluids (Gegen Gasbohren 2012; Deutscher Bundestag 2012). The following section gives an outline of the toxicological assessment of fracking fluids and a summary of the contamination of drinking water with pollutants from natural gas production.

On the way to safe use of chemicals it is necessary to define the conditions under which this is possible. The relevant test follows a procedure which collects and collates information of varying quality and is outlined below.

In general, assessment of the risk of exposure to chemical stressors is performed in accordance with the Risk Assessment Paradigm of the National Research Council of the USA; this requires two separate analyses to be performed (risk identification including dose-effect relationship, and exposure determination) (NRC 1993). To identify the risk one needs to know the most sensitive end points of an effect on health, and also to determine and assess the (long-term) exposure scenarios. To assess the health risk, for example, it is necessary to determine data on the duration of the quantitative and qualitative contamination of drinking water and its distribution in time and space, including in the air if appropriate. These findings then have to be correlated either with information from empirical studies of the exposed population or workforce, or with epidemiological studies, and evaluated. However, since there is a lack of information about exposure to chemicals used in fracking, it is not possible to make a conclusive risk assessment, and special attention must therefore be paid to the precautionary principle.

The following section gives a summary of the assessment of chemical additives.

Assessment of chemical additives

41. Chemical additives are assessed more or less in line with the paradigm mentioned above. The first step is to classify the hazardous characteristics of the chemicals on the basis of their properties and effects in standard test systems. At this stage in the assessment it is not yet significant what quantitative contamination (might) occur at the workplace or in environmental media if these substances are used. The information on classification of chemical additives used in Germany in line with the CLP Regulation (EC) No. 1272/2008 (CLP – Classification, Labelling and Packaging) was compiled by EWERS et al. (2012), MEINERS et al. (2012) and SCHMITT-JANSEN et al. (2012). For example, out of 69 chemicals used, 31 proved to be acutely toxic, 9 carcinogenic, 2 teratogenic, 4 probably toxic to reproduction, and 13 substances were acutely and chronically dangerous to water (MEINERS et al. 2012). In a study conducted by the Tyndall Centre Manchester for the United Kingdom, 75 out of 260 additives investigated were classified as unsafe (17 ecotoxic, 38 toxic, 8 carcinogenic to humans, 7 mutagenic and 5 toxic to reproduction) (BRODERICK et al. 2011).

42. The diversity of the substances used is reflected in studies of the fracking fluids used in the USA. Between 2005 and 2009, some 2,500 different fluid mixtures were used in the USA. These contained 750 chemicals and other components. Methanol, isopropanol, 2-butoxyethanol and ethylene glycol were the substances most frequently used. Thirteen different carcinogenic substances were used in 95 products. Pollutants of the BTEX group – the aromatic hydrocarbons benzene (B), toluene (T), ethyl benzene (E) and xylenes (X, or dimethyl benzenes according to IUPAC nomenclature) – were present in 60 products (WAXMAN et al. 2011). On the basis of published data the U.S. EPA has identified some 1,100 chemicals as potential components of fracking fluids (EPA 2011a). One cannot exclude the possibility that some of the many substances used for fracking in the USA will be of interest for German projects.

43. As well as assessing the hazardous nature of the individual chemicals, it is also necessary to assess the actual mixture or fracking fluid as used at the various sites. As a result of dilution, the ready-to-use fracking fluids or fluid mixtures contain such small concentrations of the hazardous components that as a rule they are not classified as hazardous under the CLP Regulation (EWERS et al. 2012; BRODERICK et al. 2011). The fluid components are probably of minor importance when it comes to the dangerous properties of the flowback. Nevertheless, the assessment of the largely unknown reaction products of the fluid components is a completely open question.

44. However, on the basis of limit, guide and maximum values under water legislation, almost all the fluid mixtures used in Germany are potentially toxic to humans and the environment (MEINERS et al. 2012; SCHMITT-JANSEN et al. 2012). Since there is a lack of information on possible exposure, the concentrations of the substances in the fluid mixtures were used for assessment purposes. This was also true of a newly developed fracking fluid, which was due in particular to the high biocide content (EWERS et al. 2012; SCHMITT-JANSEN et al. 2012; MEINERS et al. 2012). Although describing the hazardous characteristics of chemical substances is an important step in the identification of risks that may be associated with the use of chemical substances and possible inadvertent uptake, it is not sufficient in itself. Thus hazard identification and characterisation on its own does not go far enough for an (eco-)toxicological assessment of the resulting risk (probability of occurrence of a specific adverse effect). This would call for the collection of information on the actual contamination situation and empirical studies on health and environmental stability. In this respect there is a lack of reliable data. This makes it all the more relevant to develop and implement safety precautions against local contamination in the event of emergency situations.

Such situations may include accidents involving damage to the containers in which the chemicals are transported or stored. Leaks may also occur when connecting equipment or if material is damaged in the well, resulting in failure of the sealing function. Long-term effectiveness of the safety measures should also be subject to regular monitoring during the operating phase. Since some substances may be persistent in the soil and not very mobile, compulsory monitoring must include soils which can perform a buffer function.

45. In view of the lack of information on possible exposure, it is difficult to undertake a more extensive risk assessment of the fracking fluids used. EWERS et al. (2012) approached this problem by assessing three different levels of dilution of the fracking fluids. For most substances, the middle and maximum dilution levels did not exceed the limit values of the Drinking Water Ordinance and the guide values based on human toxicology. For assessing substances on which there was little or no information they fell back on the health guide value proposed for unknown substances by the German Drinking Water Commission and the Federal Environment Agency ("*gesundheitlicher Orientierungswert*" – GOW; also known as "precautionary value"; = 0.0003 mg/l). Even at the maximum dilution level the concentrations exceeded the health guide value, though in the opinion of EWERS et al. (op. cit.) that value is definitely on the low side. EWERS et al. (2012), MEINERS et al. (2012) and SCHMITT-JANSEN et al. (2012) complain that it was not possible to uniquely identify all chemicals used in the fracking fluids with the aid of a CAS number (CAS – Chemical Abstracts Service). As well as a lack of full details of the identity of substances, there was also a lack of data on their effects, especially their potential toxicity to the environment, or such information was not accessible (op. cit.).

46. The current tendency in fracking fluid formulations is to use fewer chemical additives and fewer hazardous substances (WEG a, no date). Voluntary undertakings by individual companies prohibit the use of additives with a water hazard class greater than 1 (Wintershall, no date).

An information platform run by the Oil and Gas Production Industry Association (WEG) provides information about the composition of fracking fluids used in Germany since 2010 (WEG b, no date). This is designed to improve transparency and forms an important basis for technical dialogue. However, the information is not sufficient for extensive assessment. Neither are data on fracking operations carried out before 2010 freely available, although they would be of great importance for an assessment of long-term effects. For this purpose there is a need for evaluation of the chemicals used and the geological framework conditions, and also for documentation of the monitoring measures performed.

Technical authorities, scientists and the public must be put in a position to assess the risks of release into the environment, and to this end they need the relevant information. The transparency aspect is particularly important for the general public. Where conflicts exist with the preservation of trade and business secrets, the relevant provisions of the Environmental Information Act should apply.

There is also a need to clarify whether the additives intended for introduction into reservoirs for the production of shale gas are adequately covered in the REACH Regulation (EC) No. 1907/2006. The same applies to the fluid mixtures used. The REACH Regulation applies to chemical substances depending on their production or import volume (> 1 t/a) and makes them subject to certain testing requirements. These requirements are not very extensive for chemical additives that are only produced in small quantities, and are therefore not sufficient for a sound and well-founded assessment of the risks of using fracking fluids. A possible procedure for bridging information deficits within REACH is a "read-across check". On the assumption that structurally similar chemical substances have similar impacts, this at least permits a certain indication of the potential risk. Substances which are intended to remain in the gas reservoirs but whose long-term effects are not known must therefore at least undergo such a read-across check. A check should also be made to see whether they can be replaced by less dangerous substances.

Contamination of drinking water and groundwater

47. If fracking fluids or flowback escape at the surface, this can cause contamination of the groundwater. In Germany individual data are available on groundwater monitoring and associated drinking water checks carried out in 2008 in connection with the three fracking operations performed to date for shale gas production (Lower Saxony, Damme region). At six positions in the vicinity of the wells the groundwater monitoring programme in Damme took samples from two groundwater measuring stations at shallow depths (8 to 25 m) and at greater depths (25 to 42 m). The two biocidal chemicals 5-chloro-2-methyl-2*H*-isothiazol (CIT) and 2-methyl-2*H*-isothiazol-3-on (MIT) and an ammonia salt were selected as analytical parameters capable of specific and sensitive detection of inadvertent contamination for monitoring purposes. This measuring programme did not find any amounts above the analytical detection limits for the substances under investigation in any of the samples or in the drinking water of the water supply utilities (ROSENWINKEL et al. 2012b; GUNZELMANN 2012).

48. Reports of drinking water contamination in the USA immediately after fracking operations typically relate to high iron concentrations, sometimes in combination with manganese and arsenic contamination. Other reports describe sudden changes in the colour of drinking water (red, brown, grey) and cloudiness shortly after drilling and fracking activities.

Hydrocarbons such as methane, benzene and toluene and the metals strontium and barium have also been detected in the water (BOYER et al. 2012). Reports also mention drinking water contamination in the region of the Marcellus shale gas field in Pennsylvania and in the region of the Barnett shale gas deposit in Texas (BROOMFIELD 2012; EPA 2012b; EWEN et al. 2012; GROAT and GRIMSHAW 2012; MEINERS et al. 2012). No clear connection with the fracking activities was shown to exist.

In 2010 und 2011 further investigations were made in the Marcellus shale gas field by taking a total of 233 samples from drinking water wells in rural regions. The aim was to investigate the effects of gas production activities on drinking water in the immediate vicinity (BOYER et al. 2012). Neither of the two programmes revealed any statistically significant change in water quality parameters as a result of the drilling and fracking activities. Thus an explanation has yet to be found for the reported cases of contamination, and they may be due to completely independent causes, e.g. inadequate casing of drinking water wells. However, this does not put an end to the controversial discussion about the possibility of fracking fluids or saline deep water rising up into higher formations (e.g. ENGELDER 2012; WARNER et al. 2012a; 2012b).

The U.S. EPA nevertheless sees a connection between fracking activities and contamination of groundwater in the immediate vicinity of the Pavillion shale gas field in Wyoming, though it has stressed the need for further research (DIGIULIO et al. 2011; TOLLEFSON 2012). The gas field there is a special situation, since the barrier layer between groundwater-bearing strata and the gas reservoir rock formations is very thin.

49. In Germany not only the drinking water supply infrastructure and the geological formations in the gas fields, but also the technical framework conditions that can be assumed to apply to the production of shale gas are hardly comparable to the situation in the USA. Thus the extent to which experience in the USA can be transferred is limited. However there are hardly any studies available for Germany of near-surface groundwater bodies close to drilling fields where fracking has been carried out. This also applies to energy sources other than shale gas (e.g. geothermal energy). There is therefore a need for systematic groundwater monitoring to ensure the safety of drilling and fracking activities.

4.1.3 Subsurface contamination

50. Fracking can contaminate the groundwater via subterranean paths as well. Such contamination is largely irreversible and difficult to contain. The following section therefore looks at a number of questions: What protection requirements exist? What are the geological framework conditions? What technical intervention is relevant? How are the scale and probability of occurrence of the contamination paths assessed? What information deficits need to be remedied?

51. Reservoirs for tight gas, shale gas and coal bed methane are located at great depths (Table 1) and are thus far removed from the aquifers that can be used for abstracting drinking water (BGR 2012). As a rule, the rock strata that separate them form robust barriers between natural gas production and groundwater utilisation.

Fracking technology creates artificial paths for the natural gas via (multilateral) horizontal wells and taps the deposits over a large area. In order to reach reservoirs at great depths, wells are drilled through near-surface groundwater bodies and deep water bearing strata (ROSENWINKEL et al. 2012b; BGR 2012). Some deep water sources are connected with thermal springs or used for mineral water extraction, and therefore need to be given large-scale protection from accidental substance inputs. The extent to which quality monitoring of such deep water is necessary and practicable should be investigated.

52. One cannot rule out the possibility that both fracking fluids and formation water may find their way directly into groundwater bearing strata as a result of leaks in gas production wells and contaminate the groundwater there. The speed with which a leak is detected and plugged is important. In the case of minor leaks which do not necessarily lead to a drop in pressure, this can take some time. This means there is a need for continuous monitoring of the integrity of the well. It is also advisable to monitor the groundwater body around the well sites. To this end it is probably necessary to drill observation wells (EWEN et al. 2012; UBA 2011).

53. After the fracking fluids have been forced into the gas formation rock, only a small proportion can be recovered as a mixture of formation water and fracking fluids (flowback). The proportion of fracking fluid recovered is put at 8% (ROSENWINKEL et al. 2012a) or 20% (EWEN et al. 2012). A survey of companies in Texas revealed a range from 20 to 80%. These figures are also closely scrutinised by the authors of the study (GROAT and GRIMSHAW 2012). In studies at Damme in Lower Saxony the proportion of fracking fluid in the flowback was initially around 100%, but then fell off very quickly and within less than 8 weeks had fallen below 10% (see Fig. 9). Thus the greater part of the fracking fluids initially remains in the rock formation fissures.

In this study the chloride concentration was used as an indicator to permit conclusions about the proportion of formation water, though this does not take account of any reactions in the flowback. In view of the lack of data and outstanding questions about the right indicator for detecting fracking fluid in the flowback, it is difficult to say anything about the substance balances. There is a need for further studies of flowback composition as a basis for substance flow management.

54. The possibility of formation water migrating into aquifers that are capable of being used for groundwater extraction is determined by local geological paths and by legacy wells or mining activities (EWEN et al. 2012; MEINERS et al. 2012). Formation water can rise up the well as a result of casing element failure (see Item 11), serious disturbances (hydraulic windows) or uncontrolled factures, which may establish a connection with a hydraulic element. Depending on the permeability of the rocks, it is also possible for formation water to rise along pressure gradients in rock formations and overlying caprocks. This may result in diffuse inputs into the groundwater.

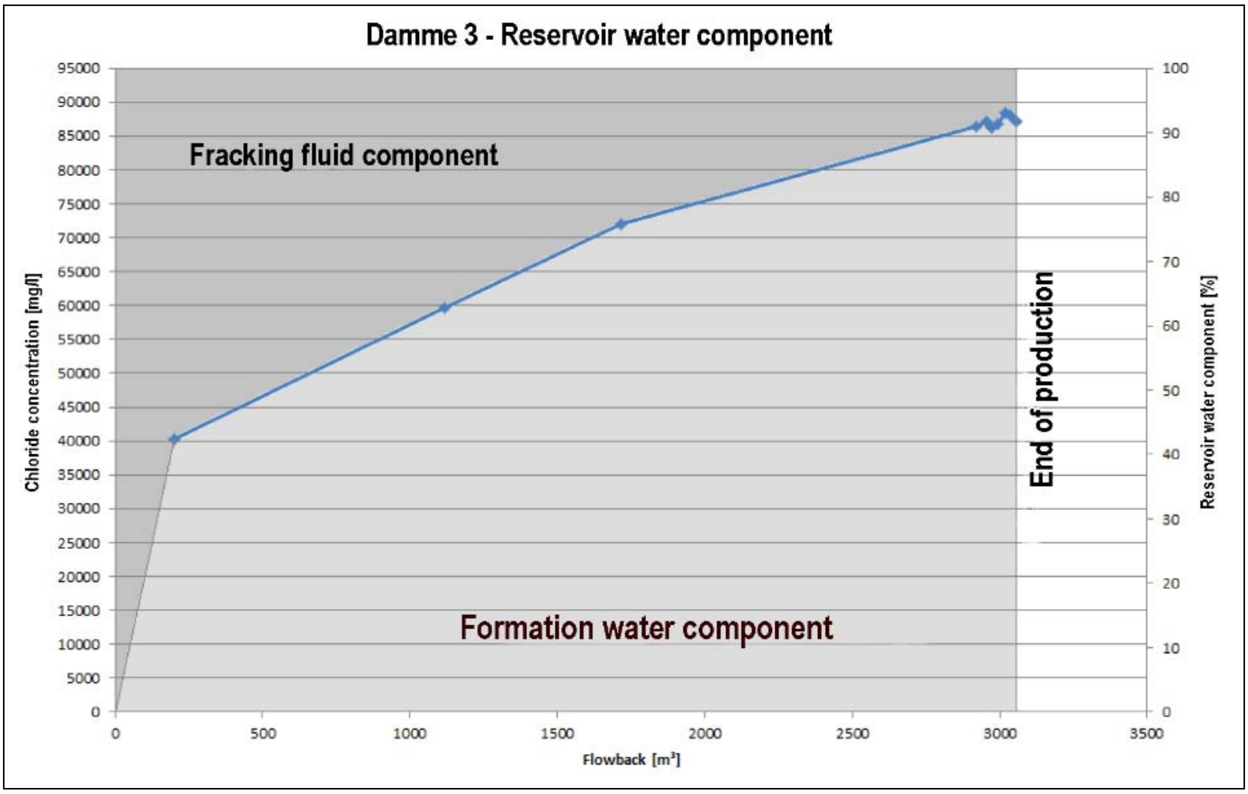
In 2011 the "InfoDialog Fracking" set up a working group of experts from various relevant technical disciplines (neutral expert group). The criteria for selecting the experts were scientific expertise and independence of the natural gas industry, especially independence of ExxonMobil, the company that initiated the dialogue and provided the financial resources for it. The aim was independent appraisal of existing knowledge, critical commentary and the publication of reports. The neutral expert group in the "InfoDialog Fracking" presented model calculations which showed that the fracking fluids could only rise about 50 m, even on the basis of conservative assumptions (EWEN et al. 2012). In the case of coalbed, horizontal transport within formation water would be possible. Thus depending on geological conditions, horizontal movement of pollutant plumes could reach about 20 m a year, which would permit a long-term range running into kilometres (op. cit.).

55. Reliable models that describe the possible routes of contaminated water depend on detailed information about the geological and hydrogeological conditions. This also includes information about the hydrochemical situation and the target formations, and information about existing legacy wells and disturbances including their hydraulic function. There is an urgent need for a publicly accessible register to bring together all the existing data on boreholes and geological data from the investigations conducted during the long history of drilling.

The responsible technical authorities need to be in or be put in a position to collect this technical knowledge deriving from the monitoring and geological recording of all deep drilling in the region and to add to it and maintain it over a period of decades. This must be ensured both across authorities and across federal states.

Figure 9

Flowback Damme 3 –
Salt concentration curve and conclusions about formation water concentration



Source: ROSENWINKEL et al. 2012b

Steps must also be taken to ensure that the licensing authorities, scientists and the public have the necessary data for assessing the risks. A transparent approach to the data, which includes publication in scientific periodicals, presentation at public forums and publication in freely accessible databases, is essential for a qualified discussion.

4.1.4 Flowback disposal

56. The flowback is contaminated with critical substances, such as salts, iron, manganese, arsenic, hydrocarbons and natural radioactive substances, and also, to some extent, fracking fluids. It is collected in the production facilities and processed in hydrocyclones, settling tanks for phase separation and filters to remove sludge and oil before being sent for disposal. Even after processing, the flowback still contains sizeable concentrations of the substances mentioned. In Germany the usual practice is to use surface pipelines or road tankers to transport the formation water and flowback from conventional wells to disposal wells, where they are pumped into deep rock strata (ROSENWINKEL et al. 2012b). As a result of various kinds of leaks, the contaminated water may escape at some point along the transport route between the production facility and the deep disposal well, leading to contamination of the soil and surface water.

Before disposal practices for formation water from conventional oil and gas production can be transferred to shale gas production, there should be a systematic compilation and evaluation of the many years' experience with injection. Well location, drilling depth, rock, quantities, monitoring and proof of permanent seal integrity are preconditions for the assumption that injection can be a socially acceptable disposal path.

The main focus should however be on avoiding the problem: Research and development work on optimising drilling and fracking operations, water-less fracking operations, minimised use of chemicals and use of less toxic substances (MÖHRING 2013) all focus on the beginning of the process chain. Processing and reuse of flowback are crucial adjustment options at the end of the process. Developments on the recycling front in the USA (see RASSENFOSS 2011, for example) can serve as a starting point for further research. This is one of the essential points that should be investigated in pilot projects.

57. It would seem that in the past the mining authorities have not classified the discharging of formation water from hydrocarbon reservoirs into disposal wells as requiring a permit under water legislation (MEINERS et al. 2012, p. B123). This is despite the fact that the injection of flowback can be expected to require an operating plan permit and, as a general rule, a permit under water law (op. cit., p. B125). Some people even take the view that injection even into deep rock formations and groundwater bearing strata is basically not permissible under water law (SCHINK 2013, p. 44). At any rate the water authorities should be involved in the authorisation procedure.

In the interests of the precautionary principle, the following aspects should be clarified in advance for any injection of formation water and flowback, in a procedure in which the water authority is involved:

- geological characteristics of the disposal well location (depth, casing, thicknesses, uptake capacity, earthquake risk);
- characteristics of the gas reservoir with regard to formation water, including its composition, the typical analytes as subsequent indicator, and the probable quantities involved;
- assessment of transport facilities (road tanker versus pipeline);
- competing uses (both applied for and planned);
- any protected areas that might be affected, whether planned or already established.

4.1.5 Summary of deficits relating to water conservation and health protection

Access to geological data and information

58. A decisive factor in the protection of drinking water and groundwater is whether a gas reservoir's basic suitability for gas production is correctly assessed, and whether adequate account is taken of the protection interests and of existing and future plans for water use. At present the quality of access to the facts and figures by the technical authorities involved and the public varies considerably. There is an urgent need for a publicly accessible register to bring together all the existing data on boreholes and geological data from the investigations conducted during the long history of drilling.

Information on the hydrochemical situation and about existing legacy wells and incidents, including their hydraulic function, must be available to the actors. The responsible technical authorities need to be in or be put in a position to collect this technical knowledge deriving from the monitoring and geological recording of all deep drilling in the region, and to add to it and maintain it over a period of decades. This must be ensured both across authorities and across federal states.

Steps must be taken to ensure that the licensing authorities and the public have all data necessary for assessing the risks.

Assessment of chemical additives

59. Unique identification on the basis of a CAS number was not possible for all the chemical additives used in fracking fluids. There is also a lack of information needed for assessing the risks to health and the environment that arise in the event of accidental inputs into groundwater and drinking water. Hazard assessment on the basis of the CLP Regulation is only a first step and is no substitute for an (eco-)toxicological assessment of the risk.

Decisions on whether to use a chemical should not only be made on technical grounds, but should also take account of factors relating to water conservation and protection of health and the environment. To this end it is necessary to have information about the behaviour and whereabouts of the chemicals both above ground and below the surface. In the absence of information on possible contamination, adequate account should be taken of the precautionary principle.

Steps should also be taken to ensure that additives intended for introduction into reservoirs for unconventional production of natural gas are adequately covered by the REACH Regulation. The same applies to the fluid mixtures used.

Collecting, transferring and transporting contaminated water

60. The flowback has to be collected and taken away. Leaks and soil contamination are known to occur during transport of formation water in overland pipelines as practised in oil and gas production (Item 39). Some of the contaminants, such as benzene or brine components, persist in the soil and may lead to contamination of near-surface groundwater. There is therefore a need for adequate and continuous monitoring of the pipeline systems to provide positive evidence of technical safety.

Technical safety and the integrity of hydraulic seals

61. To date no contamination of the groundwater aquifers investigated has been found in connection with fracking operations under exploration projects in Germany. However, in view of the sporadic nature of the measuring programmes, such data can only be regarded as an indication, and not as sufficient evidence of technical safety. The integrity of hydraulic sealing must cover all process stages and be ensured over a long period – including for abandoned and plugged boreholes. Monitoring requirements must be reviewed to ensure they are suitable for protecting drinking water and groundwater.

Medium and long-term impacts of large-scale development

62. The new technology for large-scale development of gas reservoirs is potentially capable of altering the physico-chemical conditions in the target formations. Changes in the gas-bearing strata might also have repercussions on the formation water and any secondary products of fracking additives in the flowback. One question still unresolved at present is what medium and long-term level of protection would be appropriate for deep groundwater, for example, and what monitoring strategies will ensure achievement of the objectives. Clarification is also needed as early as possible regarding other planned or foreseeable uses of deep saline groundwater aquifers, e.g. deep geothermal energy, or possible communication with thermal waters, in order to decide whether the relevant saline aquifers should remain untouched.

4.2 Air

63. Unconventional gas production involves emissions of particulates, diesel exhaust fumes, VOC and methane (EPA 2011a; EWEN et al. 2012). The following sections deal explicitly with methane and VOC releases only.

Contamination with methane

64. During fracking operations there is the possibility that increased quantities of the climate-relevant gas methane (Chapter 4.5) may find their way to the surface or into the groundwater. Methane extracted with formation water can theoretically ignite. In addition to the leaks already mentioned in the cementation of boreholes and disturbance zones, releases of methane may also be due to leaks in pipelines (OSBORN et al. 2011; EWEN et al. 2012).

The main methane intake path for humans and animals is respiration. The quantity taken into the body is breathed out again unchanged within a short time. High methane concentrations in the air (30 percent or more by volume) lead to oxygen displacement which results in deficiency symptoms and adverse effects on the central nervous system. Methane is thus an asphyxiating gas. However, the probability of such high methane concentrations occurring in the immediate vicinity of gas production facilities is very low. No substance-specific adverse effects are known in the event of chronic exposure.

Apart from the aspect of health risks, the climate relevance of methane is important, so releases of methane should be avoided as far as possible and reliable surveillance should be ensured by appropriate monitoring. Since methane may originate from numerous sources, including the soil, it is important to ascertain a baseline for the normal background level before the fracking operations, so that the monitoring system can use this as a guide for detecting any rising methane. It is therefore advisable to start methane monitoring before the actual fracking operations (see also EWEN et al. 2012).

Contamination with volatile organic compounds

65. VOCs occur naturally in natural gas, which means that oil and gas production facilities are important emitters of VOC. VOC emissions, especially BTEX, are currently the subject of controversial discussion in the USA as a possible health risk of unconventional gas production. Studies at various sites indicate increased air pollution (e.g. EPA 2012a; Wolf Eagle Environmental 2009; GROAT and GRIMSHAW 2012), though there are great variations in the air pollution found in the various gas production fields. In one case unconventional gas production was identified as the primary source of VOC contamination, in other cases the contribution due to traffic was considerably higher than that of gas production (GROAT and GRIMSHAW 2012). Contamination of the air with VOCs is basically very likely in the immediate vicinity of gas treatment plants and compressor installations.

In an epidemiological study in the town of Dish (Texas, USA) on internal exposure of the population to VOC, no correlation was found between shale gas production and VOC emissions. The blood and urine samples of people living in the immediate vicinity of gas production facilities did not show any increased VOC levels (Texas Department of State Health Services 2010). By contrast, McKENZIE et al. (2012) found evidence of a connection between the proximity of the home to a production facility and increased exposure of the population to hydrocarbons, and concluded that this meant an increased risk of cancer. However, the authors pointed out that these findings needed further verification.

In general, there are a number of open questions in the USA regarding VOC contamination due to fracking and its contribution to health risks.

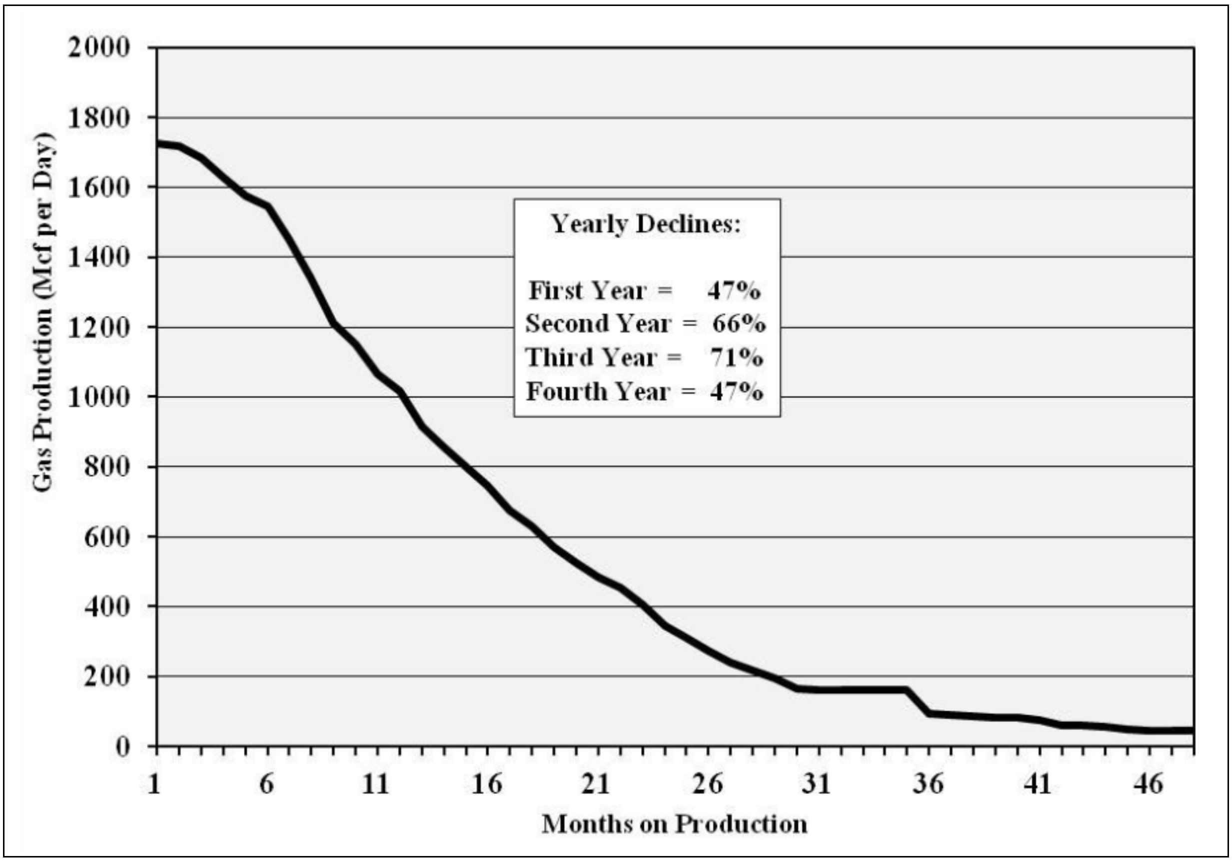
66. State-of-the-art drilling (and production) facilities in Germany are basically closed systems in which the solid, liquid and gaseous components of the flowback are separated in separators. The various components then undergo appropriate further processing or are disposed of. The requirements are laid down, for example, in the deep drilling ordinances (BVOT) of the federal states, e.g. Section 33 of the Lower Saxony BVOT, and in the states' technical rules for handling substances dangerous to water (ordinances on facilities for handling substances dangerous to water and on specialist enterprises (Facilities Ordinance – VAwS)). The question of what technical equipment is used in the individual case depends on the specific processes involved and the characteristics of the medium produced (personal communication by Dr. Hans-Joachim Uth, 13 March 2013).

4.3 Soil and land use

67. Development of unconventional reservoirs and the production of natural gas on a significant scale call for the establishment of numerous well sites and therefore always involve land use. Each well site requires between about 2 (SCHNEBLE et al. 2012) and 3.6 hectares (BROOMFIELD 2012) of land, depending on the drilling method and the phase in question (exploration, production). In addition to the actual well site, which is sealed, this area may include storage and parking spaces, access roads, gas and fluid pipelines and green peripheral areas. About 1.4% of the area above a shale gas reservoir is necessary to make full use of it (BROOMFIELD 2012).

Figure 10

Production rates in the Marcellus shale gas field (eastern North America)



Source: HUGHES 2013, p. 65

Experience in the USA shows that the gas quantities produced per well start with a maximum and fall sharply within a few years (COOK and CHARPENTIER 2010). An example of such a curve is shown in Figure 10. This means that to maintain a constant production quantity it is constantly necessary to develop new well sites (GÉNY 2010).

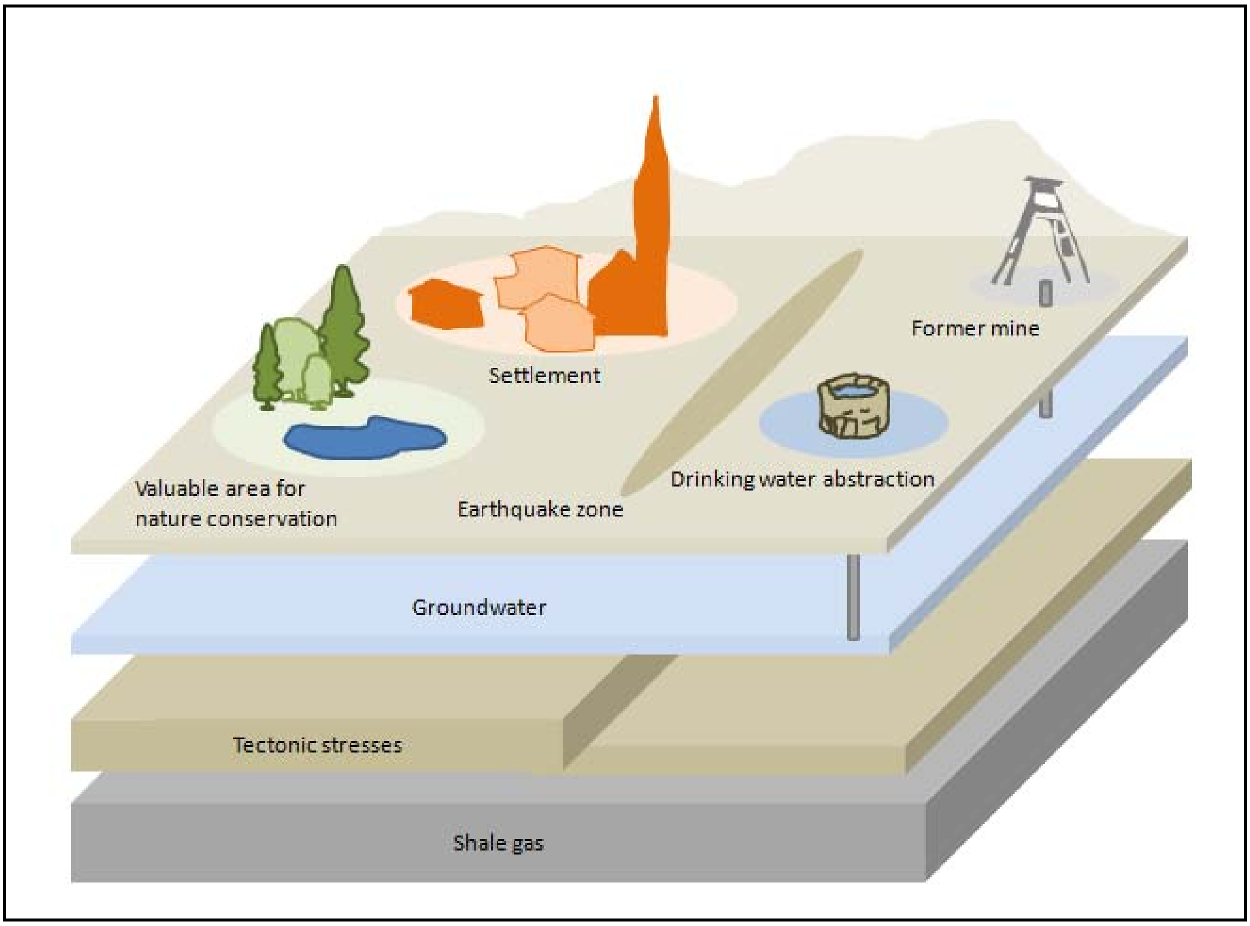
The energy yield per hectare of land used on the surface depends on various framework conditions such as the number of holes drilled per site and the productivity of the reservoir. The land area per kWh generated with natural gas tends to be rather smaller than for renewable energy sources (ExxonMobil 2012a). When making this comparison, however, it is important to bear in mind how long and how frequently a piece of land can produce a defined energy yield (renewable versus finite energy sources).

As a result of buildings, surface sealing, landscape changes, loss of landscape elements and land fragmentation, the creation of well sites can have a wide variety of impacts on the various legally protected goods such as water, soil, biodiversity and local climate. In the long term a large proportion of these impacts are potentially reversible if the site is restored to its original state after production ceases. Only changes in soil structure due to compaction are largely irreversible (Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen 2012).

Not only the spatial dimension of land use plays a role, but also the time dimension. Whereas land is only used for a few months or years during the exploration phase, land on which production actually takes place usually remains in use for several decades (Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen 2012).

Figure 11

Potential protection and investigation areas for the exclusion of fracking technology



SRU/Statement No. 18–2013/Fig. 11

In a densely populated industrialised country like Germany, land use for shale gas production competes with other uses, especially agriculture, forestry and human settlement, and also recreation and nature conservation. This is particularly true of the reservoirs in Lower Saxony and North Rhine/Westphalia, which are covered by land used for intensive agriculture where there is already great pressure on land. This increases the competition for use, and the reduced availability of land can lead to intensification of agricultural use. It also increases the pressure on land not used for agriculture.

Production of shale gas also has an impact on the landscape (e.g. structural elements such as hedges or shrubs, recreation areas etc.). The visual impact radius of a well site with impairments that may require compensation is estimated to be around 400 to 600 m and the acoustic impact radius up to 500 m (SCHNEBLE et al. 2012).

68. To protect people and the environment it is possible to restrict or exclude the use of land for the production of shale gas (Fig. 11).

Of Section 48 of the Federal Mining Act *(Bundesberggesetz – BBergG)* ensures that fracking is subject to all existing general legal prohibitions and restrictions. This means that existing rules under which land is dedicated to a public purpose or is protected in the interests of a public purpose continue in force (e.g. nature conservation areas or water conservation areas). However, exploration is to be restricted as little as possible by the application of the provisions, and exceptions are often permitted, e.g. by protected area ordinances. In the context of fracking, the Lower Saxony Agency for Mining, Energy and Geology (LBEG 2012) has put forward more details of the public purposes mentioned in Section 48 paragraph 1 of the Federal Mining Act. It describes such areas as follows:

- Protected areas and protected elements of nature and landscape (see Sections 20 ff. of the Federal Nature Conservation Act, *Bundesnaturschutzgesetz – BNatSchG)*: Nature conservation areas, national parks, national natural monuments, biosphere reserves, landscape reserves, nature parks, natural monuments or protected landscape elements or Natura 2000 areas),

- Areas protected under the Federal Water Act: Water conservation areas, medicinal spring conservation areas, flood areas or other areas dedicated to water conservation purposes,
- Cultural goods (e.g. constructional or earthwork monuments) and
- Other areas dedicated to public purposes.

As a rule, such areas are subject to a statutory ordinance, e.g. a conservation area ordinance, or other statutory protection. There may be a need for an individual investigation that examines the possible adverse effects on the protection purpose, for example an impact assessment under the Habitats Directive.

Various actors regard the following as exclusion areas for fracking operations (exploration, production, flowback disposal):

- Water conservation areas within the meaning of Sections 51 f. of the Federal Water Act (Zones I to III) and other drinking water abstraction areas (cf. BMU 2012; BDEW 2011; LBEG 2012; Zones I and II only: EWEN et al. 2012),
- Areas with tectonic conditions that could provide paths for methane, fracking fluids and flowback (tectonic disturbances, earthquake zones, former mining areas) (cf. LBEG 2012; EWEN et al. 2012).

Special protection is also needed for areas that may in future be important for drinking water abstraction, in other words priority and reserved areas for drinking water protection (drinking water resources earmarked for use, sensitive parts of groundwater catchment areas).

The possibility of using horizontal wells to traverse under conservation areas must also be subjected to critical scrutiny, since unforeseen paths may present risks to drinking water supply.

69. A high level of protection for man and the environment may mean considerable restrictions on the shale gas potential that is actually usable. The North Rhine/Westphalia Ministry for Climate Protection, Environment, Agriculture, Nature Conservation and Consumer Protection, having regard to the aspects of human health, landscape protection and recreation, nature conservation and conservation of groundwater and other bodies of water, made an assessment of the spatial resistance (degree of compatibility of the project with the potential of the natural region (SCHOLLES 2008)) for the fields in North Rhine/Westphalia for which permits had been applied for or granted. Nearly half the areas had a very high spatial resistance, in other words major legal or environmental restrictions can be expected in the authorisation procedures (mining, nature conservation and water legislation aspects) (Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen 2012).

4.4 Biodiversity

70. The use of fracking potentially has a number of direct and indirect impacts on biodiversity, and represents a new and additional pressure (SCHNEBLE et al. 2012; Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen 2012). These impacts result partly from the land use (Item 67), and partly from the operation of the facility itself.

Land use and the associated removal or alteration of the existing vegetation, and also the construction of buildings and sealing of the surface, result in loss of habitats and landscape elements. The well site and access roads are potential barriers to the spread of individuals and species. They can lead to fragmentation of habitats and thus exacerbate the present situation in Germany. It must be borne in mind that the production of energy from renewable sources also involves adverse impacts on biodiversity.

The operation of the gas production facility may cause animals to flee from or avoid the site and thereby act as a migration barrier interfering with spatial and temporal functions. While such impacts are not specific to fracking, they do create additional pressures. This may result in acoustic, visual and/or physical impairments or total loss of genetic exchange between sub-populations, and also in separation of sub-habitats and sub-populations. Disturbing effects may also be triggered by movements associated with the construction and operation of the facility (e.g. truck movements), and also by noise and light emissions and vibrations occurring during drilling and fracking operations in particular.

Moreover, ecosystems may also be affected by substance inputs in connection with fracking operations. On a local scale the removal of large quantities of groundwater (Section 4.1.1) may have impacts on the water balance and hence on ecosystems influenced by the groundwater, such as rivers and wetlands in general. A further potential factor is inputs of substances into surface waters (ENTREKIN et al. 2011). If incidents, accidents or leaks occur, this may result in contamination with toxic additives, fracking fluids or flowback that affects the ecosystems involved (Chapter 4.1). The surrounding ecosystems may also be affected by gaseous emissions at the surface (e.g. due to drilling, traffic), particulate emissions (e.g. due to drilling, traffic, infrastructure development) and substance emissions from the subsurface (e.g. uncontrolled methane emissions, formation water with a high salt content, heavy metals and radioactive substances) (Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen 2012).

These various impacts on biodiversity may give rise to conflicts with the protection and maintenance objectives of conservation areas and protected elements of nature and landscape. Biodiversity protection is largely governed by the Federal Nature Conservation Act (BNatSchG), which among other things contains the impact regulation (Sections 14 ff. BNatSchG), the requirements relating to compatibility with the conservation objectives of Natura 2000 areas (Section 34 BNatSchG) and special protection of species (Section 3) (SCHNEBLE et al. 2012, p. 51). Plans and projects which could substantially affect a Habitats Directive area require an assessment of compatibility with the conservation objectives laid down for this area. Under Section 34 paragraph 3 no. 1 of the Federal Nature Conservation Act, if the result of the assessment of the implications is negative a project may only be carried out if it is necessary for compelling reasons dictated by an overwhelming public interest – including social or economic interests. This cannot be assumed in the case of a fracking project (Section 3.2.2).

Moreover, it can be assumed that fracking projects will not be carried out in settlement areas, residential areas or other built-up areas, but outside such areas. Depending on the location, they may affect not only agricultural areas, but also areas that are still in a near-natural state or under non-agricultural nature-friendly use, but not under protection. The relocation of agricultural use to such areas would also have impacts. In view of the risk factors that already exist for local biological diversity, fracking would thus result in new and additional pressures.

4.5 Greenhouse gas balance

71. Shale gas production in Germany also has to be examined in the light of its impact on climate. In principle, greenhouse gas (GHG) emissions that occur during the combustion of fossil fuels account for the greater part of total GHG emissions (e.g. FORSTER and PERKS 2012, p. 64 ff.). However, the indirect GHG emissions from the upstream chain, such as the energy requirements for drilling or for transporting oil, natural gas or coal, also have to be taken into account.

Fugitive GHG emissions, especially methane, are important indirect GHG emission sources in the life cycle of fossil fuels. In surface or underground mining of coal, methane present in the coal or in the surrounding rock escapes. In underground mining, methane may escape into the atmosphere through ventilation systems, but there are also technical means of harnessing the escaping gas mixture. Methane may also escape during the processing and transport of coal and from abandoned production sites (CARRAS et al. 2008, p. 4.6 ff.). Numerous sources of fugitive GHG emissions also exist in oil and natural gas production. Gas containing methane escapes as a by-product during oil production or in the course of gas production. There are however technical means of harnessing the escaping gas or flaring it off, which gives rise to the less climate-damaging CO_2 (CARRAS et al. 2008, p. 4.32 ff.).

Fugitive methane emissions are also at the centre of the discussion about reducing GHG emissions by substituting natural gas for coal and oil, and about the climate impacts of shale gas production (ALVAREZ et al. 2012; HOWARTH et al. 2011a). Methane reaching the surface with flowback on completion of the well is described as a major source of fugitive GHG emissions arising from shale gas production in the USA and characterised as a crucial difference from conventional gas production (BURNHAM et al. 2012). There are however technical mitigation measures in unconventional gas production, known as “reduced emission completions” or “green completions”. Here methane and other gases are separated from the flowback during well completions and sent for commercial use where possible, thereby reducing the climate impact (EPA 2011b, p. 1). As from 2015 the use of reduced emission completions will become compulsory for new hydraulically fractured wells in the USA (FORSTER and PERKS 2012, p. 35).

According to experts, closed systems are to be regarded as state of the art for unconventional natural gas production in Germany. The various components of the flowback are passed through separators, and methane contained in them is fed into the gas network or flared off (personal communication from Dr. Hans-Joachim Uth, 13 March 2013). The technical requirements are derived among other things from the federal states’ deep drilling ordinances, (see e.g. Section 33 of the relevant ordinance of Lower Saxony) and from technical rules for handling substances dangerous to water. This suggests that there is no reason to expect production in Germany to result in high methane emissions from the flowback if the latter is classified as a substance dangerous to water. This should be the subject of further investigation, however, and it is important to check whether the relevant rules provide sufficient safeguards for avoiding methane emissions from flowback.

72. One important step in assessing the climate impact of shale gas production is to compare the GHG balance (GHG footprint) of shale gas with other energy sources which could potentially be replaced by shale gas. In a GHG balance, all GHG emissions arising during the life cycle of a product are quantified and expressed in relation to a functional unit. In the case of fuels, the GHG emissions due to production, processing, transport and combustion (depending on the system boundaries chosen) are calculated and usually shown in relation to the heating value, the electricity generated or the distance travelled.

73. The following studies on the GHG balance of shale gas indicate the range of assessments in scientific discussion. In the course of the InfoDialog Fracking (Item 54), FRITSCHE and HERLING (2012) performed the only study to date of the GHG balance of shale gas in Germany. They defined various scenarios which differed in the assumed drilling input and recoverable gas volume and in the methane emissions that might migrate to the surface after the end of production. Methane emissions from the flowback were not included in the calculations, as the use of technical mitigation measures was assumed to be compulsory at German production facilities. FRITSCHE and HERLING (2012, p. 47) determined a range of 25.8 to 127.5 g CO_{2eq}/MJ in gas for the production, processing and transport of shale gas. The wide range of results is primarily due to the variation in the recoverable gas volume and the variation in energy use in drilling. Much lower GHG emissions of 8.3 g CO_{2eq}/MJ in gas are quoted for the present gas mix in Germany. One possible use of natural gas is for generating electricity. If the direct GHG emissions from combustion of the gas to generate power are included, the authors arrived at 146.4 to 318.3 g CO_{2eq}/MJ for shale gas and 112.2 g CO_{2eq}/MJ electricity generated for the current gas mix (FRITSCHE and HERLING 2012, p. 47).

Studies of gas production in North America, however, found much lower figures for the GHG balances of shale gas and smaller differences from natural gas from conventional sources. From six peer-reviewed publications, WEBER and CLAVIN (2012) derived ranges for the GHG emissions arising from the production and transport of shale gas and natural gas from conventional sources. They quote 11.0 to 21.0 g CO_{2eq}/MJ for shale gas and 12.4 to 19.5 g CO_{2eq}/MJ in gas for natural gas from conventional sources (op. cit., p. 5691).

In a study for the European Commission, FORSTER and PERKS (2012, p. 67) calculated GHG emissions for power generation from shale gas that were 4 to 8% higher than for pipeline gas from conventional production in Europe. Avoiding fugitive methane emissions reduced the difference, resulting in GHG emissions that were 1 to 5% higher. However, compared with pipeline gas from Russia and Algeria and imports of LNG, shale gas displayed a better GHG balance. The authors attribute this to the energy needed to compress the pipeline gas, and to leakages during transport over long distances. Production of LNG requires additional energy input (op. cit., p. 65). This demonstrates the importance of differentiating by origin and processing when comparing shale gas with conventionally produced natural gas.

74. Shale gas can also potentially be used to replace gasoline in the mobility sector. Few studies compare the GHG balance of shale gas and gasoline. For the entire life cycle, BURNHAM et al. (2012, p. 623) calculated about 90 g CO_{2eq}/MJ for gasoline and approx. 70 g CO_{2eq}/MJ in fuel for shale gas. In terms of distance travelled, a car running on shale gas emits about 10% less GHG emissions per kilometre than one powered by gasoline (op. cit., p. 624).

75. In Germany, coal is mainly used for generating electricity. Direct GHG emissions per unit of electricity produced are lower from natural gas combustion than from coal, and natural gas is therefore regarded as the more climate-friendly source of energy (e.g. PACALA and SOCOLOW 2004). In addition to direct GHG emissions due to combustion, GHG balances normally take account of GHG emissions from the upstream chain as well. In a comparison of GHG emissions arising throughout the life cycle of shale gas and imported coal used to generate electricity, FRITSCHE and HERLING (2012, p. 47) calculated that the GHG emissions for shale gas were between 39% lower and 33% higher than for coal. The wide variation in the results is primarily due to differences in assumptions about the energy use in drilling and the recoverable gas volume. JIANG et al. (2011, p. 1) found 20 to 50% lower GHG emissions for shale gas used for electricity generation in the USA than for coal. The figures obtained by HULTMAN et al. (2011b, p. 8; 2011a) showed 44% lower values for electricity generated from shale gas. This conflicts with findings by HOWARTH et al. (2011b) who found that as a result of high fugitive methane emissions during shale gas production and using a different time span (twenty instead of one hundred years global warming potential) the GHG balance of North American shale gas was no better than that of coal. However, both the authors' methods and underlying data used are the subject of criticism (CATHLES et al. 2012; STEPHENSON et al. 2011).

76. Determining the GHG emissions of shale gas as exactly as possible is not only important for assessing its climate impacts compared with other fossil fuels. It is also a prerequisite for determining the GHG emissions from possible shale gas production as part of the German GHG inventory which is prepared annually for reporting under the United Nations Framework Convention on Climate Change and the Kyoto Protocol (UBA 2012).

Some of the GHG emission sources during the life cycle of shale gas are the same as for natural gas from conventional sources, and they can be determined by using modified existing methods. FORSTER and PERKS (2012) studied existing reporting rules and national inventory reports and identified adjustments necessary for including the GHG emissions specific to shale gas. The authors come to the conclusion that as yet there are no activity data, emission factors or identification methods for recording shale gas production in the EU (op. cit., p. 113). The IPCC Guidelines (CARRAS et al. 2008) do not contain any emission factors or methodological rules for registering GHG emission sources specific to unconventional gas production. According to FORSTER and PERKS (2012, p. 103), one central item in the new GHG emissions that need to be recorded is the fugitive methane emissions, having regard to the technology used. In order to register the GHG emissions due to shale gas in the German GHG inventory, there is a need to determine emission factors and differentiated activity data on production. These are requirements that will have to be met by all states that report their national GHG emissions under the Kyoto Protocol and the Framework Convention on Climate Change.

77. The differences and controversies surrounding the findings about the GHG balance of shale gas demonstrate the uncertainties that exist and the need for further research efforts. In this connection it should be noted that the preparation of GHG balances for shale gas is still in its infancy, as the first peer-reviewed publication only appeared in 2011. Most studies are concerned with North American shale gas reservoirs; only one study exists for Germany. On the basis of present knowledge it seems likely that the level of fugitive methane emissions, the energy use in drilling and the recoverable gas volume are decisive parameters for the GHG balance.

The extent to which studies from the North American region can be used to assess shale gas production in Germany is limited. There is a need for GHG balances which reflect the specific situation of shale gas production in Germany, and this requires a broad basis of data (recoverable gas volume, drilling depth, technology used etc.). In particular, the fugitive methane emissions from the flowback need to be determined against the background of the technology used in Germany. The figures here can be expected to be lower than in the existing studies of shale gas production in North America. To permit an objective comparison between shale gas and other fossil fuels, it is also necessary to identify and communicate uncertainties relating to the GHG balance of natural gas from conventional sources, oil and coal. There is also a need for a differentiated view of the individual energy sources, such as differentiation of natural gas from conventional sources by origin.

4.6 Need for action and research on environmental impacts

78. It is clear from the above that the environmental impacts of fracking present considerable challenges for the long-term conservation of water, health, air, soil, biodiversity and climate.

These can be grouped in the following categories:

- Research needs or deficits in knowledge about general environmental risks. These gaps must be filled to make it possible to assess the basic risk,
- Need for regulation and appropriate environmental management concepts to minimise the environmental impacts,
- Knowledge of site-specific conditions, which can only be determined for each project separately to classify suitability in the individual case.

Research needs or deficits in knowledge about general environmental risks that need to be filled to make it possible to assess the basic risk

79.

- Impacts of the special technical features of shale gas production (such as horizontal drilling, pipe stress due to high pressure and chemicals, large number of boreholes) and, where appropriate, further development of technical safety standards.
- Long-term effect of fracking on the stability of the strata in the rock formation and in relation to potential microbial processes along the fissures created.
- Probability and intensity of seismic events.
- Suitability of existing safety assessments for subsurface use of the additives and mixtures used.
- Information about the effects, behaviour and whereabouts of the chemical additives in fracking, over and above the assessment of the chemicals under the classification of the CLP Regulation. For instance it is unclear what secondary products may form in chemical reactions between the additives and brine components of the formation water at high temperatures and pressures.
- Search for technically adequate alternatives to the chemicals used.
- Summary of experience with injection of formation water from conventional oil and gas production in Germany, systematic evaluation (location of wells, drilling depth, rock, quantities, monitoring and evidence of permanent integrity).
- Possibilities for processing and reuse of flowback.
- Extent of diffuse losses of volatile components (methane and other hydrocarbons) and means of minimising them.
- Greenhouse gas balance of shale gas taking account of conditions specific to German reservoir (drilling depth, production volume, technology used etc.), and in comparison with other fuels.
- Assessment of land use to be expected in Germany against the background of the National Sustainability Strategy’s objective of 30 hectares per day by 2020, and more far-reaching land conservation objectives.

Need for regulation and appropriate environmental management concepts to minimise the environmental impacts

80.

- Define areas to be excluded on precautionary grounds.
- Ensure complete access to and exchange of decision-relevant facts and figures between the

actors (companies, water and mining authorities, scientists, public); archive information for long-term use; prepare data for modelling and long-term monitoring.

- Select suitable parameters for a monitoring programme capable of registering possible events at depth.
- Draw up strategy for and further develop safety monitoring for occupational and environmental protection at the production facilities and the associated infrastructure. Prepare an early warning plan, including the relevant parameters for decisions.
- Impose requirement to justify the need for additives.
- Define a safety level for flowback disposal and devise an authorisation procedure that ensures appropriate integration of the water authority and weighs up conservation interests and conflicts of use.
- Ensure the use of closed systems, so that volatile (methane-) emissions in the flowback are captured by technical means and not released.
- Supplement the conservation investigations/ screening with fracking-specific questions relevant to biodiversity (e.g. consequences of high water extraction over a short period for surrounding areas sensitive not directly affected, cumulative impacts of individual projects, degree of landscape fragmentation).
- Design a long-term biodiversity monitoring programme to show the additional pressures that may arise at regional level due to the use of fracking.

Obtain knowledge of site-specific conditions which can only be determined for each project separately to classify suitability in the individual case

81.

- Determine the geological conditions, such as the barriers to gas and water between the surface and the reservoir rock: their number, individual thickness and geological characteristics of the rock.
- Register and assess the physical and chemical properties of the reservoir rock.
- Register and characterise all aquifers.
- Collect information about possible geological disturbances, e.g. legacy wells, how they are filled and their present state; evidence to be provided in the form of integrity tests.
- Model the spread of fissures in fracking.
- Ascertain the properties of the process water and formation water.
- Determine the risk of the site-specific additives, check for less dangerous alternatives.
- Physical and chemical properties and quantities of flowback.

5 Precautionary principle

82. Although the SRU takes the view that, strictly speaking, fracking is not a new technology, it is supposed to be used in what is for Germany a new field of application – shale gas production. Moreover, the description of its environmental impacts in the preceding chapter shows that there are still numerous uncertainties and knowledge deficits with regard to the environmental impacts of fracking. For example, at present one cannot basically rule out the possibility that contamination of aquifers used for producing drinking water may result in introducing fracking fluids into wells. Neither has there been any conclusive clarification of the risks associated with disposal of the flowback. Long-term hydrogeological consequences of fracking operations can only be modelled. In the absence of practical experience, no reliable forecasting models exist for the geological formations found in Germany. This applies particularly to potential pathways and connections between saline deep water and injected fracking fluids at groundwater-bearing strata. Also, it is still not clear how good the greenhouse gas balance of shale gas is compared with other fossil fuels, having regard to the specific conditions of reservoirs in Germany.

Apart from the environmental impacts such as land take that cannot be avoided if a large number of projects are authorised, in the case of fracking there is also the problem that the state cannot impose any precise and reliably effective requirements for preventing adverse impacts because of the lack of empirical knowledge of all the causes of damage and their consequences. The use of fracking in the new field of shale gas production involves risks. In many cases their nature and scale will only emerge during the production process . However, where the uncertain dimensions mean that the adverse impacts could occur on a scale for which the polluter is unable to provide financial compensation, the classic instruments of state safeguards in the form of hazard protection, state authorisation duties and private damage compensation inevitably reach their limits (GRIMM 1991, p. 211 f.).

5.1 From hazard protection to risk precautions

83. Since the extent to which the research sector offers effective approaches to self-restriction and responsibility for impacts is at best limited, and since in competition on the free market there is basically no other limit than profitability, the state, as holder of the monopoly of power, is entrusted with a duty of protection deriving from basic rights and from Article 20a of the German Constitution *(Grundgesetz*

– GG) to ensure safety in the sense of classic hazard protection (CALLIESS 2001), in the course of which it has to set limits to the creation of risks to society. In law, the state task of guaranteeing safety is traditionally defined in terms of safeguarding legal interests against concrete dangers – effected by means of the state instrument of hazard protection (DI FABIO 1994, p. 30 ff.; CALLIESS 2001). The crucial factor for the existence of a hazard in a legal sense is a knowledge of circumstances on the basis of which it is possible to draw conclusions about the *probability* of a specific adverse impact on a legal interest based on the use of a forecast or empirical rule (BVerwGE 45, p. 51, 57). Thus the focus of providing effective safety is on “knowledge” about a potential adverse event that is based on general rules of experience. However, where there are no experiments confirming the cause of the damage and no scientific findings based on them, it is not possible to establish a sufficient probability since the necessary assessment is not certain. Thus if certain indications point to a remote probability of damage, the borderline between hazard on the one hand and risk on the other is reached (WAHL and APPEL 1995, p. 86). Against this background, the state task of hazard protection which could be performed on the basis of direct attribution and short causality processes is joined by the complex task of risk precautions – mediated via the precautionary principle (DI FABIO 1994, p. 30 ff.; CALLIESS 2001).

The legal term “risk” moves on from the term “hazard” to denote an area in which the occurrence of the damage is merely an *abstract possibility*. Here the state institutions have greater latitude, in that they are no longer restricted to taking protection measures solely in the case of a demonstrable specific hazard, but can take action in the event of an abstract concern in the sense of an initial suspicion backed up by scientific evidence.

The precautionary principle is recognised in German and European environmental law as an important manifestation of the state objective of environmental protection, but also as a consequence of fundamental duties of the state to protect the individual as a constitutional principle. Article 20a of the German Constitution underlines the importance of the precautionary principle by placing state institutions under an obligation to exercise long-term responsibility in relation to future generations. Basic citizens’ rights to health and freedom from bodily harm also give rise to an obligation to protect the public. Indeed, the European Commission and the European Court of Justice (ECJ) consider that the precautionary principle enshrined in Article 191 paragraph 2 sentence 2 of the Treaty on the Functioning of the European Union (TFEU) is not confined to European environmental law, but constitutes a general legal principle of the entire law of the European Union (European Commission 2000, p. 12; ARNDT 2009, p. 80 ff.). The norms mentioned give rise to a “ban on insufficient action” – also recognised by the Federal Constitutional Court – that must be catered for by the development of an effective protection strategy by the legislature. As a result, the precautionary principle is explicitly enshrined in numerous pieces of environmental legislation (CALLIESS 2001).

5.2 Requirements dictated by the precautionary principle for dealing with uncertainty

84. For constitutional reasons alone, the precautionary principle has to ensure efficient management of risks. In that respect, it is important to distinguish between the legislature and the enforcing environmental authorities.

The precautionary principle serves the purpose of providing a legal rationale for the risk decisions that have to be taken on the basis of uncertain forecasts and at the same time limiting the costs arising from the information deficits. The aim must therefore be to define the cause of concern in a way that avoids precaution for precaution’s sake.

The cause of concern is to be understood as a situation in the course of which precautionary measures can be taken. For a cause of concern to exist, a reasonable ground for concern is sufficient, in other words a theoretical initial suspicion, is sufficient reason for precautions. Unlike pure speculation this must be based on scientific plausibility factors, but does not have to be strongly supported by empirical evidence or even scientifically proven in the sense of a majority opinion. Initially, therefore, there is a need for full and if possible exhaustive investigation of all significant information relating to the cause of concern. Thus the first step must be scientific investigation and, in an ongoing process, research into the nature and scale of the individual risk potential (provisional scientific risk assessment). Only then is it possible, on this basis and having regard to the public interest in the technology to be assessed, to estimate whether or not the individual risk potential can be accepted and what measures should be taken to counteract it on the sliding scale of safety dogma (hazard - risk - residual risk) (provisional political risk assessment). This assessment is the responsibility of the legislature, which has a certain latitude with regard to estimates, assessments and forecasts within the limits of the constitutional requirements mentioned. On the basis of criteria for relief and concern which should be devised with scientific assistance it is possible to develop formulas for determining this initial suspicion. Such formulas can be used to devise specific rules for a precaution-oriented approach to uncertainty (SRU 2011a, Items 435 ff. and 718 ff.).

However, it is not sufficient merely to cite the Federal Constitutional Court’s case law on residual risks when assessing new technologies. Although the legislature does not have to rule out violations of the constitution with absolute certainty, they are not, for example, to be tolerated merely on the grounds that the state of knowledge is inadequate (as evidently assumed by ROßNAGEL et al. 2012, p. 99; as here recently JAECKEL 2011, p. 3 on the Federal Constitutional Court's decision on the CERN accelerator).

It is rather the case that, in the context of determining the cause of concern, the precautionary principle implies a reversal of the burden of proof which has to be specified by the legislature and which – having regard to constitutional limits (see CALLIESS 2001) – can act on the lines of a refutable presumption of danger. To shake this presumption, the party causing the risk is required to present facts and prove them in the sense of substantiated probability. On the basis of the allocation of the burden of proof under the theory of spheres, which also corresponds to the precautionary principle in environmental law, this would seem justified simply because it is the party pursuing the project that confronts the general public with a risk potential. The risk originates from his sphere of influence, and factual questions which cannot be clarified also fall within his sphere of influence. In other words, because of his proximity to the issue the party within whose sphere of influence the uncertainty has arisen possesses an information lead that the legislature can make use of (SRU 2011a).

In relation to the precautionary measure to be taken, the legislature can – having regard to the precautionary principle – identify various intervention stages of differing intensity in the commercial freedom guaranteed by the constitution.

In this respect it is not a matter of imposing preventive prohibitions with authorisation requirements from the outset, but frequently of generating information likely to clarify the existing uncertainties to accompany a provisional risk estimate. Thus there is also a need for systematic monitoring. A legal foundation defined in this way allows the legislature and the environmental authorities to take action to implement the precautionary principle and give more concrete shape to it.

5.3 Conclusion

85. On the basis of the precautionary principle, and in view of the findings in Chapter 4 and the need for research and action, the SRU advocates that shale gas production with the aid of fracking technology should initially only be allowed in pilot projects that permit meaningful findings about the risks involved in fracking.

In preparation for the selection of pilot projects, criteria should be drawn up on the basis of a transparent public debate to ensure that the projects generate as many findings as possible that are capable of generalisation. The data collected should be compiled in a central place and made available to authorities, scientists and the public in the interest of maximising transparency. To this end a database should be set up for inventorying and publishing the measures taken, including the data on the fracking fluids used. A systematic evaluation of these pilot projects should serve to ensure more detailed investigation of potential environmental risks and undertake risk research to accompany the projects for a certain period (monitoring). The public should be permanently integrated in the process and in the evaluation of the pilot projects. This applies particularly to the conditions under which fracking can be authorised in the long term. The cost of the pilot projects must be borne by the industry. The data provided and the resulting findings should permit a valid assessment of whether fracking can be permitted in Germany in the long term. The statutory rules to be created should also create a certain latitude for the administration, allowing it to make an appropriate response to risks in a specific case.

6 Legal aspects

86. With regard to the proposed pilot projects and the possibility of widespread fracking operations, extensive studies of the existing legal situation in relation to fracking indicate that there is currently a lack of specific provisions for dealing with the – sometimes special – risks of unconventional gas production (ROßNAGEL et al. 2012, p. 87). There is an undeniable need for legislative action, particularly in the legal fields mentioned below.

Production of shale gas raises numerous legal issues in connection with drilling wells, procuring, using and introducing the necessary chemicals and disposing of the waste water (flowback), issues that cannot be dealt with in the limited space available here. In shale gas projects it is mainly mining law aspects (with their more detailed provisions under laws of the *Länder*, i.e. laws of the federal states) and aspects of water law and legislation on substances and the disposal of mining waste (*Allgemeine Bundesbergverordnung*, General Federal Mining Ordinance) that are relevant. The question of whether further development of mining law is desirable and necessary should be investigated (e.g. FRANKE 2011, p. 20). At any rate there is a need for closer investigation and, where appropriate, regulation of the different levels of environmental requirements of mining and water law, and for more detailed specification of water-law requirements with regard to the fracking process (GAßNER and BUCHHOLZ 2013, p. 146). The requirements under mining and water law involve complex legal issues. One example is the question of whether a permit procedure under water law is required because it is a case of "genuine" water use for which a permit is needed (e.g. in cases where the borehole is drilled through an aquifer, REINHARDT 2012, p. 1370; also in cases where groundwater is found at the deepest point in the well or in the zone exposed to the influence of fracking, MEINERS et al. 2012, p. B74), or a case of "non-genuine" water use likely to bring about a permanent or non-trivial change in the quality of the water (MEINERS et al. 2012, p. B74; SEUSER 2012, p. 14–17; DIETRICH and ELGETI 2011, p. 314; ATTENDORN 2011, p. 568–569). If water law were to apply as a matter of principle – which the responsible mining authorities have not so far assumed to be the situation in all cases – this would have the significant consequence that the principles of water law would always apply. Assuming genuine use, these principles would specifically include the duty of concern in accordance with Section 48 of the Federal Water Act, or otherwise, in all cases, the management discretion provided for under water law. In the past it has not always been the mining authorities' standard practice to require a permit procedure under water law (GAßNER and BUCHHOLZ 2013, p. 144).

Fracking also needs substantial quantities of water (Item 37). If the necessary supply of water is obtained by extracting groundwater or surface water, this is a use within the meaning of Section 9 paragraph 1 no. 1 or no. 5 of the Federal Water Act which always requires a permit under water law. This is issued by the mining authority after consultation with the water authority.

There is also a need for clarification of other legal issues. In particular, one central question here is how to ensure monitoring of the environmental impacts of fracking that covers the entire spectrum of environmental impacts (see the remarks in Chapter 4.6 regarding the need for monitoring). This would be a matter of special importance, because the environmental impacts of mining projects – unlike many other projects of environmental relevance – are difficult to estimate, which means that adequate forecasting in the context of an environmental impact assessment (EIA) is hardly possible (GAßNER aqnd BUCHHOLZ 2013, p. 148). However, the need for research also relates to the question of whether exploration and unconventional production of natural gas make it necessary to control subsurface uses by means of "three-dimensional" underground regional planning (for subsurface regional planning, see HELLRIEGEL 2013; ERBGUTH 2011; ARL 2012; SGD 2012). Another subject of discussion is the classification and treatment of flowback from a legal point of view (SCHINK 2013). And finally, there is also the question of what legal regime would apply to avoidance and remediation measures in the event of adverse impacts on groundwater and soil, i.e. whether the Environmental Damage Act would apply or whether the Federal Mining Act has more specific provisions that take priority. Furthermore, there is a need for further analysis of whether an integrated authorisation procedure, as advocated by the SRU for industrial permitting legislation (SRU 2012), might contribute to a complete coordination of all authorisation procedures. Two particularly relevant aspects are singled out below, even though they cannot be examined in detail.

Water conservation areas

87. An evaluation of examples of water conservation area ordinances reveals that the latter currently contain reservations regarding drilling and bans on the underground introduction of wastewater and substances dangerous to water (MEINERS et al. 2012, p. B128). This means that while an exemption by the responsible authorities would be necessary for fracking projects in such areas, it would not be out of the question either. In view of the precautionary principle (see Item 82 ff.), shale gas production could not be permitted in water conservation areas designated by the *Länder* in accordance with Section 51 ff. of the Federal Water Act, unless the risks to the groundwater could be ruled out with certainty (reversal of burden of proof) (see also REINHARDT 2012, p. 1369; see Item 84). However, fracking in water conservation areas should preferably be excluded entirely (as also advocated by BMWi and BMU 2013). Similar protection should also apply to areas that may in future be important for drinking water abstraction, especially priority and reserved areas for drinking water protection (drinking water resources in use or earmarked for use, sensitive parts of groundwater catchment areas).

Environmental impact assessment

88. Under the Environmental Impact Assessment Act *(Gesetz über die Umweltverträglichkeitsprüfung – UVPG)* and the Federal Mining Act *(Bundesberggesetz – BBergG)* in conjunction with the associated Ordinance on the Environmental Impacts of Mining Projects *(Verordnung über die Umweltverträglichkeitsprüfung bergbaulicher Vorhaben – UVP-V Bergbau)*, an obligation to perform an EIA currently exists only in respect of natural gas production for commercial purposes with a production volume in excess of 500,000 m³ per day (Section 3b paragraph 1 sentence 1, Annex I No. 15.1 of the Environmental Impact Assessment Act in conjunction with Section 1 No. 2 a of the Ordinance on the Environmental Impacts of Mining Projects). Such production volumes are unlikely to be reached in shale gas production (BGR 2012, p. 35). Also, the authorisation of shale gas production does not involve any preliminary screening of the individual case to decide, in accordance with the criteria of Annex II to the Environmental Impact Assessment Act, whether an EIA is necessary in the individual case on the basis of features, location and possible impacts of the project. In exceptional cases an EIA is required if, under Section 3b paragraph 2 of the Environmental Impact Assessment Act, several projects of the same type which are to be implemented simultaneously by the same developer or more than one developer and which are closely related, together exceed the relevant size or capacity figures. This also applies if, under Section 3bparagraph 3 of the Environmental Impact Assessment Act, the relevant size or capacity figures are reached or exceeded for the first time as a result of the modification or extension of an existing project that did not previously require an EIA.

As a rule, no EIA is currently required when unconventional natural gas production is authorised in Germany (for a full account, see MEINERS et al. 2012, p. B28 ff. and B135 ff.; ROßNAGEL et al. 2012, p. 22 ff.). One consequence is that there is no participation of the public. Another is that the assessment of environmental impacts which is made as part of a mining-law authorisation with regard to the minimum requirements demanded of operating plans for fracking; e.g. by the State Agency for Mining, Energy and Geology in Clausthal-Zellerfeld (LBEG 2012), falls short of what would have to be assessed in an EIA.

In the opinion of the SRU the legal situation outlined above is rightly regarded as deficient. Article 4 paragraph 2 of the EIA Directive 2011/92/EU requires that in the case of deep wells within the meaning of No. 2 d) Annex II and surface facilities for natural gas production within the meaning of No. 2 e) Annex II, a decision must be taken on the basis of preliminary screening or previously defined threshold values or criteria to determine whether an EIA is to be carried out. However, the member states must not, as happened in the Mining EIA Ordinance, select threshold values or criteria in such a way that in practice all projects of a particular type are generally exempted from the EIA requirement (ECJ, judgement of 21 September 1999, Case C-392/96). Since No. 2 d) Annex II of the EIA Directive ties the requirement to perform an EIA to the fact of a deep drilling, it would make sense in a fracking context to perform at least a preliminary EIA screening for all deep drilling, regardless of whether the borehole is for exploration or production. This is particularly important in view of the fact that no adequate information is available at present on potential environmental impacts and that risk assessment is subject to numerous uncertainties (MEINERS et al. 2012, p. A59 ff., A75 ff., A86 ff. and C48).

In the opinion of the European Commission, fracking projects with a daily production volume of less than 500,000 m³ of natural gas must undergo preliminary EIA screening (European Commission 2011a, p. 3). Failure to do so is an infringement of the EIA Directive. This has the consequence that the EIA Directive ought to be directly applied *ex officio* (GAßNER and BUCHHOLZ 2013, p. 147 f.; FRENZ 2011). This opinion is also shared by MEINERS et al. (2012, p. B138), DIETRICH and ELGETI (2011, p. 314 f.), LUDWIG (2012) and FRENZ (2012, p. 125). If no preliminary screening is performed, any permit issued in this way can be contested by a legal remedy under Section 4 of the Environmental Appeals Act *(Umweltrechtsbehelfsgesetz)*, resulting in an uncertain legal situation for the companies concerned.

Various recommendations have been under discussion since 2011 for making the fracking process subject to an EIA (for a full description of the legislative proposals, see ROßNAGEL et al. 2012, p. 87 ff.). In 2011 the Arnsberg district government advocated an amendment to Section 1 of the Mining EIA Ordinance to include a new set of elements for drilling – for both exploration and production – which would provide for general preliminary screening of the individual case in accordance with Section 3c of the EIA Act. As well as the production volume, additional elements leading to an EIA requirement should be formulated for the production of shale gas (Bezirksregierung Arnsberg 2011). At the end of 2012 the Bundesrat presented a draft ordinance providing for a requirement to perform an EIA for oil and gas production projects with three or more drilling sites operationally interconnected by pipelines. Furthermore, individual boreholes, especially for gas exploration and production, are also to be subject to a mandatory EIA if the project involves the use of hydraulic pressure to bring about or support the fracturing of rocks. General preliminary screening of the individual case in accordance with Section 3 of the EIA Act is to be performed for all other deep drilling relating to oil and gas exploration and production (Bundesrat 2012). In its resolution passed in early February 2013, which calls for a moratorium on the authorisation of fracking projects, the Bundesrat also repeats its demand for a mandatory EIA and public participation (Bundesrat 2013). The draft act of February 2013 includes an addition to the Mining EIA Ordinance to the effect that in future oil and gas exploration and production for commercial purposes shall also be subject to a mandatory EIA in the following cases (BMWi and BMU 2013):

- Exploration by deep drilling with rock fracturing by hydraulic pressure,
- Production by deep drilling with rock fracturing by hydraulic pressure (proof).

Information should also be supplied about treatment of the reservoir water and the fluids used.

The SRU endorses this proposal, but – as outlined above – furthermore takes the view that at least preliminary EIA screening of the individual case should be also be performed in all other cases of deep drilling that do not involve fracking.

Public participation

89. The SRU is basically of the opinion that public participation is essential, particularly where a controversial technology is being introduced. The introduction of such a technology must be accompanied by transparency about planning, and adequate information must be made available. An interested public should be aware of the risks involved in the technology. Accordingly, the risk assessment should be carried out in such a way that the public is in a position to arrive at a valid appraisal. The existing controversy about fracking in Germany shows that the issue of acceptance may be the crucial factor in deciding whether this technology can be put to widespread use in Germany. For example, one oil company with exploration concessions for shale gas in North-Rhine/Westphalia has announced that it will only start producing if there is sufficient public acceptance. The efforts made by one of the production companies in an innovative information and dialogue process to clarify issues relating to the safety and environmental impacts of using fracking technology for gas production also show that the companies concerned attach great importance to public acceptance of the future use of fracking (ExxonMobil 2012b).

90. The main reason for the present total lack of opportunities for public participation in fracking projects in Germany is inadequate implementation of the EIA Directive (Item 88). If an EIA were introduced at least for shale gas production , and possibly also for exploration, this would result in a formal public participation procedure which would, in accordance with Section 9 of the EIA Act in conjunction with Section 73 paragraph 3 sentence 1 and paragraph 4 to 7 of the Administrative Procedures Act *(Verwaltungsverfahrensgesetz – VwVfG)*, include the announcement of the project, the exhibition of the planning documents, the possibility of objections, a date for public discussion, and the final decision on the authorisation procedure. The European Commission and the European Parliament have rightly stressed this point (European Parliament 2012c, p. 7). An EIA with public participation is a minimum requirement, because public confidence in careful independent assessment and monitoring of the environmental impacts by the responsible authorities is especially important in the case of projects like shale gas production which are the subject of particular public controversy (MEINERS et al. 2012, p. C91). It must also be noted that the possibility of public participation exists as part of a Strategic Environmental Assessment in cases where the authorisation procedure under mining law is preceded by regional policy planning (ROßNAGEL et al. 2012).

7 Summary

91. Shale gas is natural gas that is trapped in unconventional reservoirs and can only be accessed by means of the hydraulic fracturing process, known for short as fracking. In this technology, water enriched with various additives is forced under high pressure into the rock strata containing the gas. This gives rise to fissures which make the rock more permeable and allow the gas to flow to the surface.

At present two basic positions can be identified in the debate about fracking. On the one hand there is the expectation that shale gas can make a contribution to climate protection and the transformation of the energy system towards renewable energy sources (the "*German Energiewende*"). Moreover, shale gas production is claimed to result in lower energy costs, thereby making the industry more competitive. On the other hand there are objections to fracking, especially on the grounds that the use of hazardous substances leads to unjustifiable and uncontrollable risks for the environment. In this statement the SRU points to the need for a differentiated assessment of the opportunities and risks of using fracking for shale gas production, and advocates a holistic approach that includes both energy policy and environmental policy aspects.

92. In the past the SRU (2011b) has drawn attention to the need for and benefits of decarbonising the energy supply on the basis of renewable energy sources. Gas-fired power plants will play an important transitional role in this process. However, shale gas production in Germany cannot be justified on the basis of climate aspects, nor on the grounds of supporting the *Energiewende*. In terms of total gas requirements, the resources of shale gas and the quantities that can be produced in Germany while maintaining high standards of environmental protection must – despite all the uncertainty factors – be rated low. Moreover, in view of the foreseeable high cost of producing shale gas in Germany, commercial exploitation of this potential in the next few years seems unlikely for economic reasons. As a result, shale gas production in Germany and the EU will not lead to any short-term reduction in natural gas prices, and it is doubtful whether this will happen even in the long term. Furthermore, for the same reasons it cannot help to make natural gas more competitive compared with other fossil fuels during the transition to largely renewable energy supplies.

By contrast, worldwide shale gas production – particularly in North America to date – is already having an influence on the relative prices of fuels in Europe. Global shale gas production basically increases the supply of fossil fuels and thereby tends to keep prices down. So far, however, it has largely resulted in falling coal prices, because the USA has been using gas to replace coal on a large scale and exporting the coal to Europe. Nevertheless, the magnitude and direction of future price effects remain uncertain. If the global shale gas situation should result in permanently lower prices for gas or coal, consideration should be given to supporting instruments that avoid negative impacts on climate protection and on the expansion of renewable energy and energy efficiency measures. In the power sector it is of great importance to avoid linking cost reduction strategies to the level of the EEG surcharge, since a reduction in the market price of electricity would automatically increase the surcharge and thereby slow down the expansion of renewable energy. One important supporting measure is a clear CO_2 price signal by the European emissions trading scheme or other instruments.

An important task is that of drawing up ambitious climate protection targets for 2020 and 2030 that will also lead to a reduction in emission allowances. This will minimise the risk that global development of shale gas as an additional resource will produce an increase in emissions in Europe.

93. With regard to shale gas production in Germany, the SRU takes the view that this will neither reduce gas prices nor increase the security of supply, and that it is therefore not worth promoting for energy policy reasons. In this respect there is no special overriding public interest in developing this source of energy, though the industry may have an economic interest.

In view of uncertainties about a number of environmental impacts of fracking, the SRU regards this technology as a case for applying the precautionary principle. The precautionary principle fundamentally justifies reasonable preventive state action to avoid risks, even in cases where there is no proof of the danger, but only an abstract reason for concern about the possible occurrence of an adverse impact. In particular, it is therefore necessary to clarify the extent to which adverse impacts are possible as a result of using fracking techniques.

The foregoing assessment in terms of energy policy has far-reaching implications for a conclusive risk assessment, as risk assessment is always a process of weighing up scientifically identified risks against the benefits of the technology for society.

In the opinion of the SRU, fracking is not strictly speaking a new technology, but it is supposed to be used in a field that is new to Germany, namely shale gas production. Fracking and the exploitation of shale gas may affect various legally protected goods. One aspect of particular importance is avoiding inputs of substances into groundwater and drinking water, which are legally protected goods of great relevance to society. It is also necessary to consider environmental impacts due to land use and effects on biodiversity and climate.

In Germany one can basically assume stringent technical requirements for all elements of the fracking process. Nevertheless, present knowledge indicates that important questions about the risks associated with fracking are still unanswered. One of these is whether and how it is possible to ensure that the drilling operations and the introduction of fracking fluids do not cause any contamination of the aquifers used for producing drinking water. Neither has there been any conclusive clarification of the risks associated with disposal of the flowback. There is also a lack of adequate knowledge about long-term hydrogeological consequences of fracking operations, and no reliable forecasting models exist yet for Germany’s geological formations. This applies particularly to potential fissures and connections to groundwater-bearing strata. Another open question is whether and how it is possible to predict and ensure the long-term integrity of boreholes and gas production facilities. There is an urgent need to bring together all the existing data from the extensive investigations conducted during the long history of drilling in Germany. Such a register should systematically document not only the basic data on location, depth and geology, but also any fracking or injection operations carried out and the existing monitoring arrangements, and should make them accessible to the public. Finally, there is a need to clarify accident risks, especially risks due to small earthquakes triggered by drilling operations or by injection of the flowback.

Further research is needed into the greenhouse gas balance of shale gas, taking account of the conditions specific to German reservoirs (drilling depth, production volume, technology used etc.). The spectrum of climate balance figures for shale gas is extremely broad, which means that greenhouse gas balance accounting is correspondingly uncertain compared with conventional energy sources.

Shale gas production – like the production of other fossil fuels and raw materials – involves cumulative effects as a result of land use and water use, interference with the balance of nature and possible losses of biological diversity, which must basically be avoided as far as possible.

Analysis of the potential environmental impacts is a prerequisite for a final assessment of the risks of shale gas production by means of fracking. It therefore forms the basis for further decisions as to whether, in the light of environmental and nature conservation aspects, permission should be given for embarking on the commercial phase. Thus the commercial phase is not possible until the knowledge deficits have been remedied by further research in pilot projects. The process of planning and implementing these pilot projects should be transparent, and should involve participation by the public. In accordance with the polluter pays principle, the resulting costs should be borne by the extraction industry.

94. Minimum requirements for the protection of health, environment and nature should be laid down for the pilot projects. To rule out the possibility of endangering the important legally protected good “drinking water”, there should be a general ban on fracking in water conservation areas. The same should apply to areas which may be of potential future importance for drinking water abstraction, and to areas with tectonic conditions that could provide migration paths for gases and liquids. Another framework condition for the use of fracking should be mandatory cooperation between the responsible technical authorities. The SRU is also of the opinion that where a deep exploration or production well is associated with fracking operations, there should be statutory provision for a mandatory Environmental Impact Assessment. In other deep drilling cases there should at least be preliminary Environmental Impact Assessment screening of the individual case. In future, an investigation of the basic suitability of the site of each individual project should be required, especially as regards the geological conditions, e.g. the nature and thickness of the barriers to gas and water between the reservoir rock and the groundwater-bearing strata or the surface. Moreover, long-term monitoring must ensure that environmental impacts which do not occur or become evident until after the pilot phase are detected and that suitable countermeasures are taken. The pilot projects should be selected to reflect representative applications of fracking.

On balance, the SRU arrives at the following conclusions regarding the use of fracking for shale gas production:

- Fracking is not necessary from an energy policy point of view and cannot make a significant contribution to the German Energiewende.
- Fracking on a commercial scale cannot currently be allowed because of serious knowledge deficits.
- Fracking can only be justified on the basis of positive findings from systematically developed pilot projects.

List of Abbreviations

AEO	=	American Energy Outlook
BBergG	=	Bundesberggesetz (Federal Mining Act)
BGR	=	Federal Institute of Geosciences and Raw Materials in Hanover,
BMU	=	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BNatSchG	=	Bundesnaturschutzgesetz (Federal Nature Conservation Act)
BTEX	=	The aromatic hydrocarbons benzene (B), toluene (T), ethyl benzene (E) and the xylenes (X, or dimethyl benzenes according to IUPAC nomenclature)
BVerfG	=	Federal Constitutional Court
BVerwGE	=	Decisions by the Federal Administrative Court
BVOT	=	Deep drilling ordinances
CAS	=	Chemical Abstracts Service
CIT	=	5-chloro-2-methyl-2*H*-isothiazol
CLP	=	Classification, Labelling and Packaging
CO_2	=	Carbon dioxide
CO_{2eq}	=	CO_2 equivalent
ECJ	=	European Court of Justice
EEG	=	Renewable Energy Sources Act, feed-in-tariff-system
EIA	=	U.S. Energy Information Administration
EIA	=	Environmental impact assessment
EIA Act	=	Environmental Impact Assessments Act
FFH	=	Habitats Directive
G&S power plant	=	Gas and steam turbine (combined-cycle) power plant
GDP	=	Gross domestic product
GG	=	Grundgesetz (German Constitution)
GHG	=	Greenhouse gas
GIP	=	Gas-In-Place
GOW	=	Health guide value
H_2S	=	Hydrogen sulphide.
IEA	=	International Energy Agency
IPCC	=	Intergovernmental Panel on Climate Change
LBEG	=	Lower Saxony Agency for Mining, Energy and Geology
LNG	=	Liquefied natural gas
MIT	=	2-methyl-2*H*-isothiazol-3-on
MJ	=	Megajoule
MWh	=	Megawatt-hour
N_2	=	Molecular nitrogen
PGI	=	Polish Geological Institute
REACH	=	Registration, Evaluation, Authorisation of Chemicals

SRU	=	(German) Advisory Council on the Environment
TFEU	=	Treaty on the Functioning of the European Union
U.S. EPA	=	U.S. Environmental Protection Agency
UMK	=	(German) Conference of Environment Ministers
USGS	=	U.S. Geological Survey
UVP-V Bergbau	=	Ordinance on the Environmental Impacts of Mining Projects
VAwS	=	Verordnungen zu Anlagen zum Umgang mit wassergefährdenden Stoffen (Länder ordinances on installations for handling substances dangerous to water)
VOC	=	Volatile organic compounds
Vol.-%	=	percent by volume
VwVfG	=	Administrative Procedures Act
WHG	=	Federal Water Act

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