INTRODUCTION

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Purpose of this Book

Large-scale extraction of shale gas in North America over the last years has led to a growing attention on the potential opportunities and risks of shale gas extraction, including in Europe, where available sources are known to exist. The US experience shows that industry-wide extraction of shale gas may positively change the game, leading notably to increased security of supply. But the US experience also demonstrates that intensive extraction of shale gas entails environmental risks, in particular due to the intensive use of horizontal drilling and hydraulic fracturing. With this book, *Shale gas in Europe*,[1] we seek to assess the specificities of shale gas extraction in Europe from the multidisciplinary point of view of engineers, environmental scientist, economists, political scientists, lawyers and sociologists. Where relevant, topics are discussed in the light of the US experience, with a particular focus on highlighting how Europe is different. Most specifically:

- **Part I** of this book focusses on international comparisons, most notably the experiences in the US and lessons to be learnt for Europe, complemented by a comparison with China. Furthermore, it provides an overview of the legal, regulatory and political situation in Europe.
- **Part II** analyses the opportunities that shale gas may provide to Europe in terms of geology, resources, logistics in densely populated areas, economics and potential contributions to the transition to a low carbon economy.
- **Part III** contrasts this with the risks and challenges of shale gas. Environmental and human health risks supporting the need for a specific

[1] In this book, entitled *'shale gas' in Europe*, authors mostly (but not always) deliberately refer to the term 'shale gas'. But, what is valid for shale gas extraction is generally valid for unconventional extraction encompassing shale gas, tight gas and coalbed methane, e.g. when it comes to the regulation of shale gas.

EU regulatory framework, including a risk management framework, climate relevance, as well as issues of public acceptance and stakeholder dialogues are assessed in detail.

- **Part IV** provides selected case studies for France, Poland, Germany and the UK, which are among the most prominent EU Member States in shale gas issues with very contrasting positions and developments.

But before addressing the above topics into great details, a few (technical) words about shale gas geology and hydraulic fracturing, and general implications for Europe.

Shale Gas Geology: Low Porosity and Permeability

Geological hydrocarbon formations are created under specific conditions from organic compounds of marine sediments. Conventional oil and gas originate from the thermo-chemical cracking of organic material in sedimentary rocks, the so-called source rocks. With increasing burial below other rocks these formations were heated and the organic material decomposed into oil and later gas. Depth, temperature and exposure time determined the grade of decomposition. The higher the temperature and the longer the exposure time, the more the complex organic molecules were cracked, finally being decomposed into its simplest constituent methane, which is the essential component of natural gas.

Depending on the geological formation, the emerging liquid or gaseous hydrocarbons escaped from the source rock and migrated generally upwards into porous and permeable strata, which in turn had to be covered by impermeable rock, what is known as 'seal', in order to create a hydrocarbon accumulation forming the conventional oil and gas fields. The relatively high oil content, the position within a few kilometres from the surface, and easy access on land make them easy to extract by drilling wells.

Some hydrocarbon accumulations exist in reservoir rocks with very low porosity and permeability. These occurrences are called tight oil or tight gas. Typically the permeability is 10–100 times smaller than in conventional fields.

Hydrocarbons can also be stored in large volumes in rocks which are in principle not reservoir rocks at all, but shales and other very fine grained rocks in which the volume necessary for storage is provided by small fractures and extremely small pore spaces. Such rocks possess extremely low permeability. This is called shale gas or shale oil.

A third group of unconventional gas is coal bed methane, which is confined in the pores of coal deposits.

Depending on the deposit characteristics the gas contains different constituents in varying shares, including methane (generally in large percentages), carbon dioxide, hydrogen sulphide, radioactive radon etc.

All unconventional deposits have in common that the gas or oil content per rock volume is small compared to conventional fields, that they are dispersed over a large area of tens of thousands of square kilometres and that the permeability is very low. Therefore, special methods are necessary to extract that oil or gas. In addition, due to the low hydrocarbon content of the source rocks, the extraction per well is much smaller than in conventional fields, making their economic production much more challenging. It is not the gas itself that is unconventional, but the extraction methods.

There is no sharp distinction between conventional and unconventional gas or oil deposits. Rather, there is a continuous transition from conventional gas or oil production from fields with high specific gas content, high porosity and permeability over tight gas fields with worse performance parameters to shale gas extraction from deposits with small specific gas content, low porosity and very low permeability. Especially, the distinction between conventional and tight gas production is not always clear, as historically the official statistics did not distinguish these two methods.

Unconventional Gas Extraction: Hydraulic Fracturing

Unconventional gas extraction relies on two essential techniques: horizontal drilling, and hydraulic fracturing, also known as fracking. Horizontal drilling is required as a simple vertical borehole does not penetrate sufficiently into the target formation – a horizontal stretch along the formation is necessary in order to be able to liberate enough confined gas. Hydraulic fracturing does this job. Water is injected into the borehole at high pressures opening cracks in the target formation and thus allowing the gas to flow to the surface. Since shale gas formations are by far the most impermeable structures, the effort required to get access to the gas pores is the highest. However, there is a continuous transition from the permeable conventional gas containing structures, over tight gas to the almost impermeable gas shales.

In order to prevent the new cracks to close again, proppants, often sand or similar agents, are mixed to the water in order to keep the cracks open. Gellants thicken the water in order to improve its transport function. Breakers allow the breakdown of gellants after proppants have been transported into the cracks. Biocides prevent bacteria that can produce acids eroding pipes and fittings and that break down gellants. Corrosion inhibitors reduce the potential for rusting in pipes and casings. Acids achieve greater injection ability or penetration, and dissolve minerals and clays in order to reduce clogging and to allow gas to flow to the surface. Scale control prevents build-up of mineral scale that can block fluid and gas passage through the pipes. Surfactants decrease liquid surface tension and improve fluid passage through pipes in either direction. These and more functions are provided by a large number of chemicals used in fracking.

Some of these chemicals are hazardous to the environment and to human health. Both accidents at the surface as well as unintended processes underground can lead to severe risks of contaminating surface or underground water bodies critical for human drinking water supply or with important ecological functions. Both geological faults and the development of hydraulic connections between the borehole and drinking water reservoirs induced by the high water pressures represent possible contamination pathways. Furthermore, improper cementing and casing of wells may lead to water contamination.

After fracking has been carried out, the fracking fluid, the mix of water and chemicals injected into the well, flows back to the surface. It mixes with formation water present in the deep target formations and thus transports back to the surface further potentially toxic or radioactive chemicals. The disposal of this mix of chemicals is generally done by re-injection into deep geological formations. Treatment and recycling is a major challenge, both technically and economically.

The amount of water required for fracking is a further area of concern depending on regional water availability and water demand based on specific geological situations.

At the surface, air pollutant emissions of the many boreholes drilled and the respective support activities including road transport of water, chemicals, sand and equipment produce further environmental and health pressures. The dense grid of wells established over large areas sometimes traversing several states represents a major impact on the landscape.

In addition to the environmental and health issues posed by unconventional gas extraction, its characteristics also pose specific challenges on the economic and legal levels.

Perspectives for Europe

In contrast to conventional gas production, unconventional extraction requires the drilling of a large number of boreholes, with each of them producing comparatively small amounts of gas. This economic challenge in combination with the technical complexity of horizontal drilling and fracking has long prevented unconventional gas from being exploited commercially. It is obvious that higher investment costs for less production necessarily lead to higher unit costs. Thus, the fact that unconventional gas extraction has been commercialised on a large scale in the US is an indicator of the fact that conventional resources have been exploited to a large extent.

It is for these reasons that unconventional resources are generally poorly researched and explored, and that uncertainties in geological and economic exploitation potentials are still substantial.

The fact that for each well production declines very rapidly requires drilling numerous boreholes within short timeframes in order to increase overall production and keep it at certain levels. In the US, the steep increase in unconventional gas extraction has reduced market prices significantly, and has led to a situation where it is difficult for commercial operators to recover costs.

In this complex situation of opportunities, challenges, risks and uncertainties, this book attempts to give an overview of the current status of knowledge of, and perspectives for shale gas development in Europe.