

Shale gas prospects for Europe

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Many studies have been recently commissioned at EU, international and national level in order to bridge the knowledge gap over shale gas resources and its extraction impact. However, the current situation in Europe is not conducive to the rapid development of shale exploitation, even in countries where the combination of geological conditions and public opinion is the most favourable such as Poland. Interestingly, the amount of funds necessary for the extraction of shale gas in Poland is so high that, according to the Polish Academy of Science¹, the combined resources of companies based in Poland are far from satisfactory for large-scale gas production. Given the extent of investments needed, knowing at what economic and environmental costs unconventional gas resources can be obtained is crucial. Technological developments can substantially influence this cost curve. At a macro level, the development of gas production from domestic sources could keep LNG imports at current levels (12-15% of demand up to 2050) or even bring them down to 9% in a shale boom scenario. Conversely, if there was no development of shale gas in Europe there would likely be an increase in LNG imports up to 28% by 2050 and indigenous gas production within the EU would

decrease to 6% of demand in the mid-21st century².

This paper brings together security of supply elements, technology breakthroughs and recent cost and resource estimates for shale gas. The paper assesses what needs to be considered if a full scale development of shale gas in Europe is to be envisaged. It draws from comparative elements with the US experience and from the Polish case, where most drilling has taken place.

Security of supply

The EU is hydrocarbon resource poor. At the end of 2013 the European Union held less than 1% [1.6 trillion cubic meters (tcm)] of proven gas reserves³ while it consumed approximately 0.4 tcm in 2013³. Conventional gas production in Europe is in decline and the EU's largest gas field 'The Groningen field' in The Netherlands will reduce output significantly over the next three years⁴. This is in sharp contrast to the situation in the US. The success of shale gas developments in the US has led to significant benefits in terms of improved security of supply and lower energy prices. US shale gas production has increased rapidly by 645% over the period of 2007 to 2012⁵. However US security of gas supply requires stable prices,

¹ Polish Academy of Sciences: Mineral Resources Management, vol. 30, no. 2, 2014, pp. 5-14.

² Pöyry Consulting, 'Macroeconomic effects of European shale gas production', November 2013.

³ BP statistical Review 2014.

⁴ www.government.nl/news/2014/01/17/natural-gas-production-reduced-and-funds-earmarked-for-groningen

⁵ International Energy Agency – Unconventional Gas Forum - <http://www.iea.org/ugforum/>

growing demand, internal gas pipeline infrastructure, appropriate drilling effort and investment in minimizing well production decline rates. As of September 2014, the natural gas drilling rig count in the US stood at approximately 340, down 14% on the same period in 2013. The level of drilling activity in the sector is dictated by respective oil and gas prices, which in turn are dictated by the supply-demand balance as a result of economic activity and existing production capacity. The price premium of USD12/GJ (~USD12/MBtu) between oil and gas has incentivized drilling efforts to switch to tight oil production with an annual increase in rig count of 16% to 1592 rigs with an overall 24% increase in horizontal drilling; typically for hydraulic fracturing. Surplus shale gas production had caused the price to drop below breakeven prices in some wells⁶.

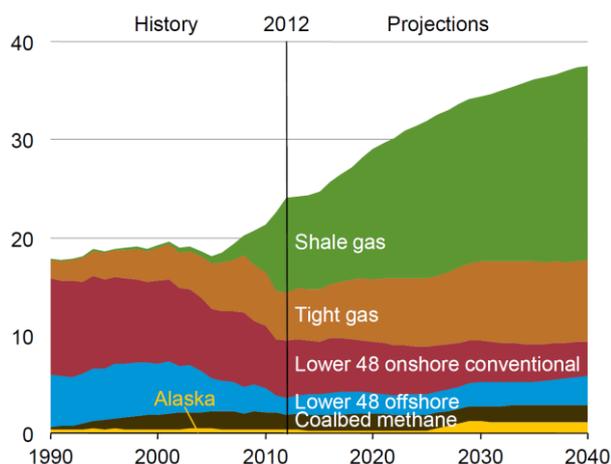


Figure 1: United States gas production history and forecast⁸

Past and forecast growth of shale gas production in the US (see Figure 1), are positive influences in diversifying US security of gas supply. They have stabilized Henry Hub gas prices below or near the historic average, counteracting price volatility. Cheap gas critically enabled timely US manufacturing

⁶ Weijermars, R., 'Economic appraisal of shale gas plays in Continental Europe', Appl. Energy 106, 2013, pp.100-115.

competitiveness compared with EU and Asian markets through cheaper feedstocks, fuel substitution and reduced electricity prices. This also had a complementary environmental benefit of reduced electricity carbon intensity⁷. Henry Hub prices are expected to increase at 3.7%/year⁸ to 2040.

If significant volumes of shale gas could be produced in Europe wholesale gas prices are expected to be lower when compared to a future with no shale gas production. Security of supply will increase as import dependency is reduced. According to the Pöyry study, the share of Russian gas in the EU-28 supply mix would be 50% by 2050 in a shale boom scenario, instead of 60% in a no-shale scenario². Reducing import dependency and improving security of supply are two key economic benefits of EU indigenous shale gas production.

Costs, resources and technology

Existing analyses show substantial geological gas resources as well as Technical Recoverable Resources (TRR) in Europe. According to the 2014 ICF Analysis⁹, Ultimately Recoverable Resources (URR) or TRR in the EU-27 amount to 12.3 tcmⁱⁱ, but another analysis indicates a TRR between 13 and 26 tcm (assuming 20-40% of recovery) according to present technology of extraction¹⁰. This brings Europe quite close to the US, where TRR amount to 15.5 tcm¹¹.

However, specific geological conditions, regulatory (environmental) constraints, and a lack of drilling equipment may increase the cost of extraction in Europe compared to the US situation. Shale gas production in Europe

⁷ US- Energy Information Administration (EIA). Annual Energy Outlook 2014.

⁸ US- Energy Information Administration (EIA). Annual Energy Outlook 2014.

⁹ ICF, 'Mitigation of climate impacts of possible future shale gas extraction in the EU', January 2014.

¹⁰ US Energy Information Administration (EIA) 2012.

¹¹ US EIA, 'Annual Energy Outlook 2013'.

could increase to a level of 30 billion cubic meters (bcm) to 160 bcm, in the case of substantial capital investment^{2,8} while the average shale gas cost (break-even price on well head) has been estimated by various groups and ranges from 220/260 USD/Mcm (thousand cubic meters) to 380-500 USD/Mc¹². This last estimate could be reduced by 40% in 2030, with the assumption of URR of 60-120 million Nm³ⁱⁱ per well¹³. According to a JRC analysis¹⁴, the possible break even cost in 2030 amounts to 225 USD/Mcm (including a 10% increase due to environmental protection)¹⁵. Despite these specificities, shale gas production in Europe has to face the same challenges as in the US: access to transport & distribution infrastructure, and high declines of gas production (up to 80% decline of gas rate in the first three years, while it is assumed that 70% of the URR have been produced in the first decade). Consequently, this requires continuous drilling and stimulation activity. Based on the US experience, it may be assumed that 70% of drilling wells will produce gas in 30 years, and about 30% will be abandoned in the first three years. According to an analysis from the Polish development program, it is necessary to invest 120 billion euros during the next 20 years¹³. Since it is closely dependent on the intensity of geological exploration and investments in mining, the full development of the shale gas

industry cannot be expected to take place before at least 2030¹⁶.

The case of Poland is particularly informative. The development (including exploration) of one shale gas concession of 200 km² requires drilling approximately 330 wells from 26 pads, including approximately 3 gathering and gas treatment centres as well as a compression unit.

	Million USD	%
CAPEX costs		
Gathering center	5.2- 10.0	
LNG and LPG separation installation and compressor	16.7	
Auxiliary pipeline ¹⁷	0.55-0.76/km	
Seismic works ¹⁸	26	
Provision (for abandon & liquidation of wells)	-	10% of drilling cost
OPEX costs		
Fixed costs (per pad)	3.15	
Variable costs	1.4\$/1000Nm ₃	
Depreciation and amortization of pipelines	-	2.5%/year

Table 1: CAPEX & OPEX estimates for the development of a 200 km² shale gas concession in Poland¹³

This would cost 15 to 25 billion USD, with an ultimate (or technical) estimated recovery of approximately 30-120 Mcm (0.03-0.1 bcm), depending on geological conditions. The average productivity could increase by 3.3% in the first five years, with a possibility of improving the extraction process up to 75% over the next 15 years¹³. In parallel, the high initial CAPEX would be reduced due to lower cost of drilling, lower cost of stimulation service and more efficient recovery. Investment costs for drilling, completion & fracking, and surface infrastructure could be

¹² Rice 6.0-7.0 \$/1000 standard cubic feet (scf) =220-260 \$/Mcm.

EON 6.0-10.0 \$/1000 scf =220-370 \$/Mcm.

Centrica 7.0-10.0 \$/1000 scf =260-370 \$/Mcm.

Pöyry (a) 4.5-11.7 \$/1000 scf =170-430 \$/Mcm - average 8.2 \$/1000 scf =300 \$/Mcm (pessimistic case)

Pöyry (b) 3.0-7.8 \$/1000 scf =(110-290 \$/Mcm) - average 5.4 \$/1000 scf= 200 \$/Mcm (optimistic case)

¹³ Krupa M., 'Efficiency model of exploration and extraction of hydrocarbon from shales in Poland, Phd thesis, AGH University of Science and Technology, Krakow, 2014.

¹⁴ Pearson, I. et. al., 'Unconventional Gas: Potential Energy Market Impacts in the European Union', JRC Scientific and Policy reports, 2012.

¹⁵ International Energy Agency (IEA), 'Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas', 2012.

¹⁶ Polish Academy of Sciences, 'Mineral Resources Management', vol. 30, no. 2, 2014, pp. 5-14.

¹⁷ Depending on diameter DN 150 mm and DN 250 mm.

¹⁸ \$1 million/pad.

lower by 48%, 19.6%, and 24% respectively compared to current levels.

Assessment of the environmental and social risks of shale gas extraction and transportation

Although there is no scientific confirmation that the use of hydraulic fracturing techniques leads to contamination of groundwater pollution¹⁹, accidental surface spills of fluids and wastewater, and changes in hydrology and water infiltration caused by new infrastructure, may affect shallow groundwater and surface water resources. Indeed, out of the 25 major accidents tied to shale gas operations in the Marcellus Play, Pennsylvania, US, from January 2008 through August 2011 (3,500 wells drilled), 19 were related to water contamination, land spill or gas migration in underground aquifers or substrates^{20, iii}. The risks associated with surface spills of chemicals (in particular those stored and used for drilling and stimulation of the hole²¹) have been minimized in Europe by introducing an obligation to protect the drill pad²² (after removing the humus layer) by a special durable thick PVC layer ("geomembrane"), which allows complete isolation of soil and groundwater. Recent experiments in Poland have showed no case of leakage of the process fluid during drilling operations and well stimulation. The development of 'green chemistry' since 2010 has resulted in new generation, cleaner fracturing fluids ("CleanSuite", "CleanStim", or "OpenFrac", etc.). The potential migration of natural gas into groundwater through the cement

protection mantle - considered as the greatest environmental risk²³ - can be eliminated by building a separate drilling column made from new generation "microparticles" cement, which counteracts the formation of microcracks. These well casing and cementing technologies fully protect the aquifers from contact with drilling fluid or chemical liquids in drilling pads. With this technology, the risk of possible pot aquifers contamination by gas migration becomes negligible, if all works are performed with the best available technologies (BAT). Beyond that, the risk of drilling mud migration into aquifers is similar to normal/conventional drilling process²⁴.

In spite of the development of new technologies consuming less water, the quantity of water required by hydraulic fracturing techniques remains controversial, especially in dry areas. Recycled water represents only between 6% and 10%²⁵ of the 10-20 million litres of water needed to hydraulically fracture a new well²⁶ on average in the US. However, this must be relativized in northern Europe where water supplies are reasonable²⁷. Moreover, water consumption for shale gas production is 25 to 50 times lower than water savings from a coal-to-gas switch in the power sector²⁸. New technologies also allow for the use of fracturing using salt water (instead of fresh in its absence²⁹) and the recycling of up to 90% backflow water (for

¹⁹ Krupnick A. J. & al., 'The Natural Gas Revolution: Critical Questions for a Sustainable Energy Future', March 2014.

²⁰ Considine T. & al. 'Environmental impacts during Marcellus shale gas drilling: Causes, impacts and remedies', 2012.

²¹ MIT, 'The Future of Natural Gas', June 2011.

²² Requirements by Mining Authority in Poland, also a recommendation from IEA, 'Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas', 2012.

²³ IEA, 'Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas', 2012; DNV, 'Risk Management of Shale Gas Developments and Operations', January 2013.

²⁴ King G., 'Hydraulic Fracturing 101: Unconventional Gas Wells', 2012.

²⁵ Mantell M. E., 'Produced water reuse and recycling challenges and opportunities across major shale plays', Chesapeake Energy Corporation, March 2011.

²⁶ NETL, 'Environmental impacts of unconventional natural gas development and production', May 2014.

²⁷ Buchan D., 'Can shale gas transform Europe's energy landscape?', Centre for European Reform, July 2013.

²⁸ Scanlon B. R. & al., 'Drought and the water-energy Nexus in Texas', 2013.

²⁹ King G., 'Hydraulic Fracturing 101: Unconventional Gas Wells', 2012. '

example in the Marcellus Play). In Texas, fracturing process optimization has resulted in a reduction of up to 50% of the amount of water used for hydraulic stimulation (in Woodford Shale Play for instance), and one would also expect the alternative fracturing technology over the next 10 years to lead to an even bigger reduction of the impact on the environment. Therefore, the main issue is where and when water is pumped¹.

→ Regulation must include strong monitoring, reporting and enforcement measures to prevent water and soil pollution. Regulation must be based on best available practices for drilling and wastewater management. Operators should fully disclose all chemicals types and quantities used to gain European citizens trust as their perception of risks is distorted by a weak onshore oil and gas culture.

A shale gas well requires between 1,000 and 2,000 one-way heavy truck trips (or 6,000-9,000 trips for an 8-well pad)¹⁶, mainly to deliver water. This may lead to traffic congestion by heavy trucks, increased noise, diesel-motor emissions and road accidents³⁰. It can also create an economic burden for local municipalities³¹ and damage rural roads and bridges that were not built to carry heavy loads. The cost of heavy truck traffic per natural gas well in Pennsylvania is estimated to amount between US\$13,000 and US\$23,000 (€10,000-17,000) in damage to state roadways (2011 data)³². However, the re-use of flowback wastewater can significantly reduce the road traffic.

³⁰ Hill J., 'Eagle Ford trucking accident risk', 2013.

³¹ Arthur J. D. & al., 'Summary of environmental issues, mitigation strategies, and regulatory challenges associated with shale gas development in the United States and applicability to development and operations in Canada', Oct. 2010.

³² Abramzon, S. et al., Carnegie Mellon University, 'Estimating the consumptive use costs of shale natural gas extraction on Pennsylvania roadways', Journal of Infrastructure Systems, 2014.

→ In any case, ex-ante water pipeline and road conception planning are needed before any shale gas drilling.

→ A distance-based truck toll should be implemented for the shale gas industry.

Partly correlated to these environmental aspects is a real estate depreciation risk that may occur depending on the distance from the nearest well and the stage of its lifecycle development^{iv}. Equally the type of connection to water pipe system may also have an impact (vs. groundwater-dependent homes)³³ as homes in the vicinity of shale gas wells are commonly suspected to withdraw water from polluted groundwater. Major US mortgage lenders and insurance companies have recently started to refuse loans and insurance policies approval for properties in close proximity to shale gas wells³⁴.

→ Part of this risk can be mitigated by the development of multi-well pads, which significantly reduces the land footprint to around a standard soccer field per pad^v.

→ Subsidies from local authorities could be implemented to compensate potential real estate depreciation.

Conclusions

Shale gas production could significantly improve security of gas supply and reduce energy dependence in Europe. Although the conditions of extraction are less favourable in Europe than in the US, for a comparable amount of ultimately recoverable resources, Europe will benefit from the technological development and learning process from the US. An enabling regulation should include enforceable principles of transparency,

³³ Muehlenbachs L. & al., 'The housing market. Impacts of the shale gas development', Dec. 2013.

³⁴ Muehlenbachs L. & al., 'Shale gas development and the costs of groundwater contamination risk', March 2013.

monitoring and risk mitigation, and impose the use of the best available technologies in order to prevent water and soil pollution. It should also make sure that the accompanying infrastructure is in place before drilling starts.

For further reading or information, please visit www.insightenergy.org

ⁱ Proved reserves-Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.

ⁱⁱ tcm=tera cubic meters, bcm=billion cubic meters, MMcm=milion cubic meters, Mcm=thousand cubic meters. All units are given in 'normal cubic meters' (Nm³), 1 Nm³ being the volume occupied by gas in specific conditions of pressure and temperature (respectively 1atm and 273K).

ⁱⁱⁱ Very few reports deal with the number of accidents related to the shale gas operations in the US.

^{iv} Property value increases once the drilling stage is complete and within one year of production. Conversely, wells that have been permitted have remained undrilled for more than a year affects the property values negatively.

^v Multi-well pads reduce land disturbance of the land above a productive shale gas zone from 13.3% to 1.4%, according to NYSDEC, 'Revised draft supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program', 2011.

Additional notice: When finalizing the present document, was released a statement from the European Academies Science Advisory Council (EASAC) on November 13th 2014 dealing with a similar topic. This statement points that there is no scientific ground to ban shale gas exploration or extraction using hydraulic fracturing in the EU since technologies to mitigate environmental, health and safety risks are available. However, the EASAC questions the economic rationale of exploiting shale gas in Europe due to uncertainties over the scale of resources in and viability of extraction.