Unconventional Gas and the European Union (EU): Prospects and Challenges for Competitiveness*

Herman Vollebergh‡, Eric Drissen and Martijn Verdonk.

PBL Netherlands Environmental Assessment Agency, P.O. Box 303, 3720 AH Bilthoven, The Netherlands.

Abstract

In this paper we study the likely impact of unconventional gas developments in the United States on EU competitiveness in both the short and the long run. The paper reviews the recent literature and brings together facts and trends in both conventional and unconventional gas production and prices as well as in other related energy markets in Europe and other world regions. We find, first of all, little evidence for a prosperous unconventional gas development in Europe. Second, the US boom already has a strong impact on both global and European energy markets. In particular, lower US gas and coal prices have changed relative energy prices both in the United States and abroad. Finally, the competitiveness impacts in some (sub)sectors will be considerable. These impacts are not restricted to gas use but also strongly relate to the production of 'byproducts' such as ethylene, propane and butane, which are transformed into products competing with similar but oil based products from the EU. These indirect impacts may even be more important in the long run, although several general equilibrium impacts may soften the adverse competitiveness impact in the EU.

Key-words: Shale gas; Hydrocarbon resources; Energy demand and supply; Non-renewable resources; Competitiveness impacts; European Union

JEL Codes: L71; O52; Q35; Q41; Q43.

* This discussion paper is prepared for DG Environment Commissioner's High-Level Economists Expert Group on Resource Efficiency (of which Vollebergh is a member). The support of DG Environment in writing this paper is gratefully acknowledged. The authors like to thank Viviane Andre, Pieter Boot, Stefan Bringezu, Corjan Brink, Alan Krupnick, Nathan Richardson, Joachim Spangenberg and Tomasz Zylicz for comments on an earlier version. Furthermore they thank Corjan Brink for providing us with the relevant GTAP indicators presented in section 5.

‡ Corresponding Author: Herman.Vollebergh@pbl.nl.

Contents

Summary

The rapid growth in shale gas production in the United States has led to a renewed interest in fossil fuels. Currently, most of the global supply of technically recoverable natural gas still comes from conventional sources. The recent boom in unconventional fossil fuels, in particular shale gas and oil, illustrates an old lesson: higher fossil fuel prices also stimulate supply side investments and technological change in fossil fuel industries, which, in turn, is likely to lead to the discovery of new reserves.

The focus in this paper is on the likely impact of these unconventional gas developments on EU competitiveness, both in the short and the long term. The growing gap between gas prices in the different world regions has raised concerns about the possible enormous challenges facing the EU economy; in particular, if a similar unconventional gas exploitation and the associated gas price reductions do not also take place within Europe. If the prospects for lower gas prices due to unconventional gas exploitation in Europe are limited or at least highly uncertain, the boom in the United States may indeed hit the European economy hard, and particularly affect the competitiveness of different European industries.

To explore such concerns, this paper reviews the recent literature and brings together facts and trends in both conventional and unconventional gas production and prices, as well as in other related energy markets in Europe and other world regions. We describe the current conventional gas market in the EU and take a closer look at the long-term developments of the gas price formation within the EU and how this relates to other world regions; in particular, the United States. We also discuss recent and potential developments in unconventional gas exploitation; in particular, in the United States and Europe. Using these insights, we are well-positioned to explore where the unconventional gas revolution is likely to hit the European economy and to provide a first impression of the likely impact on the competitiveness of different European industries.

We find, first of all, little evidence of possibilities for a prosperous unconventional gas development in Europe, in either the short or longer term. Explorations are still underway, but exploitation seems relatively expensive, compared to that of the US shales, although uncertainties are large. Therefore, we do not expect EU gas prices to fall as a result of a rise in European unconventional gas production. A certain amount of exploitation, however, may be important to also help renegotiate existing natural gas contracts with suppliers, such as Russia.

Second, the US boom already will have a lasting impact on both global and European energy markets. Unconventional gas has turned out to be relatively cheap in the United States, which changes relative energy prices both on a national level and abroad. This, in turn, puts a lot of pressure on existing input choices and location decisions made by firms. This impact is most visible within the power sector in the United States, where gas has become so cheap that it even outcompetes coal, its traditional substitute.

Our final finding is related to another direct effect, namely the joint-production characteristic of unconventional gas exploitation. Unconventional gas production fields not only produce gas but also so-called Natural Gas Liquids (NGLs), such as ethylene, propane and butane. These by-products are even more attractive, from an economic perspective, because they can be sold as or refined into oil products or, in the case of ethylene, used in the chemical industry to produce plastics. These indirect effects may even be more important in the long term. For processes that use gas and NGLs as feedstocks, adaptation in the industries usually takes a long time because of the type of industrial processes involved. For instance, the technical lifetime of petrochemical installations is relatively long and adaptation is costly and time consuming. The pace at which unconventional gas has penetrated has been so fast that existing specialisation patterns across sectors face a large amount of additional stress, even in the short term.

However, the impact on the overall economy is likely to be modest, because these industries only form a small part of it.

Indirect impacts, however, soften these direct impacts. For example, the indirect impact of the unconventional gas boom on relative US coal export prices, which, in turn, have induced many more coal shipments to the EU. Coal import from the United States happens on a much wider scale than ever before. Coal consumption in the power industry across the EU is already rising, which, in turn, reduces electricity prices. Another indirect impact, which is already happening, is the shipping of LNG to the Asian market, where gas prices recently have rocketed. This trend will be enhanced if the United States would start to export gas, too, in particular through LNG trade. Because of the much higher prices in Asia and Europe, the profitability of shipments abroad has increased, considerably. Moreover, larger exports would also be beneficial for the EU; in particular, when traded on spot markets, because this also would help in renegotiating long-term contracts with Russia.

1. Introduction

The rapid growth in shale gas production in the United States has led to a renewed interest in fossil fuels. Currently, most of the global supply of technically recoverable natural gas comes from conventional sources. For quite some time, reserves were thought to be limited and restricted. Some argued that this restriction inevitably would induce a period of peak oil and gas (Hubbert, 1962). The question was not if it would happen, but when. Not so very long ago, observers claimed we would already be facing this period today (Blackmon, 2013). In particular, the rapid rise in fossil fuel prices, in the first decade of the new millennium, worked as a propellant for such ideas. How different this discussion is today. The recent boom in unconventional fossil fuels, such as shale gas and oil (see also Text box 1), relegated such ideas to the background. At the same time, this boom illustrates an old lesson: higher fossil fuel prices also stimulate supply side investments and technological change in fossil fuel industries, which, in turn, is likely to lead to the discovery of new reserves (Odell, 1994). This is what the recent multiple upward adjustments of the potential supply of both conventional and unconventional gas illustrate (IEA, 2012a).

Textbox 1 - Definitions of unconventional gas

Shale gas often is referred to as an unconventional gas, as is tight gas and coalbed methane. Although the chemical content of unconventional and conventional gas is similar (namely methane), the sources and production methods are different. Tight gas is found in rock formations, similar to conventional gas sources, but with lower permeability. Coalbed methane is natural gas contained in coalbeds, originally extracted from coal mines to make them safer, but nowadays also from non-mineable coalbeds. Shale gas is contained in rock formations known as shale. These rock formations are characterised by very low permeability and low porosity. The depth may range from near surface to several thousand metres deep.

Most conventional sources of gas are found in Eastern Europe and Eurasia (mostly Russia) and the Middle East. Currently, known reserves of unconventional sources are mainly found in Asia-Pacific (e.g. China) and North America. Production from unconventional sources in North America has exploded over the last decade, and is now responsible for a new fossil fuel resource boom. Moreover, US gas prices have collapsed, which, in turn, created new comparative advantages for some industries, and greatly reduced the cost of US climate policy (see also Krupnick et al., 2013). To some observers, this US bonanza would also provide a promising future for Europe. Such a future is particularly attractive in view of current concerns about strategic dependency on Russian gas.

Whether and to what extent Europe could benefit from its own boom of unconventional gas production is still an open question. It is currently very uncertain how large the actual unconventional reserves are, and also whether companies will be allowed even to explore them in Europe, let alone exploit them (European Commission, 2014). Less uncertain seems the potential major impact of the North American unconventional fossil fuel boom on the European economy, in the short and medium term. The growing gap between gas prices in the different world regions has already raised concerns about the possibly enormous challenges facing the industry within the EU economy; in particular, if a similar unconventional gas exploitation and associated gas price reduction not also take place within Europe. Concerns about competitiveness, however, not only apply to the natural gas sector. Incidence effects matter, too. Changes in unconventional gas prices will affect energy substitution processes through changes in relative energy prices, such as those of coal and electricity. In addition, price increases may also be passed on to other markets. Other studies, using general equilibrium models, argue that both macroeconomic and sectoral impacts would be limited when viewed over the long term (e.g. Spencer et al., 2014; ICF, 2014).

The focus of this paper is to analyse the likely impact of unconventional gas developments on EU competitiveness, in the short and long term. For this purpose, the paper reviews the literature and brings together facts and trends in both conventional and unconventional gas production and prices, as well as in other related energy markets in Europe and other world regions. We also discuss recent and potential developments in unconventional gas exploitation; in particular, in the United States and Europe. Using these insights, we explore where the unconventional gas revolution is likely to hit the European economy, and provide a first impression of the potential impact on the competitiveness of various European industries.

We also find little evidence in the literature for a prosperous unconventional gas development in Europe, in either the short or longer term. The US boom, however, is already priced into the markets and already has an impact on both global and European energy markets. Cheaper gas in the United States has changed relative energy prices, both nationally and abroad, which, in turn, puts a lot of pressure on existing input choices and location decisions made by exposed firms. This impact is most visible within the power sector in the United States, where gas has become so cheap that it even outcompetes coal, its traditional substitute. Somewhat unexpected, and probably overlooked by recent studies using general equilibrium models, are the impacts of the joint-production characteristic of unconventional gas exploitation. Unconventional gas production fields not only produce gas but also so-called Natural Gas Liquids (NGLs), such as ethylene, propane and butane. These by-products are even more attractive, from an economic perspective, because they can be sold as or refined into oil products or, in the case of ethylene, used in the chemical industry to produce plastics. These impacts may even be more important in the long term. However, several indirect impacts soften the direct impacts. For example, the lower US coal export prices, which, in turn, induce lower gas and electricity prices within the EU. Another indirect impact is the shipping of LNG to the Asian market where gas prices recently have rocketed.

In this paper we do not analyse whether a European unconventional gas boom would physically be possible. This question is beyond our expertise. Nor does the paper discuss the linkage between the unconventional fossil fuel boom and the environment. Serious concerns exist about the impact, for instance, on local drinking water conditions, climate change emissions through methane leakages (flaring and venting), and local disturbances of the environment (see e.g. Olmstead et al., 2013). The environmental impacts of shale gas production tend to be higher than those of conventional gas production methods (IEA, 2012b). And finally, the paper also does not answer the question whether or not Europe should facilitate unconventional gas exploration, from a social welfare perspective. Benefits and costs related to unconventional gas are difficult to assess; in particular, the environmental impacts. Instead, as a first step, the analysis focuses on the potential direct economic consequences of shale gas and leaves an evaluation from a social welfare perspective to another occasion.

The paper first provides a short description of past and recent developments in the European gas market. Subsequently, it focuses on long-term price developments in global fossil fuel markets in search of indications of recent changes in these markets. Chapter 4 discusses prospects for future developments related to recent shale gas developments. Finally, Chapter 5 shows how and where these developments may have an impact on European power generation and industry.

2. The conventional gas market in the EU

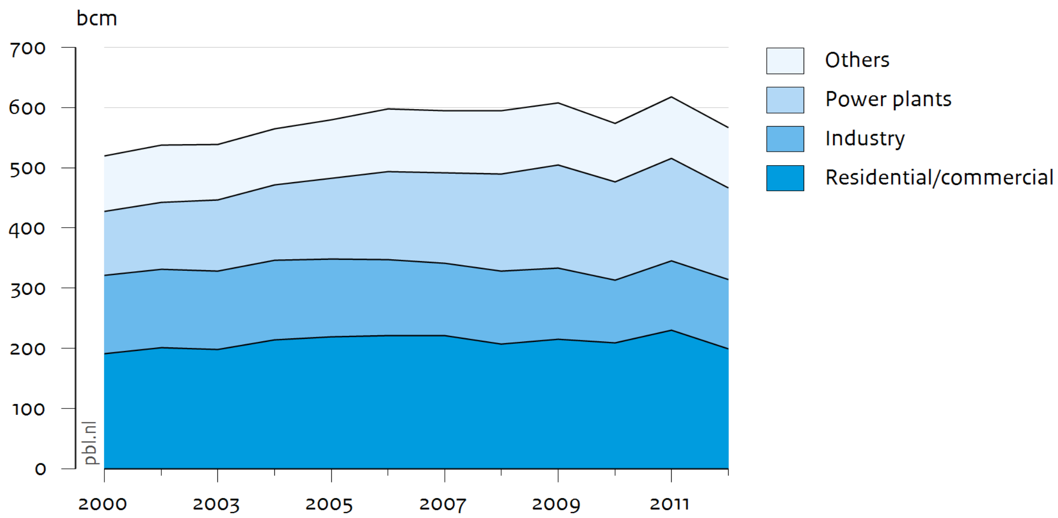
This section starts with description of the current conventional gas market in the EU. We start with demand and supply developments in the EU gas market, including the import and export of conventional gas for various EU Member States. Next we take a closer look at the long-term gas price developments within the EU. In particular, the increasing role of spot markets across the EU is shown and how this is likely to result in a breakdown of the indexation of the natural gas price to the oil price.

2.1 Historical perspective

Natural gas is mainly consumed for heating purposes and power generation, and as an industrial feedstock within the EU. The composition of demand shows that, in particular, power companies increased their use of gas in the first decade of this century (Figure 1). The overall consumption of natural gas in the OECD Europe was 618 billion cubic meters (bcm) in 2011, roughly fifteen percent of the global consumption (IEA, 2014). Almost forty percent of natural gas is used for heating purposes by residents and commercial and public services. While demand by power companies increased for a long time, it is declining since 2009, but still consists of more than 25 percent of the natural gas consumption in OECD Europe. IEA expects demand to have risen again, slowly, after 2013, due to improving prices in favour of gas (compared to coal), but recovery to pre-crisis levels is not projected before 2018 (IEA, 2013a). Gas demand is largest in the larger EU countries, in particular in Germany, Italy and the United Kingdom (IEA, 2013b).

Figure 1

Gas demand in OECD-Europe, 2000-2012

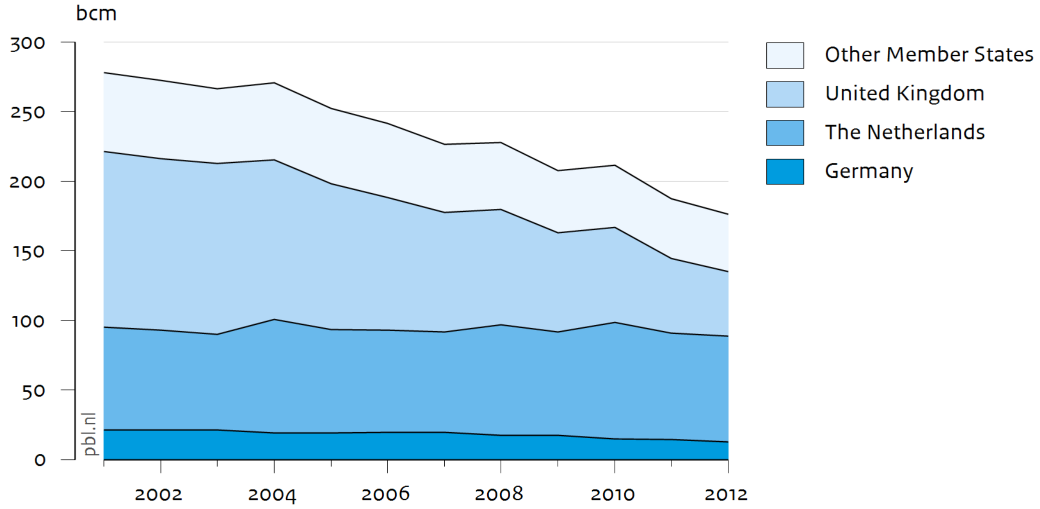


Source: IEA, 2014

On the supply side, gas is only produced from conventional sources. Production is concentrated mainly in Norway, the United Kingdom and the Netherlands. Not surprisingly, export is mainly restricted to the gas producing countries, in particular to Norway, the Netherlands and the United Kingdom. The trend in conventional natural gas production within OECD Europe is clearly downwards (see Figure 2). Especially production in the United Kingdom has fallen rapidly in the last decade, while the production in Norway and the Netherlands fluctuate around a constant level. Exploitation of new gas fields is likely to stabilise UK production in the coming years (IEA, 2013a). In other countries, production is more stable. Nevertheless, long-term projections indicate a further decline in domestic natural gas production in the OECD Europe. IEA expects production to fall by over 50%, between 2010 and 2030 (assuming a 20 bcm increase in unconventional gas production within Europe) (IEA, 2012a).

Figure 2

Natural gas production in the EU-28, 2001-20012

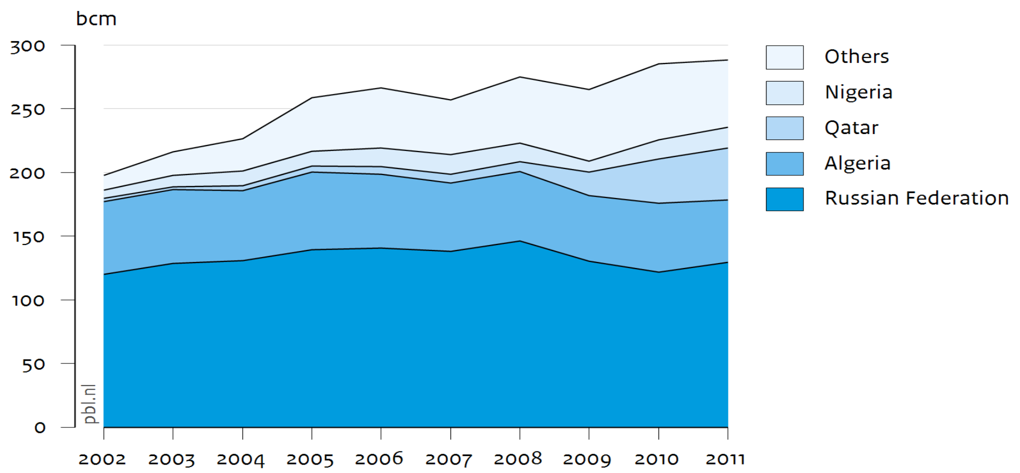


Source: Eurostat, 2014

The overall import share of final gas consumption in OECD Europe was 46 percent in 2011 (IEA, 2014). This share is expected to increase to in order to compensate for declining domestic production within OECD Europe in the next decades. Major importers of gas are Germany, Italy, France and, to a lesser extent, Spain. Figure 3 shows the main suppliers to the EU. Imports supplied to OECD Europe using pipeline infrastructure are from the Russian Federation (130 bcm in 2011) and Algeria (49 bcm in 2011). LNG is imported from Qatar. New supply may be provided by the international LNG market, with newcomers such as Africa, Australia and the United States, and new suppliers using a 'southern corridor', such as via Azerbaijan.

Figure 3

Imports of Natural gas to OECD-Europe, 2002-2011

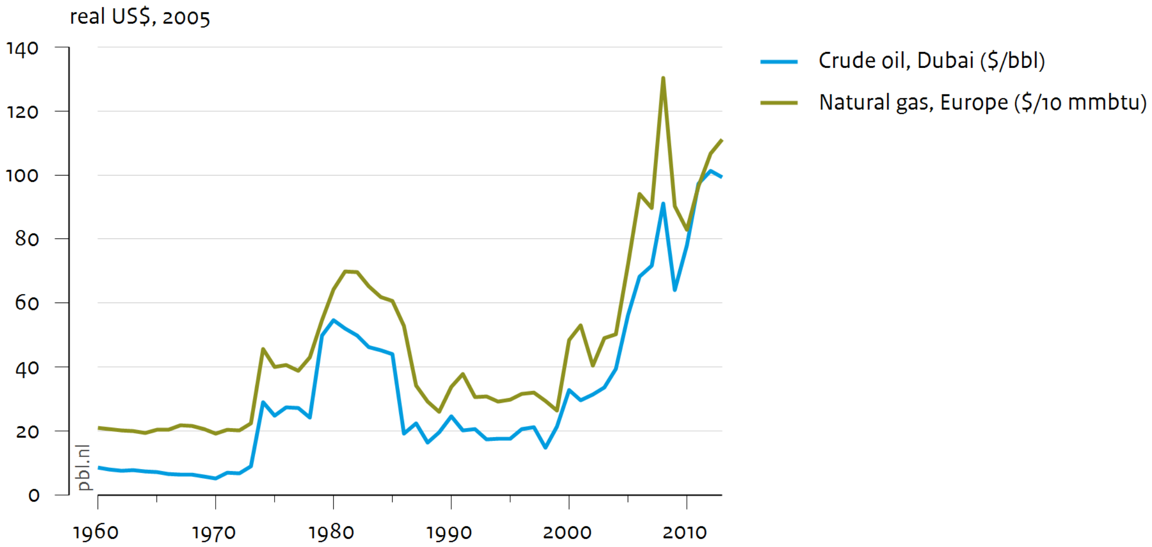


Source: IEA, 2013b

Price formation on the European gas market has been dominated by long-term delivery contracts with indexation of gas prices to the price of oil – once a substitute for gas – for a long time. This is clearly illustrated by the real price developments in Figure 4, although a more or less constant difference, in real terms, can be observed, over a long period of time, between European average natural gas prices (in USD2005) and the world market price of crude oil. Indeed, a typical contract with Gazprom (Russia's supplying company) concerns natural gas delivery for 20 to 30 years, using take-or-pay clauses with an indexation of the gas price to the international oil price (The Economist, 2012; Stern, 2007). Figure 4 also clearly shows that both oil and gas prices reached their highest levels, in real terms, by the end of the period, although it also shows a sharp increase in volatility, in particular after the start of the economic crisis in the EU.

Figure 4

European natural gas and crude oil prices, 1960-2012



Source: World Bank Commodity Prices

2.2 Recent developments in the EU gas market

A closer look at the average European natural gas price index presented in Figure 4 reveals a decline in gas price relative to oil, by the end of the period. Indeed, gas-to-gas competition or spot trading has increasingly become important for gas price formation over the last decade (IEA, 2013b). More European producers, mainly from the United Kingdom and the Netherlands, are trading their supplies on a spot basis. Spot trading was responsible for 20% of the gas supply in 2005, but currently about half of the gas supplied in Europe is traded at competitive market prices (The Economist, 2012; IEA, 2013a; Gény, 2010). The rising impact of spot markets, such as the National Balancing Point (NBP) in the United Kingdom and Title Transfer Facility (TTF) in the Netherlands, is clearly illustrated by Table 1.[1]

[1] Spotmarkets are the National Balancing Point (NBP) in the UK, Zeebrugge in Belgium, Title Transfer Facility (TTF) in the Netherlands; Punto do Scambio Virtuale (PSV) in Italy, Points d'Echange de Gaz (PEG's) in France, GASPOOL and NetConnect Germany (NCG) in Germany and Central European Gas Hub (CEGH) in Austria.

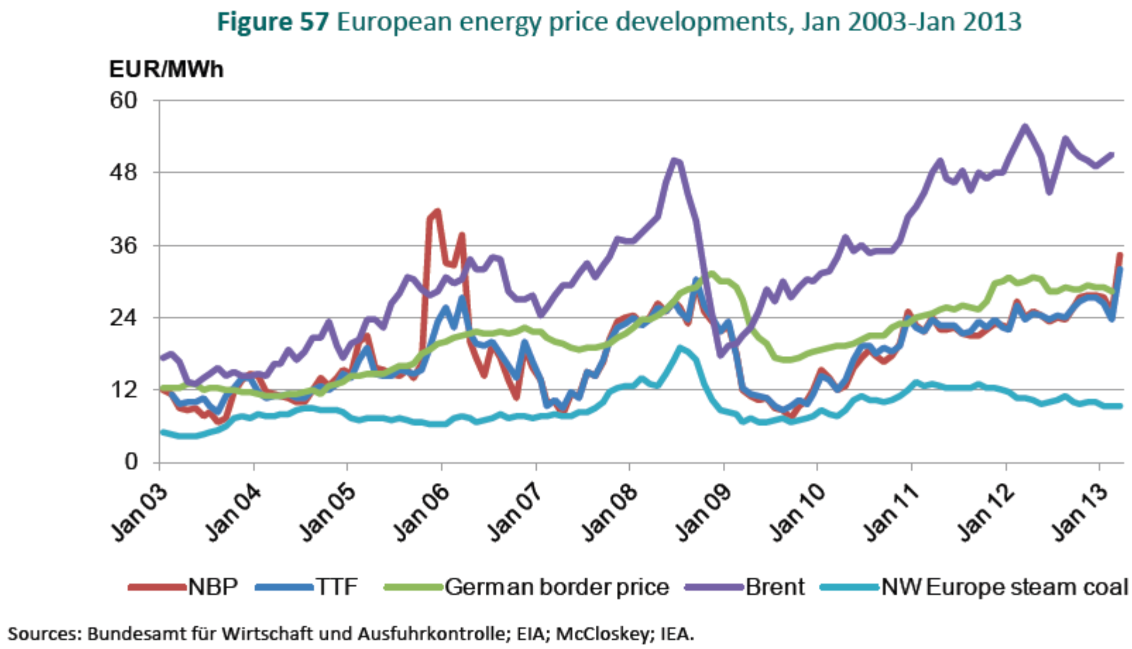
Table 1 Physically delivered volumes at national hubs as percentage of gross inland consumption

	UK	Belgium	Netherlands	Italy	France	Germany	Austria
2003	53	61	3	0			
2004	52	61	5	1	1		
2005	54	50	9	2	6	0	7
2006	64	49	15	6	8	1	53
2007	70	45	19	8	11	7	82
2008	68	52	46	10	14	21	58
2009	82	73	61	15	18	44	87
2010	97	85	69	27	18	71	114
2011	98	86	89	31	30	87	128
2012	114	75	104	36	38	103	155

Source: IEA, 2013a, p.172

Spot market contracts do not use oil price indexation and are more likely to reflect market fundamentals, such as changes in demand and production. The increasing impact of gas-to-gas competition on energy price formation is illustrated in Figure 5 below, as well. This figure presents nominal development of different fossil fuel energy prices on the EU market in euros per MegaWatthour Electricity (EUR/MWh). Presented are in particular the oil price (Brent), the North Western European steam coal price, and several gas prices indicators, such as the prices on the gas spot markets of NBP and TTF in the Netherlands, as well as the German Border Price (GBP) – which is a basket price reflecting long-term contracts with oil indexation with Russia and Norway, as well as spot traded gas.

Figure 5



Source: IEA, 2013a, p.167

Obviously, the GBP price has smoothened the more volatile gas spot market prices relative to the oil price, because of the share of gas prices directly linked to the oil price index. The GBP price more or less followed the Brent oil price, with some delay at the beginning of the period. A clear, widening gap is visible for the more recent years, however; in particular, after the turbulence of the economic crisis. The same holds for the spot market prices. The gap increases over time, coinciding with growing trading volumes as a share of the overall gas market. The growing importance, however, is not yet so clear if one considers the development of the average gas price for the whole of the EU, as presented in the previous section.

Decoupling of the gas price from the oil price is likely to increase, as long-term gas delivery contracts using oil-price indexation are increasingly being negotiated (IEA, 2013a, IEA, 2013b). Although spot trading has increased considerably, further liberalisation of energy markets remains a challenge. Most gas is still supplied by a few state-owned companies, such as Russian Gazprom and Norwegian Statoil, using state-owned pipelines. Nevertheless, European customers, such as RWE and EON, are increasingly successful in renegotiating the terms of their long-term contracts. Renegotiation is possible once every three years, if market conditions have changed 'materially'. This indicates that Europe's main suppliers may be able to renegotiate their contracts and to realise price cuts even for the gas share that is not traded on the spot market (The Economist, 2012).

2.3 Conclusion

Conventional gas production in the EU has been dominated by a few Member States; in particular, by the Netherlands and the United Kingdom. Over the last decades, EU production, however, has not been large enough to meet EU demand. Gas imported from outside the EU, for this reason, has played an increasing role. In the same period, spot markets have developed across the EU; in particular, in the large gas producing countries, but increasingly also at other hubs. The increasing role of spot markets is likely to result in more flexibility in the indexation of the natural gas price to the oil price within the EU.

3. Past and recent developments in global market prices of fossil fuels

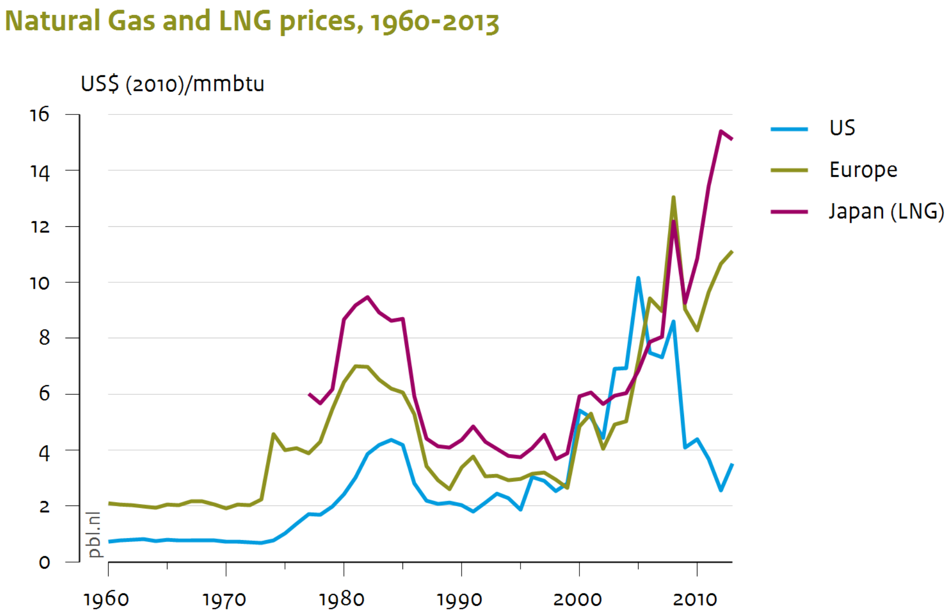
The EU gas market is typically connected with other gas markets, as well as with coal and oil markets. Interconnections exist both directly and indirectly, because of the possibility of interfuel substitution and trade. At the same time, fossil fuel markets differ considerably, including their interregional linkages. The long-term developments in the most important markets of gas, coal and crude oil provide interesting insights into the underlying structural changes of and linkages between these markets as well as in their co-movements of prices.

To better understand the possible impact of the shale gas revolution on EU energy markets, it is important to understand long-term developments in the major fossil fuels markets across the world; in particular, those of natural gas, coal and oil. In this section we describe major historical changes by discussing past and recent price developments in the developed world. In particular, it compares real prices on the major markets of the EU, the United States and Japan, between 1960 and 2013. All prices were derived from the World Bank and are free-on-board, that is, without excises, other taxes or import tariffs and are presented in real 2010 USD.

3.1 Gas markets

The oil market is a typical global market for a relatively homogeneous product, whereas gas markets are primarily regional, because of limited interconnectivity. Pipelines do not easily run across continents, such as those of North America, Europe and Asia. However, recent developments in creating liquid natural gas (LNG) may change this in a fundamental way. The main trends for the most important natural gas markets are depicted in Figure 6. Similar to the European real gas price, other gas prices also peaked after the second oil crisis of the early 1980s, and again in the last decade. Interestingly, the US natural gas price (Henry Hub) has always been lower than EU prices (average import price), except for during a relatively short period (2000–2004). Indeed, the rapid increase in gas prices in the United States at the beginning of the new millennium is even considered to be one of the reasons for the rapid development of shale gas in the 2000s (Wang and Krupnick, 2013).

Figure 6



Source: World Bank Commodity Prices

Since 2005, a remarkable disparity can be observed between the US gas price and the other two major markets. Recent US shale gas developments already have an impressive impact indeed. After the US gas price reached its peak in 2005, a clear downward trend is visible in the succeeding years. By contrast, gas prices in Europe and Japan both have an increasing trend after 2005. US prices are now almost below the level of the early 1980s, whereas prices for both other regions are well above their peak levels and have even reached all-time highs. The Japanese gas market is very different from the European and US gas markets because it is highly dependent on LNG. LNG is more costly to produce and trade, which explains why it is usually more expensive (shown is average import price). The very high peak at the end of the period was caused by the Fukushima disaster, which, in combination with a cold winter, induced very high spot prices for LNG in Japan in 2012 (IEA, 2013b, p.267). But also in Europe, prices around mid-2012 were 5 times higher than in the United States, although the ratio declined to 3 times higher by the end of 2013.

A closer look at the latest trends suggests that both the declining price trend in the United States and the rising trend in the EU and Japan have come to a halt. Because inflation has been very low in recent years, there has been no further decrease in the (real) US natural gas price since 2009. The price seems to fluctuate around a real value of USD 4. Also, the rise in the gas price in Japan has come to a halt, very recently, which is also partly explained as a result of a revaluation of the Yen against both the euro and the US dollar. [2] Therefore, the growing gap between the different gas prices seems to have stabilised, recently.

3.2 Coal markets

The main trends for the most important coal markets are depicted in Figure 7. Prices on three major export markets, namely the coal markets for Australia, Colombia and South Africa, are compared with the US market price[3] The different coal prices reflect more or less the same pattern as the gas prices, that is to say, with a peak at the end of the 1970s and again a considerable rise since 2000. However, the rise is less pronounced compared to that of gas. In fact, prices are not that much above the price hike of the 1970s and 1980s.

On average, there is not much difference between coal prices in the different exporting regions, such as Colombia, Australia and South Africa, and in the United States which was less exposed to international competition until around the beginning of 2000. Since 2000 a strong increase in volatility could be seen in the more export-oriented coal markets. However, the difference with the US market is remarkable. US prices follow a clearly autonomous pattern with an increasing disparity with the other, mainly exporting, coal-producing countries. Also, the price is less volatile than that of the coal from other countries. In fact, despite a recent rise, US coal prices are still considerably below the US price hike of 1970s. The shale gas revolution also leaves its mark here; power plants within the United States increasingly switch to gas, thus creating a clearly downward pressure on relative US coal prices (see also Wang and Krupnick, 2013). At the same time, a clear trend becomes visible, for instance in Europe, where power companies increasingly switch to cheap US coal.

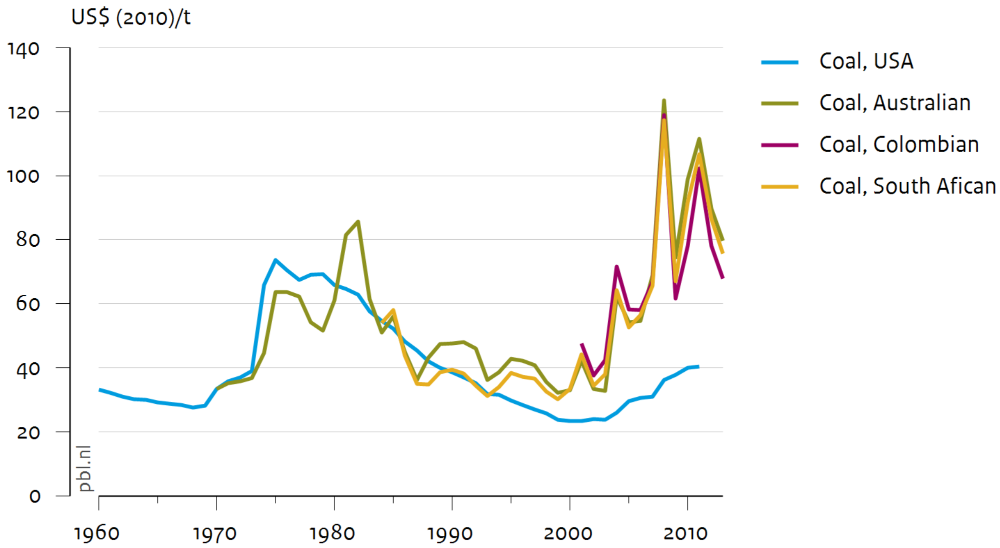
[2] Exchange rate fluctuations also play a role here. After 2000, the euro initially revaluated relative to the US dollar, but the exchange rate has stabilised since the economic crisis of 2008. The US dollar and the Yen were on parity until the crisis. After the crisis, the Yen first revaluated strongly against the US dollar, but devaluated in 2013 (see also IEA, 2013c, p.281).

[3] World Bank Commodity Prices do not report a US-specific coal price. For this series, we relied on data from the Energy Information Administration.

Recent developments provide no indications of a further rise in the coal price trend , following the economic crisis (see also IEA 2013b, p.268). The sharp increase was followed by a sharp decline in 2012, and the price seems to have stabilised in 2013. Overall coal prices on the major export markets remain, on average, at a level of twice that of the 1980s, with the usual small differences, but with a clear structural break in the trend of US coal prices relative to that in the other markets.

Figure 7

Coal prices, 1960-2012



Source: World Bank Commodity Prices; Energy Information Administration EIA (Price of US Coal)

3.3 Oil markets

Similar to the other fossil-fuels, oil prices also showed a spike in the 1970s and 1980s, with a clear downward trend afterwards, followed by a steep rise, on average, in real terms, since 2000. Recent prices are almost twice as high as the oil price peak of the 1970s and 1980s. To what extent price volatility will increase is not entirely clear, although the impact of the financial crisis is clearly visible in the trend. After a strong recovery following the economic crisis of 2008, oil prices have stabilised since 2011.

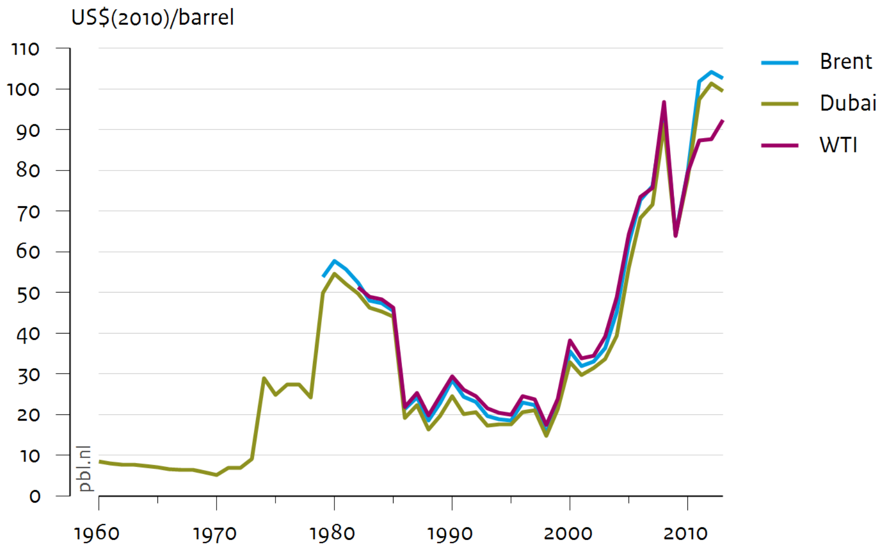
As for the oil market, a very clear co-movement of prices from different markets is visible from Figure 8, as well. Because competition on the oil market is fierce and easy – oil shipping is relatively cheap – price convergence has already been the norm for a long time. Oil prices on the different markets have shown almost no difference since the end of the 1970s. However, the US price (WTI) has followed a somewhat different pattern recently, and has started to deviate towards the end of the period. This price is now substantially lower than the Brent and Dubai prices of 2011.

Recent developments suggest that this is likely to be a temporary phenomenon. The recent difference can be explained by the increased production of tight oil (also from shale formations) that supplies the US refineries (EIA, 2013b). The USD 20 price differential between WTI and Brent during 2012 was due to limited capacity for the transport of light tight oil to the Gulf coast (EIA, 2013c).[4] The recent expansion of the pipeline capacity within the United States seems to be mainly responsible for the recent market arbitrage that reduces the price gap between the different oil markets.

[4] See Text box 2 below for an explanation of the linkage between shale gas and tight oil.

Figure 8

Oil prices, 1960–2013



Source: World Bank Commodity Prices

3.4 Relative fossil fuel price changes

Clearly, the general trend, over the last decade, has been one of rising real prices of fossil fuels with one exception – the US gas price. Furthermore, the price gap between the United States and other coal suppliers is rising, as well. And also a small, though not irrelevant difference can be observed between US oil and other oil prices. Finally, volatility of all prices seems to be visible, as well, although this seems likely to be strongly related to the financial crisis of 2008. To what extent this volatility in fossil fuel energy prices may also reflect an increasing propensity to speculate in these markets is yet unclear (the large increase in volatility itself may already be an indication of this influence).

Apart from these trends within each fossil fuel market, interfuel substitution is another important factor driving incidence and competitiveness effects in other sectors. These substitution processes on the energy market relate mainly to the relative prices between the different markets. Last year, the IEA provided some very useful data to assess these changes over the last decade and they are reproduced below (see Table 2).

These prices for natural gas, oil and coal, are standardised in terms of their energy content and also compare prices across the different regions. First of all, the data confirm earlier observations; US gas and oil prices were relatively high at the beginning of the period, but are now the lowest on all major fossil fuel markets. At the end of the observation period, Japan was facing the highest prices, while in the EU prices were moderate, for both gas and coal.

Second, the strong impact of the shale gas revolution in the United States is visible in these data, as well. For instance, within the United States, gas prices halved during this period, whereas prices in the EU and Japan rose by almost a factor of 3. EU gas prices are three times higher compared to those in the United States at the end of the period. Oil prices were also the highest in the United States in 2003, and the lowest in 2012, although the differences are small. Coal prices have always been low in the United States. By the end of the period the price gap had increased considerably.

Third, relative prices between the markets also have been influenced. Compared to coal, gas was more than four times more expensive in the United States in 2003, whereas in 2012 the price difference almost equalised, per unit of energy. In Japan, gas was a factor of 3 more expensive than coal, per unit energy, in 2003, but the price differential is even four times higher in 2012. A similar trend can be observed in the EU market. If such price developments are stable and lasting, they are very likely to have strong consequences for fuel input choices throughout economies, as well as on firm location decisions.

Table 2 Fuel prices (USD/MBtu)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Natural gas										
Henry Hub (US)	5.47	5.90	8.84	6.75	6.98	8.86	3.95	4.39	4.00	2.75
NBP (UK)	3.33	4.47	7.34	7.64	6.03	10.47	4.77	6.56	9.02	9.48
German border price	4.06	4.30	5.83	7.88	8.00	11.61	8.53	8.03	10.62	11.09
Japan LNG	4.79	5.19	6.02	7.12	7.74	12.66	9.04	10.90	14.78	16.70
Oil										
WTI (US)	5.36	7.14	9.73	11.38	12.46	17.18	10.63	13.69	16.36	16.23
Brent (Europe)	4.97	6.59	9.38	11.23	12.50	16.72	10.60	13.70	19.18	19.25
JCC (Japan)	5.02	6.27	8.79	11.05	11.90	17.65	10.45	13.65	18.81	19.79
Coal										
US Appalachian	1.32	2.38	2.38	2.09	1.81	4.27	2.07	2.67	3.07	2.43
NW European steamcoal	1.83	3.03	2.55	2.69	3.72	6.18	2.96	3.82	5.10	3.89
Asian coal marker	1.53	3.04	2.60	2.37	3.55	6.22	3.31	4.43	5.28	4.43

Source: IEA (2013a, p. 182)

3.5 Conclusions

Long-term developments in the most important markets of gas, coal and crude oil provide interesting insights in underlying structural changes of and linkages between these markets. Clearly the general trend in all fossil fuel markets is a price spike in the 1970s-1980s, a trough in the 1990s and again a steep rising trend since 2000. Also relatively stable differences exist in the absolute fossil fuel price differences across regions. These prices are in absolute terms lowest in the United States, highest in Asia (Japan) and moderate within the EU. This is particularly true for the gas market, but, somewhat surprising, also for the coal market. These price developments clearly demonstrate a substantial impact of the US unconventional gas revolution on world energy markets. Whereas relative fuel price differential between gas and coal shows natural gas prices were much lower in the EU compared to the United States in 2003, this price difference is now entirely the other way around. Interestingly, the current gas price difference between the United States and the EU is indeed quite large, but this is clearly not unique in history (see Figure 6). In fact, the period between 1995 and 2004 seems more of an anomaly. By contrast, the price differential for coal is relatively new.

4. Projecting unconventional gas and its impact on EU fossil fuel markets

Projecting developments of fossil fuel markets and their impact on the wider economy is a notoriously difficult task (Kilian, 2008). A close interaction exists between fossil fuel prices on the different markets, as well as with wider economic developments, such as the recent upsurge of developing countries or the recovery in Europe from the economic crisis. Moreover, both demand and supply in the different markets interact, and sudden shocks in one market usually have a strong impact on the other markets, as well. The oil market of the 1970s was a case in point, but the current boom in unconventional gas and oil in the United States may be another example.

Future developments clearly depend on whether this unconventional boom will spread across the different regions. But even without the development of unconventional gas within the EU, the US boom will have a strong impact on its own. This section discusses current projections of future developments in unconventional gas markets and their likely impact on both the gas and other fossil fuel markets in the EU. It starts with a discussion on the supply side of unconventional gas exploration and exploitation, both within and outside the EU. Subsequently, we explain how the EU gas market and its price formation may develop in the future, under various expectations, as well as how the other local EU markets for fossil fuels may be affected.

4.1 Current and potential production of gas within and outside the EU

Although unconventional gas production in the United States has grown rapidly, most of the global supply of technically recoverable natural gas is still found in conventional sources (see Table 3). Most conventional sources are in eastern Europe, Eurasia (mostly Russia) and the Middle East, while unconventional sources are more likely to be found in the Asia-Pacific, such as in China, Africa and North America. However, estimates of the potential supply of both conventionally and unconventionally produced gas have been adjusted upward at multiple instances (IEA, 2012a).

Table 3 Mean estimates of remaining technically recoverable gas resources (tcm)

Region	Conven-tional	Tight	Coalbed Methane	Shale		
				Low	mean	high
United States	27.2	12.7	3.7	8.0	23.5	47.4
Canada	8.8	6.7	2.0	1.4	11.1	28.3
Europe	11.6	1.4	1.4	2.3	8.9	17.6
China	12.5	9.9	2.8	4.2	19.2	39.8
Rest of world (implied)	364.9	14.6	15.6		34.7	
Global	424.9	45.4	25.5	7.1	97.4	186.4

Source: JRC (2012)

Most authoritative sources indicate that European production potential of shale gas seems to be limited compared to other regions (IEA, 2012b; IEA, 2013b; JRC, 2012; EIA, 2013). In the EU, shale formations would be less rich in hydrocarbons than those in the United States. The uncertainty, however, is very large. For instance, the number of estimates of shale gas sources for Europe is very limited (JRC, 2012). JRC estimates ranges from 2.3 to 17.6 tcm, with a mean of 8.9 tcm, whereas the IEA estimates a potential of 16 tcm for OECD Europe (IEA, 2012a). The recent estimation of global reserves by the US Energy Information Administration is 18% higher than the high estimates from JRC (2012). For Europe the estimate is even 42% higher (EIA, 2013a).[5]

[5] This difference can be explained by the inclusion of additional countries such as Russia. For the US the EIA has a 31% lower projection than JRC.

The main areas with potentially large shale gas reserves in the EU are concentrated around the Baltics and Poland, and within the triad of the United Kingdom, France and Germany (JRC, 2012; EIA, 2013a). Outside the EU, other European countries with substantial reserves are Russia (8 tcm) and the Ukraine (4 tcm) (EIA, 2013a).

Whether technically recoverable sources are valuable enough for exploitation depends on exploitation costs as well as on the benefits of the extracted fuels. The costs are determined by a number of factors, such as access to the shale formation, availability of water, environmental regulations, and proximity to demand and/or infrastructure. These costs include drilling, well construction, infrastructure, water usage, loans and payments to land owners, but also the financial consequences of complying with environmental regulations (EIA, 2013a; IEA, 2012b). Within the EU, exploitation costs are estimated to be at least double those of the United States.: the range for well production is currently between USD 2 and 9 million in the United States, while the estimated costs in Europe range from USD 5 to 20 million (JRC, 2012).

Benefits depend, in the first place, on the price of unconventional gas paid on the market. At spot gas prices of around USD 10/MBtu, shale gas exploitation is unlikely to be profitable in the short term, in Europe (see Gény, 2010 and JRC, 2012, Table 3.20). Estimations for break-even costs in Germany and Poland are in the range of USD 8–12/MBtu although more recent estimations indicate prices of USD 28/MBTu (today), USD 7/MBTu (within 5 years) and USD 4/MBTu (within 10 to 15 years). The costs of producing conventional gas in Europe and the United States in 2007 and 2009 has been estimated to have been around USD 10/MBtu and USD 6/MBtu, respectively.

Break-even costs also depend on the joint production of by-products from the same wells. By-products or liquids, such as ethylene, propane and butane, can be sold or refined into oil products (see also Text box 2). The importance of these by-products can be nicely illustrated by recent developments on the US shale gas market. With US gas prices of around USD 2–3/MBtu in 2012 and early 2013, unconventional gas was probably produced below economically viable levels. Break-even costs in the United States, without taking the revenue from the by-products into account, are estimated at at least USD 4/MBtu (JRC, 2012; EIA, 2013a). Nevertheless, production of shale gas still increased, during this period. This increase is likely to be explained by the revenue of the liquids from the same wells (JRC, 2012). However, also other factors played a role, such as the co-production of gas and oil, and lease conditions which often require drilling within a certain time period, often years (see Krupnick et al., 2013). It has been estimated that, with these low gas prices in the United States, the liquid content must be around 40% in order for exploitation to be profitable (IEA, 2012a). To what extent the US case would also be applicable to the EU is an open question.[6]

Text box 2 – Relation between shale gas and tight/shale oil production

Exploitation of shale formations not only produces shale gas, but also unconventional liquids, such as tight oil (or shale oil if produced from shale plays). In the same rock formations that are drilled for shale gas, liquids such as ethylene, propane, butane and other hydrocarbon-rich condensates ('light tight oil') may also be present. This is known as 'wet gas', whereas 'dry gas' contains much less Natural Gas Liquid (NGL) than conventional dry natural gas. In most shale basins in the United States, natural gas contains 4 to 9 times the amount of NGLs found in dry natural gas, although there are some basins in Texas and Colorado/Wyoming where the amount of NGL is smaller, at 2 to 3 times that of dry natural gas. In particular, the ethane content in shale gas and oil is high (Keller, 2012).

[6] According to JRC (2012, Table 3.20), break-even costs including NGL would be 40%-45% lower under current market conditions (see also Text box 2). However, these cost estimates assume that NLG liquid production levels for the EU, on average, are similar to those in the United States.

The amount of NGL that can be recovered depends on the technology used. The recovery of ethane depends much more on the technology used than that of butane and propane. From 'Lean Oil' plants, only 15% to 30% of the ethane can be recovered, whereas for butane this is almost 100% and for propane 65% to 75%. Refrigeration plants that use propane to cool the gas to remove more Natural Gas Liquids, are able to recover all the propane and butane and up to 80% to 85% of the ethane. The recovery rate of ethane can be further improved, up to 85% to 90% when using the more expensive Cryogenic technology (Keller, 2012).

Ethane is almost exclusively used in the petrochemical industry. Butane and propane are also used for other purposes; butane as petrol in engines and propane as a fuel, for example, in space heating (Keller, 2012; Ebinger and Avasarala, 2013). The 'business case' for exploiting shale gas clearly also depends on the market value of these by-products. Indeed, ethylene, propane and butane are economically attractive to retrieve, because these by-products can be sold as or refined into oil products, or used in the chemical industry, to produce plastics in case of ethylene (see also section 5). If local gas demand is low and infrastructure for gas transport is absent or too costly, substantial amounts of shale gas are vented and/or flared.

The joint production characteristic of unconventional gas exploitation also raises additional environmental concerns. If gas prices become 'too low', it becomes attractive to simply flare or vent the shale gas or methane, in order to reduce unconventional gas output, and, thereby increase market prices. However, the US federal Environmental Protection Agency (US EPA) issued regulations in 2012, also referred to as 'green completion', which requires well operators, from 2015 onwards, to capture instead of vent or flare methane from their wells. Although the captured methane can be reused and sold, and therefore offers a potential opportunity to increase revenues, this is likely to increase production costs.

Our previous gas price analysis (see Figure 10) indicated that US prices have been recovering to nearly USD 4/MBtu in 2013. One reason for this recovery is that producers increasingly switch production from shale gas to oil. Riggs are relatively mobile and can be moved to other sites that are more profitable. Demand for gas is also increasing because US power companies are increasingly switching from coal to gas (IEA, 2013b). The other reason is that the production of unconventional gas from wells levels off at some point, but it might be too early for this type of supply constraint.[7]

Predictions about long-term expectations of the exploitation of the global unconventional gas reserves are notoriously difficult. According to their New Policies scenario, the IEA (2013c) expects production in the United States to be the largest, by far. Under this scenario, conditions in the United States remain the most favourable, compared to those in most other countries. The reasons for this is that the United States has already developed a petrochemical industry and service sector with experience in other unconventional gas production, such as tight gas and coalbed methane; has favourable regulations with regard to the ownership of mineral resources; has a deregulated gas market; and has a culture of private entrepreneurship. Under this scenario, IEA's expectations of the future production of unconventional gas in the EU are very conservative. Production would grow slowly to around 20 bcm by 2035, according to their

[7] There is currently not much evidence of rapid decline curves as a supply constraint. Most well pads have one or two wells on them, when they could hold 8 or more. So, it is relatively easy for companies to go back in and drill for more gas. Further still, technologies are improving rapidly. Finally, for any given gas extraction (fracking) effort, it appears as if only 50% of the available gas is being recovered from within the fracking zone.

New Policies Scenario (IEA, 2012a). Estimates for countries such as China, Canada and India are more optimistic.

The IEA also examined the future production of unconventional gas in the EU, separately (IEA, 2012b). Under their most optimistic scenario, the so called 'Golden Rules' scenario, which also assumes clear environmental and social regulations, production would rise to around 77 bcm by 2035 (see also Table 4 for a comparison of different scenarios). Similar to the New Policy Scenario, it takes time to develop this industry, up to 2020. This scenario, however, assumes optimistic production costs of between 5 and 10 USD/MBtu as well as full accessibility of the entire unconventional gas reserves in the EU, including countries that currently have moratoria on this type of production in place.

Our previous gas price analysis (see Figure 10) indicated that U.S. prices are recovering to nearly US$4 / MBtu in 2013. One reason that may explain this recovery is that producers increasingly switch production from shale gas to oil. Riggs are relatively mobile and can be moved to other sites that are more profitable. Also demand for gas is also increasing because US power producers are increasingly switching from coal to gas (IEA, 2013b). The other reason might be that production of unconventional gas from wells levels off at some point but it seems too early for this type of supply constraint.

Predictions about long run expectations of the exploitation of the global unconventional gas reserves are notoriously difficult. According to the New Policies scenario, the IEA (2013c) expects production to be the largest by far in the U.S.. In this scenario conditions in the U.S. remain most favorable compared to most other countries. The reason is that the U.S. has already a developed petrochemical industry and service sector with experience in other unconventional gas production like tight gas and coalbed methane, has favorable regulations with regard to ownership of mineral resources, and has a deregulated gas market and a culture of private entrepreneurship. In this scenario the IEA expectation of the future production of unconventional gas in the EU is very conservative. Production would grow slowly to around 20 bcm by 2035 in their New Policies Scenario (IEA, 2012a). Estimates for countries such as China, Canada and India are more optimistic.

Table 4 Natural Gas Indicators in the European Union by scenario

		Golden Rules scenario		Low Unconventional scenario	
	2010	2020	2035	2020	2035
Production (bcm)	201	160	165	139	84
Unconventional	1	11	77	0	0
Share of unconventional	1%	7%	47%	0%	0%
Cumulative investment in upstream gas, 2012-2035			434		235
Unconventional			181		-
Net imports (bcm)	346	432	480	423	510
Imports as share of demand	63%	73%	74%	75%	86%
Share gas in energy mix	26%	28%	30%	26%	28%
Total energy related CO_2 emissions (mln ton)	3633	3413	2889	3414	2873

* Difference between the Golden Rules and Low unconventional scenarios
** Investment in billion USD 2010
Source: IEA (2012b), Table 3.6

The IEA also examined the future production of unconventional gas in the EU separately (IEA, 2012b). In their most optimistic scenario, the so called "Golden Rules" scenario which also assumes clear environmental and social regulations, production would rise to around 77 bcm by 2035 (see also Table 4 for a comparison of different scenario's). Like in the New Policy Scenario it takes time to develop this industry up to 2020. This scenario, however, assumes using optimistic production costs between 5 and 10 U.S.$/MBtu as well as full accessibility of the entire unconventional gas reserves in the EU, including countries with current moratoria.

Production of shale gas under this optimistic Golden Rules scenario would be much higher than under the New Policies Scenario and this level would be enough to offset the decline in production from conventional fields (IEA, 2012b). The IEA expects demand to increase to 692 bcm by 2035, under their Golden Rules scenario, which is somewhat higher than the 605 bcm under the New Policies Scenario (IEA, 2013b). Under both scenarios, gas consumption increases most of all because of climate policies that induce the substitution of gas for coal. Russia and North African countries are expected to supply most of the growing European demand, but a substantial part of this growing demand may also be covered by new exports from the Caspian region, due to the opening of the Southern Corridor pipeline.

4.2 Potential effects of future unconventional gas developments on EU fossil fuel prices

How future unconventional gas development will affect EU natural gas prices not only depends on the growth in local exploitation within the EU, but also on the likelihood of growth outside the EU, and the possibility of shale gas becoming a globally traded good. If gas markets remain local because of the necessity of pipeline connections, price formation will also be mainly influenced by local developments, and only indirectly by other fossil fuel and energy markets. If gas will become a tradable good, local gas prices are much more likely to be affected by the combined impact of production and transportation cost within a global gas market, in the first place.

Current prospects for unconventional gas exploitation within the EU in the medium term seem rather limited (see Section 4.1). The main impact on EU gas prices in the next decade will depend on the further development of unconventional gas exploitation in the United States in the first place. Whether US unconventional gas will become a globally traded good not only depends on within United States production and consumption developments, but also on political decisions whether or not to allow for large scale exports of gas. This, in turn, depends also on how much US producers could gain by selling the gas to other world regions. Despite strong growth in demand for gas within the United States recent forecasts predict that the United States would still become a net gas exporter (EIA, 2013b).

To what extent natural gas will be traded across continents strongly depends on the development of the Liquefied Natural Gas (LNG) market. LNG can much more easily be transported (similar to using oil tankers) and, thus, is likely to compete with the traditional way of gas delivery through pipelines and their associated long-term contracts. Global LNG trade has grown rapidly, recently (IEA, 2012a). The capacity of terminals that liquefy and degasify for export is currently limited and mainly concentrated in Qatar. However, new gasification terminals are being planned around the world, especially in Australia, to facilitate export, as well as various degasification terminals to facilitate import within Asia and Europe.[8] Under the New Policies Scenario of the IEA, for instance, LNG trade is assumed to double, by 2030, to more than 575 bcm. Larger amounts of gas being traded around the globe are also more likely to induce convergence of international gas prices.

---

[8] In the US, investors tabled plans with a cumulative capacity of 200 bcm per year, but it seems unlikely that all plans will be permitted and constructed. Also Shell announced to built several huge so called floating LNG plants (see Shell, http://www.shell.com/global/aboutshell/major-projects-2/prelude-flng/revolution-natural-gas-production.html). Interestingly, LNG exports haven't changed last year (BP, 2014).

An increase in global LNG importing and exporting capacity will have an impact on EU natural gas prices if LNG exports from the United States (or elsewhere) would indeed go to Europe. Whether this will happen – and to what extent – is not so evident, however. The substantial price differential between Asia and Europe (see Figure 7) illustrates that most LNG may very well be exported to Asia instead, because gas prices are substantially higher. Exporters currently achieve a much higher rate of return if they ship LNG to Asia, where prices are higher. For some years, LNG export from Qatar to the EU was on the rise, but this has changed, recently. Since the Fukushima disaster in Japan, gas demand has increased, considerably, in Asia, and more LNG has been shipped to Asian markets (BP, 2014). Also, recent predictions for the development of a potential LNG export market for the United States reflect these market forces (EIA, 2013a).

Finally, to what extent increased trade in LNG will lower gas prices within the EU also depends on the likelihood of more gas being handled on a spot basis. Section 2.2 shows that the increase in gas traded on spot markets seems to have had a significant impact on European gas price formation. Whether trade in LNG will also increase delivery on a spot basis is likely but remains uncertain. Investors in LNG terminals try to reduce their risk on return, because high capital costs are involved. Without sufficient risk reduction, such as through long -term contracts, potential investors may even withhold their investments in LNG capacity. In contrast, two US LNG exporting facilities in the United States use indexation to the Henry Hub spot market. This supply is flexible and may change direction in case of price opportunities for delivery.

To what extent other global fossil fuel markets will be affected by shale gas exploitation depends on interfuel substitution. For instance, cheaper gas may induce a shift from coal-fired to gas-fired power generation, and oil to gas based motor fuels. Recent developments within the United States illustrate how fast gas demand could rise at the expense of coal. Coal use in the US power sector declined from 53% in 1990 to 43% in 2011, while gas use increased to around 30%. This switch from coal to gas in the US power sector is not only due to the change in the gas to coal price ratio (see Table 2) but is also supported by more stringent environmental regulations (IEA, 2013b). As a consequence domestic demand for coal in the United States is under pressure reducing nominal coal prices (EIA, 2013b; EIA, 2013c).

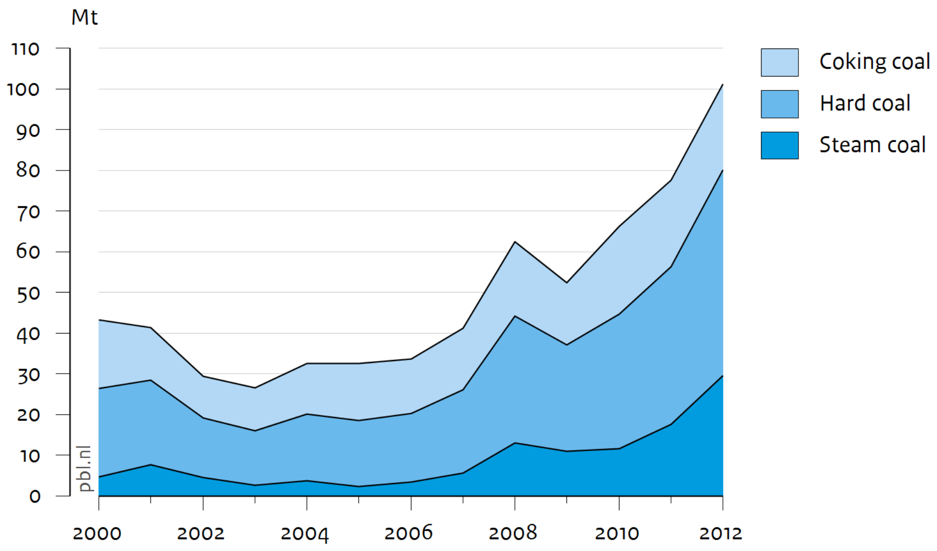
This reduction in demand for coal within the United States also reduced US coal export prices, relative to that of their competitors (compare Figure 7). In turn, the lower US coal prices induced an increase in (cheap) coal imports by the EU. Indeed, Figure 9 shows that imports from the United States into the EU is rising rapidly for the most important types of (traded) coal, i.e. hard, cooking and other bituminous coal, since 2007.[9] This trend is likely to continue in the next few years as long as the price differential between different coal prices would remain or even further increase in favour of US coal. This trend will have an upper bound due to growing public resistance. In the longer term, US exports could also stabilise because costs of exporting coal to Asia through the west coast ports may be less economically attractive (IEA, 2013b).

The lower US coal price clearly is the most direct visible impact from US unconventional gas production on EU fossil fuel prices. Whether this impact will be sustainable depends on future developments of unconventional gas exploitation in the United States in the first place. If future US unconventional gas exploitation would become more expensive, the gas-for-coal substitution in the United States and the European Union may be reversed. Interestingly, the most recent trends suggest that this is not a far-fetched possibility (EIA, 2013c).

[9] In some countries, such as the Netherlands, imports started to rise only recently, i.e. since 2012.

Figure 9

Coal Imports from the US by OECD-Europe, 2000–2012



Source: IEA/OECD

4.3 Conclusions

Long-term expectations of global unconventional gas exploitation generally see little room for a strong role of the EU. This would happen even with a business case for unconventional gas exploitation that not only depends on the revenue from selling the gas itself, but also to a large extent on the revenue to be obtained from selling by-products, such as ethylene and butane. Current low US gas prices already induce fracking strategies that also take stock of potential higher rate of returns from those by-products (IEA, 2013b). However, such prospects are not yet envisaged for the EU despite the high oil prices and the large investments in current oil based production of these by-products. Production will remain by far the largest in the United States followed by China and Canada.

With modest EU unconventional gas exploitation, the likely impacts will come from abroad, in particular from the United States. A direct impact on the gas price is only to be expected if the United States changes into a gas exporting country, mainly through LNG shipping. But even in that case Asia is likely to benefit more from this development in the short term. The benefits and costs for the EU are mainly related to the indirect impact of a lower demand for coal within the United States and the associated decrease in the US coal import price to the EU.

5. Impact of changes on the competitiveness of EU economies

The growing gap between gas prices in the different world regions has raised concerns whether EU economies wouldn't face serious competitiveness disadvantages. These disadvantages would materialise in particular if a similar unconventional gas boom and associated gas price reduction within Europe may not be possible. This section explores how EU economies and, in particular, what sectors would be affected. After a short review of the potential impact channels, we explore which sectors seem to be most vulnerable in the EU for a sustainable gas price gap as well as more indirect channels such as changing electricity prices. Finally, we also discuss competitiveness issues related to the production and trade in NLGs.

5.1 Impact channels of unconventional gas exploitation on competitiveness

Natural resources, such as conventional or unconventional gas, are an important factor for international specialisation because they provide a strong comparative advantage for countries. Fossil fuel producing countries are more likely to specialise in sectors and technologies that also exploit these fuels. A particular specialisation pattern, however, will be challenged if a major shock hits the existing equilibrium. Unconventional gas production is such a shock, even if the shock would remain restricted to the United States

As explained in Section 2.1, gas is mainly used for heating purposes, power generation and as an industrial feedstock within the EU. The most important downstream natural gas (methane) applications are:

- use for *heating* by households, service and industrial sectors, as well as horticulture;
- use for *heating* in industrial sectors for manufacturing food products, textiles, metals, chemicals and paper, for product processing under low temperatures in the manufacture of food products, in potteries, for the hardening of plastics, for the heat treatment of metals, and for high temperature processing of steal, metals, glass and enamel;
- use in power plants to generate electricity;
- use as a *feedstock* in the fertiliser industry for the production of ammonia, which serves as the primary ingredient in most nitrogen fertilisers and is an essential ingredient in many phosphate fertilisers;
- use as a *feedstock* in the petrochemical industry for the production of methanol, which is a primary petrochemical, and a feedstock for plastics, pharmaceuticals, electronic materials and many other products (American Chemistry Council, 2013).

In addition to these natural gas (methane) applications, also the by-products NGLs (mainly ethane, propane and butane) have important industrial applications (Keller, 2012; Ebinger and Avasarala, 2013; IEA, 2013b, p.275ff):

- use of ethane and propane which are both used by the petrochemical industry to produce ethylene and propylene, which are then turned into plastics and a variety of other products;
- use of butane as petrol and propane for space heating.

The impact of the US gas price shock is related to several direct and indirect impact channels. The first direct impact is that lower gas prices reduce gas energy cost both for heating and feedstock use in the United States and, if traded, elsewhere. Gas inputs are often only part of the overall energy input cost mix and similar sectors in other countries even may use other energy inputs. A second, more indirect impact is interfuel substitution. Substitution is related to numerous factors as well such as its technical feasibility in the short and long term (e.g. substitution may be easier for heating than for feedstock use). In addition the gas price is likely to induce changes in other energy inputs too, such as lower coal and electricity prices. Again these changes are also likely to be affected by international trade both in the energy market as in traded goods. Third, an indirect impact through which unconventional gas is likely to affect EU industry is its impact on the CO_2 price on the ETS market. This impact works through different channels in the complex energy system, for instance because imported coal became cheaper which, in turn, is likely to adversely affect the CO_2-price because demand for permits would rise. Fourth, and most indirect, are the general incidence effects in the economic system as a consequence of a gas shock. For instance, lower gas prices induce demand shifts if gas intensive products become less expensive. Finally, note that all four channels apply to the potential impact of the by-products, too.

As a consequence the overall impact of the unconventional gas boom in the United States on the competitiveness of sectors in the EU is not easy to predict and depends on many factors. Competitiveness issues are linked to all impact channels mentioned. First, a changing gas price in the U.S is most likely to have an impact on energy-intensive industries that use gas for heating or as feedstock both within the United States as for its trading partners. Changes in fuel costs of sectors between regions affect input decisions at the margin (including the production of feedstocks), i.e. decisions regarding how much output to produce and what inputs to use in what region. Also interfuel switching is most likely to affect sectors with high energy input costs in sectors that are also exposed to international competition. Apart from such marginal impacts on trade, changes in the gas price also affect decisions at the extensive margin, i.e. decisions where to expand or locate (new) industries. Those decisions are typically linked to inframarginal cost of (capital) investment which, in turn, may be driven by energy cost consideration for energy-intensive sectors.

5.2 Competitiveness impacts on the EU

To what extent the incidence effects are likely to play a role depends on the existing pattern of specialization of industries within and across the EU. In this section we provide an indicative analysis of how a change in the gas price itself is likely to have such an impact using some rough (initial) indicators on natural gas use and its costs. For this purpose we start with a descriptive analysis of the gas input share in different sectors across countries as well as its exposure to international competition based on the well-known GTAP dataset. This dataset provides international comparable data on both physical and economic differences in gas and energy use as well as its cost across sectors and countries.[10] Finally we discuss how more indirect channels may be affected. In the next section we zoom in at the subsectoral level to discuss impacts through the use of feedstocks and the additional supply of the 'byproducts' of NLGs. Our focus is on relative position of the EU in the world markets and we do not look at potential different impacts within the EU and its internal market.

5.2.1 Gas input shares in different sectors across countries

Apart from household heating gas use is most likely to play a role in the industrial and power sector in an economy. For an indicative role of natural gas as an input in major energy-intensive industrial sectors we use gas input values (volume*price) as a share of the overall value of production (output*price). This indicator shows the economic value of gas in generating a given amount of output value across sectors. Figure 10 presents this

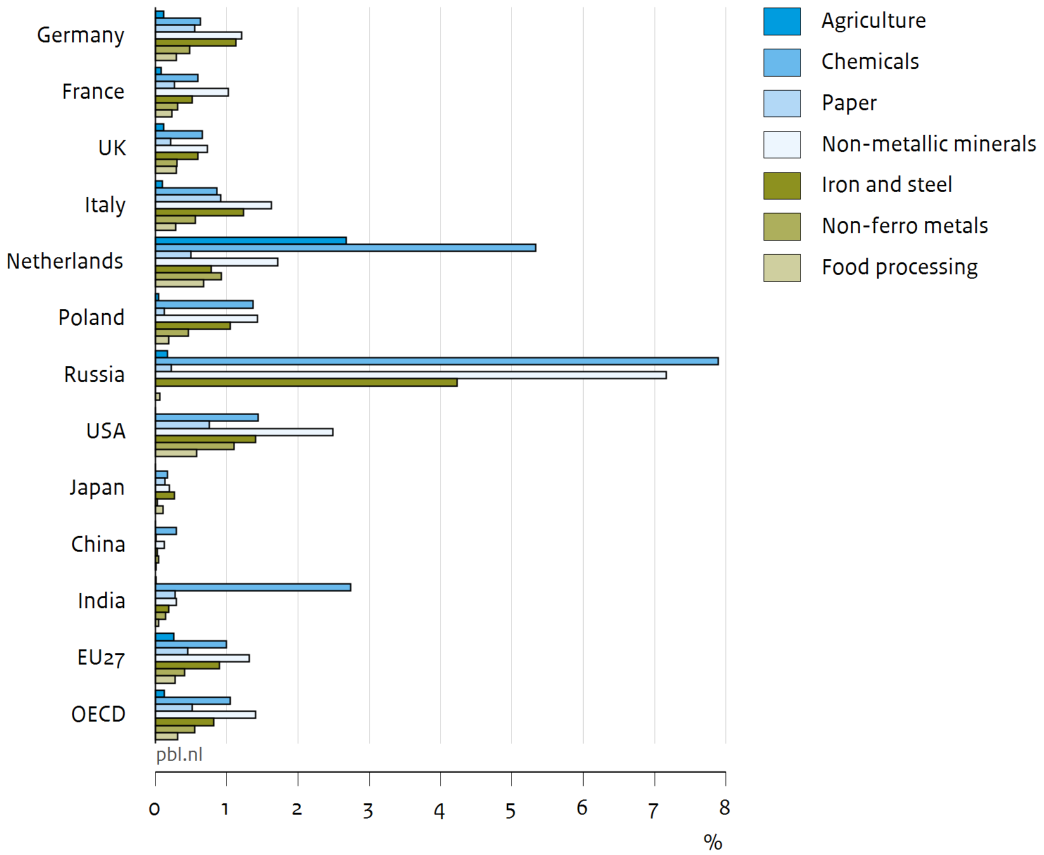
[10] The GTAP database is a global database with economy-wide coverage combining detailed bilateral trade, transport and protection data characterising economic linkages among regions, together with individual country input-output data bases which account for inter-sectoral linkages within regions through trade (Narayan et al., 2012). These data are commonly used by existing CGE models, such as the WorldScan model and the GEM-E3 model, that assess different policies across countries and world regions. The advantage of using GTAP data is that considerable effort has been put in making the data comparable between countries. The disadvantage is that the most recent trends are not captured by the data set. Currently, the most recent data available are from 2007.

indicator for different sectors, such as the chemical, rubber, and plastic products industry, and the base metals industry, in the largest economies around the world. We also include gas use in the agricultural sector for comparison.

The figure shows, first of all, that the share of gas input value or cost relative to the value of production is quite low on average both within the EU and the OECD. On average this share is around 1% in the more gas intensive sectors. Even in sectors in countries that use a lot of natural gas, the share never crosses the 8% level. Indeed, gas input costs are usually a small share of overall input costs because in many sectors labour costs are much more important. However, the gas input shares can be much higher within these sectors (e.g. at 2 digit level). For instance, the chemical, rubber and plastic product industry (CRP) includes the highly energy-intensive petrochemical industry, but this level of detail is not provided by the GTAP database (see next section).

Figure 10

Share of gas input in the value of the output for energy-intensive industrial sectors, 2007



Source: GTAP, 2007

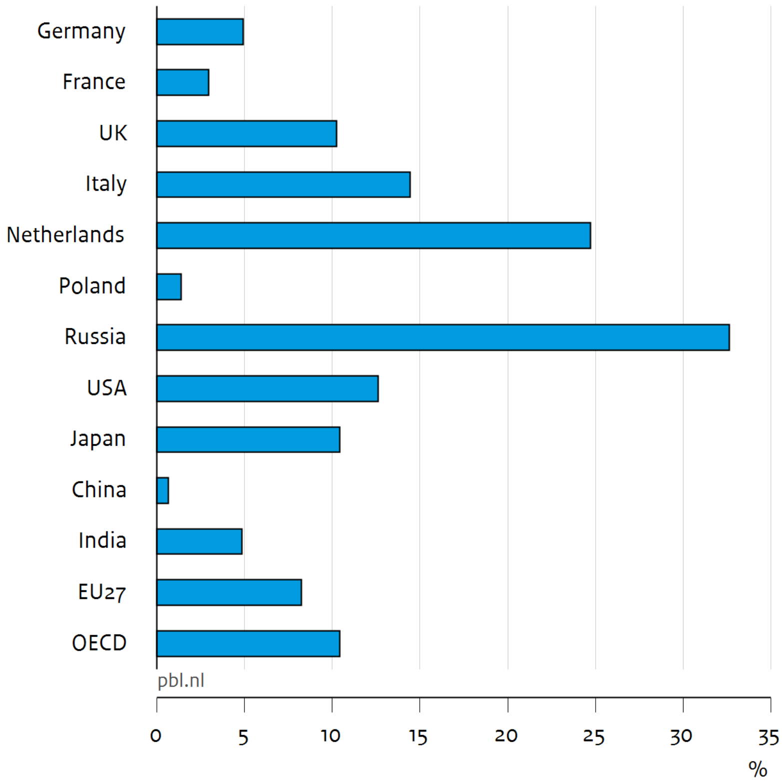
Second, gas use is, on average, largest in the non-metallic minerals sector and chemicals. Gas use is also quite high in the iron and steel industry followed by non-ferro metals and paper industry, but the variety across countries is large within sectors. The same type of sector may consume considerably different amounts of gas in different countries. For instance, the chemicals industry uses a lot more gas in the Netherlands and Russia than in countries such as France or Italy. Similar differences apply to other sectors.

Sometimes exceptional patterns can be observed in some countries. Usually agriculture does not use much gas at all. However, agriculture in the Netherlands uses even more natural gas than in most other sectors in the other countries. The reason for this exception is the large (greenhouse based) horticulture (sub)sector which uses a lot of natural gas. The Base Metal industry in the United States is another example. Indeed, gas shares are often correlated with the amount of gas available within a country. Typical gas producing countries as the Netherlands and the United States use a lot more gas on average in all sectors compared to other non gas producing countries.

Another sector where gas plays a direct role as an input is the power sector. Obviously this impact depends on the existing role of gas in the electricity portfolio mix. Obviously energy input shares simply provide the bulk of the overall input costs in this sector. The gas input share in the overall value of power generation differs strongly, however as Figure 11 illustrates. Again Russia and the Netherlands have very high shares for gas while the shares are very low for China (mainly coal based) and France (mainly nuclear based). Again gas plays the largest role in countries that produce gas themselves, such as Russia and the Netherlands. Note, however, that the data are from 2007 and do not capture recent changes in the mix.

Figure 11

Share of gas input value in total value of electricity production, 2007



Source: GTAP, 2007

We conclude that the importance of gas use differs considerably between sectors and countries. Furthermore, the general pattern is that sectors using more gas can be mainly found in gas producing countries. Gas input value shares at 2 digit sectoral level only provide a very rough indication of the potential impact of the unconventional gas production and trade boom on international competitiveness of sectors, however. In the first place sectors with a relatively high gas share should also compete on the international market. Such sectors are likely to be affected more directly than sectors not exposed to international competition. Moreover, industries at the *subsectoral level* may still suffer considerably, in particular if their gas use is large, which is often the case for applications as feedstock but also if NGLs matter. Finally, even though the power sector is not exposed to international trade across the globe,[11] exposed sectors consuming large amounts of electricity may still be affected indirectly.

5.2.2 Gas-intensive sectors and their exposure to international trade

The second step in identifying whether and how the unconventional gas shock will have an impact on international competitiveness in the EU is by exploring to what extent particular (gas) intensive activities are also *exposed* to international competition from outside the EU. We define the exposedness of a sector as the share of export in the total value of production in each sector. Figure 12 illustrates the diversity in export shares across the different sectors in different countries.

The figure illustrates that export intensities differ considerably between gas-intensive sectors as well as between EU Member States and other countries. Some countries are clearly much more exposed than others. For instance, most energy-intensive sectors in the small open economy of The Netherlands are all much more exposed than comparable sectors in other countries.[12] Also exposedness of most EU Member States is– on average – much higher than other countries in the world.

It should be noted, however, that our trade data also include *intra*-EU exports. Accordingly, the vulnerability of sectors for an *international* gas shock is likely to be overestimated because intra-EU exports tend to be much larger than exports (and imports) to other non-EU countries. [13] Therefore the right hand side of Figure 12 shows exposedness of sectors to non-EU countries as well. Interestingly, the exposedness across countries is much less divergent if intra-trade is excluded.

Furthermore, differences between *sectors* are large as well. The electricity industry itself is clearly non-exposed even with intra-EU trade included. Only France (9%) and Germany, (6%) are exporting some electricity. However, the chemical sector as well as the iron & steel and the non-ferro metal industry belong to the most exposed industries in all countries. Export intensity of other energy-intensive industrial sectors, such as the food processing, beverages and tobacco industry as well as the paper and non-metallic mineral industry is much smaller. Again this picture does not change if intra-EU trade is excluded.

Combining the exposedness of sectors with their gas use intensity we conclude that the direct impact of an unconventional gas price shock is most likely to hit the quite heavily exposed chemical industry, the non-ferro metal industry as well as iron & metal across the whole EU. Although the non-metallic mineral products sector also uses quite some gas on average, this sector is much less exposed.

---

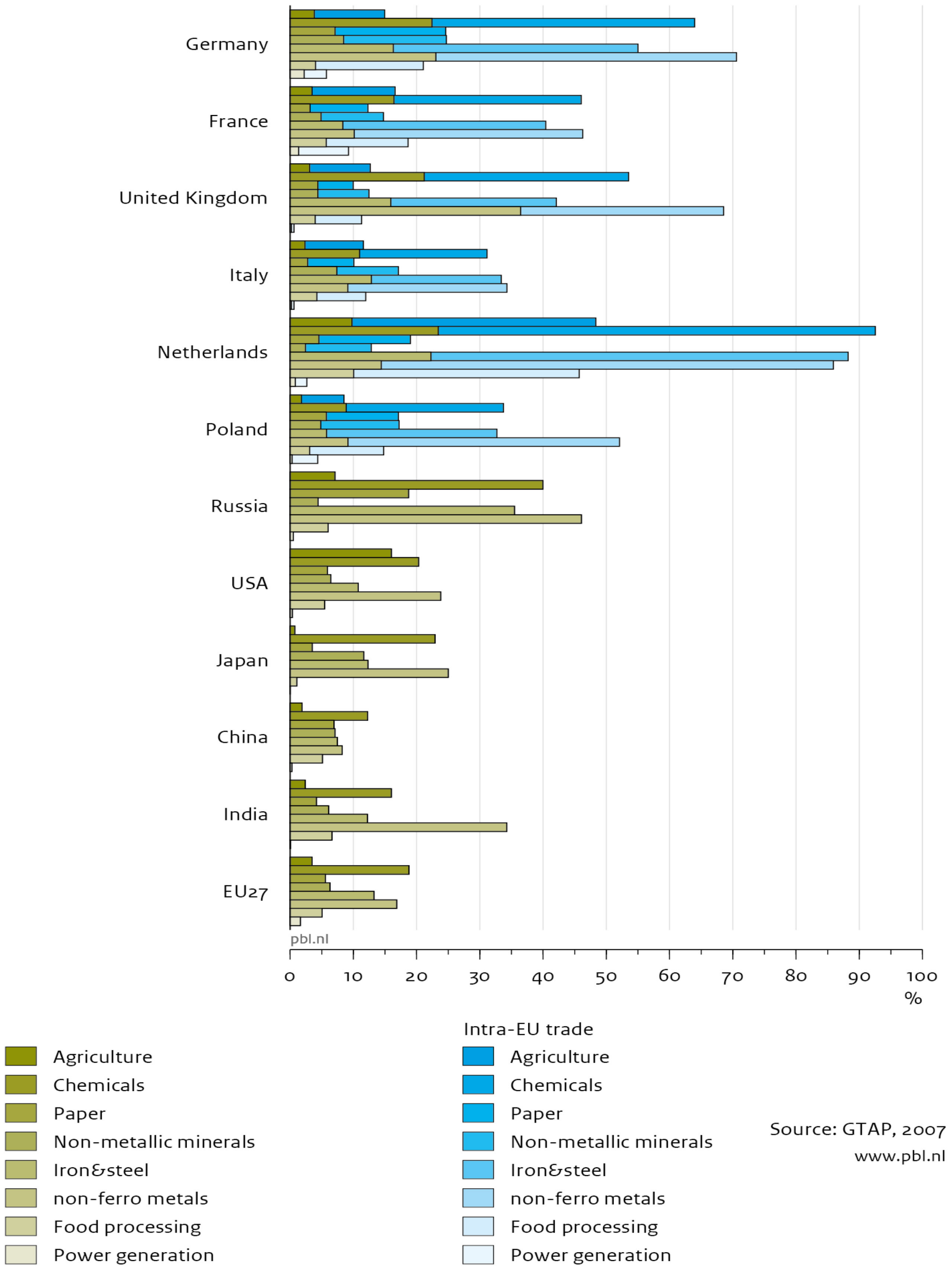
[11] Also intra EU trade in electricity is still limited though growing as trade in electricity across borders is growing within the EU. Depending on the electricity portfolio mix, some countries are therefore more vulnerable than others for a gas shock.

[12] Interestingly the exposedness of several of these basic material sectors in China is not large compared to other countries. It should be noted that these shares include intra-EU trade as well.

[13] Therefore our data only provide a rough first approximation for the relevance of unconventional gas shock in the United States to EU exposed sectors.

Figure 12

Share of export in total production of energy intensive sectors, 2007



5.2.3 Indirect channels

Previous sections have illustrated that indirect price changes already are having an impact. In particular, lower input costs reduce electricity prices which, in turn, affect downstream sectors using electricity as an input. Falling gas prices induce lower electricity costs in the United States which improves the competitiveness position of electricity-intensive industries in this region if other regions do not face similar cost reductions.

Interestingly, interfuel switching with gas substituting for coal in the United States also has a dampening indirect impact in the EU. Because coal prices fell, export of US coal to the EU increased, which, in turn, also created a downward pressure on electricity prices within the EU. Indeed, the smaller gas/coal differential in the EU has already had a significant impact on the functioning of the EU electricity markets in recent years. Because coal has become relatively cheap compared to natural gas (see Section 3.4), power plants across Europe are increasingly switching from gas to coal (see also IEA, 2013a). The switch from gas to coal combustion in electricity power plants softened the rise in the relative disadvantage that occurred because of the US shale gas boom.

Another indirect impact runs through the CO_2-price in the ETS market. This impact works through different channels in the complex energy system. In particular on the power market, fossil fuel inputs, electricity and carbon prices are strongly related. The smaller gas/coal differential also has an upward impact on the EU ETS price because CO_2-emissions for a coal fired power plant are roughly 2 times higher than for a natural gas fired plant. From empirical studies we know that a stronger demand for coal has such an upward impact, whereas a fall in gas demand reduces it. Even though carbon prices are more or less completely passed through in electricity prices this upward effect is unlikely to be very important, however, because the current carbon price is very low due to the large overhang of permits in the market (see Fell et al., 2013).

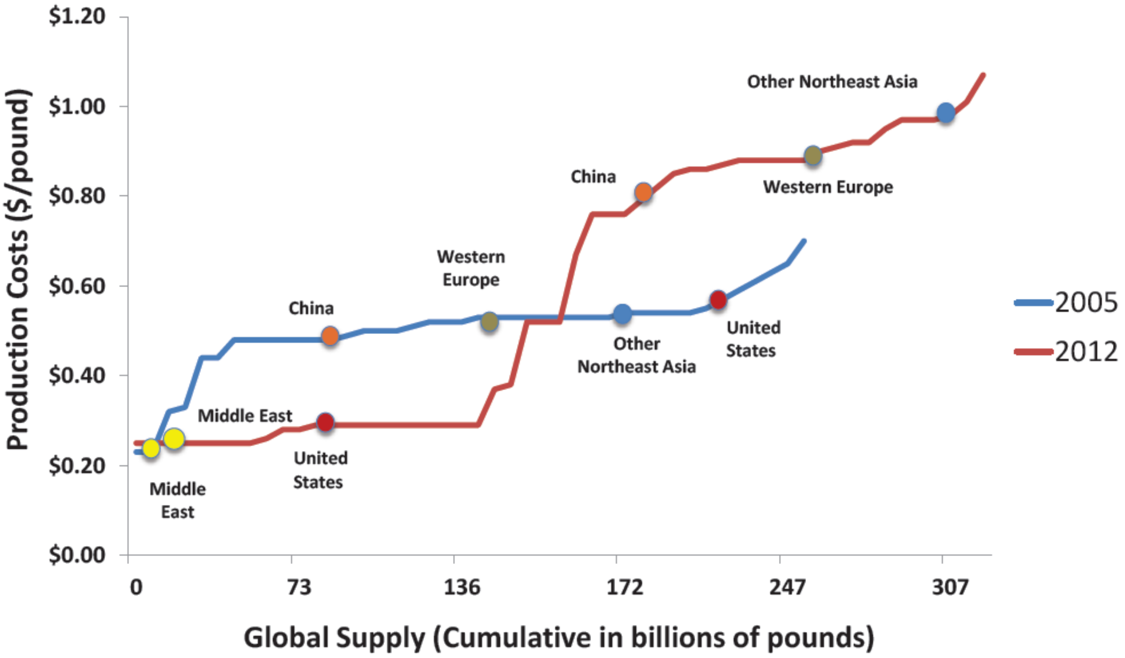
5.3 Competitiveness impacts on subsectors in the EU

Even if competitiveness concerns may not appear very severe and even dampened through indirect channels, some subsectors may still be severely affected. In particular exposed firms and industries using a lot of electricity, gas as a feedstock or NGLs are likely to be still seriously affected. The choice of particular energy-intensive industries to locate in a specific country or region as well as their choice to use gas, oil or other inputs is usually also closely linked to the access industries have to fossil fuel and electricity markets. Existing specialisation (or location) of industries reflects those comparative differences. If, however, the fundamentals in these comparative differences change due to an energy (price) shock, industries may reconsider their (long term) strategy.

The most serious competitiveness issues of the unconventional gas revolution are related to the use of gas (methane) and its NGL by-products (ethane, butane and propane) as feedstocks. One example is switching in feedstock from naphtha, derived from oil, to ethane, derived from gas in the United States. Almost all ethane and around one third of all propane is used by the petrochemical industry to produce ethylene and propylene. These compounds are then turned into plastics and a variety of other products. Worldwide only 15% of the market for NGL consists of ethane and about two thirds is butane and propane (Keller, 2012). The share of ethane on the US market, however, is almost twice as high. Over 97% of ethane originates from gas processing and fractionation. For the other NGLs on the US market this figure is three-quarters while only 20% originates from crude oil refining, while the rest is imported (Keller, 2012; Ebinger and Avasarala, 2013).

This very different pattern in the US market can be well explained by the US unconventional gas revolution. The costs of producing ethylene from natural gas in the United States are now about a quarter of their historical level. Ethylene, today, can only be produced at lower costs in the Middle East (PWC, 2012; Ebinger and Avasarala, 2013; American Chemistry Council, 2013). Figure 13 illustrates the dramatic change between 2005 and 2012. The position of the United States on the cost curve for ethylene has shifted from being one of the most expensive producers in 2005 to one of the cheapest in 2012. Indeed, the United States overtook China, Western Europe and Other Northeast Asian countries in this short relatively period (ACC, 2013).

Figure 13 Change in the global cost curve for ethylene



Source: ACC, 2013, p.21

This shift in the US petrochemical sector has huge impacts on the same sector in the EU which is dependent upon oil-based naphtha to supply ethylene (Deloitte, 2013). Petrochemicals became cheaper in the United States even when oil prices peaked. Indeed, NLG-based chemicals provide cheaper raw materials for than naphtha-based chemicals, and may also be exported to compete with the world's lowest-cost producers such as the state-owned petrochemicals firms in the Middle East. As a consequence the EU petrochemical industry already faces strong competitiveness challenges and this is likely to remain so in the near future. This will also have impact on their location strategy. Naphtha crackers cannot be readily converted into ethane crackers, and a key prerequisite is a competent source of ethane, either through import, local production or both. For example, firms such as Dow Chemical have announced numerous new investments in the United States to take advantage of low gas prices (PWC, 2012). Indeed, the United States may export fewer cheap raw materials to countries with low labour costs to be made into goods to export back to America, but could now process the raw materials by itself, shortening the supply chain and returning manufacturing jobs to the United States in industries where petrochemicals are a large part of the cost base.[14]

Apart from ethane, however, also other industrial sectors take advantage of unconventional gas exploitation. The American Chemistry Council calculated the effects of an increase of unconventional gas production with 25% on the production of eight energy-intensive manufacturing industries using the Input-Output model IMPLAN (American Chemistry Council, 2012; Krupnick et al., 2013). They report that approximately 85% of output gains comes from the Chemicals and Plastics and Rubber Industry, where the direct output gains increased with 14,5% and 17,9%, respectively.

[14] PWC (2011) estimates that lower feedstock and energy costs could result in 1m more American factory jobs by 2025.

The gains in other sectors follow mainly from lower energy prices, with the strongest increase in output in the Aluminium sector (7,6%) and Iron and Steel sector (4,4%).

Another chemical industry that benefits from conventional gas production is the *fertiliser industry*. This industry uses the gas (methane) itself for the production of ammonia, which serves as the primary ingredient in most nitrogen fertilisers and is an essential ingredient in many phosphate fertilisers. For nitrogen fertilisers, the cost of ammonia is about 70 to 90% of the total costs. During the 2000s, production capacity of ammonia in the United States shrank by 40%, but large scale, low cost shale gas resources have reversed the trend and brought significant cost savings to the production of ammonia. In the last years, two major manufacturers of fertiliser products in the United States, CF Industries and Orascom Construction Industries, announced large scale investments in nitrogen fertiliser production plants (Krupnick, Wang and Wang, 2013).

Table 5 Indication of the significance of industry for the economy per subsector and region, 2011

	Energy use	Value added		Net trade	Employment	
	share of industry total (%)	Share of GDP (%)	Share of industry total (%)	As % of value added	People (*1000)	Share of industry total (%)
Chemicals						
United States	36,3	2,3	11,2	14	700	6,6
Japan	33,2	2,5	9,3	15	340	4,5
European Union	*32,0*	*0,5*	*2,1*	*155*	*1160*	*3,9*
China	19,6	2,4	5,2	-7	25810	12,9
World	27,8	2,2	7,2	-4	77930	10,4
Refining						
United States	15,1	0,5	2,6	-55	60	0,6
Japan	6,2	0,2	0,9	-142	10	0,2
European Union	*11,1*	*0,1*	*0,6*	*-1247*	*120*	*0,4*
China	3,1	0,1	0,3	n.a.	1630	0,8
World	7,5	0,2	0,5	n.a.	4810	0,6
Aluminium						
United States	2	0,1	0,3	-49	50	0,5
Japan	0,2	0,1	0,3	-146	10	0,1
European Union	*2,3*	*0,1*	*0,2*	*-611*	*90*	*0,3*
China	3,9	n.a.	n.a.	n.a.	n.a.	n.a.
World	2,7	0	0,4	23	n.a.	n.a.
Iron and steel						
United States	6,5	0,6	3,1	-13	290	2,8
Japan	27,5	0,9	3,3	80	220	2,9
European Union	*13,9*	*0,2*	*0,6*	*46*	*560*	*1,9*
China	35,9	1,3	2,9	3	15440	7,7
World	20	0,7	2,2	-1	29720	4

Note: Data on energy use are for 2011, while data on value added, net trade and employment are for 2010, due to data availability constraints.

Source: IEA (2013b), p. 277

Finally, methane is also used in the petrochemical industry as a feedstock, in particular for the production of methanol. Methanol is a primary petrochemical and also a feedstock for plastics, pharmaceuticals, electronic materials and many other products (American Chemistry Council, 2013). The American Chemistry Council expects a revival in the methanol production in the United States. Methanex Corp. the world's biggest methanol producer, announced to dismantle a methanol plant in Chile and rebuild it in Louisiana in the United States (Krupnick, Wang and Wang, 2013).

Despite these sometimes serious impacts at industry level, the impact on the overall economy is not as dramatic. Recently the IEA presented some useful indicators to put these subsectoral impacts in perspective (IEA, 2013b, p.277). Table 5 presents for some of these subsectors indicators that illustrate the relevance of several of these industries, such as chemicals and refining industry, in different world regions. For comparison also two other energy-intensive sectors are included.

5.4 Conclusions

This section explores to what extent the specialisation pattern in the EU is likely to be hit by the cheap gas and NLGs boom. This boom changes relative global energy prices which, in turn, puts a lot of pressure on existing input choices by gas- and energy-intensive firms as well as on their location decisions. However, only sectors will be vulnerable in countries where gas, NGLs and electricity play a relatively large role in either cost or benefits of firms. Moreover, to what extent such a shock will be important for competitiveness also depends on the exposedness of industries to international trade with countries or regions outside the EU. As far as natural gas or its by-product is used in sheltered sectors, i.e. in sectors that do not compete with US or Asian businesses, no such impact is to be expected.[15]

We find that the current use of gas and NLGs differs considerably between sectors and countries. The general pattern is that sectors use more gas in gas producing countries. When combining gas use intensity with the exposedness of sectors, the direct impact of the unconventional gas price shock is most likely to hit the chemical, iron & metal and the non-ferro metal industry across the whole EU. Although the non-metallic mineral products sector also uses quite some gas on average, the sector is much less exposed. Industries that are particularly vulnerable though are those using gas and NGLs as feedstocks such as the exposed chemical and refining industry in some EU countries. For those industries the impact can be quite dramatic but their role in the overall economy is rather limited, however. This also explains why recent macro-economic analysis did not find much substantial overall economic effects on the EU economy as a whole (ICF, 2014) .

These findings put concerns about competiveness properly into perspective. Although the unconventional gas shock is a real energy price 'shock' in economic terms (Kilian, 2008), its impact on competitiveness should not be exaggerated. Even in industries that use natural gas in their production process, technical skills of employees and the quality of their technology is usually more relevant for location decisions. Finally, overall energy costs are also determined by other fossil fuel input cost and, as we have seen before, some impacts of the US unconventional gas shock also spill over to the EU through lower coal prices, and, in turn, electricity prices.

[15] Of course, even sheltered sectors may suffer or benefit from more indirect incidence effects, but we do leave an analysis of these effects for future work.

6. Conclusion

This paper has shown past, current and potential changes in some global fossil fuel markets in relation to unconventional gas exploitation with a particular focus on consequences for EU competitiveness. Much of the impact is already 'priced' into the market. We have shown a clear and dramatic disparity between gas prices in the United States, the EU and Asia in recent years. Further reduction of the US gas price is unlikely because costs of extracting unconventional gas stabilise or even increase in the next few years. Some arbitrage between the highest (Asian) and the lowest (US) gas markets may be expected, in particular if US LNG exports would take off. In that case Asia will benefit more than the EU although the current imbalance has an advantage for the EU.

We have found little evidence for a prosperous unconventional gas development in Europe, not in the short but also not in the longer term. Exploration is still underway and exploitation is relatively expensive compared to North American shales. Uncertainties of existing estimations are large, however. Accordingly we do not expect EU gas prices to fall due to a rise in European unconventional gas production. These relatively bleak prospects for lower gas and, in turn, electricity prices due to unconventional gas exploitation in Europe suggest that the EU firms and consumers have to cope with the US unconventional gas price shock. Unconventional gas remains relatively cheap in the United States which changes relative energy prices both on a national level and abroad. This, in turn, puts a lot of pressure on existing input choices by firms as well as on their location decisions.

Indeed, the gas boom has an impact both through direct and more indirect channels. The current direct impact is most visible within the power sector in the United States, where gas has become so cheap that it even outcompetes its traditional substitute in the power sector, which is coal. Moreover, cost pass through of lower input prices also benefits US companies consuming a lot of electricity because these prices in the United States will remain (much) lower relative to European prices. Similar shocks to the comparative advantage for firms using gas as a feedstock are underway.

Another direct, but less known direct effect is related to the joint production characteristic of unconventional gas production. Unconventional gas production fields not only produce gas but also NGLs such as ethylene, propane and butane. Production of these so-called by-products is economically even more attractive because they can be sold as or refined into oil products or used in the chemical industry to produce plastics in case of ethylene. These impacts may even be more important in the long term, because the technical lifetime of petrochemical installations is quite long and adaptation costly and time consuming.

Indirect impacts soften these direct impacts, however. One would be the indirect impact of the unconventional gas boom on (relative) US coal export prices which, in turn, has induced much more shipment towards the EU. Coal import from the United States happens on a much wider scale than ever before. Coal consumption in the electricity industry across the EU is already rising, which, in turn, reduces electricity prices (Fell et al., 2013). Another indirect impact is shipping of LNG to the Asian market where gas prices rocketed recently. This trend will be enhanced if the United States would start to export gas too, in particular through LNG trade. Due to the much higher prices in Asia, profitability of shipments towards countries such as China, Korea and Japan rises. Moreover, larger export quantities would also be beneficial for the EU; in particular, when traded on spot markets, because this also would help to renegotiate long-term contracts with Russia.

Current competitiveness concerns within the EU have strongly increased and up to some point with reason. The pace at which unconventional gas has penetrated has been so fast that existing specialisation patterns across sectors face a large amount of additional stress, even in the short term. However, only sectors will be vulnerable in countries where these applications play a relatively large role in either the cost or benefits of firms. Note that these concerns are not restricted to gas use and their by-products because also indirect impacts matter, such as changing electricity prices, in particular if input (cost) shares are large. To what extent such a shock will be important for competitiveness also depends on the extent to which firms that use gas, its by-products or electricity are also exposed to international trade with countries or regions outside the EU. As far as natural gas or its by-product is used in sheltered sectors, i.e. in sectors that do not compete with US or Asian businesses, no such impact is to be expected. Currently most trade within the EU is also intra-EU trade even in the energy-intensive sectors. Therefore it is likely that the impact on the overall economy will be modest. These industries are only a small part of the overall economy with relatively low employment levels.

References

American Chemistry Council (2012), Shale Gas, Competitiveness and New US Investment: A Case Study of Eight Manufacturing Industries. American Chemistry Council, Economics and Statistics Department, Washington, DC.

American Chemistry Council (2013), Shale Gas, Competitiveness, and New US Chemical Industry Investment: An Analysis Based on Announced Projects. American Chemistry Council, Economics and Statistics Department, Washington, DC.

Blackmon, D. (2013), As Fracking Rises, Peak Oil Theory Slowly Dies, Forbes, July 16th 2013.

BP Statistical Review of World Energy 2014.

Deloitte (2013), The shale gas revolution and its impact on the chemical industry in the Netherlands - Addendum to VNCI Vision 2030-2050, Amsterdam.

Ebinger, C. and G. Avasarala (2013), Natural Gas Briefing Document #1: Natural Gas Liquids. Brookings Energy Security Initiative, Natural Gas Task Force, Washington, DC.

European Commission (2014), COM(2014), 23 final, Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions, Brussels.

EIA (2013a), Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. U.S. Energy Information Administration, Washington DC

EIA (2013b), Annual Energy Outlook 2013. U.S. Energy Information Administration, Washington DC

EIA (2013c), Short term energy outlook – September 2013. U.S. Energy Information Administration, Washington DC

Fell, H., B. Hinterman and H.R.J. Vollebergh (2013), Carbon Content of Electricity Futures in Phase II of the EU ETS, CESIfo Working Paper 4367, Munchen.

Gény, F. (2010), Can Unconventional Gas be a Game Changer in European Gas Markets, Oxford Institute for Energy Studies, NG 46.

Hubbert, M. King (1962), *Energy Resources*,Washington: National Academy of Sciences, Publication 1000-D, p.73-75.

ICF (2014), Macroeconomic impacts of shale gas extraction in the EU, Brussels.

IEA (2012a), World Energy Outlook 2012. OECD/IEA, Paris

IEA (2012b), World Energy Outlook Special Report on Unconventional Gas. OECD/IEA, Paris

IEA (2013a), Gas: Medium Term Market Report. OECD/IEA, Paris

IEA (2013b), World Energy Outlook 2013, OECD/IEA, Paris

IEA (2014), World Energy Databases, http://www.oecd-ilibrary.org/energy.

JRC (2012), Unconventional gas: Potential Energy Market Impacts in the European Union. Joint Research Centre of the European Commission, Petten

Kilian, L (2008), The Economic Effects of Energy Price Shocks, Journal of Economic Literature, 46, 4, 871-909.

Keller, A. (2012), "NGL 101 – the Basics," Midstream Energy Group, Presentation at the EIA NLG Workshop June 6, 2012.

Krupnick, A., Z. Wang and Y. Wang (2013), Sector Effects of the Shale Gas Revolution in the United States. Discussion Paper, Resources for the Future, Washington, DC.

Narayanan, G., Badri, A. Aguiar and R. McDougall (Eds.) (2012), Global Trade, Assistance, and Production: The GTAP 8 Data Base, Center for Global Trade Analysis, Purdue University

Odell, P. (1994), World Oil Resources, Reserves and Production, Energy Journal, 15, 89-114

Olmstead, S.M., L.A. Muehlenbachs, J. Shih, Z. Chu, and A.J. Krupnick (2013), Shale gas development impacts on surface water quality in Pennsylvania, Proceedings of the National Academy of Sciences, 110, 13, 4962–4967.

PricewaterhouseCoopers (PwC), 2011. Shale Gas: a Renaissance in US Manufacturing?, New York.

PricewaterhouseCoopers (PwC), 2012, Shale gas Reshaping the US chemicals industry, New York,

Spencer, T., O. Sartor and M. Mathieu (2014), Unconventional wisdom: an economic analysis of US shale gas and implications for the EU, IDDRI, Paris.

Stern, J. (2007) Is There A Rationale for the Continuing Link to Oil Product Prices in Continental European Long-Term Gas Contracts? Working paper NG 19. Oxford Institute for Energy Studies, Oxford.

The Economist (2012) Gas pricing in Europe – Be careful what you wish for. July 14th 2012

Wang, Z. and A. Krupnick (2013) A Retrospective Review of Shale Gas Development in the United States: What Led to the Boom? Discussion paper, Resources for the Future (RFF), Washington DC

World Bank Commodity Price Data (2014), http://databank.worldbank.org/data/databases/commodity-price-data