MSc Program
Environmental Technology & International Affairs

A European Perspective on the Shale Gas Revolution

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 26 May 2014

Affidavit

I, **KLEMENS SCHWARZ**, hereby declare

1. that I am the sole author of the present Master's Thesis, "A EUROPEAN PERSPECTIVE ON THE SHALE GAS REVOLUTION", 97 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Abstract

The shale gas revolution has become a ubiquitous presence in media and scientific circles, and has started to permeate political agendas across the globe. The hype spread from the US, where major technological advancements have rendered the exploitation of unconventional gas profitable and unleashed a virtually unbridled quest for the resource. The sudden increase of supply has caused gas prices to plummet and now provides the US industry and households with cheap energy and significant competitive leverage.

After the diagnosis that the revolution had the potential to leave a lasting impact on global energy markets, not only carrying widespread economic, but also geopolitical implications, the question most naturally arose to what extent and under what conditions the US success could be replicated elsewhere.

The aim of this paper is to provide a comprehensive analysis of the potential, challenges and limits of European shale gas.

The potential has been heatedly debated and it is safe to say that uncertainty remains prevalent. Exact estimates continue to be scarce and the economic implications of the exploitation on the continent somewhat of a mystery.

However, experts largely agree that considerable amounts of technically recoverable gas are trapped in European shale and could, despite more elevated costs due to geological constraints, higher wage-levels, less developed infrastructure and regulatory bottlenecks, go a long way to ensure security of supply, diversify energy sources and carry major welfare gains for European economies.

Yet, the political debate remains highly divided and fluid. In large parts of Europe environmental qualms continue to dominate the headlines and nurture a lack of public acceptance, which appears to dampen political will and ultimately constrain the establishment of a shale gas industry.

Shale gas would not solve all problems and surely has its drawbacks, but if used strategically, as a substitute for more carbon-intensive energy sources and a complement to renewables, the benefits seem to outweigh the costs and Europe would perhaps be well-advised to take a more pro-active approach towards the resource.

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List of Abbreviations

BGR	Bundesanstalt für Geowissenschaften und Rohstoffe [Federal Institute for Geosciences and Natural Resources]
BGS	British Geological Survey
Bcf	Billion cubic feet
Bcm	Billion cubic meters
EIA	Energy Information Administration
ERR	economically recoverable resource
EU	European Union
EUCERS	European Centre for Energy and Resource Security
GHG	greenhouse gas(es)
Gtoe	Giga tons oil equivalent
IEA	International Energy Agency
IGU	International Gas Union
MIT	Massachusetts Institute of Technology
MMBTU	Million British Thermal Units
OGIP	Original gas in place
OGP	International Association of Oil and Gas Producers
Tcf	Trillion cubic feet
Tcm	Trillion cubic meters
TOC	Total organic carbon
TRR	technically recoverable resource
URR	ultimately recoverable resource
US	United States
USGS	United States Geological Survey
WEC	World Energy Council

Acknowledgements

I would like to express my gratitude to my supervisor Prof. Hans Puxbaum for his support throughout this process, for approving my topic, providing me with valuable advice and guidance, for linking me to some experts of the field, most notably DI. Dr. Gerhard Ruthammer, and even driving me to remote towns in Lower Austria to interview them. I could have not asked for more.

Furthermore, I would like to thank my parents and family, who have generously and continuously supported me throughout my studies and life, even when it became obvious that a part-time job would not do all the funding. I am truly grateful for all the opportunities they have given me.

And finally, I would like to thank my gorgeous partner Jasmin for putting up with me over the last two years. I know that it has not always been easy, but I am incredibly grateful for everything she has done for me, in the good and the not so good times, and for doing an incredible proofreading job.

1 Introduction

The shale gas revolution has become a ubiquitous presence in media and scientific circles, and has started to permeate political agendas across the globe. The hype spread from the US, where major technological advancements have rendered the exploitation of unconventional gas profitable and unleashed a virtually unbridled quest for the resource. The sudden increase of supply has caused gas prices to plummet and now provides the US industry and households with cheap energy and significant competitive leverage. (Wang, *et al.* 2014)

After the diagnosis that the revolution had the potential to leave a lasting impact on global energy markets, not only carrying widespread economic, but also geopolitical implications, the question most naturally arose to what extent and under what conditions the US success could be replicated elsewhere.

Large parts of Europe have been diagnosed with remarkable reservoirs; yet, there is surprisingly little enthusiasm in regard of their extraction.

While some countries, most notably Poland, have openly embraced the potential of the resource and have supposedly gone to great length to attract international investors, most have indeed opted for a rather cautionary and not overly accommodating approach towards the establishment of a shale gas industry. (Advanced Resources International 2013) Historical legacies of energy mixes and associated interest groups, complex geological settings, environmental concerns, as well as a highly alert public have all contributed to turn political will against the exploitation and essentially halted all developments before even knowing what the true potential is. And even in Poland, despite lofty geological prospects, commercial production has still not commenced, as regulatory and bureaucratic hurdles have been more disruptive than anticipated and fostered scepticism among the industry.

Serious question marks thus remain as to the chances of shale gas to gain an enduring foothold on the European continent.

The aim of this paper is to provide a comprehensive analysis of the potential, challenges and limits of European shale gas.

For this purpose, it shall be structured as follows:

The first three chapters are dedicated to the resource itself and shall explain what shale gas is, how it is detected and evaluated, and decrypt the technologies that have rendered its production so successful. Given that the European public has been rather sceptical about the supposedly harmful impacts of shale gas exploitation for the environment, the chief arguments shall also be scrutinized and tested in light of the existing empirical literature.

In order to understand the promise and hype surrounding shale gas, it is inevitable to understand its origins. Part four will thus concisely depict the developments in the US, provide numbers as to the exact potential and effects of the boom, yet also look at some critical views on the potentially overly optimistic outlooks.

The immediate implications of the American revolution for European markets in terms of supply and global gas prices will be discussed under point five.

Section six shall then outline the geological potential of the resource on and below European soil; numbers are plentiful, but reliable estimates appear rather scarce. Intertwined with the geology, the chapter will also look at the economics of shale gas, dismantle probable production costs and assess whether the exploitation in Europe would be within the ambits of economic feasibility.

Staying within the economic realm, Chapter 7 will depict the possible macroeconomic implications of a European shale gas industry, which will – given the prevailing uncertainties – be premised on two different production scenarios, a conservative and a rather optimistic one.

Despite fairly astounding forecasts, commercial production has yet to enter the European continent, which naturally triggers the question why; Chapter 8 thus aims to elucidate whether the US success can truly be replicated in Europe. It will therefore decrypt the key enablers of the US revolution and scrutinize whether comparably favourable conditions prevail in Europe. A case study of both Poland and Austria will help to identify and illustrate the crucial parameters that have thus far hampered, constrained and halted developments. The section will conclude by providing an outlook for the European shale gas industry under the current framework.

Europe has at times been heavily criticized for what appears to be a rather (pre-) cautionary approach and warned about the potential negative repercussions on

economies across the continent. The last section will thus provide arguments as to whether Europe has indeed chosen a wise path.
A conclusion will sum up the findings.

2 What is shale gas?

Shale gas is, as its very name suggests, to be found in shale, a common form of fine-grained, low-permeability sedimentary rock deposited in quiet environments on the floors of calm seas and lakes. Shale gas forms when black shale, a peculiar form of shale that sedimented in particularly anoxic conditions and carries large amounts of organic compounds from animal, plant and bacterial matter, has been subjected to heat and pressure over millions of years. (Ridley 2011) The gas remains tightly enclosed in the rock and is chiefly composed of methane, with smaller quantities of propane, butane and some other compounds. (International Energy Agency 2011)

Shale gas is commonly classified as *unconventional gas*, referring to sources that require higher stimulation to be extracted as compared to conventional sources and have thus traditionally been deemed too difficult or too costly to produce. (International Energy Agency 2011)

The distinction between conventional and unconventional gas is somewhat blurry. However, the majority of the literature refers to conventional sources as high-permeability reservoirs from which the gas can easily migrate to the wellbore after drilling is completed, whereas unconventional resources are generally found in less permeable rock formations, where gas will not readily flow to the surface after drilling, but requires further stimulation, which renders the production process significantly more complex. Due to the intrinsic characteristics of the reservoir rocks, subsequent recovery rates differ widely, reaching up to 80% for conventional and only 15-30% of the original gas in place (OGIP) in the case of unconventional sources. (GEA 2012, European Commission Joint Research Centre 2012)

Another way of distinguishing the two is based on whether the gas is formed in a source rock, and subsequently migrates into a reservoir rock (conventional sources) or one rock formation serves all purposes (unconventional sources). (Hamblin 2006)

Unconventional gas in literature and science encompasses coalbed methane, tight gas[1] and shale gas, with the latter being widely deemed the most abundant and lucrative, thus serving as the centrepiece of this paper.

[1] Tight gas is at times deemed to be a hybrid between conventional and unconventional sources as tight gas sandstone and limestone are only reservoir rocks.

3 Detection and evaluation of shale reservoirs

Modern technologies for seismic explorations allow companies to locate and map underground rock formations that are suitable for the exploitation of shale gas by using soundwaves and digital 3D models. (Alexander, *et al*. 2011)

The quality of shale rocks as a source of gas varies widely and depends on a range of parameters, prominently including the total organic carbon (TOC) content, thermal maturity levels (vitrinite reflectance), mineralogy, porosity, permeability and thickness, all of which are typically assessed via different geophysical methods. (Passey, *et al*. 2010)

TOC is defined as the total amount of organic material in the rock, expressed as a percentage of the weight. (Speight 2013) Organic compounds from animal, plant and bacterial matter provide the requisite carbon, oxygen and hydrogen atoms needed to create natural gas and thus constitute an important parameter for the gas generation potential of a shale formation. (Advanced Resources International 2011). Reports have shown that the gas content is directly associated with the TOC abundance in a rock. (Passey, *et al*. 2010) As illustrated by *Table 1*, ideal contents lie between 4 and 10%. The minimum for economic production is commonly set at 2%. Gas shales can feature TOC values of up to 30%, but very high TOC values are typically an indicator for thermal immaturity. (Littke, *et al*. 2011)

Total Organic Carbon, Weight %	Resource Potential
< 0.5	Very poor
0.5 to 1	Poor
1 to 2	Fair
2 to 4	Good
4 to 10	Very good
> 10	Unknown

Figure 1: TOC and Resource Potential
Source: (Alexander, *et al.* 2011)

TOC contents of unconventional reservoirs are still rather poorly quantified in most regions outside the US, but numbers are naturally growing with the proliferation of the industry. Methods to determine the TOC of a prospective area include gamma ray log data, meaning the reflection of gamma radiation from a certain formation, arithmetical means based on the original TOC and various influences including pressure and thermal maturity, (Romero-Sarmiento, *et al*. 2013) or even combustion techniques, where a sample is first treated with phosphoric acid to separate inorganic carbon and then combusted at

1,350°C in an oxygen-rich environment. The organic carbon is oxidized to form CO_2, which is measured to extrapolate the TOC content. (Alexander, *et al*. 2011) Given the vast effort, the latter method is, however, rarely applied in practice.

The *thermal maturity* of a formation refers to the degree to which a formation has been exposed to high heat required to break down organic matter into hydrocarbons. It is typically determined by the vitrinite reflectance (R_0%), a measure of the amount of light or other EMR reflected by the vitrinite proportion in the rock's organic component. Values typically range from 0-3%. R_0 of 0.7-1% is a sign for oil generation, wet gas is typically found at R_0 of 1-1.3%. Measurements above 1.3% are an indicator for dry gas formation. The values are directly correlated to the exposure to high temperatures over time, with a *window* for each of the above products. (Alexander, *et al.* 2011, Advanced Resources International 2013)

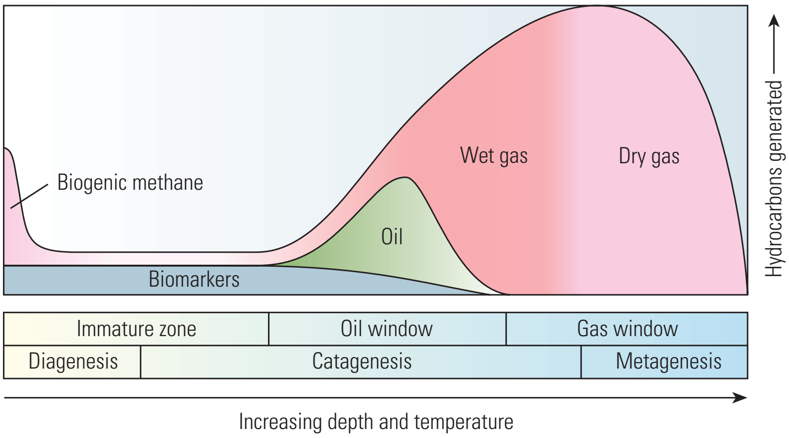

Figure 2: Maturation stages in hydrocarbon generation
Source: (Alexander, et al. 2011)

Permeability is a crucial parameter for the determining the ability of gas to flow within or migrate from a rock formation. In conventional gas reservoirs, the gas is fairly mobile and can flow more or less freely through a reservoir at a permeability of about 10^{-2} darcies. Shale, in contrast, features ultra low permeability from 10 to 100 nanodarcies, which means that the gas is virtually trapped in the small pores in the rock. In order to achieve reasonable recovery rates, additional stimulation is thus needed to enhance the permeability of the shale. (Speight 2013) Hydraulic fracturing serves this purpose and will be discussed in detail in Chapter 4.2.

Mineralogy refers to the composition of the rock, which determines its brittleness and fracturing patterns. (Littke, *et al*. 2011) Low clay contents and high shares of quartz, feldspar and carbonates provide favourable conditions for hydraulic fracturing and amplify the likelihood of cracks and fractures upon pressure increase, whereas clay-rich formations are more ductile and less responsive to hydraulic stimulation. Clay contents above 50% are generally considered unsuitable for hydraulic fracturing. (Advanced Resources International 2011)[2]

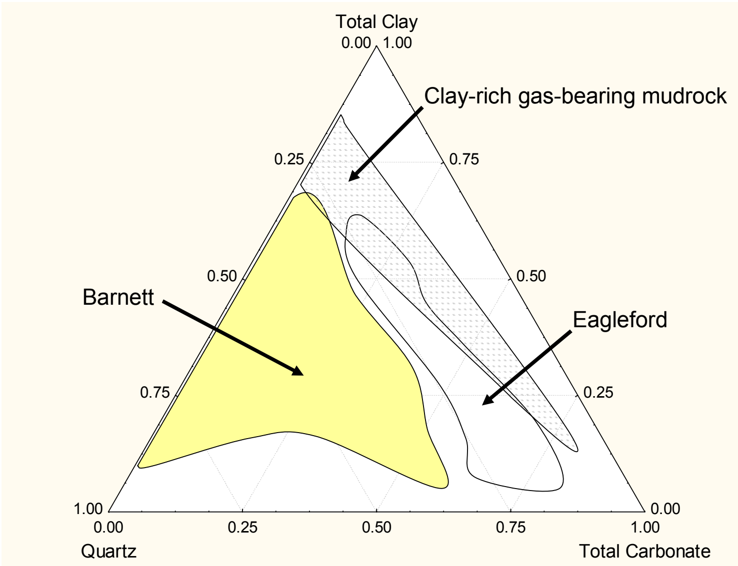

Figure 3: Mineral composition of shale gas reservoirs
Source: (Passey, et al. 2010)

Porosity is a measure of the void spaces or overall volume of pores in a material, expressed as a fraction of the total volume. The porosity of the shale matrix essentially determines the storage capacity of a rock. (Darlak, *et al*. 2011) One of the difficulties with shale gas is that the vast majority of pores available for gas storage are well below 0.1μm, so by about a factor of 100 smaller than in conventional reservoir rocks, which renders the determination of the overall volume as well as the extraction much more complex. (Littke, *et al*. 2011)

Depth and *thickness* are rather self-explanatory. Depth varies widely from near the surface deposits to some several thousand meters under ground, while the thickness of the shale belt fluctuates between only a few to several hundred meters. The depth criterion is important as areas lower than 1000m feature lower reservoir pressure and

[2] For a detailed analysis see Pervukhina M., *et al*. (2011): Parameterization of elastic stress sensitivity in shales. Geophysics 76(3), 147-155.

thus less driving force for gas recovery. Areas deeper than 5000m, on the other hand, are not well understood, but are assumed to carry risks of reduced permeability due to enormous pressure, and much higher drilling and development costs. (Advanced Resources International 2013)

All of the above parameters carry important implications for reservoir properties and are basis for the calculation of the *free gas in place* (GIP), which commonly relies on the following standard reservoir engineering equation:

$$\text{GIP} = \frac{43{,}560 * A\, h\Phi(S_g)}{B_g}$$

$$\text{Where: } B_g = \frac{0.02829zT}{P}$$

"*Where*:

A is area, in acres […].

h is net organically-rich shale thickness, in feet […].

Φ is porosity, a dimensionless fraction […].

(S_g) is the fraction of the porosity filled by gas (Sg) instead of water (SW) or oil (So) […].

P is pressure, in psi […].

T is temperature, in degrees Rankine […].

Bg is the gas volume factor, in cubic feet per standard cubic feet and includes the gas deviation factor (z), a dimensionless fraction. (The gas deviation factor (z) adjusts the ideal compressibility (PVT) factor to account for non- ideal PVT behavio[u]r of the gas; gas deviation factors, complex functions of pressure, temperature and gas composition, are published in standard reservoir engineering text.)"

(Advanced Resources International 2013, 2-13)

A similar formula is applied to calculate the *adsorbed gas in place*, referring to gas that is adsorbed to organic matter and clay rather than being stored in the matrix of pores. The sum of free and adsorbed gas in place reveals the *total or original gas in place* (OGIP), the foundation of all resource estimations.[3]

Predicting recoverability and production rates, however, is a rather delicate task. Reliable estimates require a comprehensive understanding of geochemistry,

[3] Permeability and mineralogy are not considered in either of the mentioned formula as both pertain only to the recoverability of the resources, not the amount of gas in place. Yet, they are commonly used together with a range of other factors to *risk* the deposits, which will be explained in Chapter 7.1.

geological history, flow characteristics and fracture properties. All of the above parameters are crucial in this process. The problem is not only that these values are highly volatile and commonly difficult to obtain, but also that the understanding of their interplay and bearings on the productivity of a well is utterly complex and still not well understood. This is not to say that production models cannot provide valuable reference data, but one should be mindful of the prevalence of uncertainty when relying on performance predictions. In the end, scholars appear to agree that we do not truly know until we *frack*.

4 How is it produced?

The exploitation of shale gas is not as new as recent reports appear to suggest, the US has produced it for over 50 years. (Montgomery and Smith 2010)

However, it is true that several factors, including most importantly technological advancements, have triggered a major burst of the resource over the last decade. (Stevens, 2010) Like many other technological breakthroughs, shale gas was not rendered profitable through one game changing invention, but rather a timely combination and improvement of existing techniques. The two key enabling technologies in the case at hand are horizontal drilling and hydraulic fracture stimulation (*fracking*), both of which had already been applied earlier, but were crucially amended to render production more effective.

4.1 Well completion and horizontal drilling

The launch of the drilling process is utterly similar to traditional gas exploitation. Once a suitable territory has been found, an area of about 200m^2 is levelled and serves as a platform for the pad and drilling devices. The process from there on is slightly different. Up to twelve holes are drilled down to the shale rock, which is typically located between 1.2 and 3.5km below the surface. The number of wells drilled varies significantly, yet it appears to be increasingly common to use one surface location to drill multiple wells (commonly referred to as *pad drilling*) and thereby develop the largest possible subsurface area. (Alexander, *et al*. 2011)

Each borehole is then coated in several concentric sleeves of concrete and steel near the surface and one sleeve further down. The coating shall ensure that high pressure gas or liquids from deeper down cannot migrate into shallower rock formations or water aquifers. (Alexander, *et al*. 2011, Andrews, *et al*. 2010)

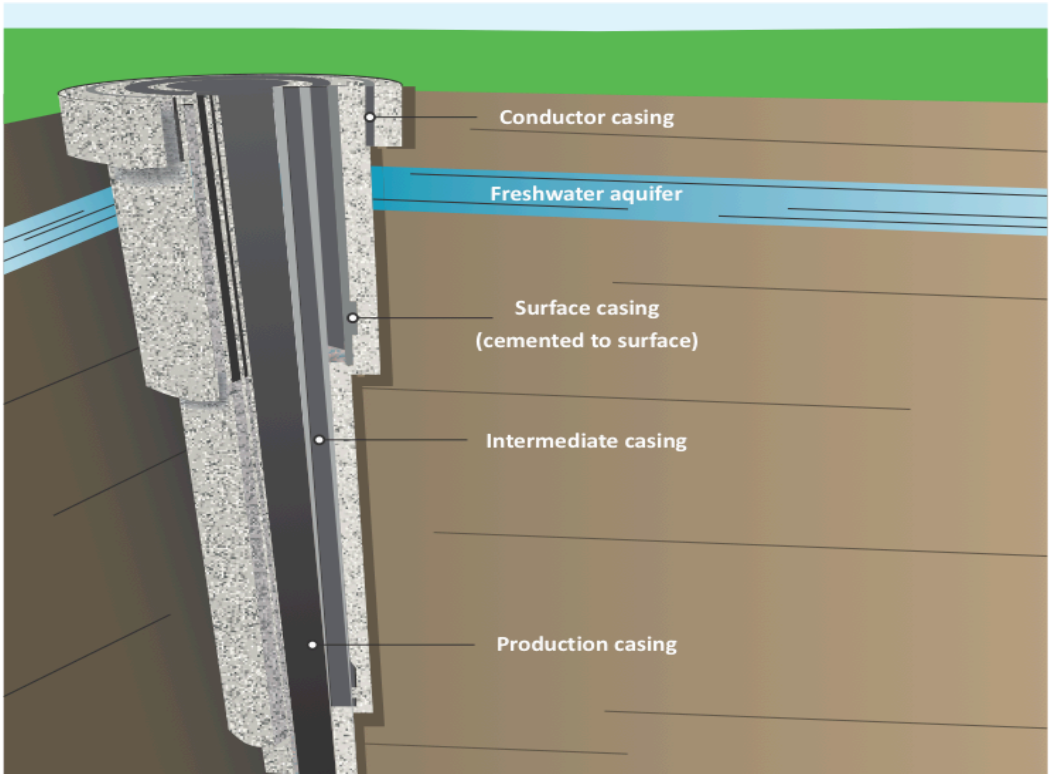

Figure 4: Typical well design and coating
Source: (International Energy Agency 2012a)

After drilling vertically until several hundred meters above the shale a different derrick is assembled on-site to drill horizontally. (International Energy Agency 2012a) The construction features a hydraulic motor between drill bit and drill pipe, which is powered by a flow of drilling mud, and allows the bit to drill in a direction that deviates from the orientation of the pipe system. Once a 90° angle is reached, straight ahead drilling can resume. The technique allows horizontal drilling into the shale formation for up to 3,000m using specific sensors to ensure it stays within the seam. (International Energy Agency 2012a) This is crucially important, given that shale formations can be relatively thin. The Marcellus shale, for instance, only has a maximum vertical span of about 60m.

Compared to traditional vertical wells, horizontal drilling allows the wellbore to access significantly larger areas of hydrocarbon carrying rock and thereby drastically increases recovery rates. A horizontal well in the Marcellus shale has been estimated to be capable of draining an area that is 4,000 times greater than that accessible with a vertical one. (Andrews, *et al*. 2010, Speight 2013)

Once drilling is completed, a final casing is installed and the void between the rock and the wellbore filled with cement to prevent natural gas or liquids from the well from migrating into the rock layers between the shale formation and the surface. (Andrews, *et al*. 2010) The casing surrounding the horizontal section is then perforated using small explosives or specific guns to enable flow of hydraulic fracturing fluids out of the well into the shale and the eventual flow of natural gas from the rock to the surface. (Speight 2013)

Due to the low permeability of the shale, the rate of hydrocarbon flow will be relatively low, which is why further treatment, in the form of hydraulic fracturing, is necessary.

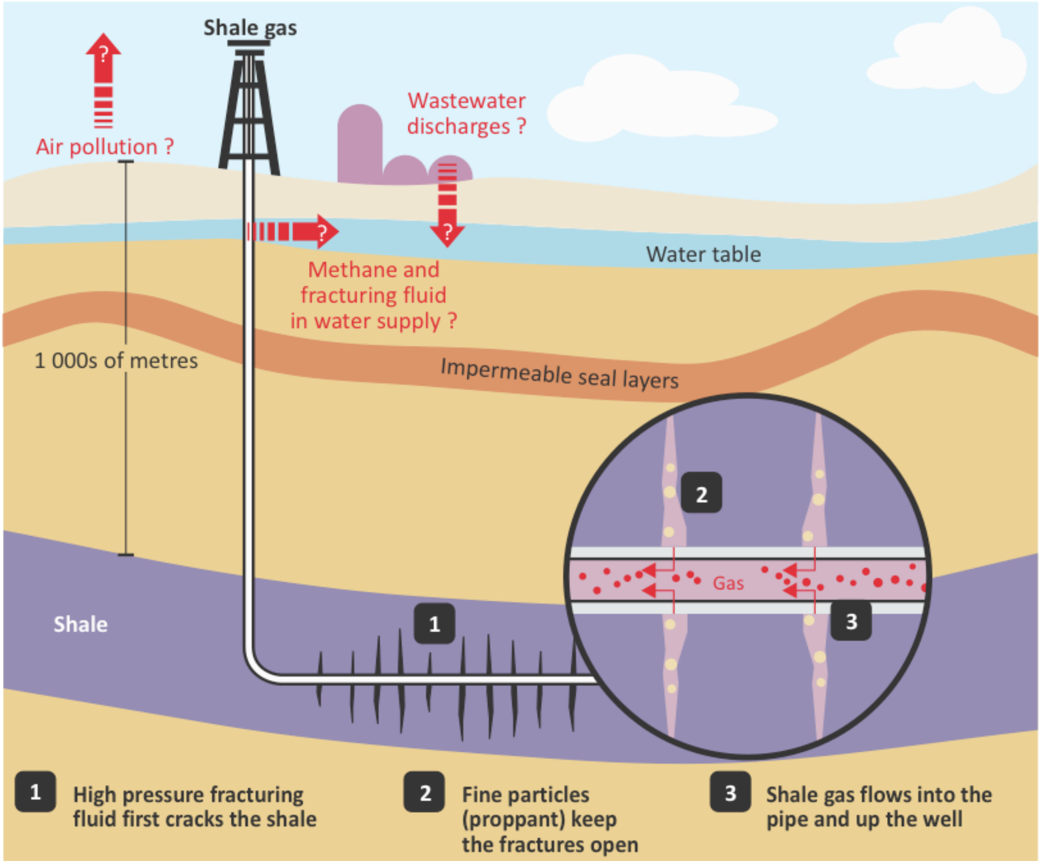

Figure 5: Illustration of the shale gas production process

Source: (International Energy Agency 2012a)

4.2 Hydraulic Fracturing

Once the well has been completed after about 30-40 days, the derrick is removed and the wellhead capped.

As alluded to in Chapter 4.1, the characteristics of shale and its low permeability will only allow very little natural gas to flow freely to the well. In order to increase these rates, fracture networks have to be formed to access the plethora of small pores in which the gas is trapped. This is where the oft-cited *hydraulic fracturing* comes in.

The application of fracturing techniques to enhance oil and gas production was already tested in the 19th century and began to expand in the 1950s, but it was not until the early 1980s and the rise of a range of technologies such as the above-described horizontal wells, multistage fracturing, slick-water fracturing and the invention of crucial supporting gear (in particular down-hole telemetry equipment) that brought the extraction of shale gas within the realm of economic viability. (Montgomery and Smith 2010)

A mixture of water, chemicals and a so-called *proppant* (typically sand) is injected into the boreholes at high pressure. Water and sand commonly amount to 98-99% of the liquid. The rest is composed of a range of chemicals, which typically include *acids*, to clean up the shale and further increase the flow capacities within it; different kinds of *gels* that enhance the viscosity of the liquid and thereby ensure better distribution of the proppant; *biocides*, to prevent organisms from growing in the warm surroundings of the shale and ultimately clogging the well; *corrosion and scale inhibitors* to maintain the integrity of the wellbore; and *friction* reducing substances that improve flow characteristics and mitigate hydrodynamic turbulences. (Speight 2013) There are a plethora of variations of hydraulic fracturing and substances used therein, but the above are the most common ones. (For a good overview see European Commission Joint Research Center 2013)

The liquid fissures or fractures the rock and creates channels that allow oil and gas encapsulated in the shale to escape and flow to the well and on to the surface. Given that the fissures would normally close again with the release of pressure, the injected proppant helps to keep them open. (International Energy Agency 2012a)

Approximately 300m of shale can be fractured at a time, meaning that each well has to undergo a multi-stage process, typically starting at the furthest end of the wellbore. Each segment is separated from the others via cement plugs, which have to be drilled out again before the gas can be extracted. Once the pressure is released, large parts of the liquid flows back to the surface. The oft-cited flow-back water can vary significantly in its composition as it not only contains the injected chemicals, but also varying quantities of minerals, salts, hydrocarbons and naturally occurring radioactive materials that leach into the liquid from the shale. Large parts of the flow-back water are typically recovered and reused in subsequent fracturing operations, but proportions can fluctuate considerably depending on the depth of the well and the specific characteristics of the surrounding rock. (Speight 2013)

Once a sufficiently permeable network of fractures is created, the gas can flow from the shale to well and on to the surface, where it captured and stored.

To put the progress triggered by hydraulic fracturing into perspective, the average initial production rate for the Barnett shale increased from 0.5 Mcf per day in 2004 to

0.65 in 2005 and 0.82 in 2007, ensuring a 64% gain in less than four years. Talisman Energy, one of the major players of the industry, has estimated that *fracking*, in conjunction with horizontal drilling, caused break-even levels in North-American shales to drop by 47% between 2008 and 2010. (Gény 2010)

4.3 Other enabling technologies

Horizontal drilling has also been aided by a range of other innovative drilling techniques, most notably multilateral drilling and stacked wells. Both had been applied for decades, but have been amended and combined with hydraulic fracturing to great effect. (Speight 2013)

Multilateral drilling refers to a process that enables companies to access a number of horizontal sections from one vertical wellbore, which not only enhances the productivity of a wellbore, but also significantly reduces the surface disturbances and impacts in terms of noise, dust, traffic and wildlife. Since horizontal drilling reaches areas of up to 3km from the well, one vertical borehole suffices to develop an area of up to 6km in diameter. It is important to note, however, that it has nevertheless become common practice to drill multiple vertical wells from the same pad and at the same time in order to improve the efficiency and recovery rates of a reservoir. (Bosworth, *et al*. 1998)

Using *stacked wells* is possible if the respective shale formation features sufficient vertical dimensions. One vertical wellbore is hereby used for horizontal drilling at different depths. The technique, if properly applied, again carries potential to significantly reduce surface disturbance, especially in terms of land use. This technology could be particularly beneficial in the commonly thicker shale formations in Europe. (Bosworth, *et al*. 1998)

Once a well reaches the end of its productive life, when extraction becomes either uneconomic or impossible, the wellhead is removed, the bore is filled with cement and the land returned to its natural state. (Speight 2013)

The application of horizontal drilling and hydraulic fracturing has enabled a major proliferation of shale gas in the US, and ambitions to drill for the resource have spread across the globe. It has, however, also stirred a delicate debate about the potentially harmful repercussions of the technology on the environment, in particular in Europe, where the concerns have led some policy-makers to ban its use. The following chapter shall provide a concise overview of the main arguments and depict their validity.

4.4 How damaging is *fracking* for the environment?

It is meanwhile well documented that unconventional sources are generally more diffuse and difficult to produce, rendering the scale of industrial operation for a given volume of output much larger than that of conventional extraction. This implicates that drilling and production activities can be considerably more invasive and ultimately lead to a more damaging environmental footprint. (International Energy Agency 2012a) This is above all due to the very nature of the substance as a gas trapped in very tight spaces and relatively small portions some kilometres below the surface. The increased industrial activity has generated a lively public debate about the environmental and social hazards of shale gas production, especially within Europe. (Schmidt, 2011)

The first and foremost concern has been the extensive use of freshwater for the extraction of the gas in the process of hydraulic fracturing. According to numbers of the International Energy Agency each well usually requires up to 20,000m^3 of H_2O. (International Energy Agency 2012a) In light of the number of permits given out to various drilling company not only in the US, but also large parts of Europe, these are enormous amounts that could be particularly problematic in areas where freshwater is scarce. The water is usually taken from sources in the proximity of the well, including rivers, lakes or boreholes to local aquifers. In places where such course of action is not possible, water is commonly trucked to the well from further abroad, which will naturally entail a bigger environmental footprint. Some authors have even gone as far as labelling the exploitation of unconventional gas equally as damaging as the use of coal for generating energy.

Another issue that has caused public concern is the extensive use of chemicals to enhance the efficacy of hydraulic fracturing. In the early stages of the shale gas movements the composition of the liquid cocktails injected into boreholes was treated with utmost confidentiality, but public pressure has prompted enterprises to more transparency, and voluntary disclosure has become the norm.

In conjunction with the specific compounds, the treatment and disposal of wastewater remains a critical issue. After being injected to the wells, some of the liquid flows back to the surface in the weeks following the fracturing activities. The exact amount depends on the geology of the site, but numbers commonly fall within the range of 20-40%, which means that at least 60% of the chemical liquids remain underground, which has naturally caused concerns in regard of ground water contamination and disturbance of the eco-system. Even for the recovered liquids, leaks in the concrete cylinder or mistreatment and -storage on the surface have been oft-cited reservations against the exploitation of unconventional gas. (International Energy Agency 2012a)

There have been reports about companies merely dumping flow-back water into surface waters, but recent regulations appear to have hampered such abuse. In the US, it is now commonly either disposed in wastewater treatment plants or injected into underground formations that are safely separated from drinking water sources. (Speight 2013)

The physical effects of *fracking* have also been alleged to cause increased seismic activity in the form of small earthquakes.

Finally, the expansive industrial efforts required to exploit shale gas have been associated with higher GHG emissions, in particular CO_2.

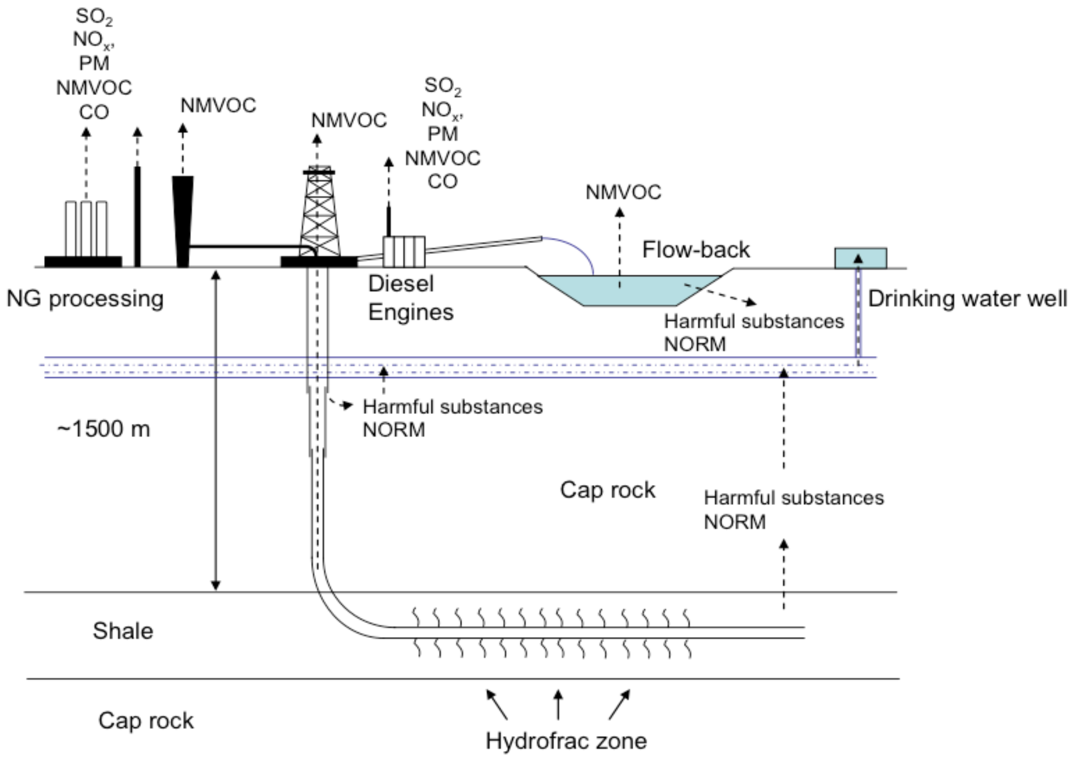

Figure 6: Overview of shale gas production and potential environmental threats
Source: (Lechtenböhmer, et al. 2011)

All of the above have cumulated in a highly alert public perception, which has not only put the shale gas industry under utmost scrutiny from civil society, but also permeated the political sphere and, as outlined in Chapter 8.2 below, led governments to widely diverging policy choices.

However, most recent studies downplay the threats and actual impact of horizontal drilling and hydraulic fracturing, if applied properly.
The (up to) five cones of concrete and steel make it virtually impossible for water or other substances to migrate. A recent study in the US conducted tests around 1,700 wells and did not find any fracturing chemicals or methane stemming from shale activities in the water. Methane intrusions into freshwater aquifers are a rather common phenomenon in the US, but they have occurred for hundreds of years and are not correlated to *fracking*. (Molowsky, *et al*. 2011) That is not to say that there is no risk of leakage, but it appears that it can be controlled.

Utmost caution is certainly due in the context of handling them on the surface, but experience in the US has thus far proven that the risk is marginal and fairly easy to handle. The liquids that stay in the deeper layers of rock are, according to most studies, likely to be absorbed by rock and other material and will not pose a threat to freshwater aquifers closer to the surface. (Rao 2012)

Similarly, surveys have clarified that seismic effects of horizontal drilling and *fracking* are highly unlikely to be felt on the surface. (Davies, *et al*. 2013, British Geological Survey 2013)

Energy resource	Range of gallons of water used per MMBTU of energy produced
Barnett shale natural gas	1.47
Coal (no slurry transport)	2–8
Coal (with slurry transport)	13–32
Nuclear (uranium ready to use in a power plant)	8–14
Conventional oil	8–20
Syngas—coal gasification	11–26
Oil shale	22–56
Tar sands	27–68
Synfuel—Fisher Tropsch (from coal)	41–60
Enhanced oil recovery	21–2,500
Biofuels (irrigated corn ethanol, irrigates soy biodiesel)	>2,500

Figure 7: Water requirements for different energy resources
Source: (Rogers 2011)

The extensive use of freshwater cannot be denied and will clearly remain controversial for some time. However, wells have significantly increased recycling rates or have otherwise filtered and cleaned the water so it can be recycled into rivers, lake etc. (Acharya, *et al*. 2011) In areas with water scarcity this is bound to cause continuous frictions though. What most commentators seem to ignore, however, is that shale gas, although requiring more H_2O than conventional gas, still demands significantly less than coal or nuclear. (OGP 2013, Jenner and Lamadrid 2013)

The one issue that can hardly be proven wrong are the increased GHG emissions. Shale gas requires more wells and more industrial activity per m^3 produced than conventional gas, which inevitably leads to higher energy use and given that energy is commonly provided by diesel engines, CO_2 emissions are a necessary evil. (International Energy Agency 2012a) Some authors have even gone as far as labelling shale gas as harmful as coal, based on the considerable amount of trucking and potential leakage of methane, a much stronger GHG than CO_2. These concerns may carry some validity if techniques are not properly applied, but studies have uniformly shown that the GHG output of shale gas over its lifecycle is still considerably lower than for both oil and coal. (Jenner and Lamadrid 2013)

The visual disturbance of surface activities can hardly be denied and it can be argued that they are more invasive than other petroleum industry processes. Multilateral drilling and stacked wells should help to reduce the impact, but some inconvenience will remain. (Speight 2013) It has also been highlighted, that shale gas still requires considerably less land than the extraction of coal. (Jenner and Lamadrid 2013)

In sum, current research suggests that the exploitation of shale gas is no serious threat to the environment; risks surely exist, yet it appears that technology has progressed to a point where they can be mitigated and controlled.

While it is true that shale gas extraction entails greater industrial operation, leading to higher emissions, one has to see that the combustion of natural gas emits considerably lower levels of CO_2 than other comparable energy sources such as coal and oil and may thus ultimately be considered the *cleaner* energy provider. (International Energy Agency 2012a, European Commission 2014)

5 The shale gas boom in the United States

Not even a decade ago, the US gas industry was concerned about the depletion of natural gas reserves in the US and experts anticipated the country to become a net-importer within several years. Given that such strong dependency would likely drive up prices, the US industry increasingly explored the potential of unconventional gas and, much to the surprise of various spectators, the methods described above rendered the exploitation commercially feasible. (Deutch 2011)

5.1 Some stunning numbers

Shale gas came from being responsible for less than 1% of US domestic gas production in 2001 to account for more than 20% in 2010 and 40% in 2012. (Advanced Resources International 2013, Kuhn and Umbach 2011)

In absolute numbers, the natural gas production from shale formations exploded from an annual production of 0.3 Tcf in 2000 to 9.6 Tcf in 2012. (Advanced Resources International 2013)

In 2009, the US surpassed Russia as the biggest global natural gas producer for the first time in history, processing 584 Bcm. (British Petroleum 2013) The overall output hit an all time high in 2011, surpassing the peak of 1973, when conventional gas exploitation was booming, and has further grown since. (IGU, 2011) In 2012, the US produced almost 100 Bcm more gas than the Russian Federation. (British Petroleum 2013)

And according to estimates of the Energy Information Administration, absolute numbers are destined to rise from 23.0 Tcf in 2011 to 33.1 Tcf in 2040, a 44% increase. Almost all of this increase in domestic natural gas production is due to projected growth in shale gas production. (EIA, 2013)

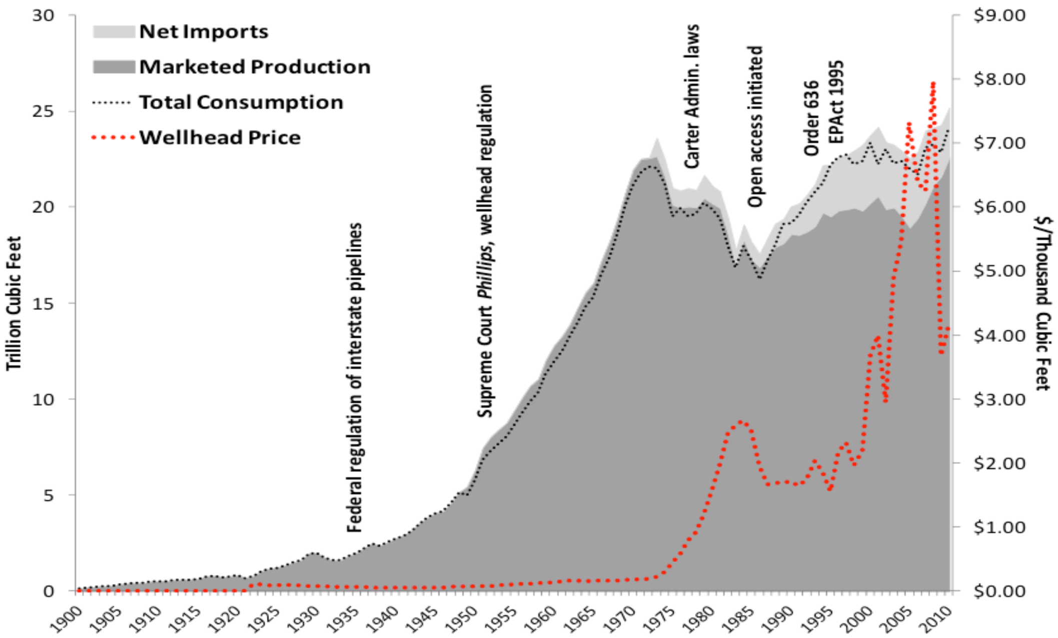

Figure 8: US annual natural gas statistics

Source: (Foss 2011)

The increased supply has naturally had a significant impact on US gas prices. After peaking at above $13 per million British thermal units (MMBTU) in mid 2008, prices started falling sharply. Despite the fact that US gas consumption hit a historic high at 24.1 Tcf in 2010, average prices at Henry Hub, the chief trading hub of natural gas in the US, were less than $5 per MMBTU for a second consecutive year. (Energy Policy Research Foundation 2011a) In 2009 Henry Hub prices even tested a bottom well below $3, including a spot price of $1.8 on 4 September 2009. Price levels then hovered between $4 and $5 per MMBTU and have stayed in that range since early 2010. (Foss 2011) Current prices at Henry Hub hit at $4.41 per MMBTU. (finanzen.at 2014a)

5.2 Concerns about the optimistic outlooks

However, despite the massive increase in shale gas production, considerable uncertainty remains as to the total size and economics of the resource. Recent years have witnessed growing doubts as to the long-term profitability of the shale gas operations with some authors finding the potential to be grossly overstated. (*inter alia* Urbina 2011, Oxford Energy 2014) The crucial question is surely how long the success in the US can be sustained.

Estimates as to the exact ambits of North American shale gas reserves vary significantly. In 2007, the US Energy Information Administration calculated that the US would possess 22 Tcf of *proven* reserves of various types of unconventional gas.[4] In 2008, with extended exploration and production activity, the EIA provided new data, correcting the overall deposits to 33 Tcf. (Deutch 2011) Most recently, the International Energy Agency again increased the numbers to 37 Tcf. (International Energy Agency 2012a) Estimates for the total technically recoverable shale gas reserves in the US (natural gas that could be recovered with today's technology, but without considering economic constraints) again diverge strongly, and have increased dramatically over the past few years. Most reports assume the deposits to fall within the range of 600-700 Tcf. (Deutch 2011)

[4] *Proven* meaning that geological and engineering data suggest that, with a reasonable degree of certainty, the reserves are recoverable under existing economic and operating conditions.

Yet, many of the well-developed plays, such as Marcellus and Barnett, are so large that only a portion of the entire formation has actually been production-tested. Early grounds are also often thought to be the *sweet spots*, which allegedly yield results that other areas will not come close to, especially in cost-revenue comparison. (International Energy Agency 2012a) Most of the shale gas wells have only been drilled in the last few years, and there is considerable variation in the educated views on their longevity. (Energy Information Administration 2012) It is meanwhile well documented that production from shale gas wells declines rather rapidly. While the overall production of a shale gas well is in a similar range as that of a conventional gas well and might last up to 30 years or longer, shale gas exploitation typically features an initial burst followed by a steep decline and a long period of relatively low production. According to recent estimates, output commonly decreases by as much as 50-75% in the first year of production. (Speight 2013, Kogdenko 2011) However, since large scale shale gas extraction is still a rather recent development, exact figures as to the lifetime of shale gas wells remain to be somewhat neboulos and appropriate methodologies for forecasting future decline rates are yet to evolve. (European Commission Joint Research Centre 2012)

The low current gas prices in the US also detriment investors' willingness to spend further capital in the resource and considerbly weakens the rentability of all existing operations. However, experts largely agree that price levels and price volatility will be moderated over the long run. (Stevens 2010) The low prices have also already induced growing consumption, and growth in natural gas utilization is being strongly encouraged by both domestic producers and policy-makers. With the ongoing economic recovery in the US, demand is set to rise further, which will naturally drive prices up again. (Foss 2011)

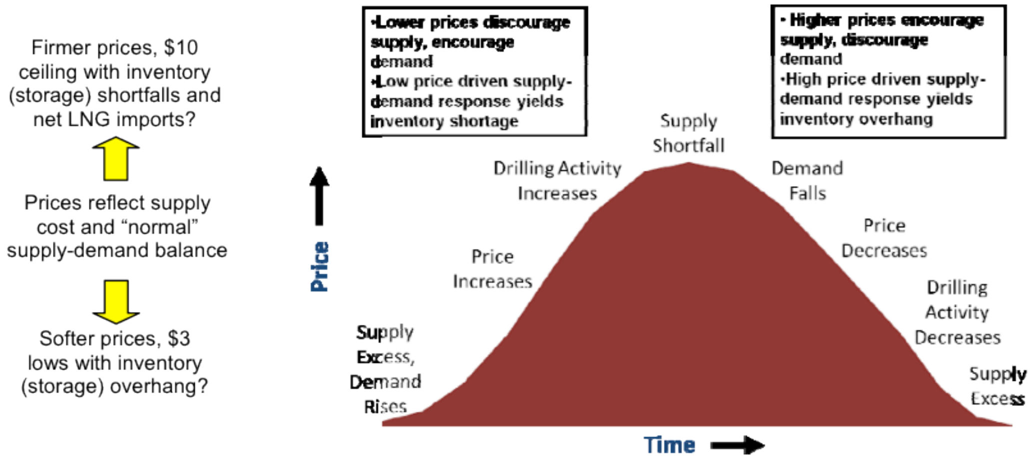

Figure 9: Economic cycle of natural gas
Source: (Foss 2011)

On the other hand, the relative recent launch of the shale gas boom suggests that there will be more technological advancements that could substantially increase long-term productivity and reduce production costs. (Energy Information Administration 2012) Costs have already fallen considerably due to faster processing methods and tighter timeframes and should only gain efficiency with more experience in the field. (Energy Policy Research Foundation 2011a)

In sum it is safe to say that current prospects on future gas supply and prices are extremely uncertain. (Foss 2011) Such ambiguity has naturally influenced both public and private sector decision-makers. Investors have started to show some scepticism as to the true potential of shale gas and have held back capital, and governments face the conundrum that adjusting industries and energy mixes to low gas prices too early might well backfire if the markets stiffen, yet the relative costs for other sources of energy, in particular renewables, are becoming significantly higher if gas prices were to decrease further. (Stevens 2010)

Either way, there is no doubt that the low energy prices implicated by the cheap gas currently provides the US industry with considerable competitive leverage vis-à-vis international competitors. And looking at estimates over the past decade surely reinstalls some optimism. In 2003, the National Petroleum Council estimated that about 38 Tcf of technically recoverable shale gas were spread across North America. By 2005 the EIA found the resource numbers to amount to 140 Tcf. In 2009, the

Potential Gas Committee put its mean estimate at just over 680 Tcf. (Medlock, Jaffe and Hartley 2011)

By 2011, ARI reported an estimate of about 1,930 Tcf for North America, with over 860 Tcf in U.S. gas shales alone, (Advanced Resources International 2011) and has corrected these numbers to 2,279 Tcf for North America and 1,161 Tcf for the US in 2013. (Advanced Resources International 2013a)

These numbers do surely not hint at a rapid decline in US production.

6 Implications for Europe

The shale gas boom has triggered a range of questions for the European continent. Will the increasing energy independence of the transatlantic ally impact prices in the *old world*? Are there similar volumes of gas to be exploited locally and to mitigate the competitive challenges European companies face in light of higher production costs? How much would Europe lose in terms of competitiveness if it refuses to jump on the shale gas train? These questions shall be decrypted in the following with an overall aim of providing a broad, yet concise picture of the European perspective on shale gas developments before looking at the potential to replicate the US success story in Chapters 7 and 8.

6.1 Influence of US shale gas on global markets

In contrast to most other natural resources, most notably oil, there is no true global market for gas due to a range of geological, geographic, market-historic and logistical reasons. The intrinsic physical characteristics of oil feature mid-range viscosity and a high energy density at normal temperature and pressure, which renders it ready for transportation via various means at moderate costs. (MIT 2011)

This has enabled the evolution of a global market where multiple supply sources satisfy global demand with relatively high transparency and price fluctuations based on transportation costs and the quality of oil. The diversity and distribution of supply and demand render the market safe for both sides and avoid strong individual dependencies.

Gas, in contrast, has different physical qualities, making it harder to control and amplify logistical requirements and expenses, which will naturally have a significant impact on the price. Given the relative immaturity of infrastructure, gas contracts are most commonly linked to substantial long-term investment for transportation. Pipelines have thus far been responsible for approximately 80% of trans-regional gas movements, but have proven to be difficult to control if built over long distances and across countries with little interest in the resource and at times questionable political stability. The same can perhaps be said about oil transportation, but the difference

lies in the level of sophistication of existing infrastructure. If a state was to invest in new projects, a delay of several months triggers significant costs and may block the flow of gas entirely due to a lack of alternate suppliers. (MIT 2011, Kogdenko 2012)
Due to the above constraints, world gas trade is concentrated in three regional markets: North America, Europe and Asia. There is significant trade within regions, but very limited between them.
Each of these markets has peculiar characteristics caused by the number and nature of suppliers, import dependencies and a range of political and geographic factors. Most importantly, the three markets feature different pricing structures. The American market is the most open and competitive one with free gas-to-gas competition and freely fluctuating prices, facilitated by the perhaps most mature infrastructure. (International Gas Union 2012b, Stern 2014)
The European and Asian gas markets have both linked gas prices to levels of other natural resources, a bundle of other fossil fuels in the case of Europe and a crude oil benchmark in Asia. (Stern 2014)
These different structures have naturally caused diverging price levels and volatility. As illustrated by the graph below, the differences have at times reached more than a factor of five(!) between the main trading hubs. What can further be seen is that the shale gas boom in the US has hardly affected prices in the other markets.

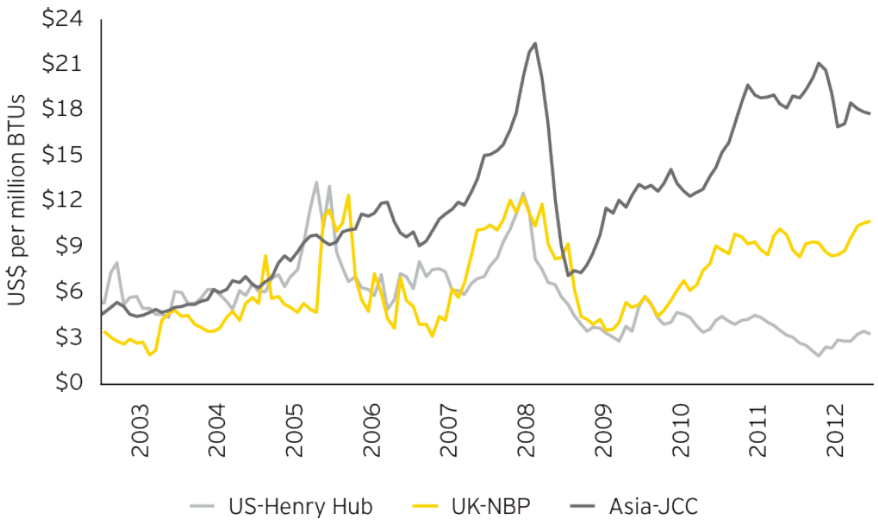

Figure 10: Natural gas spot prices in major global markets
Source: (Ernst & Young 2013)

It remains to be seen whether further integration across the regional markets will change these numbers, but it is hardly perceivable that Russia or other chief suppliers currently hold interest in having to compete with US shale gas prices and will try hard to avoid any increased influence on their demanders.

What the boom has surely done, however, is to show that the extraction of unconventional gas is no longer non-profit territory, and the replication of the shale gas revolution elsewhere may well implicate major turnovers on the gas markets.

Major uncertainties in assessing recoverable volumes of shale gas at both regional and global level remain ubiquitous, but it is clear from various reports that the potential is considerable. As one of the more prominent authorities in the field the IEA has estimated the unconventional gas resources to be almost as high as the globally remaining conventional deposits. Although early predictions tend to be dangerous, it is fairly obvious from the US numbers, that the gas markets would not go unscathed if countries started to exploit shale gas on a bigger scale. The economic and political significance of these resources would furthermore not solely lie in their size, but also in their large geographical distribution, which stands in stark contrast to the concentration of conventional gas. (International Energy Agency 2012a, Kogdenko 2012)

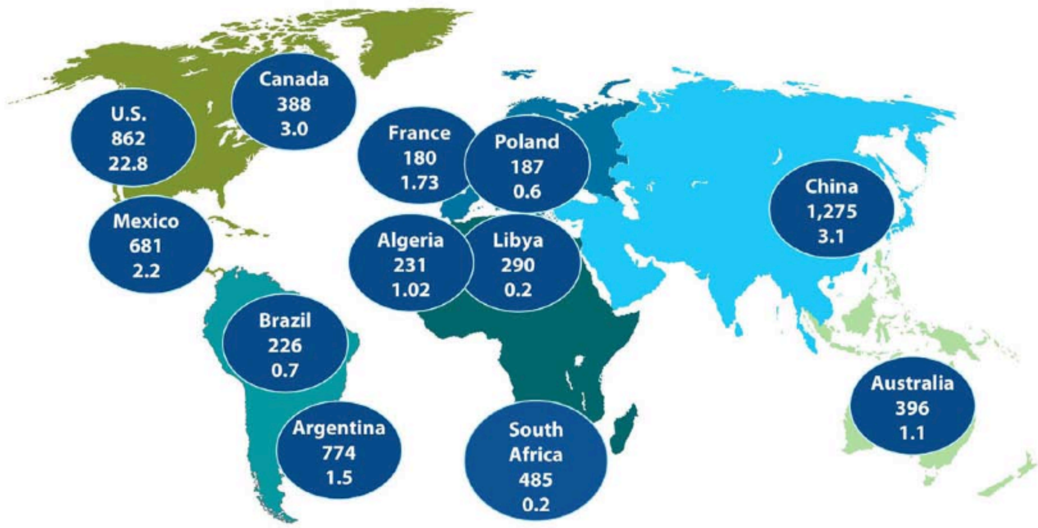

Figure 11: Estimates of global shale gas deposits and 2009 consumption (in Tcf)
Source: (Advanced Resources International 2011)

Many countries, in particular China, which holds the largest share of global shale gas deposits, are widely believed to draw heavily on the new technologies in the future, yet do not yet possess the knowledge or resources to exploit it economically. (Ernst & Young 2013) Shale gas exploitation outside North America remains at an infant stage and projections are rather sceptical about the prospects of commercial exploitation before 2020, at the earliest. However, there are increasing tendencies towards a more globalized natural gas market with Liquefied Natural Gas (LNG) as the key enabler and, according to commentators, potential game changer in the strive for global competition. (MIT 2011)

6.2 LNG a game changer?

As alluded to above, the bottleneck for the development of a global natural gas market chiefly lies within the very nature of the substance. Natural gas is highly fugitive and difficult to transport over long distances. Changing the state of aggregation of the matter is widely perceived as being the future and LNG might indeed go a long way towards truly globalising natural gas markets. (MIT 2011) However, some notable hurdles remain and it is unlikely that the market will ever resemble the flexibility of its oil equivalent.

The high costs of LNG transportation still render it difficult to move the commodity physically over long distances. Liquefaction and regasification infrastructure require sizeable investments and continuously large amounts of energy. Relatively low capacities of liquefaction plants and tankers have further long implicated that importing countries, in particular in Asia, had very limited diversity of supply and were consequently prone to sub-ideal treatment in terms of pricing. (Jensen 2004)

However, recent years have seen a remarkable growth in capacity building across the globe. The rise of LNG exporting infrastructure was primarily anchored in the belief that the US would be a premium market in light of the dawning decline of domestic consumption and the US themselves heavily invested in import capacities in the early 2000s. (International Gas Union 2014)

After shale gas shattered the market, there was a sudden oversupply in global gas markets, which was partly absorbed by the growing Asian gas markets. Japan, Korea and Taiwan, the traditional LNG importers in Asia, have recently been joined by

China, India, Indonesia, Thailand and Malaysia as major LNG destinations. All of them look to diversify their energy mix and import dependencies and are projected with significant increases in demand in the near future. (International Energy Agency 2013)

The growing LNG opportunities also provide ample potential for the European market. The increase in supply triggered by the capacity building in combination with the loss of the US market may well present consumers in Europe with an alternative to Russian pipeline supplies. While LNG is unlikely to truly be able to compete with Russian prices due to the high ancillary expenses, the scare of loosing portions of its most important market has already prompted the Eastern powerhouse to index some of the exports to spot natural gas prices at European hubs, rather than oil prices, which constitutes a major paradigm shift.[5] (Medlock, Jaffe and Hartley 2011)

LNG volumes have steadily increased over the past decade, and the construction of liquefaction and regasification capacities is set to continue. (Ernst & Young 2013)

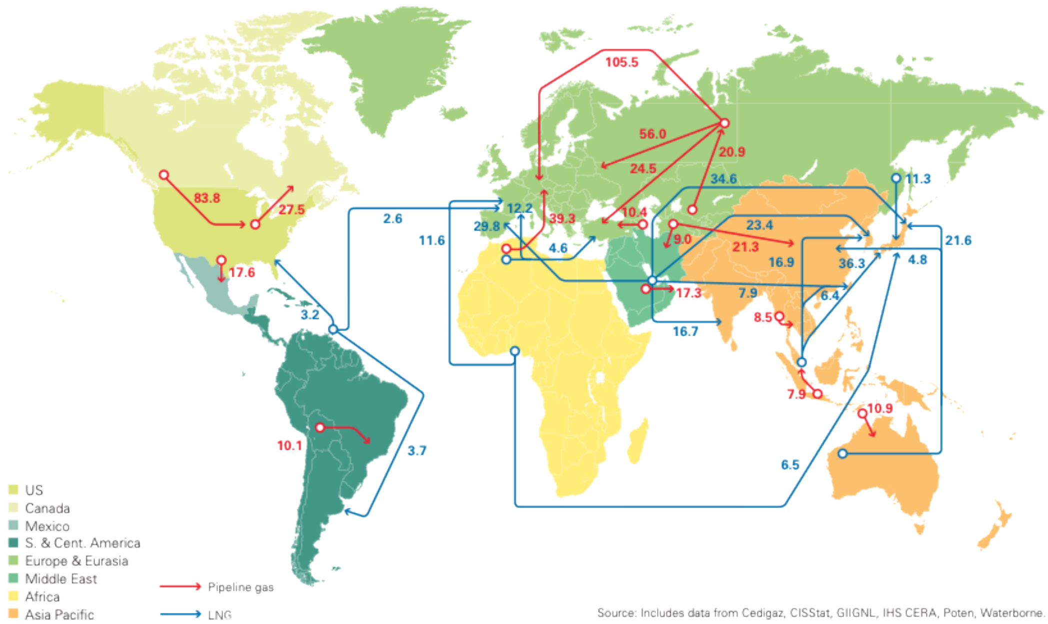

Figure 12: Global natural gas movements in 2012
Source: (British Petroleum 2013)

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[5] European gas pricing will be elaborated in more detail in chapter 7.5 below.

Although LNG trade still only accounts for about 10% of global demand, large capacity building and growing demand in the emerging Asian markets will surely contribute to the rise of the technology. (International Gas Union 2014) The US themselves have recently become increasingly vocal about the prospects of exporting LNG, in particular to the lucrative Asian markets, but also the EU. (Choi and Robertson 2013, Kuhn and Umbach 2011a)

However, the large costs of infrastructure required for liquefaction and regasification are likely to keep prices at a high level and reinforces the temptation to take a closer look at the extraction of unconventional gas in Europe, at least as a complementary source of supply.

7 The potential for extraction within Europe

7.1 Terminology: resources, reserves *et al.*

The shale gas boom remains a relatively recent phenomenon and plenty of numbers are swirling across reports and evaluations. What renders their comparison particularly difficult is the wide-ranging and differing nomenclature used in various documents. Before delving into depicting current estimates it is thus crucial to outline the exact meaning and scope of different termini.

The largest figure that can be given as regards a potential reservoir is the initial or *original gas in place* (OGIP), which equals the total volume of gas estimated to be present in a country, basin or region.

The first subcategory is *ultimately recoverable resources* (URR), sometimes also referred to as *estimated ultimate recovery* (EUR), which denotes gas that is not recoverable with current technology, but is expected to be recovered from a certain field or region in the future.

The *recovery factor* (RF) hereby describes the ratio of the above (and below) subcategories to the OGIP, being expressed as RF * URR (or any other of the ensuing subcategories) = OGIP.

This contains the fraction of *technically recoverable resources* (TRR), which typically describes the amount of gas that is extractable from a technological viewpoint.

Economically recoverable resources (ERR) portray the fraction that is technically and economically feasible. In addition to the above parameters, the gas prices play a major role here and explain why reserves estimates have at times varied significantly.

The last subset of resources are *reserves*, which essentially equal the ERR definition in many reports,[6] but are weighted as to the probability of their occurrence and subdivided into proved (1P or P90, indicating 90% probability to be exceed by the time production ceases), proved and probable (2P or P50) and finally proved, probable and possible reserves (3P or P10). (European Commission Joint Research Centre 2012)

It is important to see that TRR, ERR and all reserves estimates inherently depend on the state and advancement of exploration and production technologies as well as on the prevailing and anticipated market prices and may thus significantly vary over time. Indeed, the additions to reserves have regularly outpaced the rise in consumption over the past 150 years. (Rogner 1997)

A problematic point is that many reports refrain from clarifying the terminology, use some of the categories interchangeably or opt for a significantly less nuanced approach. However, the majority of geological surveys and the major reports rely on the above or similar nomenclature, which can be embedded into a McKelvey diagram resembling the one illustrated in *Figure 13* below.

[6] See *inter alia* Rogner H.-H. (1997): An Assessment of World Hydrocarbon Resources. Annual Review of Environment and Resources 22, 217-262.

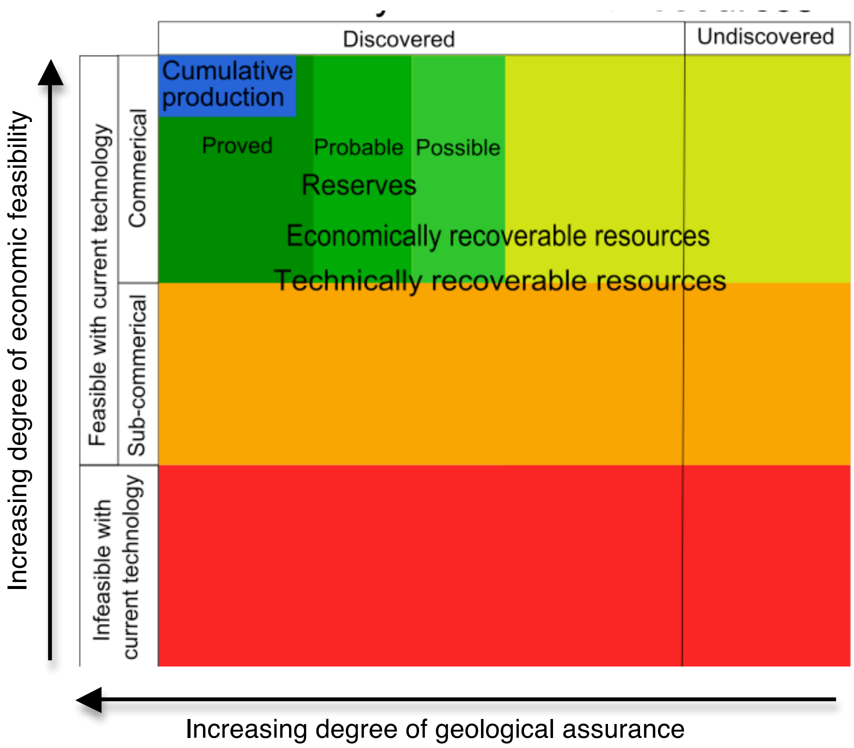

Figure 13: McKelvey diagram for resource classification
Source: adapted from (McKelvey 1972); similarly in (Rogner 1997)

While the above definitions appear to somewhat over-sophisticate things, the intrinsic ambiguity of shale resources and the vast impact of minor variations on investment decisions implicate the necessity to draw a clear picture of the true potential and all associated uncertainties. (European Commission Joint Research Centre 2012)

Yet, the same argument may as well be deemed to hint at rendering such precise categorization virtually impossible, at least until exploratory drilling has progressed to the latter stages, which has thus far only happened in the US or data has not trickled to the public.

In either case, this paper will use the introduced nomenclature to provide a nuanced picture of the European shale gas potential in the ensuing chapters, which should reflect both available information and uncertainty. Fitting various sources into this matrix will naturally require some judgement, which will be considered in the wording.

7.2 How is potential evaluated?

A last crucial step before looking at the actual numbers is to shortly portray the methods by which they have been calculated. As aptly elaborated in a recent report of the *Joint Research Centre* of the European Commission, there are four broad approaches that have been applied to evaluate shale gas resources in Europe and across the globe:

a) bottom up analysis of geological parameters,
b) expert judgement,
c) literature review and
d) extrapolation of production experience.

(European Commission Joint Research Centre 2012)

The advantages and disadvantages and at times inevitable overlaps and conglomerations of these methods should be fairly obvious and are well-documented across literature,[7] rendering it unnecessary to depict them in detail at this juncture. It is, however, important to note that a significant share of the reports does not specify the methods the authors employed in the research, which has to be considered a major flaw.

Most authors rely on a combination of the above methods, which appears logical given that exploratory drilling remains rather scarce on the European continent and even if operations have progressed, much of the information on shale gas potential remains with private companies, which are often hesitant to disclose data that is typically fundamental to the success of their investment. In light of the considerable geological differences of various shale formations caution is also due in the attempt of extrapolating information on the basis of experiences in the US, where data is far more abundant. However, the ever-expanding empirical industrial knowledge will surely yield some guidance.

It is finally important to remark that all of the available reports are based on data from a very early, if at all, stage of the detection and production processes as described in Chapters 3 and 4, which naturally implicates a high degree of uncertainty.

[7] For a comprehensive overview see McGlade C., Speirs J., and Sorrell S. (2013): Methods of estimating shale gas resources - Comparison, evaluation and implications. Energy 59, 116-125.

7.3 Actual estimates

As alluded to before and in contrast to the US, available estimates of the recoverable volume of shale gas in Europe are rather scarce.

An early analysis, conducted by H-H. Rogner in 1997, provided some at the time eye-opening numbers for potential shale gas resources across the globe, indicating that 14 Gtoe, equalling 15.56 Tcm of shale gas would be beneath European soil. However, he provided little insight as to what extent they could be technically recoverable, let alone economic to produce, which is hardly a surprise in light of the lack of data at the time. In fact, Rogner himself labelled his numbers as being *speculative* and explicitly instructs the reader to take them as such. (Rogner 1997)

In an equally vague prognosis the 2010 shale gas survey the World Energy Council relied on a range of literature from the International Gas Union, the US Geological survey and others to estimate the shale gas potential in Europe to amount to 31.65 Tcm, doubling Rogner's estimates, yet without specifying whether this would be URR, TRR or even ERR.[8] (World Energy Council 2010)

Refraining from providing any clear sources or methods Medlock *et al.* provided some more conservative numbers in early 2011, forecasting the TRR to be in the range of 220 Tcf (=6.23 Tcm), split between Sweden, Poland, Austria, and Germany, with the largest proportion (about 55%) in Poland. (Medlock, Jaffe and Hartley 2011)

However, since then a number of surveys have been published to provide scientific debt to the debate.

ARI, on behalf of the EIA, provided the first comprehensive projection and issued a report in 2011, which evaluates the potential of shale gas exploitation in 14 different regions outside the US. (Advanced Resources International 2011)

The agency thereby scrutinized the geological characteristics of 15 clearly defined shale formations situated in 12 basins over 11 countries across the continent. It is thus important to note that it is *not* an analysis covering entire Europe.

The report further only considers *high quality* areas of each basin and formation, leaving aside the less promising resource areas in these basins. The determination of

[8] The named sources provide equally little insight; in an updated report in 2012 the WEC relied solely on estimates of the ARI 2011 report, which are significantly lower.

what was to fall within the scope of these categories is based on preliminary geological and reservoir data including:

- Depositional environment of shale (marine vs. non-marine);
- depth (to top and base of shale interval);
- structure, including major faults;
- gross shale interval;
- organically-rich gross and net shale thickness;
- total organic content (TOC, by wt.);
- thermal maturity (R_0).

Both the in-place and recoverable resource values for each formation are risked to incorporate: a) the probability of whether the shale gas formation will or will not feature sufficiently attractive gas flow rates to become developed; and b) an expectation of how much of the prospective area set forth for each shale gas basin and formation will be developed in the at the time foreseeable future. (Advanced Resources International 2011)

The report concluded with some remarkable statistics that provide ample material for further investigations.

There are considerable deposits in a number of countries with France and Poland standing out by some margin. France supposedly holds technically recoverable resources in the range of 180 Tcf, equalling 5.01 Tcm or 184.32 trillion British thermal units. Poland is even projected with a sum of 5.3 Tcm. Large volumes can also be found in Norway with 2.35 Tcm, the Ukraine, which perhaps holds growing interest in diversifying supply and gaining independence from Russia, with 1.19 Tcm and Sweden with 1.16 Tcm. Notably low is the shale gas extraction potential in Germany with only 226.5 Bcm of technically recoverable shale gas. However, at an annual consumption of 87.23 Bcm this would still suffice to cover a significant share of the German gas supply over some decades. (Energy Information Administration 2014) To put the other numbers into perspective, according to numbers of the International Energy Agency, the natural gas demand of the entire EU was 0.492 Tcm in 2011, indicating that Poland's reserves alone would cover the demand for over a decade. (International Energy Agency 2013)

Continent	Region	Country	Risked Gas In-Place (Tcf)	Technically Recoverable Resource (Tcf)
Europe	VI. Eastern Europe	Poland	792	187
		Lithuania	17	4
		Kaliningrad	76	19
		Ukraine	197	42
			1,082	*252*
	VII. Western Europe	France	720	180
		Germany	33	8
		Netherlands	66	17
		Sweden	164	41
		Norway	333	83
		Denmark	92	23
		U.K.	97	20
		Subtotal	*1,505*	*372*
	Total		**2,587**	**624**

Figure 14: Risked gas in-place and technically recoverable shale gas resources 2011

Source: (Advanced Resources International 2011)

Risked Gas In Place is even four times higher and might at least partly be recoverable with expected advances in technology and infrastructure.[9]

Building upon their analysis from 2011 ARI has issued another, more expansive report in 2013, decrypting recoverable shale oil and shale gas resources in 41 countries outside the US. (Advanced Resources International 2013) Within Europe, it increased the number of scrutinized areas to 24 shale formations spread across 17 basins and 14 countries.

The institute also amended some of its criteria, *inter alia* applying a strict minimum TOC content of 2%, and drew on more recent geologic research as well as drilling results that were not available for use in the 2011 report to come up with some interesting changes. (Advanced Resources International 2013)

[9] *Risked Gas In Place* is a terminology used by the EIA and is calculated on the basis of the OGIP and then adjusted according to factors such as the current state of knowledge (or lack thereof) about the play, data quality and the current state of technology. The EIA only then applies a recovery factor to determine the technically recoverable resource. The term is widely used as a synonym for the above definition of URR.

Continent	Region	Country	Risked Gas In-Place (Tcf)	Technically Recoverable (Tcf)
Eastern Europe	VIII. Poland	Poland	763	148
		Lithuania	4	0
		Kaliningrad	20	2
	IX. Russia		1,921	285
	X. Other Eastern Europe	Bulgaria	66	17
		Romania	233	51
		Ukraine	572	128
	Subtotal		872	195
Western Europe	XI. UK		134	26
	XII. Spain		42	8
	XIII. Other Western Europe	France	727	137
		Germany	80	17
		Netherlands	151	26
		Denmark	159	32
		Sweden	49	10
	Subtotal		1,165	221
Europe	**Total**		**4,895**	**883**

Figure 15: Risked gas in-place and technically recoverable shale gas resources 2013

Source: (Advanced Resources International 2013)

It significantly downgraded the potential in Poland from 5.29 Tcm to 4.19 Tcm due to the more rigorous application of the requirement that a shale formation have at least a 2% TOC, which along with better control on structural complexity, reduced the prospective area by some margin. The most notable decline hit the Lubin Basin, which dropped from 1.25 Tcm in the 2011 report to 255 Bcm.

Similarly, it corrected the French potential to a much smaller number based on recent re-evaulations of the South-East Basin. Despite considerable drilling operations in the onshore and offshore portions of the basin, no significant oil and gas deposits have been found, causing the institute to temper expectations. The report also completely ignores the initially considered resources of Norway in the range of 2.35 Tcm, naming disappointing results obtained from three Alum Shale wells drilled by Shell Oil Company in 2011 in the more promising Swedish part of the formation, which led the institute to label the Norwegian share of the Alum Shale a purely *speculative area*. (Advanced Resources International 2013)

However, there were also some remarkable changes to the positive:

For Europe as a whole, the resource estimates increased from 17.67 Tcm in 2011 to 25 Tcm in 2013. This was largely due to more optimistic outlooks in the Ukraine, where the inclusion of a major basin in heightened the prognosis from 1.19 Tcm to 3.62 Tcm, upgrades in Germany (from 226 Bcm to 481 Bcm), the Netherlands (from 481 Bcm to 736 Bcm) and the inclusion of Romania, which added another 1.44 Tcm. All of these numbers refer to TRR with URR estimates again being about four times as high. (Advanced Resources International 2013)

Similar numbers have recently been published by the German Federal Institute for Geosciences and Natural Resources (BGR). The only noteworthy deviation concerns more optimistic outlooks for Germany itself with an estimate of 0.7 to 2.3 Tcm, as opposed to not even 0.5 Tcm from the EIA report 2013. (BGR 2013)

The number of in-depth analysis of individual shale formations and basins are growing, with the German GASH (Gas Shales in Europe) project taking a leading role for the European perspective.[10] However, dissecting every individual basin to its geological origins would surely be beyond the scope of this paper and is not necessary for its purposes. It is assuring though, that they mostly conclude with estimates similar to the ones above.

Nevertheless, it has to be repeatedly emphasized that estimations in regard of recoverable shale gas vary significantly and there is no certainty as to the above numbers.[11] As Medlock *et al* aptly put it, "[t]he estimates for regions outside of the US and Canada in particular are very preliminary and are thus full of uncertainty". (Medlock, Jaffe and Hartley 2011, 26)

Even with the most sophisticated methods of seismic detection, the projection of shale gas reserves and their economic recovery remains somewhat of a mystery and clarity can only be achieved once drilling is commenced.

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[10] See *inter alia* Littke R., *et al*. (2011): Unconventional Gas Resources in the Paleozoic of Central Europe. Oil & Gas Science and Technology 66(6), 953-977; H.-M. Schulz, Horsfield B., and Sachsenhofer R. F. (2010): Shale gas in Europe: a regional overview and current research activities. Petroleum Geology Conference series 7, 1079-1085; Bernard S., *et al*. (2012): Geochemical evolution of organic-rich shales with increasing maturity: A STXM and TEM study of the Posidonia Shale (Lower Toarcian, northern Germany). Marine and Petroleum Geology 31, 70-89; Matyasik I. (2011): Geological-geochemical assessment of occurrence and extraction of shale gas in Poland. Oil and Gas Institute Krakow, NAFTA-GAZ ROK LXVII, 310-320.

[11] For a summary of different methods and data used by various authors see inter alia European Commission Joint Research Centre (2012): Unconventional Gas: Potential Energy Market Impacts in the European Union. [Online] http://ec.europa.eu/dgs/jrc/downloads/jrc_report_2012_09_unconventional_gas.pdf (accessed 25 May 2014).

It is clear, however, that there are significant technically recoverable resource capacities on and below European soil, which naturally raises the question whether these resources can be exploited economically.

7.4 Is economic recovery possible?

It surely oversimplifies things if one was to compare the above numbers to the US success story and simply extrapolate similar potential. The uncertainty of the geological potential in Europe has already been repeatedly emphasized and is aptly summarized in the words of the IEA saying, "each shale formation has different geological characteristics that affect the way gas can be produced, the technologies needed and the economics of production". (International Energy Agency 2012a, 22)
In light of the above and without any well in commercial operation at present, opinions diverge rather widely when it comes to putting concrete numbers on the economics of shale gas production on the old continent.
Rather naturally, it is first and foremost a matter of the production costs. Table 1 nicely illustrates the extraction expenses of various US providers per Mcf (million cubic feet) on a three-year average.

Table 1: Comparison of production costs per Mcf of different US operators (3-year average)

	Bit finding, development and drilling costs in $	Lifting costs per Mcf production in $	Total production costs per Mcf in $
Ultra petrolium	0,75	1,17	1,92
quicksilver resources	1,15	1,84	2,99
Southwestern Energy Company	2,21	0,88	3,09
Range Resources	1,89	1,24	3,13
XTO Energy	1,67	1,54	3,21
EOG Resources	2,1	1,19	3,29
EnCana	2,12	1,23	3,35
Cabot Oil & Gas	1,99	1,75	3,74
Devon Energy	2,44	1,53	3,97
Apache	2,53	1,78	4,31
Newfield Exploration	3,08	1,6	4,68
Noble Energy	4,09	1,12	5,21
Forest Oil	3,66	1,63	5,29
DenburyResources	2,92	2,56	5,48
Pioneer Natrual Resources	4,41	1,37	5,78

Cimarex Energy	4,42	1,73	6,15
St. Mary Land & Exploration	4,3	1,87	6,17
Chesapeake Energy	6,18	1,16	7,34
Anadarko Petroleum	6,09	1,77	7,86
Swift Energy	6,08	1,88	7,96

Source: adopted from (European Commission Joint Research Centre 2012)[12]

Academic literature concurs that numbers are likely to be slightly to significantly higher in Europe due to elevated costs of labour, population density, environmental regulations and the higher depth of most shale belts. (Shale Gas Europe 2013)

The cost-intensive nature of shale gas exploitation is further exacerbated by the lack of infrastructure, which is commonly assumed to represent up to 30% of production expenses. Although the network of pipelines across the continent is fairly well established, it does not stand the comparison of the US maturity. Severe equipment shortages have also been named as likely constraint and additional burden for European shale gas production. The US accommodates a plethora of rig facility companies and can draw on an experienced drilling workforce, which currently operates up to 2,000 onshore gas-drilling rigs at a time. Europe, in contrast, has just over 50, with Poland as perhaps the most promising shale nation featuring only seven. (Kefferpütz 2010)

The density of population in most parts of Europe will further hinder access to sites, render transportation costs for the set-up of the well and later the gas more difficult and therewith drive up costs. (Vihma 2013)

However, most reports suggest that in Europe would still be able to compete with the upper range of the abovementioned American producers. Medlock *et al* have *inter alia* held that break-even prices in Europe would be in the range of $6-7.50 per thousand cubic foot (mcf). (Medlock, Jaffe and Hartley 2011)

[12] Given that, as indicated above, current prices at Henry Hub are in the range of $3.64 per MMBTU, which equals $3.72 per Mcf, it is rather interesting to note that many of the listed companies are currently producing at a deficit.

EUROPE	Austria	40.0	$	6.25
	Germany	30.0	$	6.25
	Poland	120.0		
	Silurian Tier 1	45.0	$	6.00
	Silurian Tier 2	75.0	$	7.25
	Sweden	30.0	$	6.50

Figure 16: Projected break-even costs of European shale gas production
Source: (Medlock, Jaffe and Hartley 2011)

The German energy service provide e·on has estimated the costs of shale gas in Hungary to $6 per MMBTU, in Poland to about $10. (Korn 2010)

The European Commission Joint Research Centre has also conducted a rather comprehensive study and concluded on an average of $7.6 per MMBTU in 2010, with a sharp decline to $5.5 projected for 2020. (European Commission Joint Research Centre 2012) Similar numbers have further been elaborated by the Oxford Institute for Energy Studies. (Gény 2010)

One also has to consider the considerable difference in current gas prices in both markets. Over the past year the market price in Germany was fluctuating between €7 and €8 per MMBTU, which at current exchange rates equal $9-11.5. (European Energy Exchange 2014)

According to statistics of *Europe's Energy Portal*, the most prominent EU-affiliated, yet independent institution for natural resource data, prices including market price, transmission through main and local networks, administrative charges, non-recoverable taxes and duties even amount to $18 per MMBTU. (Europe's Energy Portal 2013)

Even if one was to assume production costs in Europe to fall within the mid to low range of the above spectrum, the potential gains are still significant.

Following numbers of *Europe's Energy Portal* Europe consumes close to 12 MMBTU per year and the amount is unlikely to decline in the near future. (Europe's Energy Portal 2013) Bearing in mind that conventional gas deposits are declining, further dependence on imports from Russia and North Africa would likely further pressurize prizes. To stay at the current volume of approximately 60% imports, Europe will have to look for alternatives within its borders and shale appears to carry significant potential. (Shale Gas Europe 2013)

A range of economic studies have recently attempted to model the profitability of shale gas exploitation in Europe and, although not for all basins, have published some promising numbers, clearly indicating that economic recovery within Europe is possible. (Weijermars 2013)

The economics of production should also be aided by the ever-expanding empirical industrial knowledge from the US. Although the exploitation has somewhat stagnated since prices hit an all-time low of less than $2 per MMBTU in 2012, the fact that shale oil production, which, due to the intrinsic, highly viscous properties of the resource is commonly viewed as being a lot more difficult to extract than gas, has massively increased in recent years is a clear indicator that technology has undergone some major advancement.

As will be delineated in more detail in Chapter 8.2, public opinion and political will across the continent remain highly divided on the potential exploitation of shale gas. To assist a decision in that regard, it is perhaps useful to look at what shale gas could or could not do, both in economic and geopolitical terms.

7.5 Implications of European shale gas production

The remarkable developments in the US over the past decade have naturally sparked the debate whether similar outcomes could be expected from European shale gas production. Bearing in mind that geological potential and economic recovery carry plenty of uncertainty, the following chapter aims to elucidate the potential impact of different prospective scenarios on European economies, first of all from a gas market perspective, then with a view on possible welfare gains from the introduction of new industries.

7.5.1 Impact on gas markets/prices

As mentioned in Chapter 5 the shale gas boom in the US has shattered the North American gas markets, causing prices to plummet from $13 per MMBTU to a spot market price of $1.8 per MMBTU in 2009. Prices have now stabilized in the range of $4-5 per MMBTU at Henry Hub, which still stands in stark contrast to the European prices. LNG apart, the question is to what extent shale gas exploitation in Europe could impact the local gas prices and thereby reduce the current competitive disadvantage.

The answer essentially depends on two factors: 1) the production costs and 2) the dynamics of the European gas market production costs.

As delineated above, commentators largely agree that shale gas production would be more costly in Europe with a range of parameters rendering it highly unlikely to enter the gas market below current spot prices in the near future. If industrial operations stay at the current level or on a generally small scale, this is unlikely to change. However, if large-scale extraction commences, advancements in technology and drilling techniques and increasing knowledge about the geological settings should be natural consequences and are destined to cause production costs to decline. In such scenario, the market side becomes more interesting.

While there is an immense amount of literature on the pricing of oil, surprisingly little, in light of the fact that the resource now approaches 25% of global energy consumption, has been written about natural gas markets, in particular about the European one. This is perhaps largely due to the at times daunting lack of transparency and accurate public domain data.

The vast majority of gas in Europe remains to be traded on the basis of long-term contracts in the range of 10-30 years with prices usually being composed of a base price, P_0, and the *index*, which determines how the base price is adjusted over time. Traditionally, the prices in these contracts were calculated following the *replacement value principle*, which dates back to the early years of Dutch gas production in the 1960s and is based on an average value of other fuels competing with gas and adjusted in light of the higher transportation and storage costs as well as potential additional taxes any taxes. Prices were generally adjusted on a quarterly basis, based on average prices of competing fuels, most importantly oil, in the preceding six to nine months, commonly with a lag of three months. (Beuret 2005, Stern 2014)

These long-term contracts are chiefly concluded between national or exporting producers and regional or national utilities and essentially created a range of monopolies, where utilities are able to steer markets at will and customize prices based on the market access and dependencies of their buyers.

However, in the late 2000s European energy regulation and competition law expanded increasing efforts to promote ownership unbundling and market access, which completely transformed the regulatory and market context in which the existing contracts were operating and enabled the creation of a European spot market. (Stern 2014)

The now freely accessible and transparent prices at gas hubs throughout Europe started to fall due to range of reasons, most prominently the proliferation of shale gas in the US and a subsequent over-supply of LNG and stuttering demand within Europe due to the ongoing recession. In combination with continually rising oil prices and consequently the gas prices of long-term contracts these developments put utility companies in an increasingly difficult situation. Most of their commitments with gas producers are equipped with so-called *take or pay clauses*, which require the buyer, rather self-explanatory, to purchase a certain pre-determined amount of gas regardless of whether that volume is actually taken or not. The now (more) open structures of the gas market implied that they could no longer dictate proceedings with their buyers in a monopolistic manner and faced a conundrum where they could either loose customers by sticking to high prices or themselves purchase and re-sell cheaper spot market gas. Both scenarios would render it very difficult to meet their take-or-pay commitments. (Stern 2014)

Things have now moved towards adapting long-term contracts to real market prices, in particular with Norwegian and Dutch contractors. The situation is more diffuse with Russian and North-African suppliers, which naturally have little interest in decreasing incomes, but it is unlikely that they will be able to resist the developments in the long run. However, with demand destined to grow further, prices will at some point start to climb again. (International Gas Union 2012b)

For shale gas, the above developments are rather promising, in particular in light of the fact that commercial production is not projected to commence before 2020, if ever. Spot markets look set to grow in importance and exert increasing influence on long-term contracts, which should in the long run lead to uniform market prices.

Shale gas at currently anticipated production costs is unlikely to pressurize prices. Most commentators also concur that shale gas would not make Europe self-sufficient in natural gas. (European Commission Joint Research Centre 2012)

However, with growing global demand, in particular from the emerging economies in Asia and the increasing Russian commitments in these areas, shale gas could help to stabilize prices in Europe and diversify supply. And in the long run, where projections hint at significant decreases in production costs, shale gas may indeed go a long way in dampening energy prices and thereby crucially contribute to the competitiveness of European industries.

7.5.2 Potential welfare gain

Even though being far from certain for the above reasons, the advantages of falling gas prices for European economies would be obvious and far-reaching. The key effects are nicely illustrated in *Figure 17*.

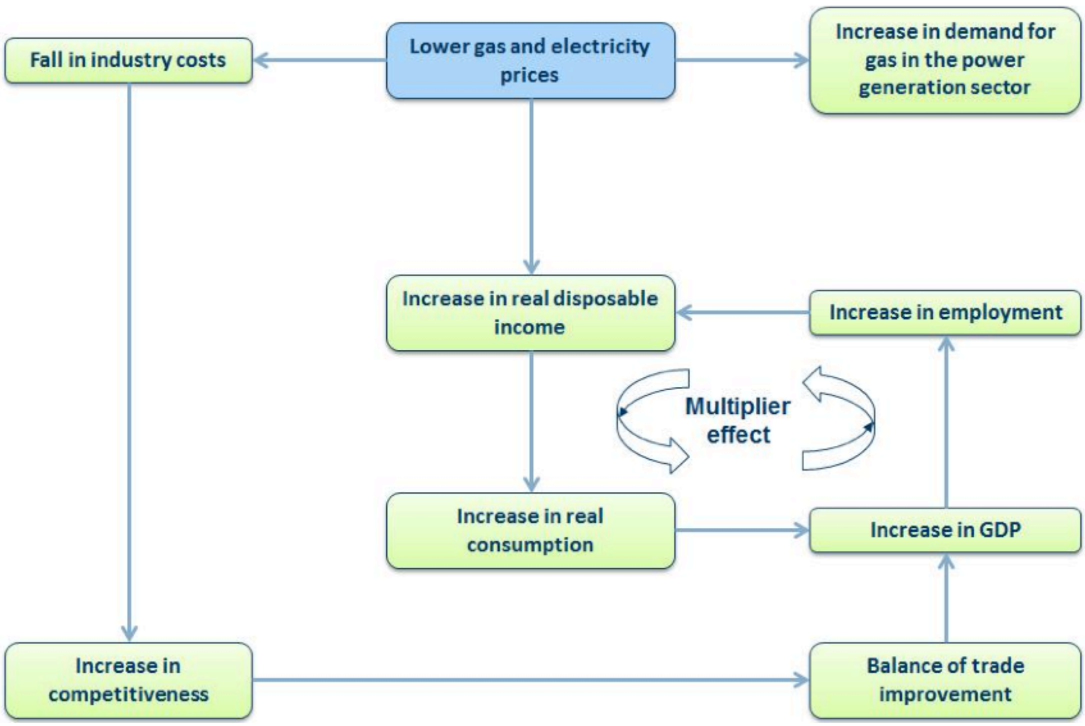

Figure 17: Potential economic impact of lower gas and electricity prices
Source: (Pöyry Management Consulting Ltd & Cambridge Econometrics 2013)

The power generation sector would be the first to benefit from the cheaper resource, which should lead to falling electricity prices and a strong incentive to increase the share of gas-fired plants in the primary production.
The declining costs of electricity production are widely assumed to be passed on to the industries and domestic consumers in the form of lower electricity prices.
The industry would hereby perhaps be the greatest beneficiary with declining production costs, in particular in the energy-intensive sectors. Only recently the Austrian steel giant *voestalpine* has named cheaper gas prices as the key incentive to move an investment of €550 million to Texas. (Die Presse online 2013) Cheaper gas would enable the industries to gain higher yields and improve their competitive stance in global markets, which will have immediate repercussions on the balance of trade and consequently the national and European GDP.

Private consumers would profit from lower resource and utility prices as well as cheaper end products, leading to an increase in real disposable income, which again triggers changes in consumption patterns and should ultimately again lead to GDP growth. These are rather fundamental laws of economics. (Bhattacharyy 2011)

A recent report published in cooperation with Cambridge Econometrics has attempted to provide figures for the extent of these developments. The authors base their model on two scenarios for technically recoverable shale gas reservoirs in Europe,[13] a *Some Shale Scenario* with 8.1 Tcm of TRR and a *Shale Boom Scenario* (SSS) with an estimate of roughly 10.8 Tcm, both of which are significantly lower than the numbers provided by ARI and others,[14] and compare these with a *No Shale Scenario*. They assume that 18% of the TRR, equalling 3% of the risked OGIP, and 1480 Bcm of gas in absolute numbers will be produced between 2020 and 2050 in the *Some Shale Scenario* (SBS) and 33% of TRR, 7% of risked OGIP and 3,525 Bcm respectively in the *Shale Boom* case. (Pöyry Management Consulting Ltd & Cambridge Econometrics 2013)

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[13] The report specifically looks at the economies of the EU-28.

[14] See Chapter 7.3.

There is essentially no change in gas prices projected for the SSS until 2030, when it starts to slowly, but continually depart from the prices without shale influence. In the SBS, a rather sharp decline can already be seen until 2030 and flattens out until the end of the projection in 2050. In total, the report anticipates, on average, a 6.2% decrease in the SSS and a 13.8% change in the SBS.

In terms of macroeconomic impact, the study finds that the SSS would yield an average reduction of 3% in electricity prices, resulting in average annual savings of €12 billion per year for the EU-28. The SBS would, with an average reduction of 8%, accordingly translate into average annual savings of €27 billion.

Household savings in terms of electricity costs would amount to €3.3 billion in 2035, €9 billion in 2050 for the SSS and €11 billion in 2035 and €14 billion in 2050 for the SBS respectively.

In terms of macroeconomic parameters, the SSS is projected to absorb the decline in domestic conventional gas production and keeps import dependency stable at roughly 70%, resulting in an expenditure reduction of €15.6 billion on average per year with immediate and substantial repercussions for the balance of trade.

Should Europe fully jump on the shale gas train, the SBS envisions a decrease in the EU's import dependency and a expenditure reduction on imported gas of €35.4 billion on average per year. (Pöyry Management Consulting Ltd & Cambridge Econometrics 2013)

Further benefits will come in the nature of employment opportunities. Although the direct output in terms of jobs will not be significant, seeing that the sector has a relatively low intensity of labour, experience shows that a major trickle-down effect for support businesses, drilling contractors, hydraulic fracturing companies, trucking companies, resulting in a clear and substantial value-added from such service sector development is highly probable. (European Commission Joint Research Centre 2012)

Finally, there will be considerable tax revenue for governments from increasing local gas production. Given that rights on hydrocarbons are in Europe typically attached to the state and licenses are only given out to contractors to exploit resources, governments most commonly install some kind of a mineral tax, based on spot market prices per m^3 of gas. In addition, corporate taxes, general income tax and social security payments from new employees will all contribute to increasing state revenues.

In respect of the overall economic impact the study anticipates an EU-wide GDP increase of approximately 0.3% by 2035 and 0.6% by 2050 for the SSS, when compared to the *No Shale* baseline. It further projects the creation of an additional 0.4 million jobs across the EU by 2035, increasing to 0.6 million jobs by 2050. The SBS foresees a rise in EU GDP of 0.8% by 2035 and 1.0% in 2050 combined with a net job creation of 0.8 million by 2035 and 1.1 million by 2050.
Cumulatively, GDP in the EU-28 could increase by as much as €1.7 trillion in the SSS and a staggering €3.8 trillion in the SBS, each in the period between 2020 and 2050. (Pöyry Management Consulting Ltd & Cambridge Econometrics 2013)

With a myriad of assumptions and simplifications, there is surely a lot of uncertainty behind these numbers and it is perhaps noteworthy, that the study has been conducted on behalf of the International Association of Oil and Gas Producers (OGP). However, it does provide one or more at least theoretically perceivable scenarios and implications for a European shale gas industry and it is needless to say that the outcome is rather spectacular, which naturally sparks the question why so little has thus far been done to tap into this seemingly huge potential.

8 Is the US success truly replicable?

The shale gas developments in the US have surely not gone unnoticed in Europe and soon sparked an at times heated debate about the potential of extraction within the EU. It is rather obvious from reactions and policy decisions across various countries that the successful recovery of the resource does not solely depend on geological potential and production costs, but a delicate combination of a range of factors.
This chapter aims to decrypt the circumstances that were crucial to enable the proliferation of shale gas in the US and subsequently see whether comparably favourable conditions prevail in Europe, for illustrative purposes with particular focus on a case study of two countries with rather different frameworks, Poland and Austria.

8.1 The key enablers of the US success

Like many other historical breakthroughs, the shale gas boom was not triggered by one game changing invention but rather a timely combination of circumstances that allowed the resource to flourish.

The impetus for taking a closer look at unconventionals came from the projections of declining conventional production in the US and the threat of increasing import dependence, which would naturally carry the risk of rising energy costs. Lofty oil prices as well as generous public funding provided the petroleum industry with plenty of capital to put heavy investments into research and development of unconventional resources. (Rogers 2011)

The enormous geological potential both in terms of existing hydrocarbons and their favourable location in relatively shallow layers is meanwhile well-documented and became economically exploitable through key technological advancements that were the outflow of large-scale R&D investment.

Elevated gas prices due to decreasing domestic production as well as tax credits targeting the production of unconventionals also helped to render the exploitation economically feasible in the early stages. There was a lot of trial and error involved in the rise of shale gas and high profit margins absorbed some of the failures naturally occurring in an infant industry. (Rogers 2011)

A vital aspect and, as will be discussed below a major difference to European countries, was and remains the comparably easy access to land that can essentially be ascribed to two factors: Firstly, population density is a lot lower in the US and it comes as no surprise that the highest yields and production rates come from some of the least populated areas. The Barnett shale West of Dallas in Texas is mostly farmland with population densities of less than 30 inhabitants per km^2. Austria, in contrast, has 102 people per km^2, France 120 and Poland 127. (World Bank 2012) Although environmental concerns have been downplayed in recent times, the invasive nature of the industry and heavy traffic implications naturally cause tensions in highly populated regions.

Secondly, the US feature a rather unique regulatory framework, where mineral rights do not belong to state or country, but the owner of the land, regardless of whether that is a private or public entity or person. This puts landowners in the remarkable position to lease, rent or sell mineral rights to the petroleum industry. Contracts may hereby feature all kinds of clauses and agreements, simple rents, royalties, signature bonuses and others with all of them sparking a substantial incentive for private individuals to contract. While some operations are beginning to face considerable local opposition in the US, the financial remuneration surely helps to bear the inconveniences. (Stevens 2010)

As for state-owned land, mineral rights are commonly auctioned off to bidders from the petroleum industry and already include the permission to drill, which also significantly eases the process. Licensing in general is based on rather simple structures and permits can be obtained even for urban areas. (Gény 2010)

Another parcel of the regulatory framework that has facilitated the proliferation of shale gas production are comparably lax environmental standards. Hydraulic fracturing has been exempted from the application of the Safe Drinking Water Act, freeing it from federal scrutiny to prevent water contamination and the compulsory disclosure of used substances. The handling of fracturing waste has been excluded from the restrictions of the Resource Conservation and Recovery Act and operators are treated favourably under the Comprehensive Environmental Responsibility, Compensation and Liability Act. Although the growth of the industry has caused some revision on both state and federal level and several bills are currently pending, the industry has surely been helped by the relative freedom, and it is safe to say that the framework remains rather accommodating. (The Royal Society and the Royal Academy of Engineering 2012, Tiemann and Vann 2013)

Environmental Impact Assessments (EIAs) have created major difficulties for the industry in some European countries. The general position in the US is that no Environmental Impact Statement (EIS), the US equivalent of an EIA, is required for private land exploration at the Federal level because authorization for the activity is commonly granted by the state.[15] Some states, including New York and California, have opted for rather cautious programs to control the environmental impact of a particular project, which have caused major quandaries in the licensing process. Texas, Pennsylvania and Ohio have in contrast chosen looser regulations and thereby

[15] Exceptions exist for exploitation on federal lands.

significantly aided the progression of the industry and allowed basins like Marcellus, Barnett, Eagle Ford and Utica to prosper. (Young, *et al*. 2013)

An aspect that often seems to be underestimated is the infrastructure available to US producers both in terms of pipeline network and access as well as a very competitive service industry to enable large-scale industrial operations. (Rogers 2011)

The US can draw on a highly developed pipeline network and a fully deregulated market with open gas-to-gas competition. This allows well operators to directly negotiate with the pipeline provider to build new connections to link their resource to the trunk line and immediately enter the market. (Gény 2010)

The rapid growth of shale gas activities caused an enormous rise in the demand for adequate drilling and completion equipment, most notably directional drilling and high-pressure pumping. The share of US onshore rigs capable of drilling horizontally increased by a factor of five in a decade from 1998 to 2008, meaning almost 500 new rigs in absolute numbers. (Energy Information Administration 2014) In one year between May 2013 and May 2014, 150 new horizontal wells were completed. (WTRG Economics 2014) The US have traditionally been equipped with a large and strong petroleum industry, which provided a solid base to expand capacities and meet the growing needs of the industry not only in terms of equipment, but also skilled personnel. It also helped that the industrial niche required for the shale gas extraction was dominated by several large companies, in particular Schlumberger, Halliburton and Baker Hughes/BJ Services, which had the financial muscle and reach to quickly adapt to the rising demand. (Rogers 2011)

Last, yet perhaps not least, political will and public acceptance have both played a major role in allowing the resource to proliferate.

Most states have openly embraced the economic drive of shale gas exploitation in terms of job creation, industrial growth and substantial tax revenues. Premised largely on the shale industry, economists have heralded a re-industrialisation of the US, and statistics appear to concur. (IHS Global Insight 2011) In 2010, the shale gas industry supported 600,000 jobs in US, and numbers are anticipated to grow up to one million until 2025. (PWC 2011) The GDP contribution has been estimated to aggregate $76 billion in 2010, and commentators have projected almost double the amount for 2015. (IHS Global Insight 2011) Rather mindful of the wider economic implications of the shale gas boom, federal and state politicians have generally been very supportive of the industry. (Rogers 2011)

The economic success has also helped to foster public acceptance and put the industry in a positive light. Drilling companies are highly alert to the growing unease within the population as regards the environmental footprint of *fracking*, but it appears that resistance has thus far remained on a small and local scale. An aspect that should perhaps not be underestimated in the comparison with Europe is the population's general familiarity with the petroleum industry in the proximate surroundings.

All of the above factors have culminated into a very accommodating framework for the growth of the industry. To sum up, the key enablers of the shale gas boom in the US are the following:

1) Vast and easily accessible geological potential;
2) significant investment into R&D;
3) technological advancements;
4) high gas prices;
5) land access;
6) favourable legal and policy framework;
7) available infrastructure;
8) public acceptance;
9) political will.

8.2 The European circumstances

Many of these aspects can be analysed on a transnational level as they pertain to all European states in the same or an utterly comparable way. Others, however, have to be assessed for countries individually. The scope of this paper does not permit to look into every single EU nation. Yet, the analysis of the two chosen case studies, Poland and Austria, should provide an apt illustration of the difficulties the European shale gas industry may face and how governments have reacted to some of the challenges.

The common European framework will be dealt with *a priori*, before delving into the specifics of the two countries at scrutiny, which feature rather different environments for some of the issues that enabled the US boom.

8.2.1 **Geology, Technology, Infrastructure *et al.***

The geological potential of European shale gas has been delineated in previous chapters and remains permeated by uncertainty. However, as previously stated, there are considerable quantities of exploitable unconventional hydrocarbons available. Some more details will be provided in the country-specific sections.

As for the technological side, it is safe to say that, despite major differences in the geology when compared to the US and, as should be clear from the deliberations in Chapters 3 and 4, necessary adaptations in the means to exploit the resource, Europe enjoys a head start in respect of the technologies that are available to the industry. Companies in the US have reported major advancements in drilling techniques, triggering lower production costs at much higher rates. (Gény 2010)

It is noteworthy in this regard that in contrast to the US, shale gas development in the EU is spearheaded by some major players of the petroleum industry. Many of them had underestimated the potential of the resource in the US and have come out second best in the combat for drilling rights. Already in 2010, more than 40 companies, including Chevron, ConocoPhilips and ExxonMobil, thus engaged in the early stages of exploring Europe's shale potential. (Kefferpütz 2010) This is important for multiple reasons: First of all, they bring valuable knowledge to an infant industry and the importance of that can hardly be overestimated. Secondly, the continuously lofty oil prices have equipped them with large amounts of capital that can be invested in the early stages of proceedings, which might not immediately yield large returns; smaller companies would risk their very existence in the financial burdens implicated by the exploration with a fruitful outcome anything but certain. And thirdly, R&D investments will at least in part come from the private sector. Once major monetary commitments have been made, these companies will spare no effort to make them profitable, and the advancement of technology and know-how will surely be crucial parcels on the path to success.

What may indeed be a bottleneck for the European industry is a comparably low sophistication of the service industry both in terms of experience with shale gas technologies, most notably high pressure pumping and directional drilling, and in respect of available capacities. If shale gas exploitation was truly launched on a large scale, it is highly doubtful whether the service sector could keep up and provide the means to develop the resource. To put things into perspective, in contrast to almost 2000 rigs in operation in the US, as of January 2014 Europe featured 126 rigs, of which only 29 were used for gas. (Energy Economist 2014) Hardly any of these are capable of drilling horizontally. The production is estimated that the production of 100 Bcm, not even a quarter of European gas consumption, would require the simultaneous operation of 530 rigs. (Gény 2010) It is rather obvious that the European service industry would struggle to meet the needs of such undertaking. American market powers should help, but will be rather busy feeding the US demand and the logistical advantages of having local suppliers should not be underestimated. Apart from equipment this is also an issue of necessary know-how and human capacity, which will be impossible to generate on short notice. An aspect that is also overlooked at times is the trucking intensity of the shale gas industry, which could also quickly trigger shortages on the continent. In sum, it can hardly be doubted that the service industry is set to at least decelerate the development of shale gas in Europe.

The gas prices and market outlooks have been extensively discussed in Chapter 7.5. It suffices to reiterate at the junction that Europe is projected to suffer from continuously high natural gas prices, which is unpleasant for consumers, but should provide the shale industry with some important leeway in regard of production expenses. The difference in geology of the European and the US shale will inevitably require some adaptations in terms of drilling techniques, applied substances and logistics. These are likely to cause some financial setbacks, but continuously high gas prices should help to mitigate the impact.

Land access, legal and policy considerations as well as infrastructure and public perception cannot be discussed in a general trans-European manner and will be dealt with in the ensuing section. However, given the omnipresence and ever-expanding potency of the EU, the overarching umbrella of the Union's legal and policy framework can and should be analysed beforehand to see how much room for manoeuvre is left to the respective governments, and what is to be expected from the Union itself.

8.2.1.1 Applicable law

Dismantling all EU legislation as to its applicability and exact interpretation in regard of drilling processes would again exceed the scope of this paper. The aim here is thus to concisely outline acts and provisions that carry the potential to interfere with the industry and hamper its development, in particular when compared to the US framework and identify the policy choices that are left to member states.

In this context it is first of all important to note that the entire realm of mineral rights and exploitation does not fall within the exclusive or shared competence of the EU as outlined in Articles 3 and 4 of the TFEU, thus leaving it solely in the hands of the member states.

However, there is a range of legislation surrounding the mining industry that may well carry significant repercussions, including in particular environmental laws, and the regulations on the internal (gas) market as stipulated in the 3rd EU Energy Package.

8.2.1.1.1 Environmental legislation

As mentioned above, there is to date no specific EU law governing shale gas exploitation or hydraulic fracturing. The EU has only recently issued a Recommendation covering a number of issues related to shale activities, such as underground risk assessment, well integrity, disclosure of chemicals, baseline reporting and operational monitoring, capture of methane emissions as well as strategic environmental assessments and planning. (Recommendation 2014/70/EU) Yet, as a Recommendation the document is merely a guideline for national policy-makers and does not carry binding legal force. However, many of the issues addressed by the Recommendation are at least tangentially covered by other legislation.

As previously mentioned, some of the major concerns regarding shale gas exploitation in Europe stem from the environmental sphere, which naturally raises two questions in context at hand: on the one hand, to what extent is EU environmental legislation applicable to the drilling processes, and on the other hand, is it detrimental to the industry?

The Commission has rather unambiguously clarified that, "unconventional hydrocarbon projects involving the combined use of advanced technological processes such as horizontal drilling and high volume hydraulic fracturing, notably shale gas exploration and exploitation activities, are covered by EU environmental legislation from planning until the cessation". (European Commission 2012a, 6)

Some of the most stringent environmental regulations concern water bodies and more generally the use and abstraction of larger amounts of freshwater.

Under the Water Framework Directive operators are bound to obtain authorization if a project requires large amounts of water form a surface or groundwater body, which will inevitably be the case with hydraulic fracturing. The Directive further prohibits the discharge of wastewater with hazardous chemicals into surface or groundwater bodies. (Directive 2000/60/EC) Somewhat surprisingly, parts of the Water Framework Directive, specifically Article 11(3)(j), which prohibits the injection of flow-back water into geological formations, are *not* considered to be applicable to shale gas activities. (Ballesteros *et al*. 2013) However, the Mining Waste Directive fills the gap, serving as *lex specialis*, and foresees rather stringent procedures for the treatment and control of flow-back water and leachate, both on and below the surface. According to the Directive the operator has to draw up a waste management plan for the minimisation, treatment, recovery and disposal of extractive waste, "taking into account the principle of sustainable development". It generally urges the extractive industry to apply the least environmentally invasive measures available for the production, and clarifies that the operators remain responsible for monitoring and eventually necessary maintenance measures in the after-closure phase of a well. Notably, it also contains provisions obliging national authorities to inform the public, hear their concerns and "duly take them into account". (Directive 2006/21/EC)

The REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulation generally binds producers to disclose and register hazardous substances that are applied in hydraulic fracturing as well as to provide information about the specific use of the substance, exposure scenarios and a plan for safe disposal. (Regulation (EC) No 1907/2006) Comparable measures are also prescribed by the Biocidal Products Directive and the Natural Habitat Directive respectively. (Directive 98/8/EC, Directive 92/43/EC)

National authorities are entitled to issue permits for the production activities, yet are thereby obliged to ensure compliance with EU law. They are also bound to monitor the conformity of operations with the ambits of the permit and can, in case of transgressions, revoke the licence at any time.
Operators are held liable and bound to bear remediation costs for any damage caused to the environment in accordance with the Environmental Liability Directive. (Directive 2004/35/CE)
These provisions are significantly more stringent than their US counterparts and include no exceptions or concessions for unconventional resources. As a Directive, much will still depend on the way it is transposed into national law, but looking closely there is little leeway and countries can only opt for an even more rigorous approach, not a lighter one. It is unlikely that the regulations will *per se* hinder exploitation, yet they will regularly be tied to laborious bureaucratic hurdles and may be one of a plethora of parcels that compromise the forthcoming of production.

A perhaps more severe disruption may come from mandatory EIAs, within the EU again regulated by a Directive. (Directive 2011/92/EU)
EIAs are a formal process used to scrutinize the environmental consequences of a plan, policy or project. In essence the transposition into national law has resulted in an exhaustive list of undertakings that have to undergo a prescribed procedure in order to receive approval for implementation. Operators thereby have to hand in a comprehensive analysis pertaining to all potential direct effects and any indirect, secondary, cumulative, short-, medium- and long-term, permanent and temporary impacts of a given project on the environment. This may include noise pollution, visual impacts, bearings on flora and fauna, waterways, tectonic settings and many more. The report must further comprise a description of the measures envisaged to prevent, mitigate and – where possible – offset any significant adverse effects on the environment, and indicate monitoring procedures for each potential influence. An important feature of EIA proceedings is the extensive involvement of all stakeholders, comprising the general public, NGOs, representatives from municipalities, provinces and whoever else has a proven interest in the matter.
The problem of EIAs for shale gas activities is essentially twofold: First and foremost it is not easy to receive approval, and secondly, even if permission is

eventually granted, the average length of proceedings is more than two years, for complex and large-scale projects four to five years are not uncommon. (Umweltbundesamt 2012)

The Directive currently only requires the proceedings for projects that exceed a certain scale of production, set at 500,000m^3 per day, meaning that exploratory drilling is exempted. (Directive 2011/92/EU)

However, the Parliament has recently proposed an amendment of the EIA Directive, suggesting that the following activities require an EIA:

> *"14a. Exploration, limited to the phase involving the application of hydraulic fracturing, and extraction of crude oil and/or natural gas trapped in gas-bearing strata of shale or in other sedimentary rock formations of equal or lesser permeability and porosity, regardless of the amount extracted.*
>
> *14b. Exploration, limited to the phase involving the application of hydraulic fracturing, and extraction of natural gas from coal beds, regardless of the amount extracted."* (Herbert Smith Freehills 2013)

In accordance with the co-decision making procedures of EU legislation the amendment has passed the Parliament and is currently pending approval from the Council to become binding law. There is no fixed timeframe for the Council to consider and vote on the amendment, but members of parliament have indicated that they hope it will be in force by 2016. (Young, *et al*. 2013) The Directive would then still have to be transposed into national law, which could take several more years, but in essence, it is only a formality.

The Committee of the Regions has been a vocal supporter of the regulatory change, saying that, "there are still too many questions related to the extraction of shale gas and oil which pose significant questions and challenges" and require the EU to "put in place safeguards to protect citizens' health and reduce the impact on the environment by urgently regulating the industry". (Committee of the Regions 2013)

The repercussions of the amendment would be significant to say the least. Formally, it derives member states of their discretion to decide whether they intended to subject hydraulic fracturing activities below the threshold of 500,000m^3 per day to an EIA or not. In practice, it adds a significant hurdle for the industry. The problem is particularly astute in the context of exploratory drilling. The uncertainty surrounding European shale gas will lead to extensive exploration activity and enterprises may well get all concessions for one spot, find out that the potential had been overestimated and would like to move their capacities elsewhere. If a new concession, even for exploratory drilling, implicates a standstill of all resources for up to five years, very few companies will be willing to commit their capital in the first place.

Under the current framework, some countries have already opted for such rigorous approach. Bulgaria and Lithuania require a mandatory EIA for both exploration and extraction of unconventional hydrocarbons whereas Denmark and Austria have expanded EIA requirements to any use of hydraulic fracturing. It is rather telling that in all of those countries, the shale gas industry was, despite early optimism, unable to even launch exploratory drilling.

Much will depend on the exact interpretation of the norm and whether the scope of issued permits cover an entire concession area, a specific well pad or even only individual wells. While the earlier would merely add a bureaucratic hurdle that can be overcome, the latter would mean that shale gas activities are essentially halted before they even commenced. As will be seen below, Poland and Austria have opted for diametrically opposed approaches with according implications.

Despite the delineated disadvantages, there are also some signs for optimism. Some authors have pinpointed the lack of third party access to the pipeline system as a major drawback of European shale gas developments as it triggers uncertainty on available pipeline capacities and prevents system and flow optimisation. In the US, the market is fully deregulated, allowing for open gas-to-gas competition. (Gény 2010) In Europe, pipeline systems have traditionally had close ties to the production side, often being owned by the same companies or directly linked to some long-term contracts, which naturally implicated some hesitance to make them available for other suppliers. However, the 3rd Energy Package of the EU, adopted by Council and Parliament in July 2009, has gone to great length to unbundle the industry and create an open and competitive (internal) natural gas market, where operators can simply negotiate with pipeline companies to build a new connection to the trunk line. (See in particular (Regulation (EC) No 715/2009, Directive 2009/73/EC) In addition, the EU has also repeatedly expressed its intent to build new connective infrastructure in order to facilitate the development of the market. (European Commission 2012, European Commission 2011b) This has to be considered a major step for shale gas exploitation in Europe.

In summary, the legal framework in Europe is significantly tighter than in the US, in particular in environmental terms. Drilling companies will have to go to greater lengths to get approval from national authorities and are held to higher standards in respect of available technology, permitted substances, their use and disposal, continuous monitoring and liability. However, the environment is not as hostile as some appear to suggest, and tight regulations may at the same time go a long way in fostering public trust in the harmless nature of the drilling activities.
Compulsory EIAs may become a game changer, but much will depend on the specific interpretation and application of the norm, which is not yet clear.

Although not *per se* binding, it is well worth to also look at the policy side of things to identify the current mood and stance of the EU on the issue as an indicator for future developments.

8.2.1.2 The policy side

It is interesting to see that the Institutions of the EU have shown rather mixed interest and enthusiasm about the prospects of shale gas. In the context of the security of supply the European Council, viewed by many as the guiding body of the EU, has repeatedly stressed the importance of unconventional resources. In May 2013 the body explicitly referred to shale gas when it called for the development of indigenous energy sources to reduce the EU's external energy dependency and stimulate economic growth while stressing the need to ensure their safe, sustainable and cost-effective extraction and respecting Member States choices of energy mix. (European Commission 2014)
Intentions of further research for the potential of unconventional fossil fuels were also incorporated in major instruments of European Energy policy, *inter alia* "Energy 2020 — A strategy for competitive, sustainable and secure energy"

(European Commission 2010) and “Energy infrastructure priorities for 2020 and beyond”. (European Commission 2011a)
However, institutions have been utterly hesitant to take a clear stance on the issue. The European Parliament initially showed great interest in unconventional resources and prompted the Commission to take action to support countries in geological research, facilitate pilot projects and assess the potential of unconventional gas for future energy supply in Europe. (Gostyñska, *et al*. 2011) However, in the ongoing debates, environmental issues started to dominate and turned the initially optimistic stance of the parliament and temporarily caused it to withdraw from the discussion by approving committee proposals stipulating that policies on developing shale gas should be set by each member country for itself, rather than by European Institutions. (BBC 2012)
With increasing public pressure the Parliament adopted two resolutions, again non-binding, in November 2012, on environmental impacts and on industrial, energy and other aspects of shale gas and shale oil exploitation respectively, but has been rather silent since.

The Commission has both emphasized the potential and voiced doubts as to the sustainability and economic feasibility of shale gas on several occasions. On a request by Polish authorities the Commission rather clearly stated that public funding of pilot projects for the exploration of shale gas were not appropriate because:

> “*(1) the industry itself had the capacity to develop proper technologies;*
> *(2) the deposits had not yet been identified in Europe, making it highly unlikely that production would occur in the near future;*
> *(3) the current data were incomplete and the possibility of gas extraction from unconventional deposits had not been unequivocally confirmed (either technically or economically)*”. (Gostyñska, *et al.* 2011, 20)

However, the Commissioner for Energy later confirmed that the European Commission perceived shale gas as a great chance for future energy supply, without ever concretizing any intent to promote development in the sector though. (Euractiv 2011)

The Commission has since expanded some considerable efforts to clarify the potential and possible implications of shale gas on the European continent. Starting in 2012, it has released a series of studies on unconventional fossil fuels, in particular shale gas, addressing potential energy market and climate impacts, risks for environment and human health, regulatory provisions applicable in a selection of Member States and the registration of certain substances potentially used in hydraulic fracturing, and REACH. The Commission even conducted a public consultation from December 2012 to March 2013, asking for the population's stance on eventual requirement of EU action related to unconventional hydrocarbon developments in the EU. (European Commission 2014)

In its resulting communication to the European Parliament in early 2014 the Commission once again stressed both potential and threats of shale gas in Europe, yet clearly appeared more favourable than in past communiqués. It restated the obvious in saying that it remains in the hands of the Member States to decide whether to extract shale gas or not, and essentially expressed its aim to provide guidance as to best practices and minimum standards for industrial operations. However, while reiterating the crucial importance of appropriate environmental regulation and the transparency of the process for all stakeholders, in particular the general public, the Commission emphasized the positive repercussions of exploitation in terms of future energy supply and diversification, decrease of gas prices, direct and indirect economic benefits in the form of infrastructure, employment opportunities and tax revenues as well as climate benefits by substituting energy sources with higher climate and GHG impact, in particular coal with the cleaner gas. (European Commission 2014)

In light of the stringent reins of the precautionary principle and the paradigm of the European energy policy towards a low-fossil future, this appears to be a rather favourable statement.

The general mindset of the EU as the leading promoter of renewables stands unchanged. (Directive 2009/28/EC, European Commission 2012) The Energy Road Map 2050 is dedicated to render the EU's energy system more sustainable and less carbon-intensive, with an ambitious target of reducing GHG emission by 80-95% in comparison to 1990 levels by 2050 without jeopardizing security of supply and overall competitiveness. (European Commission 2011) The road to decarbonisation will heavily rely on renewable energy and increasing energy efficiency, yet also sees gas as a critical transitional fuel to complement green technologies and substitute the more carbon-intensive oil and coal. Europe may hence need more gas in the future to master the switch to an energy system chiefly based of renewables. Yet, the EU remains undecided whether the supply should stem from local shale. (European Commission Joint Research Centre 2012)

8.2.2 Country specifics

8.2.2.1 Poland

Poland has been diagnosed with the greatest unconventional reserves among European States and has openly embraced the potential the resource could bring for the country's economic and industrial development. The government has voiced great confidence that the risks associated with the extraction of shale gas can be managed effectively, and made efforts to accommodate investment. As the EIA put it, "Poland has some of Europe's most favo[u]rable infrastructure and public support for shale development". (Advanced Resources International 2013, VIII-1) However, developments have not gone as quickly as many anticipated, which can be ascribed to a number of reasons: As repeatedly stressed, shale formations vary significantly and the technologies applied in the US have not translated as well as hoped to the Polish basins. While Poland's authorities appear very fond of the idea of growing a large-scale shale gas industry, parts of the regulatory framework and time-consuming bureaucracy also remain a burden for investors. The following section aims to depict the status quo of shale gas production in Poland and highlight some of the difficulties the industry continues to face.

8.2.2.1.1 Status quo of the industry

The Polish Geological Institute estimated the TRR of the Baltic Podlasie-Lublin Basin to be in the range of 346-768 Bcm when applying similar criteria as the ARI report. (Polish Geological Institute 2012) The latter itself has calculated TRR for the entire country to reach 4,190 Bcm. (Advanced Resources International 2013)

With an annual consumption of 16.6 Bcm, this would result in over 250 years of self-supply, which is rather significant. In early 2010 the prospects tempted Radoslaw Sikorski, at the time Poland's Foreign Minister, to call the country a second Norway. The optimistic outlooks attracted some of the major forces of the international petroleum industry, including the American companies ExxonMobil, Chevron, ConocoPhilips, Marathon oil, Canada's Talisman Energy and BNK Petroleum as well as a range of others. In May 2013, 107 concessions for prospecting and exploration of hydrocarbons from shale gas formation were granted, covering an area of approximately 87,000 km^2, almost 30% of the Polish territory. (Polskie tupki 2013a) *Figure 18* illustrates the territorial distribution of shale gas licences in Poland with the fields marked in red indicating granted permits.

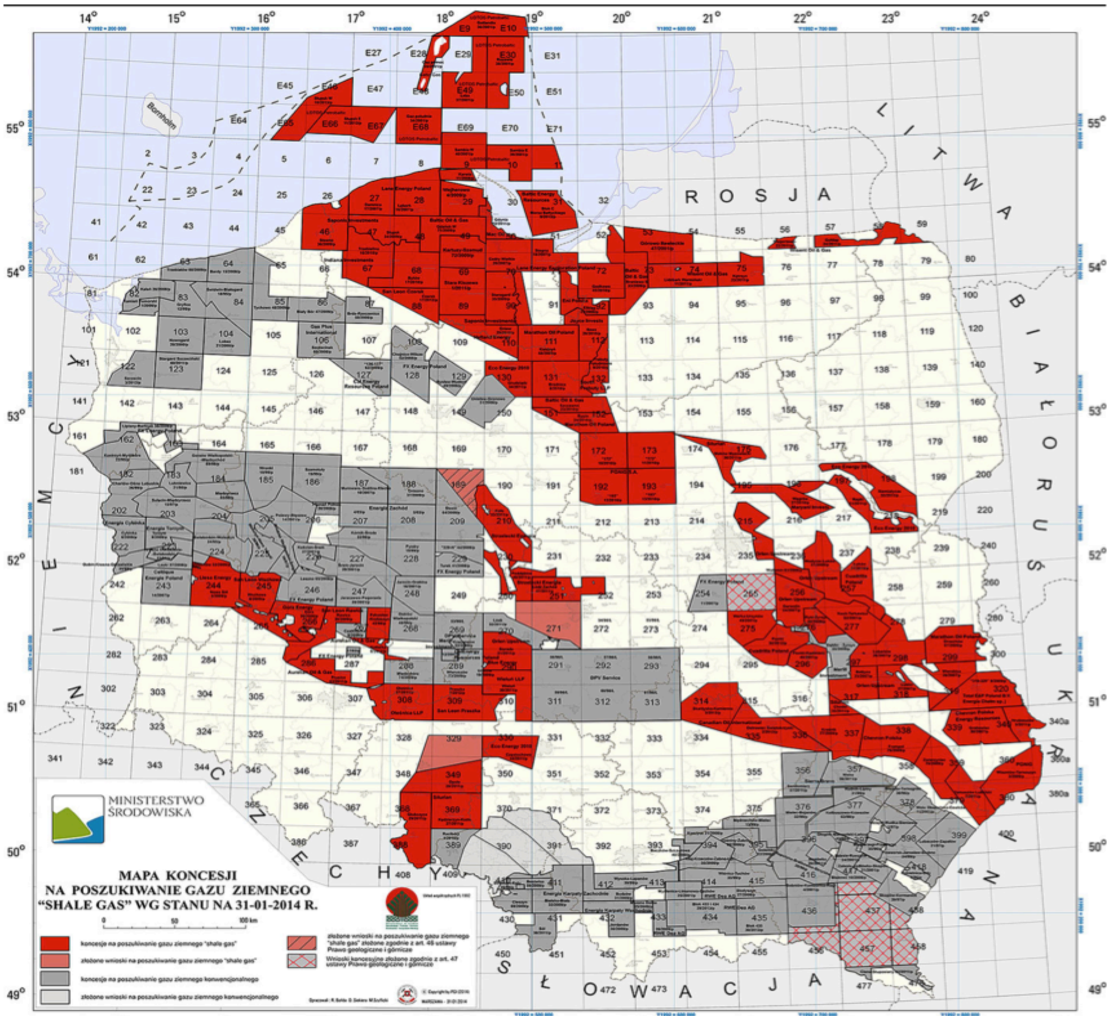

Figure 18: Shale gas licences in Poland

Source: (Polish Geological Institute 2014)

As of July 2013, 51 wells were completed with three more in the process of being drilled. (Polskie tupki 2013)

Although drilling has proved that the rock indeed contains gas, the output of most wells has been disappointing thus far.

Tomasz Maj, country manager of the Canadian *Talisman Energy* was interviewed in 2012 saying that,

> "*[...] [t]hings are developing more slowly than we'd hoped. I think other companies are also taking a cautious approach. The geology has turned out to be more complex, more difficult than people anticipated so it requires a lot more close analysis*". (Easton 2012)

Poland's ambitions suffered a heavy blow when ExxonMobil decided to pull out of operations in 2012, saying there had been "no demonstrated sustained commercial hydrocarbon flow rates" in two test wells in Eastern Poland and added that it had "completed its exploration operations in Poland". (Cienski 2012) Some other major market forces such as Marathon Oil and Talisman Energy have followed Exxon Mobil and have caused some anxiety with other providers. (Barteczko 2013)

However, the vast majority of companies have stayed, with the UK-based 3Legs Resources reporting it found "encouraging" quantities of gas in shale near the Baltic coast. (Cienski 2012) San Leon Energy Plc announced in early 2014 that a vertical well drilled in the same area yielded as much as 60,000cf per day during tests and an even more productive horizontal well is planned to follow as early as July 2014. (Strzelecki and Swint 2014)

Indeed, another 333 wells are planned to be drilled by 2021, locking Poland in as the European country with the highest shale gas ambitions for the upcoming decade. (Wozniacki and Bar 2013)

8.2.2.1.2 Legal and policy framework

Despite remaining a main attraction within Europe, Poland has felt increasing pressure from foreign investors to facilitate and speed up the production process, in particular on the bureaucratic side. The waiting times on licences and uncertainty over future regulation and taxation have supposedly stunted the industry. (The Economist 2014)

Concessions to prospect, explore or exploit hydrocarbons including shale gas are based on a tender procedure and issued by the Polish Ministry of Environment. They are granted for periods between three to 50 years. Given that all hydrocarbons on or beneath Polish soil are owned by the state, operators also have to enter into an *usus fructus* agreement with the country, which allows them to dig for the resource at own cost. (Wozniacki and Bar 2013)

The core regulations pertaining to shale gas extraction in Poland are contained in the general Geological and Mining Act. One of the main points of criticism has been that operators must currently obtain two separate concessions for their exploring and extractive activities and that even amending a concession following minor changes in the drilling program takes several months. (Easton 2012)

The growing grievance from the industry has caused the Polish government to announce plans to improve regulation on shale gas production in the hope of encouraging investors to continue their explorations for the fuel. (Speak 2013)

The government has thus recently proposed several amendments to the Geological and Mining Act as well as the introduction of a special hydrocarbon tax.

The changes in the Geological and Mining Act specifically concern the following:

- streamlining concessions to one joint permit for the prospection, exploration, and extraction of hydrocarbons;
- exempting exploratory drilling wells not deeper than 5,000 m from compulsory EIAs (and screening);
- ensuring that NGOs partaking in an EIA procedure must be registered at least twelve months before the start of the project;
- stipulating that in case of certain changes in the concession (*e.g.*, changes to the depth of the borehole or changes to the timeframe and schedule of the exploration and exploitation activities) a new EIA will not be needed. (Wozniacki and Bar 2013)

The amendments would be significant to say the least. Polish shale gas resources typically lie at the depth of 1,200 to 2,500m in the North, and at about 2,500 to 4,500m in the South, which means that the vast majority of exploratory wells would be excluded from an EIA.

It has to be noted, however, that the amendment may still be adapted and has yet to pass the Polish parliament.
As alluded to above, a law on a special hydrocarbon tax is also in discussion and intended to establish a preferential tax regime for unconventional fossil fuels, in particular shale gas, rendering the exploitation tax-free until 2020. (Polcyn and Molyneux 2014, Industry Week 2014) This is yet another sign that the Donald Tusk-led government is serious about creating a favourable environment for the shale industry.

Land access has, as evidenced by the amount of licences granted and the area they cover, not been a problem in Poland despite relatively dense population. Infrastructure, including an LNG port on the Northern shore, is being built in accordance with EU strategies and as part of the overall strive to diversify resources and get away from carbon-intensive coal, which still accounts for 55% of Polish primary energy supply and 92% of electricity generation. (International Energy Agency 2011a)

Recent reports suggest that Poland has made major strides towards launching the first commercial shale gas production on European soil. The planned removal of some legislative and political hurdles should further facilitate the developments and could yield significant benefits for the country within the next years. EU policy developments, in particular regarding EIAs, will be closely watched and might prove costly, but it seems that Poland is on course to lead the way for shale gas exploitation in Europe and thereby play a crucial role in the perception and developments of the resource in other regions.

8.2.2.2 Austria

Austria has somehow flown under the radar in the grand debate about shale gas in Europe. However, the country has been diagnosed with resources that could cover its demand for up to 30 years. The European Parliament has even listed Austria alongside Poland and Sweden as the countries with the highest shale gas potential across Europe. (European Parliament 2013)

Austria's shale resources lie in the Northeastern part of the country in the Vienna Basin, which is part of the Upper Jurassic Mikulov Marl Formation that stretches further North into the Czech Republic. The formation is about 1.4-2 km thick with 0.2-10% TOC, (Österreichische Geologische Gesellschaft 1992) and has been labelled a "world-class source rock[...]". (Advanced Resources International 2013, VIII-7)

It has repeatedly been emphasized, however, that the geological potential as well as economic and technical feasibility of Austrian shale gas in anything but certain. The formation lies over 5,000m underneath the surface, which is commonly considered to be the borderline of technical capabilities due to the enormous pressure prevalent at these depths. (Advanced Resources International 2011)

Due to its clay-rich lithology, which increases the ductility of the rock and renders *fracking* significantly more difficult, and relative immaturity, the Mikulov Marl is by some authors considered a high-risk shale gas target. (Advanced Resources International 2011)

Yet, the Austrian oil and gas producer OMV AG secured exploration concessions for approximately 2,000km^2 in the Vienna Basin in the late 2000s and confidently estimated TRR to be in the range of 5.66 to 8.5 Tcm. (Advanced Resources International 2011) The company planned to drill two exploratory wells in early 2013 to get greater knowledge about the formation and some clarity as to its true potential.

OMV has actively sought community support for shale gas development, assuring that its activities would be undertaken in a safe and responsible manner based on new methodologies developed in cooperation with the University of Leoben. Promoted as *clean fracking* the company proposed a procedure that uses a mixture of water, sand and cornstarch, and dispense with any potentially harmful chemicals. (Natural Gas Europe 2012)

However, no well has been drilled to date as the project faced strong opposition from local citizen groups and environmental NGOs, which have ultimately caused the local government to lobby against the industry and call for an amendment of the Austrian EIA Act to ensure that any kind of hydraulic fracturing is subject to an in-depth environmental assessment. (Natural Gas Europe 2012)

The amendment has meanwhile passed parliamentary scrutiny, notably with surprising ease and seemingly little consideration of the wider economic implications, and became binding law in late 2012. (Nationalratsprotokoll 2012)
The Austrian EIA Act now stipulates in Annex 1, Nr. 27, lit. a that all hydraulic fracturing activities applied in the exploitation of unconventional oil or gas resources, regardless of whether exploratory or producing, are subject to an EIA, which strongly resembles the EU proposal that is waiting for the Council's approval.
The law has caused OMV to withdraw from its plans and abandon all shale gas activities in Austria. The company has heavily criticized the manner in which both the general public as well as Austrian politicians have dealt with the situation, allowing the debate to be dominated by emotional rather than factual arguments, which could have a lasting impact on the local industries. (Die Presse online 2012)
Similarly, the IEA has explicitly urged Austria to rethink its approach toward shale gas and seize the local potential. (International Energy Agency 2014)
The development is perhaps the outflow of a number of factors, including in particular the already mentioned strong opposition from the general public, heavy involvement of environmental NGOs and the relatively dense population structure of the area, which have accumulated to lead Austrian policy-makers to adopt a rather conservative approach.

The general legal framework of Austrian hydrocarbon exploitation is utterly comparable to the Polish one. In principle, all hydrocarbons on or below Austrian soil belong to the state, which again means that petroleum companies have to enter into a *usus fructus* agreement with the state. For this concession, companies have to pay a fee relative to the size of the area for which it is being granted as well as a progressive tax, currently 7-19% of the average annual import price depending on the extracted volume, for every m^3 of gas produced. (§69 of the Austrian Mineralrohstoffgesetz)
A clear working program specifying the project in terms of scope, duration, safety measures and including, if *fracking* is applied, an EIA has to be submitted to the Minister of Economic Affairs for approval.
Land access is negotiated between the company and private individuals on whose property the drilling is supposed to take place. The latter retain the property rights

and are compensated financially for the constrained use of their land. If negotiations fail, the drilling company can consult public authorities to either force the permission by the landowner or even transfer all property rights and award appropriate compensation in both cases respectively. (§§147 *et seq.* of the Austrian Mineralrohstoffgesetz)

In sum, the legal paradigm – apart from the EIA conundrum – appears rather favourable. However, other influences have stalled the development of the resource. Austrian authorities have historically been utterly careful to act against public will and the pattern is set to continue with shale gas. The traditionally strong environmental lobby had a major say in a number of critical policy decisions in the past, prominently including the prevention of a number of hydropower plants along the Danube as well as the activation of the readily built nuclear power plant in Zwentendorf, and has seemingly spent great efforts to steer scepticism in the region, which rendered a factual assessment and discussion very difficult. This has come as a surprise to many as the province has long featured a strong oil industry with oilrigs virtually in the centre of villages. However, the extensive use of chemicals and the advertised threat to groundwater provided strong arguments for the public eye and were enough to halt the development.

In any way, it illustrates rather neatly how difficult it may and will be to establish a shale industry in the country.

8.2.2.3 *Quo Vadis* Europe?

As exemplified by the scenarios in Poland and Austria, opinions on shale gas remain highly divided within Europe. Comparable discussions have arisen across the continent and led to a wide array of policy choices among governments.

Together with Poland, France was originally seen as one of the most promising prospects for shale gas exploration in Europe, given the generous and optimistic outlooks of early geological reports. (Advanced Resources International 2011) However, in 2011 the French government imposed a moratorium on hydraulic fracturing for shale gas based on concerns in regard of its potential detrimental impact on the environment. The powerful French nuclear lobby might have also had a say, but little is known to the public. (Robert 2014) A number of licences have since been revoked and President Francois Hollande has not hesitated to reemphasize the ban on hydraulic fracturing in France and called for the further revocation of several outstanding permit applications for hydraulic fracturing operations. The issue has naturally sparked a heated debate within industry, environmentalists and public authorities. However, given that Hollande has recently reiterated that, "[a]s long as [he is] president, there will be no exploration for shale gas in France", the French approach is unlikely to change within his reign. (BBC news 2013)

Germany has remained rather neutral in the discussion. The government decided not to ban hydraulic fracturing, but emphasized the environmental sensitivity of the technology and issued several laws to control its application. (Shale Gas Europe 2014, Stevens 2012)

Denmark amended its EIA legislation in a similar manner to Austria and subjected all hydraulic fracturing activities to compulsory EIAs while Bulgaria even requires an EIA for any exploration or exploitation of unconventional resources. (Ballesteros, *et al*. 2013)

The UK has recently become very vocal about its intent to exploit shale gas, but the political will has not yet trickled into any substantial activity. (Stevens, Shale Gas in the United Kingdom 2013) In Romania, however, Chevron has just started exploratory drilling. (Marinas 2014)

All of these decisions have been driven by a wide array of factors, very much depending on the specific characteristics of the respective nations, their geological circumstances, energy mix, legal and policy framework as well as other influential factors. (Oil & Gas Financial Journal 2014) *Figure 19* provides an apt visualisation of how much it takes to launch commercial production and how many factors have to accumulate for the industry to prosper.

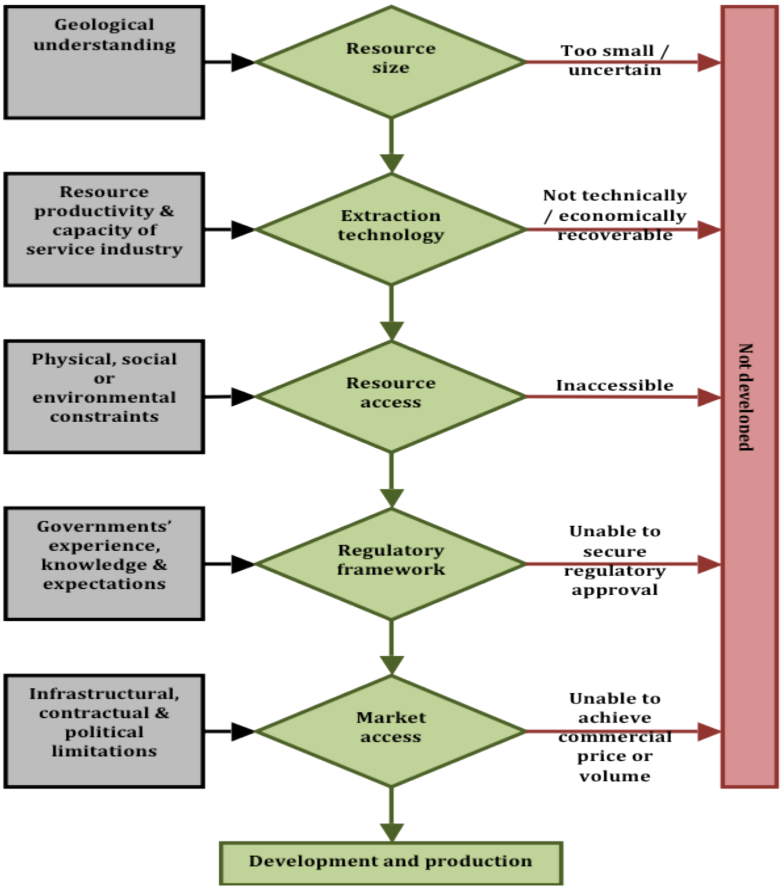

Figure 19: Criteria for development and production of shale gas
Source: adapted from (International Energy Agency 2011)

It is obviously rather difficult to fit entire Europe into such paradigm, yet several observations and assumptions can be made:

The economics of European shale gas remain permeated by uncertainty and face some obvious difficulties in the form of higher production costs, difficult geological material and service industry that lags behind its US counterpart.

Yet, geological and technological aspects are unlikely to hinder the industry for long. Techniques will have to be adapted to the particularities of the European underground, but major advancements have already been made and are likely to continue with the growth of an industry. The service sector will be a concern and is likely to decelerate the growth.

Higher population densities as well as the lack of a clear, immediate and potentially significant financial benefit, as provided in the US, are both set to restrict land availability for drilling, and render the persuasion of land owners as to the benefit of a shale gas industry in their neighbourhood considerably more difficult. Most legal regimes would allow public authorities to force exploitation and compensate the landowner financially even against his will, but decision-makers are very unlikely to offend the populace.

The US industry is highly alert to the growing threat of an environmental movement and tighter standards, both of which are already ubiquitous in Europe. The seemingly higher awareness of environmental issues and the fact that Europeans are commonly less familiar with drilling operations in their proximity have perhaps contributed to a widespread lack of public acceptance, which again is likely to have bearings on decisions in the political and legal sphere. (Pöyry Management Consulting Ltd & Cambridge Econometrics 2013)

The EU's ambiguous stance on the matter also seems likely to last and uncertainty remains despite the Commission's considerable efforts to clarify regulatory surroundings and overall ambitions of the EU, in particular in the Union's environmental *acquis* and the dawning threat of compulsory EIAs.

It seems probable that commercial shale gas exploitation will be launched in the not too distant future in some European countries, above all Poland, but the majority remains rather sceptical.

Many hence believe that it will not really be the doubts as to the profitability of the resource that will hinder the exploitation, despite being debated at length, but a lack of political will and strong opposition from civil society. As one expert has recently put it, "the main challenges [in Europe] lie in the political sphere". (Shale Gas Europe 2013)

Read in conjunction with all of the above examples the statement perhaps illustrates rather nicely what has become obvious in the broad discussion in Europe, namely that shale gas exploitation will be a lot more difficult here than it was in the US.

8.3 Has Europe chosen the right path?

As delineated at length above, Europe has thus far been rather hesitant to decide on a clear strategy in regard of the exploitation of unconventional gas. The reasons are manifold, but appear to be chiefly anchored in a lack of public acceptance and political will. Debates in member states remain highly divided and EU institutions seem afraid of doing more harm than good whatever way they go, truly living by the oft-cited Precautionary Principle.

The question arises, however, whether such approach might not prove costly in the long run. European conventional gas resources are projected to decline rather rapidly within the coming decades and strong dependencies on imports, especially from Russia, are the inevitable consequence. If Europe was to rely exclusively on gas from abroad, prices are rather unlikely to stay at the current levels. Constraints by long supply chains over other countries with at times questionable political stability or precarious relations with the major gas exporters are likely to further affect security of supply. (MIT 2011) LNG might help to diversify sources, but prices are set to reflect the sizeable costs associated with building the necessary infrastructure.

Higher prices will naturally impact the competitiveness of European enterprises, which are going to suffer from increasing energy and hence production costs. A number of large industrial ventures are threatening to move abroad or have already done so. (Die Presse online 2013) In particular the energy-intensive steel and chemical industries will face stiff challenges and may have little choice but to look elsewhere. The wider economic implications of such development in terms of jobs, GDP, trade balances and tax revenues are well-documented, and would undoubtedly be substantial. And even if renewables live up to their envisioned role in decades to come, it will be very difficult to lure industries back to Europe.

Yet, there is widespread consensus within the European public that the EU should continue its path as the foremost promoter of renewables, and that investing in a new source of fossil fuels would be detrimental to the strive for greener energy. However, renewables still only accounted for 14.1% of gross energy consumption across the EU-28 in 2012, (Eurostat 2013) and some considerable obstacles remain to be overcome on the path to the 2050 goals. The high volatility of renewable sources, especially wind and solar, triggers major difficulties in terms of grid stability and disqualifies them as a dependable cover of the base load. Energy storage technologies are still inadequate, the well-suited hydro storage capacities are only available on a very limited scale, and battery-based solutions are too costly.

Gas is widely seen as an ideal complementary and bridging technology. Gas-fired power plants are well suited for *peaking* requirements as gas injection can be adjusted fairly easily, rendering it a perfect, and comparably low-carbon, accompaniment to intermittent renewable energy generation, which would ensure grid stability and security of supply in a very efficient way.

The EU itself has indeed repeatedly emphasized the growing importance of gas and assigned the resource a key role on the road to decarbonisation. Yet, shale gas does not seem to get much love.

Europe has already drawn some heavy criticism for its approach. OMV CEO Gerhard Roiss has recently urged European states to rethink their approach towards shale gas, saying that the Union is entering a dead end in terms of energy policy, being unable to set clear priorities and thereby risking the continent's status as a primary business location. European companies might soon not only feel the competitive detriments of the globally highest costs of labour, but also the largest energy expenses. Roiss thinks that shale gas is a necessary part of a sustainable European energy mix. (Die Presse online 2012) Numerous international experts and commentators of the energy sector have voiced similar views. (Financial Times 2012, The Wall Street Journal 2012) Relying on Maria van der Hoeven, Executive Director of the International Energy Agency, one author has recently said that it could be argued that,

> *"[…]there is nothing more European political leaders could do for the mass ranks of unemployed and highly skilled European youth – perhaps Europe's biggest long term economic and social problem – than encourage an environment where domestic shale gas can be developed"*. (Energy Transformation 2013, 10)

And even current Energy Commissioner Oettinger has recently found some rather favourable words stating that, "[Europe] should see the potential that shale gas has, and create the necessary legal framework for demonstration projects and practical tests", and stressing that, "[i]f we allow test drilling we will be much smarter in a few years and know more about the costs, too. That would be very advisable[…]". (Reuters 2013) Yet, little has happened.

Environmental hazards remain at the forefront of contentions used against the development of a European shale gas industry and despite the large majority of recent reports downplaying the potential threats, arguments are catchy and will very probably continue to bode well within the populace. Although kilometres of rock will make it impossible for chemicals to migrate into freshwater aquifers, it does – in the eyes of many – hardly render pumping a plethora of hazardous substances into the deep layers of the earth a sustainable technology. There are a range of valid risks, in particular pertaining to leakages on and sub-surface, which will have to be closely monitored. It can obviously not be ruled out entirely that incidents will occur and environmental detriments be caused.

In economic terms, this is a classic example of negative externalities via pollution, a theme well-known to environmental economics. It essentially means that social costs, including expenses for health care, mitigation of environmental damages and rebuilding of destroyed territory, are higher than the costs of production, which again equal the benefit to the economy. Given that the overall benefits, indicated as *private equilibrium* in *Figure 20*, are thus lower than the overall (environmental) costs, there is a welfare loss for the economy. The size of such loss obviously depends on the difference between marginal private cost and marginal social cost. (Pearson 2000, T. C. Kinnaman 2011)

There are different means to counter such imbalance: First of all, minimizing the environmental risks via regulation will considerably mitigate the detrimental effects before occur, and reduce the social costs. Secondly, taxes may be introduced to elevate the production costs, thus shifting the supply curve to the left, thereby reducing the overall production, as demand will decline with rising prices, and again lowering the risk of environmental harm. And thirdly, production limits may be set at certain quantities, meaning that the government can control production and weigh the risk of additional output against the potential of associated harm.

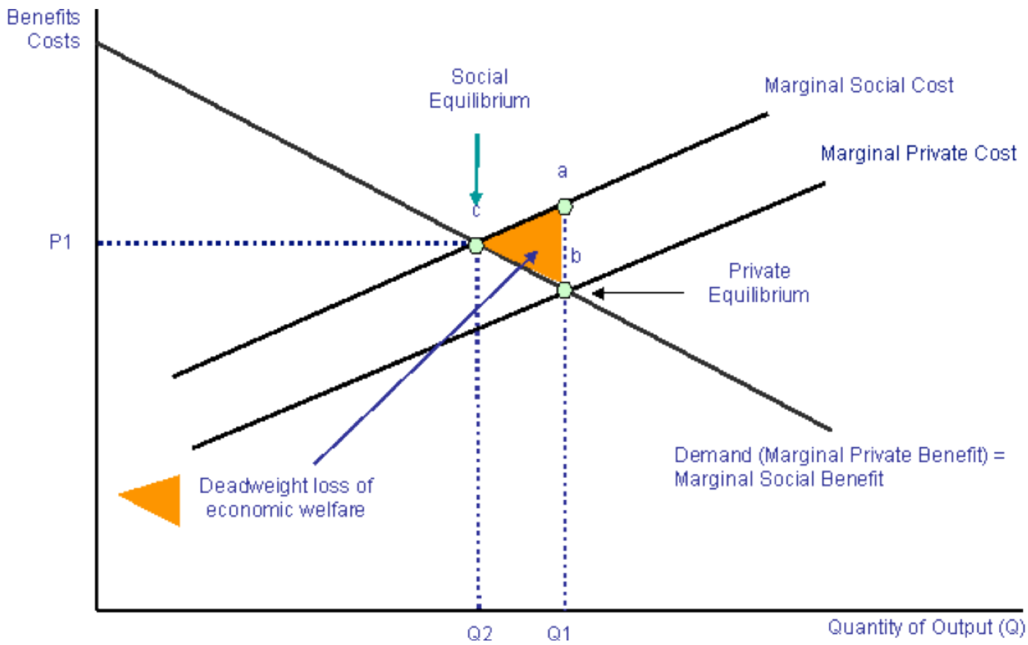

Figure 20: Illustration of the welfare effects of pollution
Source: adapted from (Pearson 2000)

The last option is commonly considered the worst among economists as it constitutes the most market-invasive measure and does not allow for the generation of a natural equilibrium upon changes in demand. These may, for example, be triggered by rising prices of alternative energy sources, perceivably by increasing taxation of carbon, which would cause consumers to switch to other fuels, including gas, and thereby shift the demand curve to the right. (Pearson 2000)

Taxes and regulations essentially function the same way and allow markets to adapt. If demand rises, prices will increase simultaneously and more compensatory means for reconstruction or increased control will be available. As outlined above, both are indeed being applied in virtually all European economies, featuring tight environmental controls as well as taxes on the resource itself.

The problem is, of course, that one can also overdo the good intent, especially if there are other suppliers offering the same resource at an ultimately lower price. This would *in concreto* entail that nobody would buy local shale gas, but rather purchase cheaper imports, which would obviously scare investors and effectively halt industrial development.

This is exactly what can continuously be observed throughout Europe. Investors are utterly mindful of the regulatory uncertainty and the hidden costs of production implicated by stringent environmental standards, tight controls, bureaucratic delays and many other already discussed factors. Given the lively interest shown by major international players, the impact seems to be acceptable in some countries, such as Poland, yet certainly not in others (France, Austria etc.); most nations across the continent as well as the EU institutions appear to remain undecided, which naturally implies uncertainty and might be almost equally detrimental.

An aspect that should perhaps not be overlooked in the context of environmental concerns is that the rapid decline of gas prices in the US has impacted demand and consequently prices of other resources, in particular coal. With the US industry's continuous switch to cheap gas, the local demand for coal has plummeted, and so has its price. (Schmidt, 2011) European energy providers have thus already been tempted to go back to the perhaps most harmful source of energy to mitigate the competitive disadvantages. Even Germany, one of the front-runners of renewable energy, has recently reactivated some plants and has heavily invested in coal. (The Wall Street Journal 2014) Other countries are likely to follow suit and the effect will only be amplified by rising gas prices.

Now, looking at the bigger picture and seeing that in its application, natural gas is a lot cleaner and less polluting than coal (and all other fossil fuels), it appears that shale gas could in the end even be the *greener* option. If the argument indeed boils down to a trade-off between the environmental hazards of coal and shale gas, it is highly unlikely that coal would win the battle. While the impact of shale gas in terms of the visual disturbance and the potential detriments for various water bodies is perhaps more visible and hence easier to grasp, the mere chemical composition of the substances dictates that the combustion of coal emits about four times as much GHG as natural gas. The considerable intensity of industrial operations associated with shale gas will mitigate the difference, but experts agree that coal remains significantly more harmful. (Jenner and Lamadrid 2013, Jiang, *et al.* 2011)

One could perhaps argue that Europe should rely on external sources until gas prices will rise as feared before switching to shale gas; this overlooks, however, that it might well be too late by then. The industry will naturally need time to grow and even only a couple of years of significant competitive disadvantage may cause irreversible damage.

A final argument that is frequently voiced is that cheap natural gas has in the US also harmed the renewable energy industry, which would again drive up social costs as illustrated in *Figure 15*, and would be a rather compelling argument for staying out of unconventional gas. (Schmidt 2011) Yet, this appears to be a matter of policy rather than markets, and could easily be prevented. If the environmental harm, in the case of coal the sizeable CO_2 output, is priced accordingly, gas will much rather substitute expensive coal than clean renewables. (European Renewable Energy Council 2013, Rao 2012)

The same could obviously be done without shale gas, but the impact on the industry would be disastrous and exacerbate the already precarious energy cost situation in Europe. If shale gas does indeed replace coal, which remains responsible for close to 20% of primary energy consumption within the EU, the resource may go a long way towards helping the Union to achieve its emission targets. (Eurostat 2013)

In the end, it seems that there is a rather compelling argument to make for Europe to look deeper into the potential of unconventional gas from shale.
As repeatedly emphasized, uncertainty remains ubiquitous and caution is thus due, yet the vast array of possible benefits not only in economic, but also environmental terms appears rather staggering and make it hard to understand why many are so hesitant to take a chance.
It is still quite possible that estimates are overblown and difficult geological conditions will not allow for any commercial production, but the persistence to not even clarify the potential appears short-sighted.

9 Conclusion

The shale gas revolution in the US has surely been among the most unforeseen and radical developments in energy markets over recent decades. It has not only caused seismic changes in the US energy markets, but also launched a wave of enthusiasm across the globe that a replication of the US success could trigger major turnovers in other markets, ensure security of supply and perhaps ultimately entail some considerable geopolitical changes.

The potential for the European continent has been heatedly debated and it is safe to say that uncertainty remains prevalent. Exact estimates continue to be scarce and the economic implications of the exploitation on the continent somewhat of a mystery.

However, experts largely agree that considerable amounts of technically recoverable gas are trapped in European shale and could at least absorb the decline of conventional gas and repel stronger import dependencies from the major gas exporters in Russia and North Africa.

Even though Europe is likely to face more elevated costs due to geological constraints, higher wage-levels, less developed infrastructure and regulatory bottlenecks, and exploitation will thus perhaps not reach the heights of the US industry, shale gas could go a long way to secure supply, diversify energy sources and carry major welfare gains for European economies. Surveys indicate that the development of a shale gas industry could create up to 800,000 jobs until 2035 and drive up GDP in the EU-28 by a staggering €1.7-3.8 trillion.

Yet, the political debate across Europe remains highly divided and fluid. Governments are driven by historical legacies of national energy mixes, economic necessities and industrial lobbies, which naturally entail varying policy choices.

In large parts of Europe environmental qualms continue to dominate the headlines and nurture a lack of public acceptance, which appears to dampen political will and ultimately constrain the establishment of a shale gas industry.

Guided by the (in)visible hand of the Precautionary Principle Europe has shown a tendency to be rather sceptical towards rising technologies and their potential risks, and there is no question that concerns need to be taken seriously, but the shale gas discussion appears to exhibit a daunting lack of balance.

Like any other resource, shale gas carries its deficiencies, but it should be judged in due consideration of the alternatives.

There is no doubt as to the envisioned role of renewables as the centrepiece of the future European energy mix, but it will take time until technologies can live up to expectations. Meanwhile, coal continues to account for almost 20% of the current EU energy mix and numbers are unlikely to decline with prices plummeting due to the oversupply triggered by the turnovers in US markets.

Shale gas will not solve all problems and surely has its drawbacks, but if used strategically, as a substitute for more carbon-intensive energy sources and a complement to renewables, the benefits seem to outweigh the costs and Europe would perhaps be well-advised to take a pro-active approach towards the resource.

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