EUCERS
European Centre for Energy and Resource Security

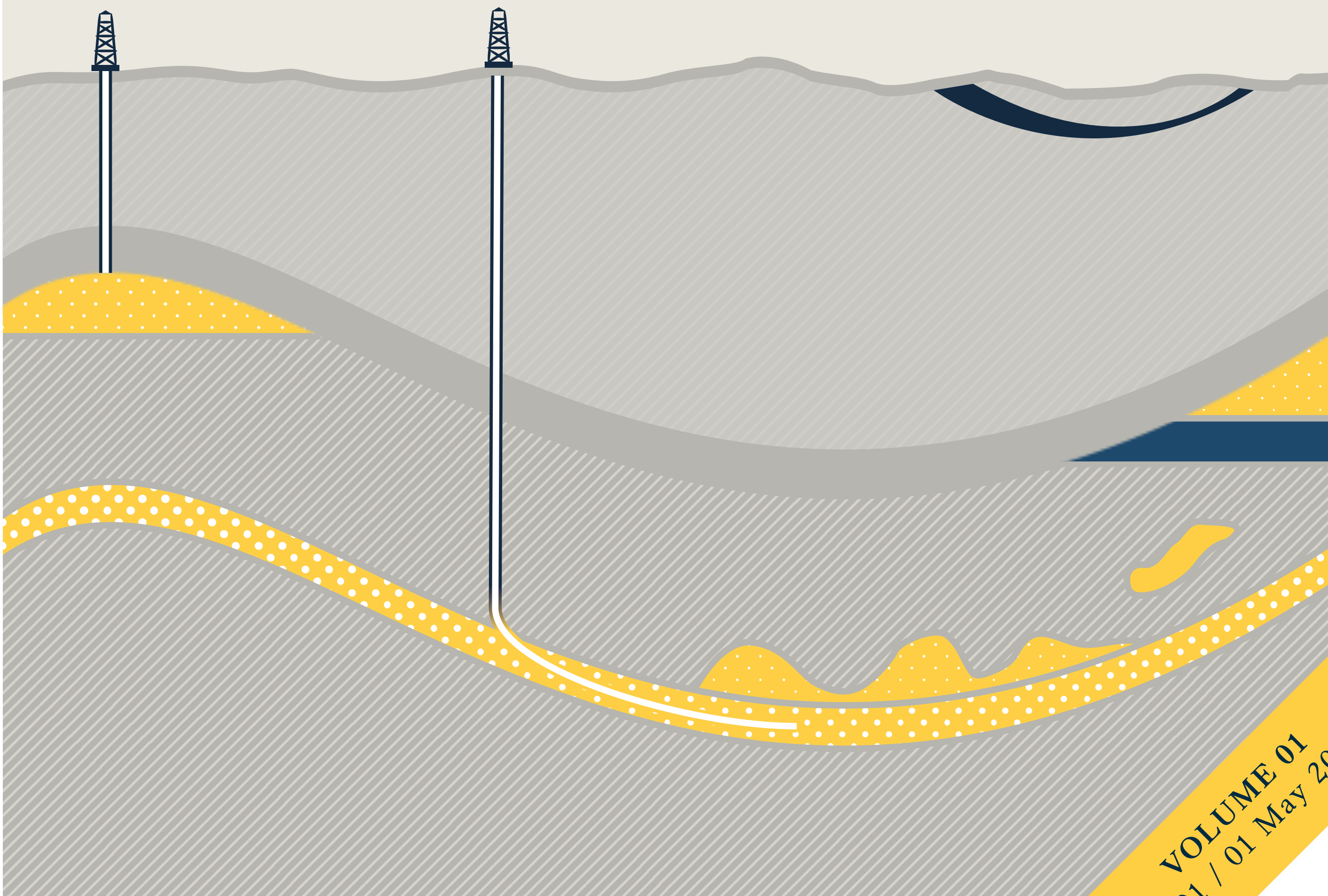
KING'S College LONDON

STRATEGY PAPER

STRATEGIC PERSPECTIVES OF UNCONVENTIONAL GAS:

A GAME CHANGER WITH IMPLICATIONS FOR THE EU'S ENERGY SECURITY

Maximilian Kuhn / Frank Umbach



VOLUME 01
01 / 01 May 2011

PUBLISHED BY

European Centre for Energy and Resource Security (EUCERS), Department of War Studies, King's College London

The European Centre for Energy and Resource Security (EUCERS) at King s College London is an academic Think-Thank engaged in research on Energy and Resource Security. EUCERS is committed to promote the understanding of how our use of energy and resources affects International Relations and to contribute to these questions. EUCERS organizes lectures, workshops and expert roundtables on fundamental issues of energy and resource security.

EUCERS publications and research results are made available through the EUCERS website:
www.eucers.eu

IMPRESSUM

EDITORIAL

Professor Dr Friedbert Pflüger
Maximilian Kuhn

European Centre for Energy and Resource Security (EUCERS)
Department of War Studies
King's College London
Strand
London WC2R 2LS
info@eucers.eu
Tel. 020 7848 1912

ISSN	2047-1041	(Print)
ISSN	2047-105X	(Online)

ISBN	978-0-9569033-0-3	(Paperback)
ISBN	978-0-9569033-1-0	(eBook-PDF)

ABOUT EUCERS:

A EUCERS STRATEGY PAPER

STRATEGIC PERSPECTIVES OF UNCONVENTIONAL GAS:

A GAME CHANGER WITH IMPLICATIONS FOR THE EU'S ENERGY SECURITY

Volume 01, Number 01, 01 May 2011

Maximilian Kuhn / Frank Umbach

STRATEGIC PERSPECTIVES OF UNCONVENTIONAL GAS:

A GAME CHANGER WITH IMPLICATIONS FOR THE EU'S ENERGY SECURITY

Maximilian Kuhn / Frank Umbach

KEYWORDS
Unconventional Gas; Energy supply security (political, economic and technical); Energy policy making; Energy sector analysis; Geopolitics of global gas supply

CONTENTS

FOREWORD / PREFACE

Dr. phil. Friedbert Pflüger Professor and Director of the European Centre for Energy and Resource Security (EUCERS) at the Department of War Studies, King's College London.

The publication `Strategic Perspectives of Unconventional Gas: A Game Changer with Implications for the EU`s Energy Security´ could not be timelier. The catastrophic events in Japan -, the earthquake followed by tsunamis, which lead to the nuclear disaster at the Fukushima-Daiichi nuclear power plant – as well as the political turmoil in North Africa and the Middle East force politicians to rethink how they are achieving their national energy mix.

These events remind us, yet again, of the need for economically viable, ecologically friendly, secure, and publicly acceptable forms of energy. It will shift the discussion, once again, to the focal issues of domestic supply policies and international initiatives to ensure stable and reasonable priced energy supplies.

Natural gas – as the low-carbon fuel of choice for the consumers – is critical in bridging the long-term fuel gap between the present and towards a renewable and sustainable energy future. Coinciding critical economic, political, and technological factors – the drop of demand linked to the global recession, an increase in incremental U.S. non-conventional shale gas production, and the arrival of new LNG delivery capacity - together created a sudden global "gas glut" and, therefore, laid the groundwork for an expanded role of natural gas in the world economy.

On the other hand, various obstacles for European unconventional and shale gas development in particular are in place, preventing the seizure of the full potential of this commodity. Important questions about the future market structure, the regulatory environment, political risk, investor confidence, public acceptance and competition with other fuels – especially renewables -, need to be answered in the months and years ahead.

This EUCERS Strategy Paper tries to answer these demanding questions by helping policy-makers to understand the importance and the broad implications of this issue.

The national and international debate over the role of unconventional gas in the global economy is in many ways still in its infancy. By providing an insightful and comprehensive introduction to these issues for policy-makers, scholars, industry executives, practitioners, and concerned citizens alike, this non-bias academic EUCERS Strategy Paper aims to shed light on this important but complex subject.

Thus far it is clear that unconventional gas has already had a major external impact on the European market. How the prospects for future European unconventional gas developments look now depends upon various critical factors. In this uncertain environment, nevertheless, one thing is certain: unconventional gas is a domestic fuel and energy resource. It is, therefore, the perfect addition to locally developed renewable energies that help increase European energy security. Simply put, unconventional gas volumes in Europe have the potential to stabilize domestic supplies in the face of declining conventional production, and in doing so could reduce dependencies and help diversify the energy mix.

From a global perspective, unconventional gas has far-reaching geopolitical implications. It has the potential to balance the EU's energy equation by breaking a market dominated by a few suppliers from EURASIA (i.e. Russia) and the Middle East, where the vast majority of the conventional gas reserves are concentrated. Now, with local unconventional gas availability enabling gas-to-gas competition, negotiating power is shifting from a hitherto sellers' market into a more balanced and favorable market for buyers, by enabling gas-to-gas competition.

Moreover, the abundance of natural gas, in combination with relatively low development cost – as demonstrated in the U.S. – incentivizes the switch from coal to gas and, therefore, would help to bring down emissions and mitigate climate change.

'Strategic Perspectives of Unconventional Gas' is an important piece in addressing these and other strategic issues connected to the development of unconventional gas. It elaborates on U.S. unconventional gas development, draws analogies (including by highlighting the differences) for the European situation and, finally, concludes by considering the global geopolitical implications of unconventional gas development.

This EUCERS Strategy Paper is the result of a previous study conducted by Maximilian Kuhn for the 11th IAEE European Conference "Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis", a presentation by Frank Umbach at the Atlantik-

Brücke in Berlin on the future global gas markets with implications from unconventional gas and an expert roundtable jointly organized by Research Analysts at the British Foreign and Commonwealth Office (FCO) and the European Centre for Energy and Resource Security (EUCERS) at Kings College London. This expert roundtable assembled prominent political scientists, economists and energy experts from Europe to address the issue of shale gas development in Europe and the geopolitics of shale gas.

I would like to commend the authors and editors Maximilian Kuhn[1] and Frank Umbach[2] for producing this invaluable piece. Furthermore, we recognize and thank the many collaborators and reviewers who have participated and contributed to the argumentation and writing process. We are especially grateful to the many speakers and panelists and, in particular, to the Foreign and Commonwealth Office (FCO) for the funding that made the expert roundtable possible.

Specifically, for taking the time to share their unique insights on unconventional gas development we would like to thank our speakers: Marco Arcelli (ENEL), Andrew Bartlett (Standard Chartered), Katinka Barysch (Centre for European Reform), Stanislaw Cios (Ministry of Foreign Affairs of the Republic of Poland), Marc de Saint Gerand (Standard Chartered), Luis Deza (ENEL), Mark Downes (Shell UK), Florence Gény (Oxford Energy Institute), Paul Gilbert (Tyndall Centre for Climate Change Research, University of Manchester), Dieter Helm (University of Oxford), Michael Holgate (Independent Energy Consultant), Brian Horsfield (GFZ German Research Centre for Geoscience), Patrick McCarthy (ExxonMobil UK), Sean Melbourne (Shell UK), Tony Melling (Independent Energy Consultant), Pierre Noël (University of Cambridge), Erik Oswald (ExxonMobil), Greg Pytel (Sobieski Institute), Alan Riley (The City Law School London), Aura Sabadus (ICIS Heren), Alex Shivananda (Aclaria Capital), Meb Somani (Barclays Natural Resource Investment), Jaroslaw Wisniewski (King´s College London), and Ernest Wyciszkiewicz (Polish Institute for International Affairs).

Last, but not least, I would also thank Grant Rudgley from King's College for helping to edit this Strategy paper.

[1] **Maximilian Kuhn** is Chief Editor, EUCERS Strategy Papers and a Research Associate at the Centre for Energy, Marine Transportation and Public Policy (CEMTPP), School of International and Public Affairs (SIPA), Columbia University. He may be reached at: mk3235@columbia.edu (Maximilian Kuhn). Special thanks to Albert Bressand (CEMTPP), Gregory Stoupnitzky (CIS Capital), Gordon Shearer (Hess LNG) and Michael Holgate for their advice, encouragement and the review of earlier versions.

[2] **Frank Umbach** is Associate Director of EUCERS as well as Senior Associate and Head of the Programme "International Energy Security" at the Centre for European Security Strategies (CESS GmbH) in Munich-Berlin. He may be reached at: umbach@cess-net.eu (Frank Umbach). The authors are solely responsible for any errors of fact or interpretation and the views expressed in this paper are solely those of its authors.

EXECUTIVE SUMMARY

Due to the "silent (r-)evolution" of horizontal drilling and "slick water" hydraulic fracturing, the rapidly expanding production of unconventional gas resources (i.e. shale gas) has transformed the U.S., almost overnight, from becoming the largest LNG import market to a self-sustaining gas producer and a net gas exporter; in 2009, overtaking Russia as the world's largest gas producer. Simply put, this has had worldwide geopolitical and economic implications. The combination of three factors: (1), a drop in demand linked to the global recession; (2), an increase in incremental U.S. non-conventional shale gas production; and (3), the arrival of new LNG delivery capacity, have together created a sudden "gas glut" – an overcapacity of LNG – that has led LNG to become less expensive than pipeline-gas (based on long-term contracts), contributing to the de-linkage of the gas prices from the oil price. This could become a permanent feature of the global energy market because remaining global unconventional gas resources are even bigger than conventional ones; however, the present lack of sufficient geological information and concrete exploration drilling test data outside of the U.S. makes the short-term future of unconventional gas production uncertain for at least the next years. Nonetheless, the new gas (r-)evolution has begun to shift to the rest of the world, with exploration test drilling in Europe, China, Australia, Canada and many other countries.

This study queries the prospects of unconventional gas production in Europe. There are a number of factors to consider. First and foremost, since the density of population is much higher in Europe, environmental concerns must be addressed as public acceptance will be the main issue for future unconventional gas development.

Yet, current environmental legislation in the EU needs to be further analyzed so that unconventional gas can offer new business opportunities and better export chances for coping with the worldwide environmental challenges of unconventional gas exploration. In contrast to the U.S., Europe lacks any detailed and reliable geological study, making it difficult to estimate the potential for unconventional gas. Additional, unit supply costs, environmental regulation, pricing mechanisms, and market structures in Europe are different from those in North America. This makes lesson- and knowledge-transfer between the continents difficult.

Nonetheless, the unconventional gas (r-)evolution has enabled a transformation of the global gas market and industry. It calls for a new mindset in Europe; particularly as, European unconventional gas is thought to be competitive at contemporary long-run average European contract prices of around 8-9 US $/ million British thermal units (MMBtu.). This development is unlikely to materialize significantly before 2020, but could mean that tight gas, shale gas, and coal bed methane (CBM) production could – in the best-case scenario – compensate for the declines (or at least some amounts of them) of the indigenous conventional gas production. Estimated total recoverable reserves in Europe amount to between 33-38 tcm, of which 12 tcm are tight gas, 15 tcm shale gas, and 8 tcm coal bed methane; whereas total conventional gas reserves in the EU amount just to 2.42 tcm. In theory, therefore, Europe's unconventional gas resources might be able to cover European gas demand for at least another 60 years. In this scenario Europe may still remain a net gas importer, but, nonetheless, the development would (1), further reduce the import dependence from unstable producer countries outside the EU-27 and (2), assist the EU in its numerous other energy policy initiatives that have been implemented to reduce its gas (import) demand and diversification of gas imports since 2007. Thus, domestic shale gas production can be very lucrative and enhance the EU's energy supply security. Also, as unconventional gas is a major domestic fuel – similar to renewables – it may offer a higher degree of policy support under a supply security-driven focus (e.g. Poland).

Given the worldwide and European prospects for unconventional gas production, it becomes clear that even if only a fraction of the potential of unconventional gas resource will become available for European and other energy markets before 2020, it will (1), undercut the very high prices of the new Siberian gas fields of the Yamal Peninsula and in particular Russia's Arctic offshore gas resources (like Shtokman), (2), offer the EU another domestic source, enabling greater diversification of gas demand and imports, (3), extend the global overcapacity of gas at least until 2020, and (4), improve the EU's energy supply security in the next decades. Nevertheless, it is important to reemphasize that one must consider public acceptance of unconventional gas development as much as one considers the geology, economics, and market structure of the European energy future.

On the geo-economic and geo-political side, unconventional gas has the potential to change the industry structure far greater then is commonly understood, and this calls for a new mindset within both industry, conventional gas suppliers – like Russia – and demand centers (e.g. Europe) and those involved in the wider public policy arena. Unconventional gas could become a major challenge for traditional exporters like Russia in the period between 2015-2030. Thus, if unconventional volumes are large enough, Russia will be forced to make strategic decisions about: (a) defending its existing market model and pricing system in an environment that would risk making unconventional gas production profitable on a large scale, with negative implication for market share; or, (b) seeking to marginalize unconventional gas production via changing the hitherto oil-indexed, long-term, take-or-pay contracts by adapting a more flexible pricing system. The latter option shows that even the threat of unconventional gas production in Europe could lead to a positive outcome for European consumers.

In sum, regardless of how the outlook on European unconventional gas development looks, and despite of whether or not unconventional gas becomes affordable and sustainable in the mid-to-long term in Europe, shale gas has already changed the European market; even before a single well has been drilled, or a single molecule of unconventional gas has been produced from the European basins.

INTRODUCTION

"I have been studying the energy markets for 30 years, and I am convinced that shale gas will revolutionize the industry – and change the world – in the coming decades. It will prevent the rise of any new cartels. It will alter geopolitics. And it will slow the transition to renewable energy." [3]

The greatest energy innovation of the decade, according to Daniel Yergin, is "unconventional" natural gas.[4] North America alone has enough recoverable unconventional gas resources to supply its total natural gas demand for the next 45 years.[5] Although unconventional gas is nothing new to the oil and gas industry, the supposed shale gas revolution is rather an unfolding evolution – a combination of several old and new technologies. Unconventional gas – from shale, coal-bed methane and tight formations – has been produced in the US since the 1800s.[6] The first commercial shale gas well was drilled in 1821 into the Devonian Dunkirk shale near the village of Fredonia, New York to provide fuel to illuminate local homes.[7] For the supply-and-demand-driven oil and gas industry, natural gas did not become an important commodity until the end of World War II. Subsequently, in the 1980s, producers began looking beyond traditional sources of natural gas production to keep up with the growing market and to compensate for depleting reservoirs. By the early 1990s, the industry began evaluating coal-bed methane and later shifted its attention to shale gas.[8] It took until around 2005, however, for the potential of unconventional gas to become fully clear. At a time of soaring gas prices, rapidly depleting conventional wells, and failed attempts to bring forth additional supplies, the U.S. was destined to become an importer of liquefied natural gas (LNG). Instead the surge in unconventional gas production in the U.S. led to a reassessment of the long-term gas balance that, in recent years, has turned U.S. supply assumptions upside down by the successful development of domestic shale gas. Now the U.S. is even considering turning its LNG import facilities into export terminals, as its shale gas reserves are estimated to be big enough to meet domestic demand for the next 30 years to come.

3 **Amy Myers Jaffe** (2010), "Shale Gas Will Rock the World", Wall Street Journal, 10 May 2010.

4 **Daniel Yergin and Ineson** (2009), "America's Natural Gas Revolution", The Wall Street Journal.

5 **Amy Myers Jaffe** (2010), "Shale Gas Will Rock the World", Wall Street Journal, 10 May 2010.

6 **Anthony Andrews** (2009), "Unconventional Gas Shales: Development, Technology, and Policy Issues", in: CRS Report for Congress.

7 **Hill, D.G., Lombardi, T.E. and Martin, J.P.** (2004), "Fractured Shale Gas Potential in New York." Northeastern Geology And Environmental Sciences. Vol. 26; Part, pp. 57-78. http://www.pe.tamu.edu/wattenbarger/public_html/Selected_papers/--Shale%20Gas/fractured%20shale%20gas%20potential%20in%20new%20york.pdf

8 **Joseph H. Frantz and V. Jochen** (2005), "When Your Gas Reservoir Is Unconventional, So Is Our Solution - Shale gas", Schlumberger, October.

UNCONVENTIONAL GAS – A PRIMER

Conventional gas is generally extracted by drilling into porous reservoirs where the gas can easily migrate to the well bore and up to the surface in relative free flow. Unconventional gas refers to gas extracted from formations where the permeability of the reservoir rock is so low that the gas cannot easily flow (e.g. tight sands), or where the gas is tightly absorbed and/or attached to the rocks (e.g. coal-bed methane). There are many types of unconventional gas resources, including tight gas that is of relative poor quality with low porosity and low permeability; the two principal types are: (a), coal-bed methane (CBM), commonly known as 'firedamp' in coal mines that is a natural gas/methane and can be produced industrially with oil technologies; and (b), shale gas derived from a source rock that has matured and produced gas. The main focus of this paper will be on shale gas.

Usually unconventional gas is found as dry and clean natural gas in the shale formations, either as free gas in fine-grained rock pores with low permeability, as free natural gas in natural fractures or by clay particles absorbed gas on organic matter and mineral surfaces.[9]

Shale formations can act as both a source and a reservoir. In the United States, these reservoirs tend to be found within a depth range of 80 to 2500 meters and have a prospected thickness of around 100 - 200 meters.[10] The major North American shale reserves are in the Marcellus Shale in Appalachia, Haynesville, on the border of Louisiana and Texas, and the Barnett Shale of Texas.

In the United States, (U.S.), the definitions of unconventional and conventional gas were arbitrarily specified by taxation issues implemented in the 1970s. According to the taxation code, conventional gas is gas produced from a tight gas well whose permeability is equal or less than 0.1 microdarcy. Depending upon the permeability, the well would receive state or federal tax credits for gas production. However, flow rates of gas are determined by a number of both economic and physical properties independent of permeability, thus, choosing a single value of permeability to define unconventional or tight gas is of limited significance. For example, in deep, high-pressure, thick reservoirs, commercial completions can be achieved when the formation permeability to gas is in the microdarcy range (0.001 md).[11] In shallow, low- gas at economic flow rates, even after a successful fracture treatment.

The National Petroleum Council defines unconventional gas as "natural gas that cannot be produced at economic flow rates nor in economic volumes of natural gas unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbores or some other technique to expose more of the reservoir to the wellbore."[12]

---

9 **Lisa Sumi** (2008), "Shale Gas: Focus on the Marcellus Shale", For the Oil & Gas Accountability Project/Earthworks.

10 **Joseph H. Frantz and V. Jochen** (2005), "When Your Gas Reservoir Is Unconventional, So Is Our Solution - Shale gas", Schlumberger, October 2005.

11 **Stephen Holditch** (2007): Working Document of the NPC Global Oil & Gas Study. NPC

12 Ibid.

WHAT IS TYPICAL UNCONVENTIONAL GAS?

In actuality, there is no "typical" unconventional gas. Generally, gas is extracted from reservoirs, and, over the last few centuries, the more accessible reservoirs have been defined as "conventional". Reservoirs can be deep or shallow, high or low pressure; high temperature or low temperature, blanket or lenticular; homogeneous or naturally fractured, and contain single layer or multiple layers. Each unique reservoir characteristics can be defined by a function, whilst the economic situation defines the "optimum drilling, completion, and stimulation method."[13] The challenge is to release the gas in each unique reservoir from rock that can be as impermeable as concrete. Hence when permeability requires stimulation to achieve sustained gas flow the process has been labeled "unconventional" gas exploration.

13 Ibid.

DEVELOPMENT OF UNCONVENTIONAL / SHALE GAS IN THE U.S.

Major oil and gas companies traditionally neglected the potential of the organically rich gas shale reservoirs. For a long time they considered these as a sealing layer rock that drillers – for conventional resources – passed through, thus avoiding the stimulation techniques that are required to exploit shale gas.[14]

Shale plays were regarded as a small-scale niche plays because of the low productivity and drillers, traditionally, sought the larger and less intensive exploitation opportunities, thus aiming at faster returns on their investments. New exploration and development technology changed the picture and made unconventional shale gas recoverable in areas previously thought to be infeasible and economically unrecoverable.

The so-called "shale gas revolution" received public attention with the reassessment of the United States' non-proven reserves in 2007/2008, when the U.S. Potential Gas Committee raised its estimate of unproven U.S. gas resources by an astonishing 45%, from 32.7 trillion cubic meters (tcm) to 47.4 tcm. Similarly, Wood Mackenzie estimated that unconventional production in the U.S. lower 48 states had risen from 33% of total output in 2000 to 59% in 2009, and predicted that its share could reach 73% by 2020.[15] Equally newsworthy was the effect on U.S. gas production and its dramatic supply impact, which led to continuing weak gas prices on the spot market. Unconventional gas production in North America now accounts for about 50% of U.S. gas production. Within a decade, from 1996 to 2006, the annual production of unconventional gas increased from 140 billion cubic meters (bcm) to 244 bcm. In 2009, U.S. total conventional and unconventional gas production accounted for 599 bcm in 2009, up 52 bcm, or 9.4%, over two years. This was driven by shale gas production, making the United States the de facto No.1 producer of gas worldwide, overtaking Russia. Furthermore, the share of unconventional gas production in the United States is expected to increase further to 60-70% by 2020, to 250 bcm in 2015, and to 288 bcm by 2030.[16]

[14] **Charles Boyer** (2006), "Producing Gas From Its Source", Oilfield Review; Stephen Holditch (2007), "Working Document of the NPC Global Oil & Gas Study", NPC.

[15] **Petroleum Economist**, (2009), "Europe awaits a shale-gas revolution", Petroleum Economist, December.

[16] **BGR** (2009), "Reserves, Resources and Availability of Energy Resources", Hannover/Germany, BGR (German Federal Institute for Geosciences and Natural Resources).

WHAT MAKES SHALE GAS SPECIAL?

The growth in unconventional gas exploration in the U.S. in the last decade was initially driven by the high gas prices of 2005-2008. It represented a "mainstreaming" of sorts, becoming a business focus of larger, more established and independent mid-cap oil and gas producers such as Devon Energy, Chesapeake Energy, and XTO Energy. It represented a culmination of years of effort by a small group of risk-taking independents, in the U.S. best exemplified by George P. Mitchell and his brother, Johnny, of Mitchell Energy & Development.

The brothers were pioneers in trying to solve the perennial problem of how to liberate and extract the plentiful supplies of "locked away" impermeable shale gas.[17] Mitchell and his team of geologists and engineers worked on the shale challenge for over 12 years, from around 1981 to 1993. They experimented with a number of different well technologies, despite these being far from commercially viable, to understand how to free up the gas and stimulate the gas flow into the wellbore. Melting together two key technologies – horizontal drilling and "slick water" hydraulic fracturing – they finally cracked the shale rock and thus cracked the code for opening up major North American shale gas resources. Their progress enabled significant yield increases in well production, leading to a series of incremental improvements that enabled operators in the United States to unlock the vast potential o f these challenging resources and to the building up of shale gas production eventually to levels where it became a significant factor in the nation's gas production.[18] By doing so, they achieved the recognition that one could "create a permeable reservoir" and high rates of gas production in deep shale formations by using enhancements perfected through a research and development of smaller "independent" oilfield service companies who, together, took a decades-old technique – horizontal drilling and hydraulic fracturing –, to get more oil and gas out of the ground and perfect it to work in dense shale formations. This changed the game for unconventional gas.[19]

Horizontal well drilling has progressed from an art to a science. Instead of drilling straight down into the resources, horizontal drilling enables sideways movement after a certain depth, opening up a much larger area of the resource-bearing formation and, therefore, a greater length of the shale gas deposit to be in contact with the well bore. The other key technology is hydraulic fracturing, which creates multiple-productivity and the same output at a quarter of the costs, in addition to having a much smaller footprint than vertical drilling.[20] Hydraulic fracturing was first used as a method to artificially stimulate oil wells, and was introduced in the late 1940s in Texas oil fields. The technique has been improved, refined over the years, and more recently, adapted to maximize exploitation of shale gas formations.

Hydraulic fracturing involves isolating sections of the well in the producing zone, then pumping a mixture of steam water, fluids and proppant (grains of sand or other materials used to hold the crack open) down the wellbore through perforations in the casing and out into the shale. The hydraulic pressure created by pumping fluid into the well, under pressure up to 8,000 psi, is enough to produce fissures in the reservoir and crack shale as much as 1000m in each direction from the wellbore, liberating the trapped gas and boosting the migration of the gas flow into the wellbore through the multiple fractures created in the rock. Even without proppant, the cracks stay open for a while, but they will eventually heal and the gas production will decline accordingly.

[17] **Daniel Yergin and Ineson** (2009), "America´s Natural Gas Revolution", The Wall Street Journal; Tom Fowler (2009) Stubborn in his vision. Houston Chronicle.

[18] **Stephen Holditch** (2007), "Working Document of the NPC Global Oil & Gas Study", NPC; Gas Matters (2010), "Shale Gas In Europe: A Revolution In The Making", Gas Strategies.

[19] **Vello A. Kuuskraa** (2009), "Worldwide Gas Shales and Unconventional Gas: A Status Report"; Stephen Holditch (2007), "Working Document of the NPC Global Oil & Gas Study", NPC.

[20] **Dar & Company** (2009), "Natural Gas Reserves Are Rising - Thanks to Technology", Risk Capital. http://www.darandcompany.com/Natural_Gas_Reserves_051.html.

The more fractures in the shale around the wellbore the faster the gas will be produced.[21] Thus, fractures are the key to good production, but keeping them open after the pressure is released, and while the well is producing, is a difficult process.[22]

Many recent developments have increased the potential per-well gas recovery factor up to 20%, these include: research and technological innovation; enhancements for prospect evaluation and core testing; shale lithotyping that determines key characteristics of productive shale; and optimizing and tailoring water-fracturing fluid chemistry for the shale and remedial treatment processes for obtaining long-term production. In short, state-of-the-art technologies have opened up new areas by reducing overall exploration, production and operation costs.[23]

Knowledge of the methodology is the most important constant in the speed and efficiency of bringing on shale gas production. Understanding the complex unconventional gas reservoirs is a critical step in designing optimal fracture geometry, fluid interactions, evaluation processes, micro-seismic surveys, tracers, and production logs. Collaboration and sharing information across disciplines, so that insights are leveraged as effectively as possible, is a key factor and central to improving production. "Ultimately, this knowledge sharing helps create a single strategy and facilitates a holistic view of the reservoir throughout its development, which brings with it various insights needed to create shared efficiencies and synergies" as the OGJ states.[24]

The combination of the benefits promised by the new combined technology, its reliability and the cost-benefit benefits in comparison with previous practices led to a rapid innovation cycle with fast adoption of horizontal drilling and hydraulic stimulation.[25] It is not only the operational improvements that both lowered the well cost and improved productivity; refined techniques since the early 1990s, such as horizontal drilling, multi-lateral well completions, fracturing and acidizing all increased the productivity dramatically. But the technological progress was also fuelled by capital incentives, such as tax breaks including the 1980s U.S. Crude Oil Windfall Profit Tax Act and the high post-2000 oil prices.[26]

Florence Gény states that the US shale gas revolution has been based on five pillars: (1) fiscal credits and the availability funding; (2), the technological nature of the industry; (3), the regulatory body; (4), the competitive market structure; and (5), the availability of service industry competition.[27]

[21] **Joseph H. Frantz and V. Jochen** (2005), "When your Gas Reservoir is Unconventional, So is Our Solution - Shale Gas", Schlumberger, October.

[22] **J. Daniel Arthur and Bruce Langhus** (2008), "An Overview of Modern Shale Gas Development in the United States".

[23] **Glenda Wylie** (2007), "Unconventional Gas Technology: Advances in Fracs and Fluids Improve Thight-Gas Production", Oil & Gas Journal.

[24] **Mark Parker** (2009), "Special Report: Understanding Process Key to Shale Gas Development", Oil & Gas Journal.

[25] **Florence Gény** (2010), "Can Unconventional Gas be a Game Changer in European Gas Markets?", NG 46, Oxford Institute for Energy Studies.

[26] **Paul Stevens** (2010), "The 'Shale Gas Revolution': Hype and Reality", Chatham House Report, London.

[27] **Florence Gény** (2011), "Unpublished Presentation under the Topic: Shale Gas Development in Europe?", EUCERS (Ed.), Shale Gas - Revolution in Europe? Kings College, London. See also Florence Gény (2010): Can Unconventional Gas be a Game Changer in European Gas Markets? NG 46. Oxford Institute for Energy Studies.

FALLING COST NOT A GIVEN?

George P. Mitchell should be credited with cracking the code that opened the shale plays across North America and, perhaps, elsewhere in the world. He is also recognized as the one who helped commercialize and bring down many of the costs associated with the exploitation of shale gas. It is currently estimated that the break-even point to exploit the resources of some key shale basins ranges between $3.50/million cubic feet (mcf) and $7/mcf. The marginal production costs are thus very competitive – partly cheaper than U.S conventional gas production costs – despite being higher than the current costs indicated on the North American market.

A fundamental variable in the cost equation is that the major U.S. shale gas reserves in the Appalachian basin, the Michigan basin, the Illinois basin, the Fort Worth basin and the San Juan basin are found in close proximity to areas of consumption: this is a clear and major factor in the profitability of these shale reservoirs. Availability of access to local pipeline systems and the short distances to consumer markets, in combination with the available service companies and the infrastructure in place, lead to cost reduction in the development of unconventional gas. The cost of fracturing requires it to be done on a large scale to be economically efficient; but, this cost could be lowered by another $1 to $1.50 per Mbtu if shale oil and gas liquids could be developed simultaneously.

Finally, while the current outlook forecasts falling costs due to technological advances for the foreseeable future, at some point costs are bound to rise again as developers move away from high performance wells and "sweet spots" into more problematic areas that would require complex hydraulic fracturing.

SIMULTANEOUS LNG AND SHALE GAS DEVELOPMENTS HAVE A MAJOR IMPACT

There is a critical international component challenging shale gas production in the U.S.

The dramatic rise in unconventional gas over the last decade has provided a solution to U.S. supply concerns, but is also affecting global spot gas prices that has created a further problem, a problem compounded by the economic recession and reduced natural gas consumption globally (particularly in Europe). In this way, natural gas is evolving from a local, stationary, non-residential commodity, into a mobile, international, primary product similar to crude oil. Almost at the same time, we are witnessing significant changes in incremental flexibility of global deliveries of liquefied natural gas ("LNG"). LNG is natural gas compressed and liquefied for transportation, then vaporized at local delivery stations (or trains). It has been expected, through the 1990s and in the early 2000, to become key component of the US and European energy mix.

Today, in the US, the combination of enhanced LNG transportation and increases in delivery capacity increases coming on stream, plus current and expected shale gas supply have changed the gas landscape and resulted in the freeing up of some previously contracted LNG volumes bound for the US. Global liquefaction capacity is expected to be up sharply this year and outpace demand for LNG. In 2009-2010, an additional 9 billion cubic meters (bcm) extra liquefaction capacity came online. These additional volumes created an excess supply in the market with immediate impact on spot market prices and on the need for imports (both pipeline and LNG). Some contracted LNG will be forced to go to the U.S. terminals, even if demand is not there.[28] This would force Henry-Hub (HH) spot gas prices further down and keep U.S. near-term prices range-bound ($4-8/mmcf). Thus, North American LNG gas prices that are naturally connected to the Henry Hub spot market prices will lead to low marginal prices for LNG in other markets like Europe and Asia.

In sum, the combination of three factors: (1), a drop in demand linked to the global recession; (2), an increase in incremental U.S. non-conventional shale gas production; and (3), the arrival of new LNG delivery capacity, have together created a sudden abundance of gas supply.

[28] **Gas Matters** (2005), "Shale Gas In Europe: A Revolution in the Making", Gas Strategies.

HOW LONG IS THIS GAS BUBBLE EXPECETED TO LAST?

The question remains, how long is this gas bubble expected to last? Many observers originally argued that the gas bubble would end in 2013-2015. Why? Because, despite the logic that suppliers should reduce production and postpone development plans, a number of factors are aligned to indicate that gas shale drilling plans would continue even in the face of weak US domestic gas prices.[29]

First, many gas drilling leases were signed with the condition they "drill or lose [their] lease". Typically, these gas leases run for five years, though the contracts are set to expire after three years if the driller does not begin production. Hence, to protect long-term assets, producers choose to drill and produce instead of forfeiting leases. To quote Chesapeake Energy (CHK) CEO Aubrey McClendon, "up to 50% of all industry drilling for natural gas is tied to the need to retain leases."[30] According to FBR Capital, this is a key factor in several areas, including the Marcellus Shale, the Eagle Ford Shale, and, most prominently, the Haynesville Shale.[31]

Second, most of the independent E&Ps companies – the pioneers of the onshore shale plays –involved in shale gas exploration and production "do not have a refining/marketing arm like the integrated oil majors to serve as a natural hedge." Consequently, they typically have very aggressive hedging programs in place to protect asset and cash flow. A simple hedge involves buying "futures" contracts to lock in prices. "For gas exploration and development companies, hedges in effect guarantee the amount of revenue that companies will receive on a future production, thus giving them some financial stability. As an example, CHK had about 55% of its 2010 production hedged at average NYMEX price of $7.52. In fact, Chesapeake boasts "$4.8°billion in realized gains from its hedging program since inception in 2001."[32] This past behavior may be modified, given that there are currently two proposed bills in Congress intending to limit speculation on future commodity prices. Hedging restrictions, as well as lower existing prices, could also adversely impact available capital for financing new projects.

Nevertheless there are key global drivers which in addition indicate that the present gas glut may extend even longer (at least until 2017-2020), especially for Europe, than previously anticipated, due to the following reasons:

- an accelerated expansion of inexpensive available LNG in the short and mid-term future;
- the prospect for unconventional gas production in the rest of the world (i.e. China, India, Australia);
- the expansion of other energy resources, notably the more rapid expansion of renewable energy sources (which may even fasten after the Fukushima-Daiichi catastrophe although the recent Fukushima-Daiichi reactor catastrophe in Japan seem to slow down rather than to change the worldwide trend of a nuclear renaissance).[33]

However this is happening despite the expected annual natural gas consumption growth of 1.4% until 2035 (44% in total between 2008 and 2035) – making it the only fossil fuel for which demand is higher in 2035 than in 2008 in all three scenarios – presented by the International Energy Agency (IEA).[34]

[29] **Dian L. Chu** (2010), "Natural Gas: Shale-Shocked in America", http://www.zerohedge.com/article/natural-gas-shale-shocked-america (Stand: 03.04.2011).

[30] Ibid.

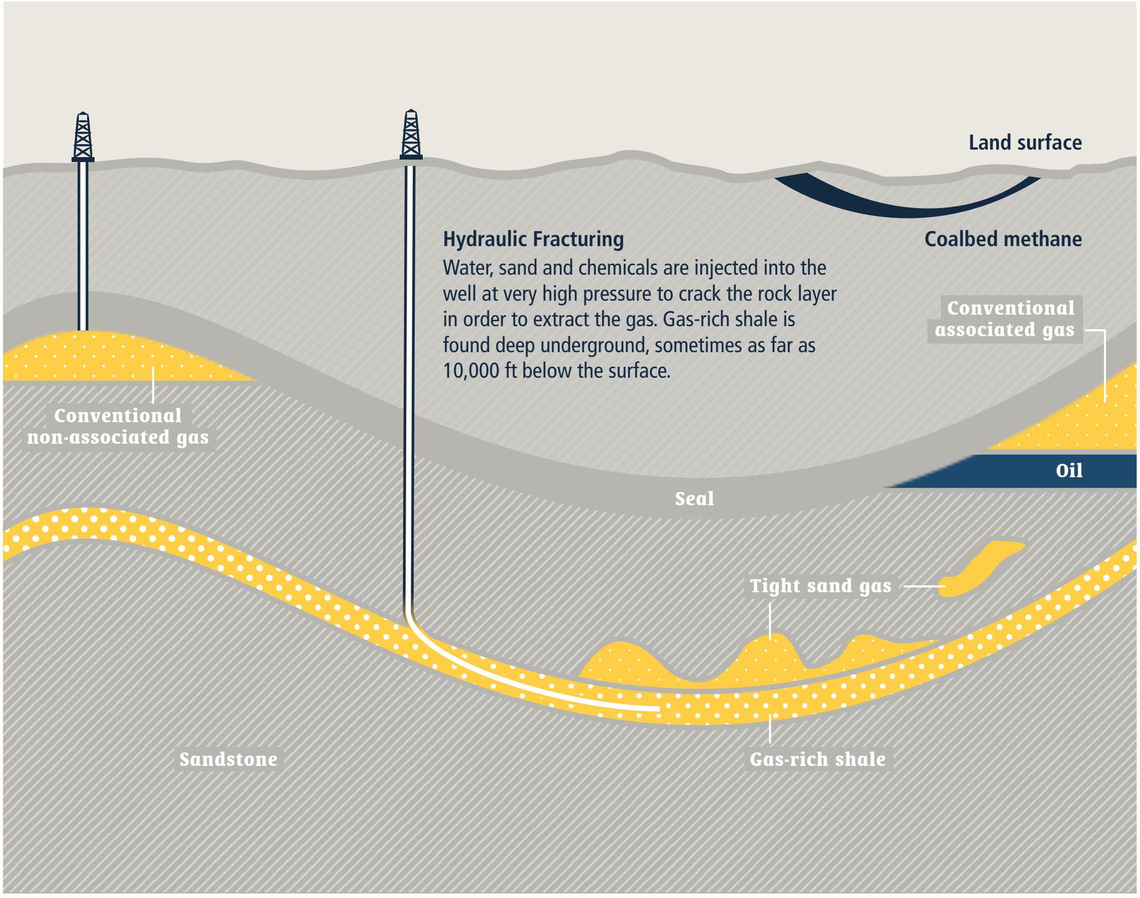
[31] Ibid.

[32] Ibid.

[33] **Frank Umbach** (2011), „Globale Renaissance der Kernenergie oder nur eine Wiedergeburt der Ankündigungen? Die Vision einer Welt ohne Nuklearwaffen und die Perspektiven der weltweiten Nutzung der Kernenergie", Österreich¬ische Militärische Zeitschrift (ÖMZ) 3/2011, pp. 267-281 (forthcoming).

[34] **IEA** (2010), "World Energy Outlook 2010. World Energy Outlook", Paris, OECD (International Energy Agency).

FIGURE 1: SHALE GAS EXTRACTION



Own graphic, adapted from: Reuters Graphic on shale "fracking" http://link.reuters.com/ryf98r

THE ENVIRONMENTAL CHALLENGES

Developing shale gas reservoirs is also environmentally controversial, particularly since production has moved into densely populated areas of the U.S. northeast, which has incentivized concerns about the effect of drilling and hydraulic fracturing on drinking water. Indeed, “major environmental concerns are over excessive water utilization, drinking water well contamination, and surface water contamination from both drilling activities and fracturing fluids disposal.”[35] The industry argues hydraulic fracturing, which involves injecting water laced with chemicals into the shale to break the rock, has no effect on water sources. However, environmental groups claim the opposite.

FIGURE 2: POSSIBLE SOURCES OF GROUNDWATER POLLUTION

Own graphic, adapted from: Leak paths adapted by Michael HolgateRef adapted from US EPA Hydraulic Fracturing Research Study – Scoping Backgrounder, 2010. Casing & cementation courtesy of Talisman Energy.

[35] **Anthony Andrews** (2009), ”Unconventional Gas Shales: Development, Technology, and Policy Issues”, CRS Report for Congress. For detailed case studies involving industrial gas drilling in the U.S. see: Craig Michaels, James L. Simpson, William Wegner (2010), ”Fractured Communities – Case Studies of the Environmental Impact of Industrial Gas Drilling” Riverkeeper.

[36] **Michael Holgate** (2011), Unpublished presentation under the Topic: Shale Gas Development in Europe?, EUCERS (Ed.), Conference Shale Gas - Revolution in Europe?, Kings College, London. ”Working Document of the NPC Global Oil & Gas Study”, NPC.

[20] **Dar & Company** (2009), ”Natural Gas Reserves Are Rising - Thanks to Technology”, Risk Capital. http://www.darandcompany.com/Natural_Gas_Reserves_051.html.

The Environmental Protection Agency (EPA) indicates that chemicals found in water from 11 of 39 wells tested around the Wyoming town of Pavillion in March and May 2009 may "cause illnesses including cancer, kidney failure, and anemia and fertility problems."[37] EPA scientists claim that the preponderance of harmful compounds in the area can be attributable to the oil and gas industry. The water in the area, their report stated, was "discolored, foul-smelling and bad-tasting."[38] What is more, there were confirmed cases reported by regulators in Pennsylvania of water has becoming flammable due to methane "migrating" from drilling into the aquifer.[39]

There are three potential leak paths, as Michael Holgate states, as to contaminate aquifers as shown below through:

- Naturally occurring or induced fractures: this is thought to be unlikely because of the separation, often thousands of feet, between the fracture zone and the aquifers. It is possible to monitor real-time fracture propagation using micro-seismic and tilt meter observations and the authors are unaware of any evidence of interaction with aquifers to date.
- Leaks on surface and migration of fluids: leakage of drilling fluids, fracturing-fluids and flow-back water can and does occur from poorly lined storage pits and is a source of groundwater contamination. However, this leak path cannot account for the leakage of gas into aquifers.
- Poor cementation: establishing a tight seal between the well casing and the formation can be technically demanding, especially in horizontal sections. Even if a good cement bond has been established, the fracturing process involves repeated cycling of hot and cold fluids and pressure changes, both of which can cause the creation of a micro annulus between the cement and the casing and/or formation and a potential leak path. This would provide a credible route for gas migration into an aquifer.[40]

These leak paths can be prevented by good oil field practices and state-of-the-art cementation and fracture monitoring techniques which should prevent drilling fluids, hydraulic fracturing fluids, or natural gas from leaking into the permeable aquifer and contaminating groundwater.

The potential for propagating fractures to an overlying aquifer may also depend on the depth separating the two. Engineers designing and conducting fracturing jobs have a strong incentive to limit the fractures to the height of the gas-producing shale zones. Furthermore, the formation tends to get more plastic and less likely to fracture as it gets shallower, which reduces the likelihood of fracture propagation near aquifers.

Afterwards, the well operator recovers a large proportion of these fluids by pumping them out of the well, and disposes of them through waste-water treatment plants or by other means as discussed below.[41] In this stage of production the risk to surficial aquifers is limited; nonetheless, "any drilling fluids or fracturing fluids spilled on the ground surface or overflowing / leaking storage pits could infiltrate downwards to shallow groundwater and pose a risk."[42]

37 **Joyce Nelson** (2009), "Frack Attack - New, Dirty Gas Drilling Method Threatens Drinking Water", The Monitor.

38 **Jon Hurdle** (2010), "U.S. Finds Water Polluted Near Gas-Drilling Sites", Reuters.

39 Ibid.

40 **Michael Holgate** (2011), Unpublished Presentation under the Topic: Shale Gas Development in Europe?, EUCERS (Ed.), Conference Shale Gas - Revolution in Europe? Kings College, London.

41 **Gene Whitney** (2010), "Energy: Natural Gas: The Production and Use of Natural Gas", Alexandria: The Capitol.Net.

42 Ibid.

Since each shale gas well is different, as previously explained, service companies adjust the proportion of fracturing fluid additives to the unique conditions of each well, which is one of the major concerns given that that proportion of "each chemical additive is kept proprietary."[43]

This leads us to one other major public concern, the reluctance of the industry to disclose the chemical composition used in fracturing-fluids, claiming commercial confidentiality. The industry in the U.S. has started to address this and chemical composition is now often disclosed. This is unlikely to be an issue in Europe because of the European REACH regulations.

The majority – 60% to 80% –- of the injected fracturing additives returned in flow-back. Typically, it "contains proppant (sand), chemicals residue, and trace amounts of radioactive elements that naturally occur in many geologic formations."[44] The flow-backwater storage issue is probably the major cause of contamination of drinking water. The U.S. Department of Environmental Protection (DEP) reported around 130 cases since 2008 where wastewater spilled into creeks and tributaries due to human errors. Flow-back water disposal is also an important issue. Local disposal often causes problems in public owned treatment works (POTW) for the processing of the waste water. Contaminants in industrial process wastewaters can kill off the biota essential to a PTOW´s operation and hence lead to a violation of water quality standards.

Treatment of flow-back water is an active area of research, but most flow-back water is transported to deep-well injection sites for disposal. However, there are few geographically convenient sites available to the typical operator and so the flow-back water often has to be trucked considerable distances for disposal with significant costs (up to $10/bbl) and environmental and social impacts.[45]

A further risk is the natural existence of deposits of methane. Once disturbed by drilling methane may flow either up the well or to ground water, a phenomenon that causes drinking water wells to explode or water from kitchen spigots to catch fire. It is a product of drilling – whether for gas or water – not of the fracturing fluids; although this can usually be controlled by isolating the deposit from the well hole with cement.

Regularly concerns are raised about the large volumes of water needed to drill and hydraulically fracture the shale, with the disposal of this water and other wastewater associated with gas extraction posing a significant water quality and quantity challenge – a challenge that merits regulatory attention. Indeed, there are several regulatory question marks for the sector in the U.S., although the development of shale gas is already subject to several regulation under relevant federal and state laws, such as the Safe Drinking Water Act (SDWA) and the Clean Water Act (CWA), in addition to other state requirements,[46] there have still been concerns over the exemption of hydraulic fracturing from the Safe Drinking Act by the Energy policy Act of 2005. This so called "Halliburton Loophole"[47] will be closed if Congress passes the Fracturing Responsibility and Awareness Chemicals (FRAC) Act, introduced in 2009, that would permit Environmental Protection Administration (EPA) regulation of all hydraulic fracturing in the United States.[48] Thus, U.S. authorities face a series of difficult choices on gas priorities that will require a more realistic appraisal of the constraints upon capacity development and policy adaptive to environmental concerns.

[43] **Anthony Andrews** (2009), "Unconventional Gas Shales: Development, Technology, and Policy Issues", CRS Report for Congress.

[44] **Daniel J. Soeder and William M. Kappel** (2009), "Water Resources and Natural Gas Production from the Marcellus Shale", USGS West Trenton Publishing Service Center.; Pennsylvania Geology (2008), "Commonwealth of Pennsylvania Department of Conservation and Natural Resources", Pennsylvania Geology, No. 38.

[45] **See NETL** http://www.netl.doe.gov/technologies/oil-gas/Petroleum/projects/Environmental/Produced_Water/00784_FracWater.html

[46] **J. Daniel Arthur and Bruce Langhus** (2008), "An Overview of Modern Shale Gas Developments in the United States.

[47] **Gene Whitney** (2010), "Energy: Natural Gas: The Production and Use of Natural Gas", Alexandria: The Capitol.Net.

[48] **Joyce Nelson** (2009), "Frack Attack - New, Dirty Gas Drilling Method Threatens Drinking Water", The Monitor.

Despite all these constraints, the North American "quiet revolution" on unconventional gas has made it less expensive than conventional gas projects. Advances in techniques have opened huge U.S. reserves of unconventional gas and made the country virtually self-reliant in terms of its gas-supply needs. Therefore, shale-gas drilling is unlikely to be stopped for environmental reasons, especially since the oil and gas majors have invested so much in its development.

Deep shale natural gas, conversely, uses water primarily during drilling and stimulation, but produces a tremendous amount of energy over the approximate 20-year lifespan of the natural gas well. When compared against other energy resources, it is by far the most water efficient of all the "base-load-level" energy resources, and when used for power generation in a NGCC power plant, is among the most water efficient at generating electricity.[49] It also touches on the often overlooked fact that compressed natural gas (CNG) is among the most water efficient transportation fuels available today. Most of the environmental concerns in the U.S. arise from a lack of environmental stewardship from small independents combined with ineffective state regulatory framework and monitoring; thus, EU regulation is more robust and European shale gas is more likely to be developed by International Oil Companies who have a good track record in managing environmental impacts, but this will come at a cost. The challenge in Europe will be for shale gas developers to develop and communicate robust environmental codes of practice that reassure both the regulators and the public that the environmental impacts can be managed successfully and that the development will provide a net benefit to the community at large.

Given that the shale gas phenomenon is a game changer in the U.S., what are the clear and immediate implications for Europe? In the first instance, Europe is benefiting from the price compression and LNG cargo re-routing towards the EU from the Atlantic basin, placing a downward pressure on natural gas prices on the continent.

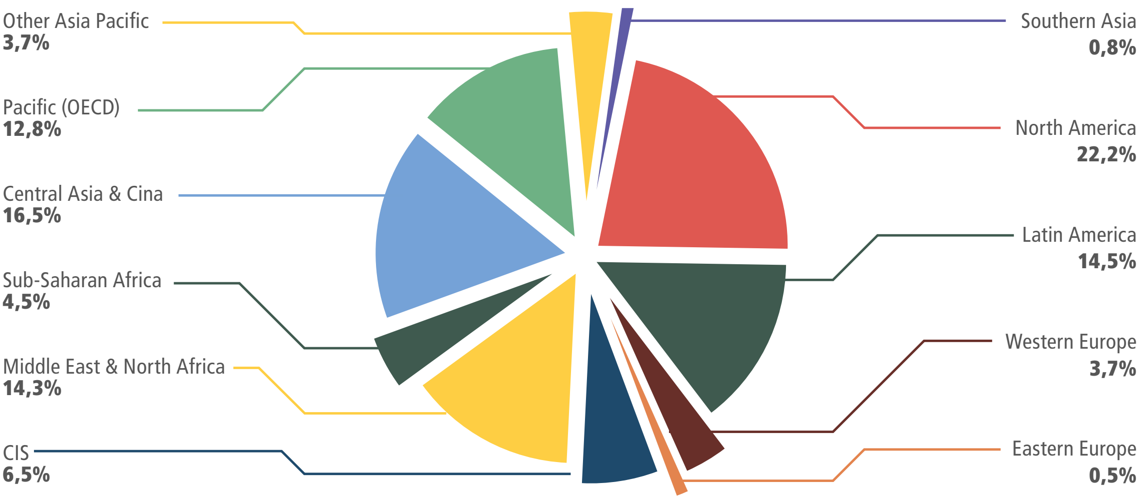
[49] **GWPC and ALL Consulting** (2009), "Modern Shale Gas Development in the United States: A Primer".

PROSPECTS FOR THE GLOBAL AVAILABILITY OF UNCONVENTIONAL GAS RESOURCES

The prize in accessing these very large unconventional gas volumes is that their potential is vast – it is a resource several times greater in magnitude than that of conventional sources.

A study by IHS Cambridge Energy Research Associates (CERA) calculates, for instance, that the recoverable shale gas outside of North America could be larger than the entire world's gas discovered to date.[50] Estimates of recoverable resources are increased at a greater pace as technological advances permit access to gas from "unconventional" resources. The most prolific shale reservoirs are relatively flat, thick, and predictable; the formations are so large that, once drilled, the wells are expected to produce gas at a steady rate for decades. Generally, it is assumed that shale gas wells flow rates are considerably lower than their conventional peers, but once the production stabilizes, the well will produce consistently for 30 years or more.[51] While recoverable conven¬tional gas resources are estimated to amount alone to 404 tcm, unconventional gas resources, meanwhile, are estimated even at over 900 tcm (according to the US Geological Survey (USGS) and the German Federal Institute for Geosciences and Natural Resources (BGR).[52] From these 900 tcm, at least 380 tcm appear recoverable, taking the total recoverable conventional and unconventional gas resources to nearly 800 tcm – equivalent to about 250 years of current production.[53] In addition to the U.S., the biggest potential of unconventional gas is currently seen in the region of the former Soviet Union (CIS), Central Asia and China. But given the present lack of sufficient geological information and credible exploration drilling test data outside of the U.S., the prospects for unconventional gas production remain uncertain for at least the next 2-5 years.

FIGURE 3: REGIONAL DISTRIBUTION OF TIGHT AND SHALE GAS RESOURCES



Own graphic, adapted from: BGR, Reserves, Resources and Availability of Energy Resources. Hannover/Germany 2009, p. 93.

50 **Tom Fowler** (2009), "Stubborn in His Vision", Houston Chronicle.

51 **H. Frantz and V. Jochen** (2005), "When Your Gas Reservoir Is Unconventional, So Is Our Solution - Shale Gas", Schlumberger, October.

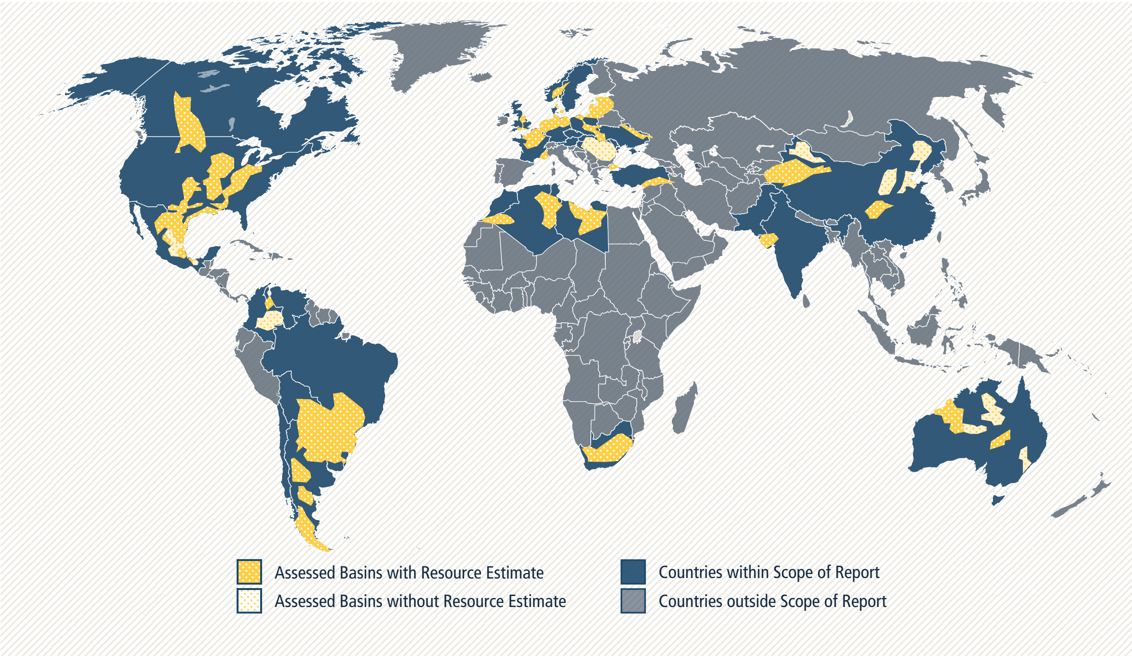
52 **USGS** (2000), "World Petroleum Assessment", Boulder/Colorado, USGS (United States Geological Survey); BGR (2009), "Reserves, Resources and Availability of Energy Resources", Hannover/Germany, BGR (German Federal Institute for Geosciences and Natural Resources).

53 **IEA** (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency). See also Alex Forbes (2009), "The Great Potential of Unconventional", European Energy Review, 9 December.

Nevertheless, exploration drilling for shale gas and coal bed methane has already started in China, Canada, Australia (i.e. coal bed methane production) and Europe (tight gas identified in Poland, Hungary and Germany).[54] The U.S. Energy Information Administration (EIA) estimated in its "International Energy Outlook 2010" that the unconventional gas production of Canada and China will amount to 63% and 56%, respectively, of their total domestic gas production in 2035 (Reference Scenario).[55] The Paris-based IEA, being very careful of any estimates for future worldwide unconventional gas production, expects that around 35% of the global increase in gas production – from 3,149 bcm in 2008 to 4,535 bcm in 2035 (44% in the timeframe) – will come from unconventional gas sources.[56]

EIA recently published a newly commissioned report by Advanced Resources International, Inc.°(ARI) that offers a new initial assessment of the worldwide shale gas resources. The report analyzed 48 shale gas basins in 32 countries, containing almost 70 shale gas formations. However it still excluded other potential regions such as Russia, Middle East, South East Asia, and Central Africa because they have either large conventional gas reserves (i.e. Russia and Middle East) or lack sufficient information to carry out an initial assessment. Although the report represents "a moderately conservative 'risked' resource" assessment for basins, the findings of the initial assessment conclude that the worldwide shale gas resource estimate is adding another 40% to the total world technically recoverable gas resources from 16,000 to 22,600 trillion cubic feet (tcf).

FIGURE 4: MAP OF MAJOR SHALE GAS BASINS IN 32 COUNTRIES



Own graphic, adapted from: EIA, World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, Washington D.C. (U.S. Department of Energy), April 2011, p. 3.

[54] **BGR** (2009), "Reserves, Resources and Availability of Energy Resources", Hannover/Germany, BGR (German Federal Institute for Geosciences and Natural Resources) and IEA (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency).

[55] **EIA** (2010), "International Energy Outlook 2010". Washington D.C., EIA (Energy Information Administration), Washington D.C.

[56] **IEA** (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency).

The EIA-report has also concluded surprisingly that China holds technically recoverable assets of around 50% more than in the U.S.. Although some important regions have not been included, the report's valuation is showing that the assessed worldwide shale gas resources are already significantly larger than in the only previous study conducted by H-H. Rogner in 1997 ("An Assessment of World Hydrocarbon Resources").[57]

In China, the IEA expects that total gas production will rise from 80 bcm in 2008, to 140 bcm in 2020 and 180 bcm in 2035 and that the "bulk of increase" in tight gas, coal bed methane and shale gas is expected within this timeframe. In November 2009 China signed a cooperation agreement with the United States on shale gas development projects. China's National Energy Administration (NEA) is currently drafting a national shale gas development plan that aims for commercial production as early as possible in order to (1), increase cleaner energy consumption and, (2), reduce reliance on carbon-intensive coal. On this, Shell is cooperating with PetroChina and is presently drilling 17 wells, including ones for tight gas and shale gas; whilst BP is currently seeking to cooperate with Sinopec on joint shale gas development projects in China. In Beijing the government has set up special research projects focusing on shale gas exploration and development technologies and, if the exploration test drilling underway proves to be successful, plans to invest $1 billion a year over the next five years into shale gas development.[58]

Special attention is also given to coal-bed methane (CBM) due to the lower capital requirements, the technological entry barriers in comparison to tight or shale gas exploration and production, and the involvement of many more players. But, while CBM production capacity was just 2.5 bcm in 2009, production volume are even lower at 0.7 bcm. At present, production targets for CBM were 5 bcm by the end 2010, and are 30 bcm by 2020 and 50 bcm by 2050. Present production costs are about 50% higher than conventional natural gas. Global resources of CBM amount alone to 135.5 tcm-372.5 tcm.[60]

Having analyzed the global potential of unconventional gas, let's take a closer look at Europe in particular.

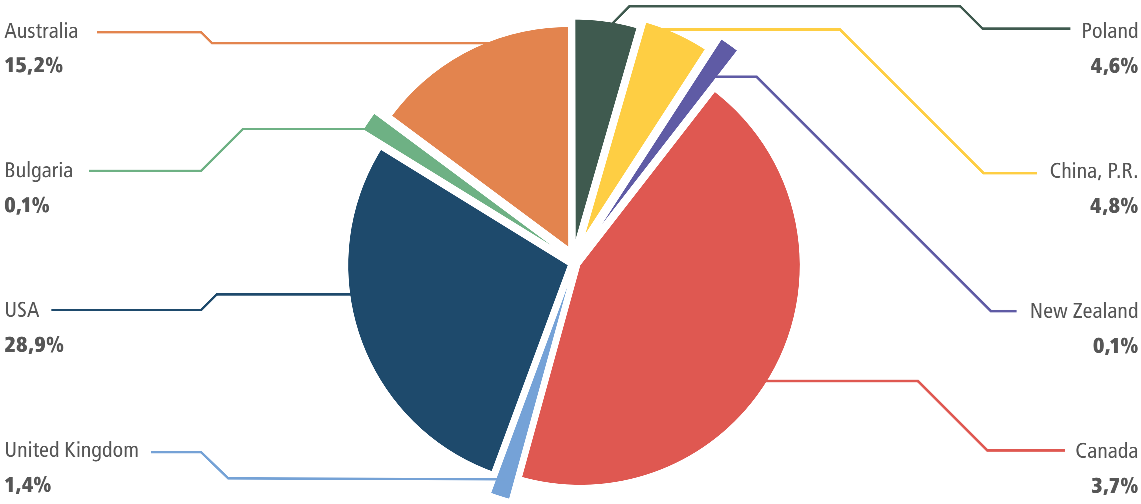
57 **EIA** (2011), "World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States", Washington D.C. (U.S. Department of Energy), April 2011; Rogner (1997), "An Assessment of World Hydrocarbon Resources", Annual Review of Energy and the Environment 22, pp. 217-262.

58 'China Energy Authority Drafting Shale Gas Development Plan: NDRC', Reuters, 28 March 2011.

59 'China Gas Sector. Key Takeaways from the Asia-Pacific Unconventional Gas Summit', Yuanta-Industry Update, 1 April 2010.

60 **BGR** (2009), "Reserves, Resources and Availability of Energy Resources", p. 95.

FIGURE 5: CBM RESERVES BY COUNTRIES IN 2007



Own graphic, adapted from: BGR (2009), "Reserves, Resources and Availability of Energy Resources". Hannover/Germany, p. 96.

SHALE GAS IN EUROPE: A REVOLUTION IN THE MAKING?

A number of energy companies as well as policy makers are actively focused on how to replicate and improve upon the North American model of unconventional gas production and use it as a blueprint for reducing European natural gas import dependence. The IOCs – who, for the most part, missed out on the first stage of shale growth in the U.S. – are engaging wholeheartedly in a land grab encouraged by cheap acreage prices (~c.50$/acre), a solid resource estimate in the EU, and the need to secure the best land in the early moves of what will likely be long-term commitments. As the EU continues to promote self-sufficiency and security in energy, the European Council places as mentioned in its first special energy meeting on February 4, 2011 much hope in unconventional gas and the possibility that it will radically change the supply outlook for natural gas within a few years, as it has done in the North American context. Indeed, unconventional gas exploration is not totally unknown in Europe either; during the late 1990s, the EU sponsored underground coal gasification projects in Belgium and Spain, and Europe's mining industry has long been using methane for power generation.[61]
Currently, three major potential shale gas Paleozoic plays have been identified:
the Cambrain-Ordovician (which stretches from Denmark through to Sweden), the Silurian (Poland) and the Carboniferous (which runs from the UK through to Poland).
Both the European Commission and the IEA believe these and other basins could be depositories of significant unconventional gas resources, with estimated total recoverable reserves in Europe between 33 to 38 tcm, of which 12 tcm are tight gas, 15 tcm shale gas, and 8 tcm coal bed methane. In comparison, total conventional gas reserves in the EU amount just to 2.42 tcm. Such sizeable resources have the potential to reshape radically the European gas supply picture, with shale gas playing a vital balancing role for regional gas markets. Therefore, in theory, they might be able to cover European gas demand for another 60 years.[62] Promisingly, the new EIA study estimated the technically recoverable Resource in Europe even higher, totaling to 624 trillion cubic feet (tcf) in comparison with 862 trillion cubic feet in the U.S., 1,069 tcf in Canada and Mexico, 1,225 tcf. in South America and 1,275 tcf in China.[63] Meanwhile, concessions for shale gas test drilling have already been granted in the Netherlands, France, Germany, UK, Sweden, Hungary, Switzerland, Ukraine and with Poland at the forefront (see also Appendix).

As Brian Horsfield, Research Director at GFZ German Research Centre for Geosciences, accurately states, critical factors moving forward are availability, cost and environmental compatibility.[64] For instance, initial Wood Mackenzie reports estimates suggest that unconventional plays are more complex, deeper (up to 8 km) and less porous than those in North America.[65] Given these uncertainties over organic content, shale pressure, and mineralogy, all of which result in risk to any forecast, there are several questions remaining as to how these unconventional resources can transform the European market.

---

[61] **Joseph Dutton** (2010), "The Shale Gale – Perfect Storm or Flitting Breeze?", Pan-European Institute (Ed.), Baltic Rim Economies. Bimonthly Review 6/2010, 17 December.

[62] **Rik Komduur** (2010), "Europe Not Ready for Unconventional Gas, Yet", European Energy Review, 21 June.

[63] **EIA** (2011), "World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States".

[64] **Brian Horsfield** (2011), "Unpublished Presentation Under the Topic: Shale Gas Development in Europe?", EUCERS (Ed.), Shale Gas - Revolution in Europe? Kings College, London.

[65] **IEA** (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency).

FIGURE 6: POTENTIAL GAS SHALE'S IN EUROPE

Own graphic, adapted from: Cedigaz Insights N7 – May 2010

FUNDAMENTALS, DIFFERENT MARKET STRUCTURE, AND CORE CHALLENGES

Several obstacles lie ahead of efforts to commercialize shale gas in Europe, starting with acute environmental concerns in Europe. The constraints connected to water can be summarized in two categories; one is the environmental concern, that fracturing of shale contaminates fresh water supplies, and the other is water scarcity concerns for drilling.

To avoid contamination of aquifers through drilling and to obey the strict environmental regulations in place in most European countries wells are drilled with multiple casing strings and the shallowest ones isolate the fresh water aquifers. Fresh water aquifers are generally found at depths that are 1,500 to 2,000m+ shallower than the productive shale's.

In comparison to other fossil fuels, for example coal, the environmental damage done by lignite mining, and also its impact on aquifers, is tremendous.

With further technological improvements the potential to develop more environmentally friendly drilling technologies will enable the oil and gas industry to find a way to cope with the many water issues related to drilling, reducing these obstacles over time. Moreover, in comparison to the U.S. European rock strata containing unconventional gas resources are generally located more deeply in the earth and beneath the groundwater, thus raising the costs for exploration drilling and lowering the risk of groundwater contamination. This is especially important because groundwater levels in countries such as Germany are rather moving up instead of sinking deeper.

The other underestimated obstacle connected to water is its scarcity. The very large volumes needed to unlock shale gas from rock formations will cause competition with the agriculture industry over water. Millions of gallons of water are likely to be needed per well for fracturing operations. Sourcing of such large quantities of water in areas where water is scarce and environmental regulations apply to large areas of the land will be an obstacle to unconventional gas development. Yet, what is often overlooked by these allegations is that in most shale plays 70% of fracturing water can be re-used, therefore drastically reducing the amount of water needed. In addition, where ground water is not present, technological improvements now make it possible to use water from brackish aquifers.[66]

European environmental legislation and water policy outlined in the EU Water Framework Directive 2000/60/EC (WFD) commits European Union member states to ground water protection, and the Commission to strategies on pollution control. Although, the Directive 2000/60/EC (WFD) may authorize member states to inject water containing substances resulting from exploration and extraction of hydrocarbons or mining activities. Due to the EU's environmentally rigid regulation, management capacities and experiences associated with the "silent revolution" of multi-fracturing horizontal drilling technologies, the prestigious Dutch Energy Council goes even further by arguing that current environmental legislation in the EU and the Netherlands is not just adequate to ensure an environmentally friendly exploration and production of unconventional gas resources in the EU but sees even business opportunities and better export chances for coping with the worldwide environmental challenges of unconventional gas exploration.[67]

As EU Commissioner Günther Oettinger has rightly stated, despite the early stage, the significant interest in unconventional gas exploration shows that companies see business potential in European shale gas. However, as he also points out, "it is important that these companies, as well as public authorities, engage actively with citizens and local communities to address their possible concerns and gain public acceptance."[68]

[66] **BNK Petroleum**, (2010), "Shale Myths - Shale Gas in Europe", http://www.bnkpetroleum.com.

[67] **Karel Beckmann** (2011), "Dutch Energy Council Embraces Unconventional Gas", European Energy Review.

[68] **Günther Oettinger** (2011), "Possibility of Using Gas from Alternative Sources in Europe", Plenary (Ed.), Brussels, EU Commission.

PUBLIC ACCEPTANCE AND THE ENVIRONMENTAL DEBATE

Public reticence with regard to accepting water and air pollution around gas rigs, compressor stations, and the general environmental surface footprint surrounding drilling pads – be that in the form of new roads or other significant obstacles – are especially important in Europe due to the continent's densely populated areas.

In France for instance "exploration work for shale oil and gas has sparked legitimate questions from populations living near the sites," said French Prime Minister, Francois Fillon, and ordered that "no unconventional drilling take place" until the government and parliamentary reports are made public". According to this recent statement, France extended a ban on searching for natural gas and oil in shale rock until two reports on the environmental and economic effects of exploring unconventional resources are published in June 2011.[69]

To prevent growing suspicion and resistance, the corporations involved in unconventional gas drilling need to pursue good stewardship of available resources and state-of-the-art technology to minimize the environmental damage. In addition, interactions – educational or otherwise – with local communities will also be key for successful unconventional gas drilling in densely populated areas.

This leads to the next anticipated obstacle: that shale gas production requires hundreds and thousands of square kilometers, compared with the tens or hundreds needed for conventional gas development. In Europe, this will be very problematic since the population density, being three times greater than in the U.S., will mean that negotiations for getting production rights and access to land will entail talking to hundreds of landowners. As an example in Poland, one million farms are, on average, only twelve acres in size. This distribution of land across the population is at tension with, as Ernest Wyciszkiewicz from the Polish Institute of International Affairs puts it, the political asset that shale gas can help fulfill political agendas and solve regional development issues. In Poland, most of the unconventional gas deposits are found in rural underdeveloped areas. Therefore, the explorations and development of these sources offers the opportunity and the potential to bring new prospects and prosperity to the region, but must be balanced with the issue of public participation and the allocation of profits to these regions.[70] How this challenge needs to be solved by each government remains to be seen, but it brings us to the next issue that needs to be addressed:

The allocation of property rights in Europe is very different to North America. In the U.S., the owner of the land also owns the subsoil and receives revenues from the resources held within. This provides an important incentive to landowners to allow gas drilling and production on their land. Contrastingly, in most European countries, the state owns the rights and receives royalties. The owner of the land does not own the subsoil and exploration and production companies must therefore negotiate with the subsoil owner – the state in most cases – and the land owner, which renders the process considerably more complicated. This has two major implications for public opinion. Firstly, since the landowner does not receive revenues from drilling, the incentive to accept the inconvenience is reduced. Secondly, the local opposition to onshore drilling from an ecologically more sensitive European public is more likely if it cannot derive any profit from their subsoil's commodities.

[69] **Cedigaz** (2011), Unconventional Gas Activities in the World. No. 55– April 2011, Thierry Rouaud (Ed.). U-Gas News Report.

[70] **Ernest Wyciszkiewicz** (2011), Unpublished presentation under the Topic: The Geopolitics of Shale Gas: Is Shale gas a "Game Changer"?, EUCERS (Ed.), Shale Gas - Revolution in Europe? Kings College, London.

This may increase a NIMBY (not-in-my-back-yard) opposition to shale-gas drilling. However, this is not unlike the path development took in the U.S., where environmentalists have raised objections to the rampant growth of the unconventional -gas sector. As an example, Chesapeake, one of the largest shale-gas drillers in the U.S., decided it would not drill in an area of New York State after opponents claimed its operations could endanger the watershed.[71] Yet, in many other densely populated areas U.S. deposits have been exploited without any comparable difficulties.

Over time, new well and reservoir management technologies are making it possible to significantly reduce the number of well pads that required. Drilling the long laterals in many directions to drain the reservoir from a single site has made it possible to reduce the land take from many individual well sites to multiple well sites with 8 to 12 wells per well pad

Another example for new drilling technologies can be found in Ukraine, where specialists have developed an alternative technology that could also be used for shale gas exploration. This technology, called "cavitation hydrovibrator", is also designed to fracture rock, but it uses a pressurized water pulse action on rock stratum to increase its degree of fracturing. It appears a much more environmentally-friendly technology by using pure water, without the use of any chemicals traditionally used in fracking.[72]

Therefore, the technological improvements are expected to reduce not only the surface footprint but also the need to negotiate with all landowners.

[71] **Petroleum Economist** (2009), "Europe Awaits a Shale-Gas Revolution", Petroleum Economist, December.

[72] We are thankful **Walter Dzerko** from Toronto for providing this information – see http://bit.ly/7BpJYn.

IT'S ECONOMICS, STUPID!

A major challenge to the development of unconventional gas is the entrenched economics of conventional gas. Conventional gas remains the least expensive, but favors gas imports due to an already established transport infrastructure that, in turn, places a heavy reliance on one supplier and has produced strong views of supply security.

The fact that shale gas has lower productivity than conventional gas and production declines faster in the first years of production adds some further economic constraints. Typically, the production decline of shale gas wells is between 70% and 90% in the first year –- according to Florence Gèney –- and, "as the free gas is depleted, the adsorbed gas bleeds slowly through the low permeability tight gas reservoir from beyond the fracture to give a low production rate that continues for a long period."[73] This means that a larger number of wells will be needed to keep up production. These wells require horizontal drilling and hydraulic fracturing, which makes the wells more expensive again. Nevertheless, the well will then keep producing for some decades as mentioned earlier, but how expensive shale gas is to produce will technically depend on the shale characteristics.

Although European geology is sufficiently well documented, the issue still remains about how much shale the rock formation contains and, crucially, at what cost the gas can be produced. The reserve estimates come from studies that were done in the late 1990s;[74] but, potential, rock properties and the specifics of the geologic structures have yet to be confirmed. What is known so far is that the geology is more disturbed and, more fragmented, where the strata of rock have, over the eras, folded back on themselves creating faults that complicate the drilling and appraisal process.

Until test wells are drilled in each prospective shale gas basin, it is impossible to know whether any individual project will be economic or not. Low gas prices in the U.S. will ensure continued acceleration of technological advances, which will increase efficiency and improve economics even further, especially if one takes into account that we are talking about a development periods of five to ten years.[75] One myth that often comes up is that the European shales are deeper underneath the surface and most probably lack sedimentary basins on the scale of those developed in America. But, as is the case in the U.S., shales in Europe are also found at a wide variety of depths, numerous shales go from outcrop to various depths just like in the U.S. The Fayetteville produces from 1200 m and Haynesville at 4000 m. In Europe, Shell is testing the Alum shale in Sweden at 900m, while other companies are targeting shales in the Baltic Basin between 2,500m and 4,000m.[76] Also, some of the European shales are thought to have more gas stored than the shale's found in America. Moreover, some of the most promising European shale's are offshore in the North Sea, and offshore production of shale gas has not been tried yet, which is more likely an issue of economics than of technology.[77]

Thus, an additional economic constraint comes from the fact that unconventional gas exploitation is at an embryonic stage and needs further development. Indeed, while Europe's gas distribution infrastructure is well developed, the services sector that would support an unconventional gas industry is not, for which subcontractors are already preparing for an anticipated increase in the level of activity. In addition, Europe also lacks suitable technical equipment, such as drilling rigs, and has extensive state control over local rig markets that reduces competition and leads to higher costs.[78]

---

73 **Florence Gény** (2010), Can Unconventional Gas be a Game Changer in European Gas Markets? NG 46. Oxford Institute for Energy Studies. P. 5

74 **Gas Matters** (2010), "Shale Gas In Europe: A Revolution in the Making", Gas Strategies.

75 **BNK Patroleum** (2010), "Shale Myths - Shale Gas in Europe", http://www.bnkpetroleum.com.

76 Ibid.

77 **Gas Matters** (2010), "Shale Gas In Europe: A Revolution in the Making", Gas Strategies.

78 **Petroleum Economist** (2009), "Europe Awaits a Shale-Gas Revolution", Petroleum Economist, December; and IEA (2010), "World Energy Outlook (2010)", Paris, OECD (International Energy Agency).

According to Baker Hughes rig count in May 2010, Europe accounted for 46 Land and 42 offshore rigs: a total of 88 (57 oil/23 gas/8 multiple rigs). Most of these rigs are unsuitable for the necessary types of drilling and hydraulic fracturing operations needed to carry out shale gas operations, but, there are sufficient rigs to drill the science wells. In Poland, for example, where prospects are believed to be at similar depths to those of Texas' Barnett Shale, there are under seven operational rigs suitable for shale exploration. Rig transfers within the EU would be relatively easy, but this would equate to only 46 land rigs, which are unlikely to be suitable for horizontal and fracturing operations, especially if the Polish shale is, as is alleged, over pressured. These figures are ominous when one compares them to the U.S., which has a total of 1,513 rigs in place, of which 1,464 are onshore. The majority of these rigs are used for unconventional drilling while only 49 are destined for offshore purposes.

It is often stated that this makes Europe dependent on importing equipment from either North America or China. This poses multiple problems. First, the U.S. imperial rig measurements provide scope for delay as it conflicts with European metric standards. Second, European import requirements and regulations make it challenging to simply import rigs from aboard, which creates a bottleneck for both rig access and service. Nonetheless, this might be a chicken-and-egg issue which can be overcome by time; Europe has excellent engineering and skilled workers who can learn from the U.S. experience, and could, once possessing the expertise, build rigs to European specifications in 9-12 months.[79]

Besides all this, the regulatory issues and the current market structure also present some obstacles. The competitive market structure is both symptom and cause of the facing material European production going forward.[80] Nevertheless, a regulatory system with potential tax credits to help push unconventional -gas development will evolve only as companies demonstrate the commercial viability of their plays. Most of the pipelines in Europe are still not independent but are affiliates of major national producers, which have an impact on their operations and strategies. The ongoing liberalization process and need for a deregulated European market brings several uncertainties even to conventional gas production and long planned investments.[81]

The long-term import contracts are also a major obstacle for new sources of gas finding their way into the market. Indeed, unconventional gas volumes are likely to depress the spot price, even in the modest spot trading that currently exists on the market. Unconventional and additional LNG also gives more flexibility and liquidity to trading hubs and spot pricing.[82] Thus, various experts at Deutsche Bank and Wood Mackenzie suggest that it is conceptually more accurate to use the spot price than the EU contract gas price when comparing how the unconventional gas break-evens with the actual realizable gas price. This is due to the fact that, at least for the next decade, unconventional gas plays seem unlikely to offer the stable supply necessary before 2020 to assume buyers will put in place long-term contracts, as Deutsche Bank states.[83]

79 **BNK Petroleum** (2010), "Shale Myths - Shale Gas in Europe", http://www.bnkpetroleum.com.

80 **IEA** (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency).

81 **Nick Snow**, (2010), "EIA Energy Conference: Experts See Shale Gas Affecting Overseas Supplies", Oil & Gas Journal.

82 **Charles Augustine, Bob Broxson and Steven Peterson** (2006), "Understandong Natural Gas Markets", AIP (Ed.), ibid.

83 **IEA** (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency).

HIGHER COST OF DRILLING

Given the infancy of the sector in Europe, we can expect initial production costs to be much higher; drilling costs for Europe are currently between two to four times more expensive on a unit cost basis than they are in North America. Labor cost are significantly more expensive than in the U.S., and, when adding up additional costs – for instance for meeting EU environmental standards and taking into account the less competition in the services sector – there are fewer drivers to bring down the price of development. Wood Mackenzie predicts the break-even price for shale gas in Europe is at around $9/mm Btu, or almost twice the price of gas in the U.S. at present, and, to go down to a reasonable economic level, needs to break even at a rate of $6/mmBtu.[84] According to the Oxford Institute for Energy Studies, the cost of producing shale gas in Europe will be up to 4 times the one in U.S. where costs of production are in the range of $2 and $6 or $7, which means costs of $8 to $27 per mmbtu in Europe. Hence, in Europe, the "sweet spots" need to be detected early on.

On the other hand, as the Petroleum Economist writes, Europe's market is well-developed and flexible enough to reward new suppliers.[85] With high and stable oil-linked gas import prices, shale gas production can be very lucrative. So, where the average import price on the German boarder was around $8.52 per mmbtu in 2009 and the average NBP spot marked price in the UK was $4.85 per mbtu.

As long as oil-price indexation in Europe continues to govern long-term gas-supply contracts, the gas market will follow crude. Gas prices estimated for 2012 are to reach $9/mmcf – 70% of which is determined by the 9-month trailing of the Brent price and the remaining 30% by government subsidies, meaning that the break-even gas price will also be much higher in the EU.[86] Despite projections for abundant gas supply in the next three years, this means that the price would be sustainable to pay for the higher CAPEX cost. If unconventional gas remains priced against the oil-price index in Europe this could make up for the lack of operational efficiencies that are unavoidable in a smaller drilling network. Significantly high returns, through either realizable high market prices or substantial cost reduction of 40-50%, as we have seen in the U.S. in the last 4-5 years, would be very positive for the economics of the European individual shale gas plays.

Several experts indicate that the overwhelming factor influencing the break-even prices of unconventional gas is the initial well cost – drilling and completion – rather than royalty rates or operating cost.[87] Given the previously discussed surface and geological issues, a steep cost reduction curve in Europe seems rather unlikely in the near-term. However, the newly built gas pipelines, i.e. from Russia's very expensive new gas fields in Yamal and other parts of Siberia, or even in the Arctic waters, coupled with the higher transportation costs for the undersea North Stream pipeline and even much higher for the planned South Stream pipeline, indicate that future pipeline gas will be much more costly than is the case with the older pipeline net and its present rather low-cost gas fields.

Explaining the land grab currently taking place in Europe can be logically explained: For major IOCs, it is strategically rational to use the first mover advantage, organically entering a market and positioning themselves in the most advantages position. Since licensing costs in Europe are in most cases very low there is little impetus to wait until the high gas break-even prices come down and production begins to become economical, either through lowered cost or tighter gas market prices. In Europe, the first movers will benefit from high profit margins, as later movers, relatively speaking, will have to pay an entry premium for the same capabilities.[88]

84 **Petroleum Economist** (2009), "Europe Awaits a Shale-Gas Revolution", Petroleum Economist, December.

85 **Petroleum Economist** (2009), "Europe Awaits a Shale-Gas Revolution", Petroleum Economist, December.

86 Ibid.

87 **IEA** (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency).

88 Ibid.

As demonstrated, although the exploration risk is low, existing economic constraints and obstacles in Europe make the cost and the development risk for shale much higher than in the United States. Even when the geological and environmental hurdles can be overcome, economic concerns, like production cost and gas-pricing issues can come to dominate. Wood Mackenzie and Deutsche Bank reports indicate that even once considerable challenges in Europe are overcome the reasonable resource potential is actually relatively low on a global scale. Indeed, Deutsche Bank reports do not expect unconventional gas to ramp up more than 9 bcm – little more than 1% of European consumption by 2020. While this conclusion seems too skeptical, even a more optimistic forecast concludes that the smaller increases in tight gas, shale gas, and coal bed methane production in Europe will be insufficient to replace the declining production rate of its conventional gas production (as happened in the U.S. during the last year).[89]

That said, there remains an upside from an expected rising trend in domestic gas pricing and by a relatively attractive fiscal framework: current royalty and corporate tax rates in each country are already very low compared with the incumbent hydrocarbon taxation.

What becomes evident immediately is that the geological data about porosity and permeability of shale and coal seams in Europe is almost universally unknown. Since this is a key factor in determining the viability of investment and development it is absolutely essential to see if and how the several test wells, which are to be drilled this year, shed light on the geological uncertainties. It is likely that by the end of this year we will have a better idea of "Doctor Drill´s" preliminary estimation on the geological issue. Yet, even if Europe's shale gas potential is realized, it is unlikely that it would happen, as predicted by the Petroleum Economist, over the next ten years (before the entire planned new import infrastructure to supply the continent's forecast demand is built).[90] With reports of consequence instead indicating that the European gas market is already tightening around 2015-17 when current oversupply will disappear and higher contract / spot prices in a tighter market will lead to increased and necessary investment in the unconventional gas sector. This, however, indicates that a significant unconventional gas production in Europe won't materialize before 2020. Nonetheless, this perspective may still be focused too much upon the present gas market and technological conditions, whilst overlooking the issue of uncertain future EU gas demand in contrast to older energy and gas forecasts (see below).

[89] Ibid.

[90] **Petroleum Economist** (2009), "Europe Awaits a Shale-Gas Revolution", Petroleum Economist, December.

BUT ROME WASN'T BUILT IN ONE DAY …

Given that the unconventional gas industry in Europe is still in its infancy and that successful E&P and service companies are absent in the European landscape, huge uncertainties in the market seem unavoidable for the time being. In this light, it is hardly surprising that some of the European energy and gas experts are rather skeptical about the prospects in Europe.[91] However, that skepticism is not very different from the skepticism witnessed in the U.S. just a few years ago, particularly from the IOCs such as Exxon Mobil, BP, Shell and Statoil. Meanwhile, these big companies are often at the forefront of the unconventional gas exploration test drilling in Europe.

Without further clarity on material well cost reductions, recovery rates, or a material increase in the market price for unconventional gas, it currently seems hard to see past the current prohibitive surface characteristics of the European situation; namely, environmental legislation, population density, water/proppant supply, and/or lack of service infrastructure.[92]

All in all, this creates a chicken-and-egg scenario. CAPEX are needed to bring down well cost so that gas break-evens can become economic. To attract investments the surface factors need to improve and issues related to geological sub-surface aspects need to be clarified. Alternatively, investment will kick in spite of the not reduced cost because the (spot) gas price has risen high enough for the plays to become economically viable even at current well costs and recovery rates. Lessons learned from comparing the factors determining the success of unconventional plays, in particular shale gas in the U.S. with the potential European outlook for unconventional gas, are as follows: unconventional play success depends on in-place reserves, sub-surface and surface factors aligning favorably – as measured by gas break-even prices and measures of investment return (NPV, IRR). The production cost can be reduced either by production costs falling, or, equally, by market gas prices rising to high enough levels. Moreover, as Amy Myers Jaffe has reminded us, we should not ignore historical lessons of emerging new energy sources: "The reserves and production of new resources tend to increase over time, not decrease."[93]

This detailed review of the North American success story suggests that there are a myriad of factors determining the viability of an unconventional play and, hence, its production potential.[94]

---

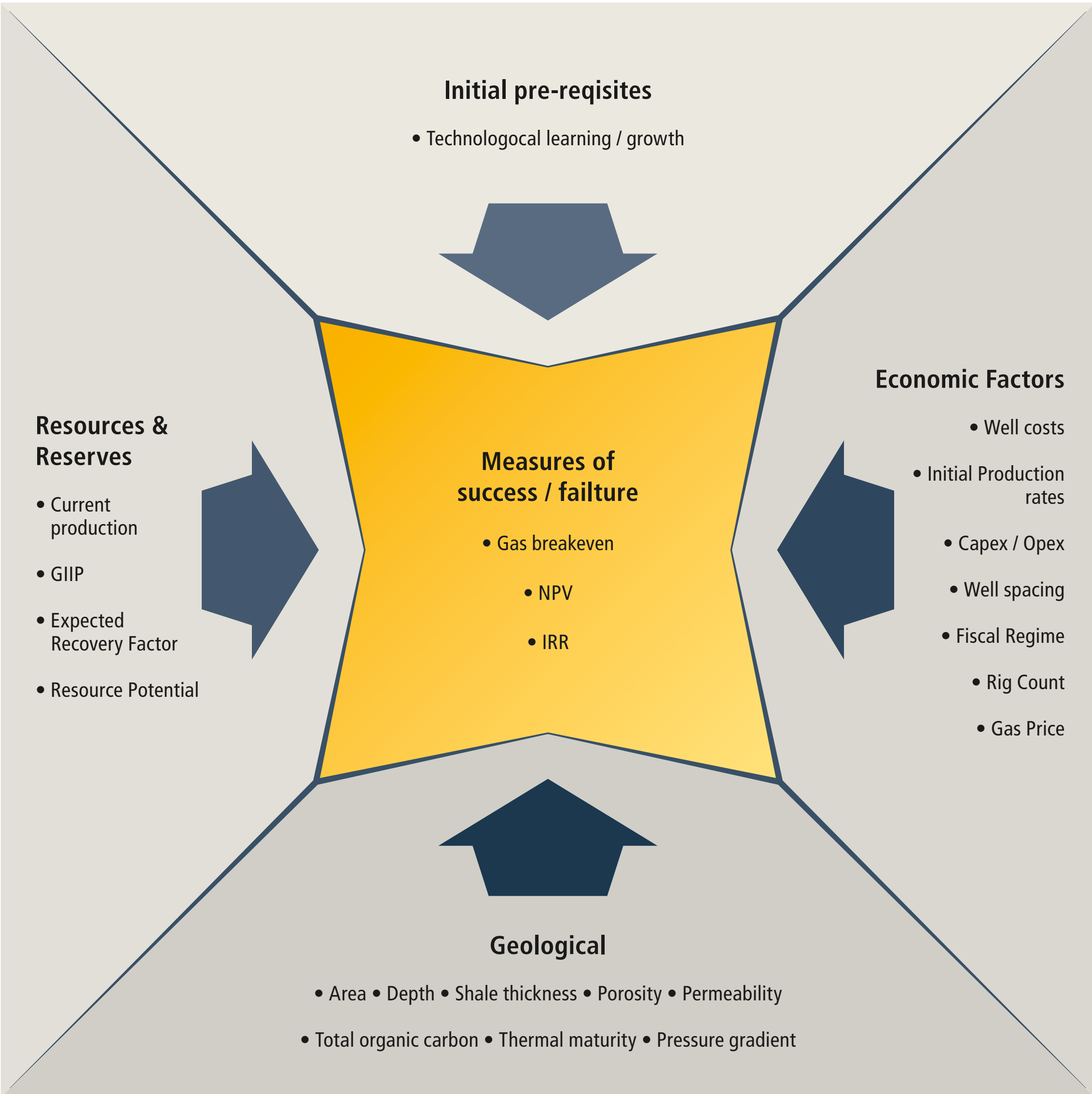
91 **Paul Stevens** (2010), "The 'Shale Gas Revolution': Hype and Reality", Chatham House Report, London, September and Roderick Kefferpütz (2010), "Shale Fever. Replicating the US Gas Revolution in the EU?", CEPS Policy Brief, No. 210, June.

92 **IEA** (2010), "World Energy Outlook 2010", Paris, OECD (International Energy Agency).

93 **Amy Myers Jaffe** (2010), "Shale Gas Will Rock the World", The Wall Street Journal, 10 May.

94 **IEA** (2010), "World Energy Outlook 2010". Paris, OECD (International Energy Agency)

FIGURE 7: FRAMEWORK FOR KEY STAGES / PRE REQUISITES AND MEASURES OF SUCCESSFUL UNCONVENTIONAL PLAY



Own graphic, own analysis, adapted from: Deutsche Bank

UNCERTAINTY IN EU-27 GAS DEMAND BY 2020 AND ITS IMPACT

Since 2006, the EU's dependence on the import of natural gas has widely be seen as the "Achilles heel" of Europe's energy security – its growing reliance on the more environmentally friendly natural gas resource creating an increasing dependency on a few problematic suppliers. In November 2000 the European Commission warned, in its first 'Green Paper', that in the next 20-30 years up to 70% (presently 50%) of the Union's energy demand will have to be imported. With regard to oil, the EU's dependence could reach 90% and, for coal, 100%. At present, 54% of Europe's energy is imported. The EU's own energy production is forecast to fall from 46% today to 36% by 2020. These imports have cost an estimated €350 billion – €700 for every EU citizen. What is more, the gas import profile of the EU-27 is not very diversified; 84% of gas is imported from three countries: Russia (42%), Norway (24%), Algeria (18%). Even worse, Sweden, Ireland, Finland and many of the new EU-member states are entirely dependent on one supplier – Gazprom, the Russian energy giant – while Greece, Hungary and Austria are more than 80% dependent on the same supplier.

Furthermore, Europe, as the main potential consumer of Caspian energy, has been sliding into a dual dependence on (1) traditional Russian supplies and (2) Russian-controlled supplies from Central Asia and the Caspian Region (CACR). Already, almost a third of the EU's total gas imports are coming de facto from this region via Russian gas pipelines and as a result of Russia's gas swap deals with countries of CACR.[95]

The EU's agreed energy security strategy, its enshrined diversification strategy of both the European energy mix and European imports, and, in particular, its declared 20-20-20 percentage objectives for expanding energy efficiency and renewables (from presently 9%) and decreasing its greenhouse gases by 2020 indicates that in the case of a successful implementation both the EU's energy demand and mix will look very different beyond 2020. Meanwhile, at least the objective for expanding renewables has become very realistic, both in the view of the Commission and the European energy industry.[96] That means overall energy consumption – electricity plus gas – across the EU would likely remain flat or even decline from its high current levels. This is in line with the EU's Energy Review of 2008 and its energy forecast analysis for 2020 as it highlighted, EU's total energy demand, gas consumption, and gas imports are shrinking. This is due to increasing energy efficiency in the heating sector and strong growth of renewable energies for power generation. Especially in the aftermath of the Fukushima-Daiichi catastrophe and its implications for the controversial renaissance of nuclear power[97] and in the current light of the global gas glut with its current `low´ gas prices, a renewed shift towards more natural gas consumption is being re-considered at least in the mid-term perspective. This is been emphasized by the triple A argument, which summarizes why natural gas – despite the declining demand – may become the "bridge fuel" for the 21st Century – towards a de-carbonized economy: Natural Gas is abundant, it is acceptable and it is affordable. The environmental benefits of natural gas fired power are tangible, substantial and immediate.[98] Thus the use of natural gas for power generation is among the cheapest and fasters ways – complementary to the renewable goals – to reduce CO2 emissions.

[95] **Frank Umbach** (2010), "Global Energy Security and the Implications for the EU", Energy Policy, Vol. 38, Issue 3, March, pp. 1229-1240.

[96] Communication from the Commission to the Council and the European Parliament (2009), "The Renewable Energy Progress Report: Commission Report in accordance with Article 3 of Directive 2001/77/EC, Article 4(2) of Directive 2003/30/EC and on the Implementation of the EU Biomass Action Plan", COM(2005)628, {SEC(2009) 503 final}, Brussels, 24 April, COM(2009) 192 final; and Frank Umbach (2010), "Promotion of Renewable Energy Sources in Germany and the EU in the Light of Their Energy Security Concepts – Objectives, Strategies, Challenges and Problems: Lessons to Learn for Japan?", Conference Edition „Renewable Energy 2010", Pacifico Yokohama/Japan, 27 June-2 July 2010, 8 pp.

[97] **Frank Umbach** (2011), „Globale Renaissance der Kernenergie oder nur eine Wiedergeburt der Ankündigungen?".

[98] **Malcolm Brinded** (2011), You can Count on Gas, Op-Ed/ Documents, MEES, Vol. 54, No. 15, 11 April 2011.

At the same time, the EU simultaneously has expanded its non-Russian-pipeline gas imports from Norway as well as of LNG from non-European countries (with a capacity of regasification terminals of more than 130 bcm, which will further been expanded till 2020). If one combines the increasing non-Russian import capacities coming from Norway, North Africa, from CACR (Nabucco) and LNG, they amount up to 300 bcm of conventional non-Russian gas imports (Russia's present levels are around 150 bcm).

In the context of uncertain future EU gas demand, most of the present pipeline discussions – i.e. Nabucco versus South Stream – are often de-linked from the major question of the future EU gas demand and import dependencies which are being debated based on old forecasts going back to 2004/5. The Fukushima-Daiichi catastrophe and the current global gas glut are likely to have an impact on future European gas demand, but this impact needs to be balanced against the changed economic, technological and overall political preconditions (20-20-20 objectives) since 2004, which are considered to decrease gas import demand.[99] Thus, the previous assumption that import demand from the EU will rise from 300 bcm to more than 500 bcm by 2030/35 (as the IEA still maintains) appears no longer valid; even when one uses the most optimistic and best-case scenario energy forecasts for the EU of 2008, this assumption still does not seem to be the most realistic either.[100] Actually, by taking the newest gas forecast for the EU into account, the EU-27's gas import demand by 2030 will be lower than 400 bcm or not significantly be higher (see below figure).[101]

FIGURE 8: EU-GAS FORECAST OF 2010

EU 27 Bcm	2005	2020 Baseline* scenario, oil price $88/bbl	2020 Reference** scenario, oil price $88/bbl	2030 Baseline* scenario, oil price $106/bbl	2030 Reference** scenario, oil price $106/bbl
Natural Gas demand	519	538	479	511	457
Natural gas production	219	130	129	88	87
Natural gas imports	299	408	349	423	370

Sources: European Commission (internal), here following Hugh Belin, To Russia with Love, European Energy Review, 2 September 2010 (http://www.europeanenergyreview.eu/index.php?id=2299http://www.europeanenergyreview.eu/index.php?id=2299).

* includes energy policy measures implemented until April 2009;
** includes 20% renewables in energy consumption, 20% less CO2 emissions, and policy measures implemented until the end of 2009 and a few energy efficiency measures.

99 **Frank Umbach** (2010), "Global Energy Security and the Implications for the EU", Energy Policy, Vol. 38, Issue 3, March, pp. 1229-1240.

100 Ibid.; see also Edward Hunter Christie (2010), "EU Natural Gas Demand: Uncertainty, Dependence and Bargaining Power", Turku School of Economics/Pan-European Institute (Finland), Electronic Publication, No. 17, Turku; Anouk Honoré (2011), "Economic Recession and Natural Gas Demand in Europe: What Happened in 2008-2010?", Oxford-Institute for Energy Studies, NG 47, January; and Stefan Nicola (2010), "Europe's Gas Industry Deeply Divided over the Future", European Energy Review, 22 November.

101 **Hugh Belin** (2010), "To Russia with Love", European Energy Review, 2 September.
http://www.europeanenergyreview.eu/index.php?id=2299

In addition the worldwide financial-economic crisis has also decreased the global gas demand, with demand in OECD-Europe declining in 2009 by 8% from 2008. Together with the rapidly expanding unconventional gas resources in the U.S., this has created a global "gas glut", a de-linkage of the gas prices from the oil price, and European pipeline prices being temporarily three times of LNG spot market prices. Given the worldwide and European prospects for unconventional gas production it becomes clear that the availability for the European and other energy markets of even a fraction of unconventional gas potential will extend the global overcapacity of gas until at least 2020 - thus, also improving the EU's energy supply security.[102] Against this backdrop, it seems unrealistic to argue that the EU, at present, needs all the gas pipelines currently being discussed or new LNG-terminals. Both the European gas industry and the EU member states need to prioritize the most economical and energy security enhancing pipelines, whilst at the same time following the same rationale when considering the options for the new regasification terminals that would facilitate higher and more flexible LNG imports in crisis.

In this regard, unconventional gas as a domestic source may definitely increase further the EU's future energy supply security; although the prospects for a significant unconventional gas production appear rather a concrete option after 2020.

Regardless of how the concrete outlook for European unconventional gas development looks–, and despite of whether or not unconventional gas will become affordable and sustainable in the mid-to-long term in Europe –, shale gas has already changed the European market even before a single well has been drilled, or a single molecule of unconventional gas has been produced in the European basins.

[102] **Josef Auer** (2010), "Gas Glut Reaches Europe. Major Impact on Prices, Security and Market Structure", EU-Monitor/ Deutsche Bank Research, No. 75, 8 July.

GEOPOLITICAL IMPLICATIONS OF UNCONVENTIONAL GAS

As pointed out, the U.S. unconventional gas success story has been a paradigm shift that has turned expectations upside-down. In essence, it has been a game changer for the emerging world gas market. The advantage of unconventional gas is that it is a domestic, national source of fuel supply enhancing the energy security of each country. Development of unconventional gas reserves brings foreign direct investment (FDI), creates new jobs, and helps to diversify away from other imported fuels, or, as is the case in the U.S., help the nation gain energy independence. In addition, natural gas is of growing importance to the European economies that will cause a rethink about energy security. Already, there is a growing realization among European policy makers that natural gas in world energy markets will have wide-ranging and major geopolitical consequences. In addition, amongst the many policy options available, natural gas can be seen as the best transition fuel to a sustainable and renewable energy future.

Hence, gas is deemed to become one of the most important fuels of the decade. The extent of the natural gas resource base means that supplies are plentiful, the infrastructure transporting it to its consumers is in place, and it burns twice as clean as other fossil fuels – making it the cleanest of the fossil fuels and publicly accepted source of power generation. Combine this with the ever-increasing role of renewables for power generation; natural gas has the potential to become the major balancing energy source.

But, the impact of the shale gas buzz is even greater. It has become the new 'elephant in the room', with global geopolitical implications that have caused a chain reaction: European gas prices are being renegotiated and revised. It has also caused an average of 15% of Gazprom's supplies to be delinked from oil-indexation. Yet, as Dieter Helm puts it, the implications are greater still: relatively cheap and abundant gas, along with the carbon advantage of gas, makes "nuclear and coal relatively more expensive than currently assumed." "By switching from coal to gas emission can be quickly reduced at a very low cost". Indeed, making gas a major transition fuel through 2030 will help renewable energy efforts to reduce emissions, at low cost, quickly in order to mitigate the impact of climate change.[103]

This chain of events also has the potential to remove Gazprom's European gas supply near-monopoly. In the fourth quarter of 2010 Decline, Russia's gas exports to Europe declined by 17% owing to a market oversupply due to re-directed LNG cargoes, and unseasonably warm weather. Unconventional gas is the 'elephant in the room'; it has helped to shift the balance from a seller-dominated market to one dominated by buyers. Unconventional gas is nowadays the 'new policy' option for European countries, giving buyers more leverage to renegotiate the high Russian oil-indexed gas price demands that are included in long-term contracts. Thus, unconventional gas, even without being produced in Europe, puts a certain price cap on high Russian gas prices, as it can become a potential source of diversification, particularly if Russian gas prices are higher than the brake-even point for European unconventional gas. All this has the potential to make unconventional gas development economically feasible and, politically speaking, more appealing. Unconventional gas, and shale gas in particular, has become a negotiating tool for Europe in a changing gas market that is enhancing the region's energy supply security by diversifying energy sources and enabling the prioritization of a domestically located resource.

---

[103] **Dieter Helm** (2010), The Coming of Shale Gas: the Implications for Oil and Energy http://www.terrafirma.com/Alternative-perspective-page/articles/295.html This is in contrast to a report from the Tyndall Centre arguing against shale gas in particular as a transition fuel and highlighting the potential risks to human health and the environment. See: Wood. R., Gilbert P., et al: 2011, Shale gas: a provisional assessment of climate change and environmental impacts. A report commissioned by the Cooperative and undertaken by researchers at the Tyndall Centre, University of Manchester. See also Robert W. Hogath, Renee Santoro, Anthony Ingraffea (2011), "Methane and the Greenhouse-Gas Footprint of Natural Gas from Shale Formations", Climate Change (Springerlink.com), 12 April 2011; critical comments to this "biased" study - see "Five Things to Know About the Cornell Shale Study", European Energy Review, 27 April 2011 (originally in: Energy in Depth) and Gregory C. Staple/Joel N. Swisher (2011), "The Climate Impact of Natural Gas and Coal-Fired Electricity: A Review of Fuel Chain Emissions Based on Updated EPA National Inventory Data", American Clean Skies Foundation (www.cleanskies.org), 19 April 2011

Russia and irrespectively Gazprom's strategic options to respond are limited. Although Russia has the largest gas reserves in the world and is geographically close to Europe, Russia is – in addition to Europe's efforts to diversify its gas imports after the Russian-Ukrainian gas conflict of January 2009 – facing very serious challenges on the energy front:[104]

- Russia is facing growing competition with CACR gas exporters for its gas export monopoly. In 2008, more than 80% of the CACR gas exports were still destined for Russia, yet by 2010 those exports had already declined to 55% in 2010.
- In comparison with the previous year, Russian gas exports to OECD-Europe decreased disproportinately by more than 30% in the first half of 2009 after the latest Russian-Ukrainian gas crisis.
- Russia's overall gas production fell by more than 20% in the first half of 2009 – the sharpest production fall since the decline of the Soviet Union.
- The Intra-FSU gas trade fell 9.2% to 80.4 bcm in 2009. But, these drastic production and export cuts have eased previous fears of a looming Russian gas crisis after 2010.
- Although the new Russian-Ukrainian rapprochement and bilateral energy cooperation (gas deal) have, since the summer of 2010, strengthened Moscow's position, the new pro-Russian Ukrainian government still has no interest to sell its pipeline system to Russia or let the Kremlin control a majority share of it.
- The United Arab Emirates (UAE) have recently negotiated huge investments in Turkmenistan to gain access to and positioning itself to exploit the country's vast gas reserves. As it is helping to develop the reserves of the world's fourth-largest gas reserve country the UAE has also supported the EU's Nabucco pipeline rather than Gazprom's planned South Stream Pipeline. As a result, the UAE and Turkmenistan may soon be competing with Russia to transport gas to Europe.

Confronted with decreasing natural gas prices and Russia's threats to Europe's supply security, Moscow's policies have become unintentionally the major enabler for unconventional gas developments in Europe. But, even if only a fraction of those unconventional gas resources become available for the European gas market, they still might be less expensive than the very high prices of the new Siberian gas fields of the Yamal Peninsula or Russia's Arctic offshore gas resources (like Shtokman) and offer another diversification source for its gas demand. Against this background, and the fear in Moscow of losing further markets shares in its most important export market for conventional Russian gas and the geopolitical game (with Gazprom being the spear-point of Russian foreign policy), it is hardly surprising that representatives of the Russian government and Gazprom try to downplay the importance of a shale gas in Europe and to portray very negative implications of unconventional gas production in Europe for its environment and the EU's climate mitigation efforts.[105]

Gazprom, hence, needs to diversify as its European export model suffers. It is expected that Gazprom will operate in three distinguished markets: (1), the traditional European market; (2), a de-regulated and compromised domestic market; and (3), a new Asian market.[106]

However, indications for a new eastern strategy for gas supplies to China –- as a new big growing market – might not solve the problem Gazprom could face. Although, China is already moving towards a more gas reliable economy for several reasons already mentioned associated with gas as a clean and relatively

[104] **Frank Umbach** (2011), "The Black Sea Region and the Great Energy Game in Eurasia", Adam Balcer (Ed.), 'The Eastern Partnership in the Black Sea Region: Towards a New Synergy', demosEUROPA (and supported by the Polish Foreign Ministry), Warsaw 2011, pp. 55-88.

[105] **'Alexander Medvedev Answers Your Questions – Part One'**, Financial Times, 18 February 2011; 'Gazprom Chief Steps Up Attacks on Shale Gas', ibid., 18 February 2011, 'Gazprom Chief Calls Shale Gas a 'Bubble', Financial Times.Com, 18 February 2011, and Andrey Konoplyanik, 'The Economic Implications for Europe of the Shale Gas Revolution', Europe's World, 13 January 2011.

[106] **Kushnir and Kapustina** (2010), "Natural (Gas) Partners - One Step at a time for Russian Energy to China", Deutsche Bank Research, Frankfurt/M.

cheap fuel. But Petrochina estimates that China may have 45,000 bcm of unconventional gas. This would be more than Russia's proven conventional reserves. China seems also to be more likely to dictate low prices connected to coal or hub pricing, than to pay such a high premium for gas as the Europeans do.

Consequently, with the high cost of building new infrastructure to China and developing expensive new upstream projects in East Siberia and the Russian Far East diversification of gas deliveries to China will not allow Gazprom to reduce its exposure to Europe. When examining the Chinese companies´ international energy investments one comes to the conclusion that these have been driven less by money-making or value-aggregation objectives and more by pure principles of energy security and diversification. In this way, the 'U.S.-China Shale Gas Resource Initiative' – an initiative dedicated to enabling the U.S., as "a leader in shale gas technology and developing shale gas resources"[107] to enter the Chinese energy market – is another hurdle preventing Russian gas from going East. In sum, China is more likely to pursue also in the future its energy security agenda and help its local economy by producing domestic unconventional gas rather than enter into new dependencies with expensive Russian natural gas.[108]

Another side effect of the 'Sino-American Shale Gas Resource Initiative' is that it reduces the Chinese dependency on the Middle East and disincentives' China from breaking the sanctions on Iran in order to satisfying its energy thirst. The less China is being made to feel vulnerable by its need to increase oil and gas imports from the Middle East and Persian Gulf via the vulnerable Sea Lanes of Communication (SLOCS) and the Choke Point of the Malacca-Strait (being blocked by the U.S. and Indian naval forces), the more it may support international sanctions and the less Beijing will be concerned about the U.S. control of the SLOCs and Choke Points of the Indian Ocean and South East Asia.

Unconventional gas not only gives consumers new leverage in balancing the supply-demand equation, but also helps to maintain energy security either as a threat (e.g. Europe) or as a domestic fuel (e.g. China). Unconventional gas thus helps to break quasi monopolies on pricing and helps to integrate the global gas markets further by adding more gas into the market or through re-directing LNG to other markets, as seen in the U.S.

Meanwhile, not only the EU may benefit from the geopolitical implications of unconventional gas resources. The Ukrainian Ministry of Environment and Natural Resources and the National Joint Stock Company (NAK) "Nadra of Ukraine" declared in November 2010 to have the biggest, or one of the biggest, shale gas deposits. The Ukrainian government is to investigate the potential volume of shale gas by mid-2012 and has invited international investors to analyze and develop the Ukrainian shale gas deposits.[109] In February 2011, at the Strategic Partnership Commission meeting of the U.S.-Ukraine Energy Security Working Group, both sides signed a 'Memorandum of Understanding' to establish a framework for technical cooperation that will assess unconventional gas resource potential in Ukraine. This agreement includes the involvement of the U.S. Geological Survey (USGS), which is currently undertaking a global unconventional gas resource assessment.[110]

Although there are hurdles for unconventional gas developments in Europe such as public acceptance, environmental standards, economics and/or price issues, unconventional gas serves as a game changer not only continentally, but also globally. This poses a major threat to Gazprom's traditional business model. But it is a threat that can be mediated by the Kremlin and Gazprom by finding new mutual agreements and business models in which suppliers, as well as consumers, benefit, without one or another dominating.

---

[107] **The White House** (2009), "Statement on U.S.-China Shale Gas Resource Initiative", Washington D.C.

[108] For a detailed report on China´s unconventional gas exploration and prospects see: **Aizhu Chen** (2011), RPT-SPECIAL REPORT: China set to unearth shale power, 20 April 2011, Reuters http://r.reuters.com/jub29r

[109] **'Ukraine Claims to Possess World's Biggest Shale Gas Deposits'**, PR Newswire, 29 November 2010.

[110] **'U.S.-Ukraine Unconventional Gas Resource MOU Signed'**, Embassy of the United States, Kiev/Ukraine, 15 February 2011.

SUMMARY AND PERSPECTIVES: GAME CHANGER, OR NOT?

Having elaborated facts of shale gas development in the U.S. and compared the fundamentals – market structures, causing different economics and other core challenges – for unconventional gas development in Europe, it is time to answer the question: is shale gas a game changer, or not?

To what extent shale gas will change the game in Europe is still unclear, however, with the restructuring efforts in the European markets unconventional gas development will be a key element to the energy portfolio of many member states, especially those in Central and Eastern Europe; and one should also not overlook how environmental issues, in the more densely populated Europe, will play out as a key factor to watch in assessing the potential of shale gas in Europe.

In the meantime, the European energy policy agenda is facing opportunities and challenges; the latter including a shortage of up-to-date technology and equipment, capital and established market norms. But, is shale gas a game changer, or not? Some of the expert, geologists and industry representatives say it will be, some of them say it will not be.

No matter what, shale gas has certainly changed North America´s natural gas market; and, within the evolving global natural gas market it has already had a causal effect on all markets, particular those in Europe. Shale gas enameled the US to remove its energy dependency and, furthermore, to reduce nearly all of its LNG import needs. The combination of this development with the economic recession, led to an oversupply of the international LNG market that placed strong downward pressure on gas prices around the world. So, regardless of how the European unconventional gas industry develops, the shale gas (r-)evolution in the U.S. has already changed the landscape of the international and first of all the European gas market.

Shale gas development has changed the energy situation around the world; and, although it has changed the European market, other than one would have expected. Shale gas has not yet changed the overall energy balance in Europe, nor is it clear if it will materialize before 2020, although it has become a game changer for the European gas market. The U.S. shale gas boom enabled a revolutionary domino-effect on the European market, with the contractual structure, based upon 20-years long term take-or-pay oil linked natural gas contracts that had hitherto dominated being re-negotiated. Consequently, shale gas is having an increasing influence on European gas prices and is anticipated to continue doing so through 2015.

Regardless of how the outlook on European unconventional gas development looks – whether or not it will enhance the EU's energy supply security by reducing dependence and/or increasing affordably and sustainably in the mid-to-long term in Europe – shale gas has already changed the European market; even before a single well has been drilled, or a single molecule of unconventional gas has been extracted from the European basins.

APPENDIX

ANNEX I COMPARISON AND DIFFERENCES BETWEEN THE U.S. AND EUROPEAN UNCONVENTIONAL GAS POSSIBILITIES

U.S. shale	European shale
Much domestic gas production	Dwindling & limited domestic production
Many effective hubs	Few hubs
Many interstate pipelines	Few integrated market players
Many integrated energy companies, market players	Landscape dominated by National regulators, not Federal regulator
Strong federal Regulator	Higher initial cost
Infrastructure, Service companies & suitable drilling rigs	Well & production cost are higher
Vast Geologic formations / plays	Higher depths of the reserves
Property rights	Varying geologic formations / plays
Landowners	Technique needs to developed and adapted
Lower population	Property / land rights owned by state
Liberalized market	Local community profits from drilling?
Access to trading hubs & pipelines	Public opinion of drilling (NIMBY)
Spot traded commodity	Dense population
	Surface footprint of unconventional gas
	Missing service industries & drilling rigs
	Market structure liberalization & deregulation
	Long-term contracts
	Few integrated market players

ANNEX II GLOBAL SHALE GAS DRIVERS IN DIFFERENT REGIONS

Location	North America	West Europe	East Europe, Caspian and FSU	Asia Pacific
Drivers	Maintain leases Cash flow generation	Diversification of supply Projected supply gap Partially linked oil pricing	Balance exports with domestic needs Rising frontier field production costs	Supply / Demand imbalance Import reliance Pricing protection
Uncertainty Drivers	**Below ground:** Different players | Different market **Above ground:** Different regulation | Different infrastructure | Different supply base | Different public perception **Commercial:** Different geologies			

Source: various company resources, own compilation, Schlumberger Business Consulting, Herve Wilczynski, Gatwick, UK, June 9th /10th, 2010

ANNEX III WHO IS DRILLING IN EUROPE – EUROPEAN UNCONVENTIONAL GAS PLAYS

Country	Basin	Companies involved	Comments
Austria	Vienna basin	OMV	15 tcf of gas potential identified in deep Vienna basin, testing shale gas in 2009-10
France	Bresse basin Lorraine basin Nord Pas-de-Calais Paris basin South East basin	Devon (DVN) East Paris Petroleum Development European Gas Limited (EPGAU) Mouvoil SA Bridgeoil Ltd Diamoco Energy Lundin Petroleum (LUPE) Toreador Resources (TRGL) Total (FP) EurEnergy Resources	Companies seeking permits in various basins
Germany	Lower Saxony basin Bodensee Trough	ExxonMobil / Wintershall Royal Dutch Shell (through partnership in BEB with ExxonMobil) 3Legs Resources	XOM plans 10 wells on 750k acres 2009-10
Hungary	Bekes basin Mako trough Penezlek	MOL / Exxon / Falcon Oil (FO) Ascent Resources (AST LN)	Completed tree disappointing hydraulic fracture tests within the Szolnok Formation on the Foldeak-1 well
Netherlands	Central Graben Vlieland London-Brabant Massif West Netherlands	Exxon / Shell Cuadrilla Resources	Hold licenses
Poland	Polish basin Timan-Pechora Baltic-basin Suliran shale (shallowest 1-2km depth)	3Legs Resources BNK Petroleum Inc. (BKX) ConocoPhillips (COP) Aurelian Oil & Gas (AUL) Talisman (TLM) San Leon Energy (SLE) 3Legs Resources Lane Energy / Sorgenia E&P BNK Petroleum EurEnergy Resources RAG RWE Marathon Oil Corp Chevron Exxon Mobile	Preliminary data shows potential for shale gas. First well to be drilled May 2010 Will drill two horizontal appraisal well program commencing June 2010 on Siekierki Gas field seismic planned this year and TLM has committed to drilling three wells as part of farm-in deal
Sweden	Alum shale Fennoscandian Border Baltic Depression	Royal Dutch Shell	Owns licenses, 3 year exploration project in Skane. 3 well programs planned for 1Q 2010
Switzerland	Alpine Foreland basin		
Ukraine	Dnieper-Donets	Maraton Naftogaz Ukrainy (NAK) JKX oil & Gas (JKX) Regal Petroleum (RPT) Cadogan Petroleum (CAD) Transeuro Energy (TSU)	MRO and NAK signed an agreement in June 07 to explore Dnieper-Donest basin. Other companies mentioned have interests in the basin or the vicinity
UK	Kincardine basin, Scotland (CBM) Cheshire basin, North west England	Composite Energy / BG Island Gas (IGAS LN) Nexen (NXY CN) greenpark Energy Marathon AJ Lucas Cuadrilla Resources EurEnergy Resources	3000ft depth, 40ft pay Total resources of 4tcf in Cheshire basin (WoodMac). First CBM production in June09 from IGAS Doe Green site

Source: various news and company resources, own compilation

ANNEX IV EUROPEAN VS. U.S. UNCONVENTIONAL GAS PLAYS, KEY PETROPHYSICAL CHARACTERISTICS AND RESOURCES AND RESERVES (2010)

U.S. shale	Area (km2)	Resource Potential (tcf)	Depth range (m)	Shale thickness (m)	Porosity	Permea-bility	Production (mmcf/d)	Expected Rf	GIIP (tcf, estimated)	Total organic carbon (TOC)
Vienna Shale	900	22	4500-8000	1500	0-7%	n/a	0	4%	750	: 1.5-2%
Germany Shale	7.500	12,1	0-2500	20-500	n/a	n/a	0	18%	94	2-12%
Lorraine CBM	1.150	2	800-1500	20-75	n/a	n/a	0	15%	12	n/a
Poland Shale	23.816	66,1	2000-4000	30-300	n/a	n/a	0	17%	844	7%
Sweden Shale	2.010	5	100-3500	30-100	n/a	n/a	0	14%	38.8	2-25%
Turkey Shale	18.000	15	2500-3500	100-400	0,06	n/a	0	15%	151	4%
UK Cheshire CBM	4.820	4,1	0-4000	20-40	n/a	n/a	0	17%	24	n/a
UK Midland Valley CBM	1.300	2	0-2000	12-24	n/a	n/a	0	18%	11	n/a
Ukraine Tight Gas	35.000	31	1000-6000	300-2000	n/a	n/a	0	11%	290	3-13%
Barnett	8.840	21	1980-2700	30-183	4-6%	0.005	4.547	25%	238	2-7%
Fayetteville	10.350	36	450-2000	6-61	4-8%	n/a	1.700	36%	253	4.5-9.5%
Haynesville	14.164	89	3200-3962	61-91	9-12%	n/a	3.600	25%	650	4%
Marcellus NE	105.356	113	1500-2590	38	6-7%	n/a	385	8%	1.628	2-10%
Marcellus SW	124.519	82	1500-2590	38	6-7%	n/a	375	34%	310	2-10%

Source: own analysis, various company reports, Wood Mackenzie, Deutsche Bank, CERA

Thermal maturity (Ro)	Pressure gradient (psi/ft)	# Prospecti-ve Seams	Well Spacing (p.Acre)	EUR/ well	Av. Well cost ($/MM)	Gas Break-even (US$/ mmBtu)	Opex/ mcfe	Other CAPEX per well	Royalty Rate	Corporate Tax
0.7-1.6	n/a	n/a	60	8	$24,5	$10.2	0,4	$1.0	10%	25%
0.5-1.5	n/a	n/a	247	4,8	$13	$8.9	0,6	$1.2	8%	30%
n/a	n/a	2-4	124	1,3	$4,7	$7.5	1,3	$0.4	0%	34%
1.0-4.0	n/a	n/a	247	4,8	$14	$8.49	0,5	$1.0	5%	19%
1.4-3.0	n/a	n/a	247	4,8	$15	$8.9	0,6	$1.4	0%	28%
05-3.0	n/a	n/a	247	2,2	$8,07	$8.9	1,2	$1.0	13%	20%
n/a	n/a	10-24	247	0,9	$2,05	$5.7	1,2	$0.7	0%	30%
n/a	n/a	4	247	1	$2,05	$5.2	1,2	$0.7	0%	30%
n/a	n/a	n/a	494	3,2	$14	$6.4	0,5	$1.2	15%	25%
0.7-3.0	0.46-0.52	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1.5-4.5	0,44	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2.2-3	0.7-0.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1-2	0.4-0.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1-3	0.4-0.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

ENDNOTES

- Aizhu Chen (2011): RPT-SPECIAL REPORT: China set to unearth shale power, 20 April 2011, Reuters http://r.reuters.com/jub29r
- Alex Forbes (2009): The Great Potential of Unconventional, European Energy Review, 9 December 2009.
- 'Alexander Medvedev Answers Your Questions – Part One', Financial Times, 18 February 2011.
- Amy Myers Jaffe (2010): Shale Gas Will Rock the World, Wall Street Journal, 10 May 2010.
- Andrey Konoplyanik (2011): The Economic Implications for Europe of the Shale Gas Revolution, Europe's World, 13 January.
- Anouk Honoré (2011): Economic Recession and Natural Gas Demand in Europe: What Happened in 2008-2010? Oxford-Institute for Energy Studies, NG 47, January.
- Anthony Andrews (2009): Unconventional Gas Shales: Development, Technology, and Policy Issues, CRS Report for Congress.
- BGR (2009): Reserves, Resources and Availability of Energy Resources. Hannover/ Germany, BGR (German Federal Institute for Geosciences and Natural Resources).
- BNK Petroleum, (2010): Shale Myths - Shale Gas in Europe. http://www.bnkpetroleum.com
- Brian Horsfield (2011): Unpublished Presentation under the Topic: Shale Gas Development in Europe?, EUCERS (Ed.), Shale Gas - Revolution in Europe,?, EUCERS, Kings College, London.
- Cedigaz (2011): Unconventional Gas Activities in the World. No. 55– April 2011, Thierry Rouaud (Ed.). U-Gas News Report.
- Craig Michaels, James L. Simpson, William Wegner (2010): "Fractured Communities – Case Studies of the Environmental Impact of Industrial Gas Drilling" Riverkeeper.
- Charles Augustine, Bob Broxson, et al. (2006): Understanding Natural Gas Markets, Aip.
- Charles Boyer, John Kieschnick, Roberto Suarez-Rivera, Richard E. Lewis, Georg Waters (2006): Producing Gas From Its Source, Oilfield Review.
- 'China Energy Authority Drafting Shale Gas Development Plan: NDRC', Reuters, 28 March 2011.
- 'China Gas Sector. Key Takeaways from the Asia-Pacific Unconventional Gas Summit', Yuanta-Industry Update, 1 April 2010.
- Communication from the Commission to the Council and the European Parliament (2009): "The Renewable Energy Progress Report: Commission Report in accordance with Article 3 of Directive 2001/77/EC, Article 4(2) of Directive 2003/30/EC and on the Implementation of the EU Biomass Action Plan", COM(2005)628, {SEC(2009) 503 final}, Brussels, 24 April, COM(2009) 192 final.
- Daniel J. Soeder & William M. Kappel (2009): Water Resources and Natural Gas Production from the Marcellus Shale, USGS West Trenton Publishing Service Center.
- Daniel Yergin & Robert Ineson (2009): America´s Natural Gas Revolution, The Wall Street Journal.
- Dar & Company (2009): Natural Gas Reserves Are Rising - Thanks to Technology, Risk Capital. http://www.darandcompany.com/Natural_Gas_Reserves_051.html.
- D.G.Hill, T.E.Lombardi and J.P.Martin (2004): "Fractured Shale Gas Potential in New York." Northeastern Geology And Environmental Sciences. Vol. 26; Part, pp. 57-78. http://www.pe.tamu.edu/wattenbarger/public_html/--Selected_papers/Shale%20Gas/fractured%20 shale%20gas%20potential%20in%20new%20york.pdf
- Dian L. Chu (2010): Natural Gas: Shale-Shocked in America http://www.zerohedge.com/article/natural-gas-shale-shocked-america.
- Dieter Helm (2010): The Coming of Shale Gas: the Implications for Oil and Energy http://www.terrafirma.com/Alternative-perspective-page/articles/295.html
- Edward Hunter Christie (2010): EU Natural Gas Demand: Uncertainty, Dependence and Bargaining Power. Turku School of Economics/Pan-European Institute (Finland), Electronic Publication, Nr. 17, Turku;
- EIA (2010): International Energy Outlook 2010. Washington D.C., EIA (Energy Information Administration).
- EIA (2011): World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, Washington D.C. (U.S. Department of Energy), April.

- Ernest Wyciszkiewicz (2011): Unpublished presentation under the Topic: The Geopolitics of Shale Gas: Is Shale gas a "Game Changer"?, EUCERS (Ed.), Shale Gas - Revolution in Europe?, EUCERS, Kings College, London.
- Florence Gény (2011): Unpublished presentation under the Topic: Shale Gas Develop-ment in Europe?, EUCERS,(Ed.), Shale Gas - Revolution in Europe?, EUCERS, Kings College, London.
- Florence Gény (2010): Can Unconventional Gas be a Game Changer in European Gas Markets? NG 46. Oxford Institute for Energy Studies.
- Frank Umbach (2011): Globale Renaissance der Kernenergie oder nur eine Wiedergeburt der Ankündigungen? Die Vision einer Welt ohne Nuklearwaffen und die Perspektiven der weltweiten Nutzung der Kernenergie, Österreichische Militärische Zeitschrift (ÖMZ) 3/2011, pp. 267-281 (forthcoming).
- Frank Umbach (2011): The Black Sea Region and the Great Energy Game in Eurasia, Adam Balcer (Ed.), 'The Eastern Partnership in the Black Sea Region: Towards a New Synergy', demosEUROPA (and supported by the Polish Foreign Ministry), Warsaw 2011, pp. 55-88.
- Frank Umbach (2010): Global Energy Security and the Implications for the EU, Energy Policy, Vol. 38, Issue 3, March, pp. 1229-1240.
- Frank Umbach (2010): Promotion of Renewable Energy Sources in Germany and the EU in the Light of Their Energy Security Concepts – Objectives, Strategies, Challenges and Problems: Lessons to Learn for Japan?, Conference Edition „Renewable Energy 2010", Pacifico Yokohama/Japan, 27 June-2 July 2010, 8 pp.
- Gas Matters (2010): Shale Gas In Europe: A Revolution in the Making, Gas Strategies.
- 'Gazprom Chief Calls Shale Gas a 'Bubble', Financial Times.Com, 18 February 2011.
- Gene Whitney, Gene Whitney, Carl E. Behrens, Carol Glover, William F. Hederman, Carl E Behrens (2010): Energy: Natural Gas: The Production and Use of Natural Gas,. Alexandria: The Capitol.Net.
- Glenda Wylie, Mike Eberhard, Mike Mullen (2007): Unconventional Gas Technology: Advances in Fracs and Fluids Improve Thight-Gas Production, Oil & Gas Journal.
- Günther Oettinger (2011): Possibility of using gas from alternative sources in Europe, Plenary, European Parliament/ EU Commission, Brussels.
- GWPC & All Consulting (2009): Modern Shale Gas Development in the United States: A Primer.
- Hugh Belin (2010): To Russia with Love, European Energy Review, 2 September. http://www.europeanenergyreview.eu/index.php?id=2299
- IEA (2010): World Energy Outlook 2010, Paris, OECD (International Energy Agency).
- J. Daniel Arthur & Bruce Langhus (2008): An Overview of Modern Shale Gas Development in the United States.
- Jon Hurdle (2010): U.S. Finds Water Polluted Near Gas-Drilling Sites, Reuters.
- Josef Auer (2010): Gas Glut Reaches Europe. Major Impact on Prices, Security and Market Structure, EU-Monitor/Deutsche Bank Research, No. 75, 8 July.
- Joseph H. Frantz, Jr. And Valerie Jochen Schlumberger (2005): When Your Gas Reservoir is Unconventional, So Is Our solution - Shale Gas, Schlumberger.
- Joyce Nelson (2009):Frack Attack - New, Dirty Gas Drilling Method Threatens Drinking Water, The Monitor.
- Karel Beckmann (2011): Dutch Energy Council Embraces Unconventional Gas. European Energy Review.
- Kushnir and Kapustina (2010): Natural (Gas) Partners - One Step at a time for Russian Energy to China, Deutsche Bank Research, Frankfurt/M.
- Lisa Sumi (2008): Shale Gas: Focus on the Marcellus Shale. The Oil & Gas Accountability Project / Earthworks.
- Malcolm Brinded (2011): You can Count on Gas, Op-Ed/Documents, MEES, Vol. 54, No. 15, 11 April 2011.
- Mark Parker, (2009): Special Report: Understanding Process Key to Shale Gas Development, Oil & Gas Journal.
- Nick Snow, (2010): EIA Energy Conference: Experts See Shale Gas Affecting Overseas Supplies, Oil & Gas Journal.

- Paul Stevens (2010): The 'Shale Gas Revolution': Hype and Reality. Chatham House Report, London.
- Pennsylvania Geology (2008): Commonwealth of Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Geology, Pennsylvania Geology, No. 38.
- Petroleum Economist (2009): Europe Awaits a Shale-Gas Revolution, Petroleum Economist, December.
- Roderick Kefferpütz (2010): Shale Fever. Replicating the US Gas Revolution in the EU?, CEPS Policy Brief, No. 210, Brussels, June.
- Rogner, H-H., (1997): An Assessment of World Hydrocarbon, Annual Review of Energy and the Environment 22, pp. 217-262.
- Stefan Nicola (2010): Europe's Gas Industry Deeply Divided over the Future, European Energy Review, 22 November.
- Stephen Holditch, Kent Perry, John Lee (2007) Working Document of the NPC Global Oil & Gas Study. NPC.
- The White House (2009): Statement on U.S.-China Shale Gas Resource Initiative. Secretary, Office of the Press,Washington D.C.
- Tom Fowler (2009): Stubborn in His Vision, Houston Chronicle.
- Ukraine Claims to Possess World's Biggest Shale Gas Deposits', PR Newswire, 29 November 2010.
- USGS (2000): World Petroleum Assessment, Boulder/Colorado, USGS (United States Geological Survey).
- 'U.S.-Ukraine Unconventional Gas Resource MOU Signed', Embassy of the United States, Kiev/Ukraine, 15 February 2011.
- Vello A. Kuuskraa (2009): Worldwide Gas Shales and Unconventional Gas: A Status Report, American Clean Skies Foundation // Research Partnership to Secure Energy.
- Wood. R., Gilbert P., et al: (2011): Shale gas: a provisional assessment of climate change and environmental impacts. A report commissioned by the Cooperative and undertaken by researchers at the Tyndall Centre, University of Manchester

PLEASE CITE THIS REPORT AS:
Maximilian Kuhn, Frank Umbach (2011):
Strategic Perspectives of Unconventional Gas: A Game Changer with Implications for the EU`s Energy Security.
A EUCERS Strategy Paper, Vol.01, No. 01, May 2011. EUCERS, London.

EUROPEAN CENTRE
FOR ENERGY
AND RESOURCE SECURITY
(EUCERS)
Department of War Studies
King's College London
Strand
London WC2R 2LS

info@eucers.eu
Tel. 020 7848 1912