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The Future European Natural Gas Market
- are lower gas prices attainable?

Abstract:
We analyse effects of various natural gas supply scenarios in a liberalised Western European energy market in 2010. Our starting point is the uncertainties about future natural gas exports from Russia and LNG-producing countries. Our results indicate that the average natural gas producer price in Western Europe is likely to be higher in 2010 than the average historical price the last 15 years, even in an optimistic supply scenario. We find only modest effects on both average natural gas producer prices and trade patterns of radical changes in supply volumes. However, there are significant country specific differences, primarily related to the reliance on Russian gas exports and the use of gas fired power generation

Keywords: Electricity, energy modeling, natural gas, liberalized energy markets, LNG, Russia

JEL classification: D58, F17, Q31, Q41

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1. Introduction

During the last decade there has been a continuous process towards liberalization in the electricity and natural gas markets in Western Europe. This process led to the adoption and proposed implementation of the so-called gas-directive in the EU member countries from August 2000, see EU (1998**)** and EU (2000a). Through deregulation the European Commission aims for stable and lower natural gas prices and increased security of supply to the European end-users. Particularly the issue of security of supply has attracted more attention, both within the EU administration (EU, 2000b) and in academic literature, (see e.g. Stern 2002), as Europe faces substantial and fast growing import requirements the coming decades, (Eurogas, 2003). In this paper we analyze the aim for stable and lower gas prices in a fully liberalised natural gas market. In a competitive and capital intensive market, where producers take both price and volume risks, we may see unwillingness to invest in large-scale production and infrastructure facilities for natural gas export. This may again lead to higher prices and changed trade patterns of natural gas in the future.

In order to shed light on this question we investigate different supply scenarios for natural gas in an assumed fully liberalised Western European energy market in 2010. We use a computable partial equilibrium model to study the effects on natural gas and electricity prices, regional trade patterns and inter fuel competition. The different scenarios, introduced below, deal with some important uncertainties in the natural gas supply situation for:

- Imports of LNG are expected to become more important in the Western European natural gas market. However, to increase LNG supplies to Europe substantially, investments in both export and import facilities is necessary. To realize future investment plans it may be crucial that the hitherto experienced unit cost reductions continue throughout the entire LNG chain. We model a high and low supply scenario for new LNG to Western Europe in 2010.
- Russia is currently the main producer and exporter of natural gas to Western Europe. Lack of capital investments in required production facilities and an aging infrastructure system threatens their position in the long run. Thus we model high and low scenarios for Russian natural gas exports in 2010 depending on different assumptions regarding investments in the Russian natural gas industry.

In the model we a priori assume completely liberalised and deregulated Western European natural gas and electricity markets. Thus we assume that the EU will reach its goals of establishing efficient and integrated internal markets for natural gas and electricity by 2010. One important feature of the gas directive focuses on negotiation- or regulation based third party access to national and international transmission lines. Other features include non-discriminatory rights to build new infrastructure facilities and unbundling of the internal accounts of vertically integrated gas sales companies.

An on-schedule implementation of the gas directive will involve huge changes in the traditional European market structure for natural gas. The directive is to be implemented for eligible consumers in three defined phases. The last phase, commencing in August 2008, entitles all gas-fired power generators and all other customers consuming more than 5 million cubic meters per year to freely choose their supplier. This will gradually alter the traditional bilateral long-term contracts between a limited number of producers and gas sales companies that have occupied most of the volumes traded to this date. Thus competition on the demand side will increase, creating access to markets for existing and new suppliers, which again may enhance competition on the supply side through incentives for smaller production units, see Golombek et al. (1998). This will change the old price mechanisms. Shorter supply contracts will emerge along with a growing emphasis on wholesale natural gas prices on a cost-of-service basis as an alternative to the traditional oil price link.

As the gas directive is fully implemented across Europe and the access to natural gas is improved, we expect a growing integration between the electricity and natural gas markets in Western Europe. Third party access to natural gas and electricity infrastructure may stimulate changes in energy trade patterns between European countries. The model we use is to our knowledge the only model that study liberalization in the electricity and natural gas markets for most of the Western European countries simultaneously. Other models that study future scenarios of Western European natural gas markets, include e.g. the gas market models “GASTALE”, see van Oostvorn and Boots (1999), “EUGAS”, see Perner and Seeliger (2003) and the CPB European energy market model, see Kingma et. al (2002).

The rest of our paper is organized as follows: First, we will briefly go through the main features of the model used. Next we elaborate on the different supply scenarios studied in the model simulations. Then we present and discuss the main model results, followed by a short conclusion.

2. The model

The model we use is the static numerical partial equilibrium model of a liberalised Western European energy market (LIBEMOD), see Aune et al. (2001, 2004). The model is calibrated to the base year, 1996. 13 model countries (Austria, Belgium [including Luxembourg], Denmark, Finland, France, Germany, Great Britain, Italy, Netherlands, Norway, Spain, Sweden and Switzerland) are producing, trading and consuming four energy goods; oil, natural gas, coal and electricity. Investments in power stations and transport facilities for natural gas and electricity are based on cost-benefit evaluations. There are global markets for oil and coal, and natural gas can be imported from countries outside the model region. All energy prices are endogenously determined within the model. The model allows us to look at natural gas both as an input in electricity production and as a competing fuel in end-user markets. This is an important feature of the model as the expected demand for natural gas in Europe is closely tied to new power generation plants, making these two markets highly integrated. Hence, inter-fuel competition in power generation is highly relevant to discuss, as the marginal input fuel will influence potential changes in natural gas producer prices between the scenarios. The model is static, and provides one unique solution for the solution year, here 2010, for given exogenous input parameters. Hence, in this paper we use long-run elasticities in both demand and supply as input for a unique solution of endogenous variables in 2010.

We assume a perfectly liberalised and deregulated market for natural gas and electricity. This means that there is no regulative authority that restricts or manipulates production or investment decisions in any way. Nor are there transport companies that make excessive profits from being the sole connection between producers and end-user markets. Environmental restrictions, such as the Kyoto protocol emission goals, are not implemented in the model scenarios in this study. In the production sectors perfect competition prevail. Thus both production and transport of natural gas and electricity as well as new infrastructure investments are endogenous. Electricity can be produced through various technologies; gas power, oil power, coal power, pumped storage power, reservoir hydro power, nuclear power, waste power and renewables. However, some technologies are not available for all countries. We assume that no investments in new nuclear power capacities will occur. Hence base year nuclear power production capacity is gradually phased out through depreciation. By 2010, 62% of the 1996 nuclear power production capacity is still in use.

Each natural gas supplying model country has a marginal cost function that endogenously determines its respective long run natural gas production. For the large producers, UK, Norway and the Netherlands, the cost functions are estimations based on individual field data. The maximum production levels for these countries are only constrained by assumed national limits to produce due to the physical resource base or assumed national strategic decisions in 2010. Thus any constraint and strategic behavior is exogenously modeled and will consequently affect the model results by design. All constraints except one[1] relate to capacities in transportation or production of natural gas and will be explained in relation to the scenario presentations.

Apart from the model countries´ production, natural gas may also be imported from countries outside the model region. Historically important sources of gas outside Western Europe have primarily been pipeline gas and LNG from Algeria and Russian pipeline gas primarily from their massive sources in Western Siberia. In this analysis we also include pipeline gas from Libya and LNG imports from Qatar, Egypt, Nigeria, Trinidad & Tobago and a Rest of Middle East region. Export volumes in 2010 from all non-model countries are based on data from various sources and are exogenous in the model. Different assumptions of Russian and total LNG export capacities will be studied in the scenarios in this paper. We will highlight the effects that the different model supply scenarios have on natural gas trade patterns, choice of transport method, producer and end-user prices and inter fuel competition in power generation.

In all the scenarios, initial transmission capacities from major producing countries equal documented or assumed pipeline capacities in 2003 including transmission lines where investment decisions are made and work are in progress, see table 1. For LNG, initial capacities are determined by 2003 capacities in existing European receiving terminals including capacities in progress. Additional LNG and pipeline capacities are exogenously determined for every supply scenario, while the destination of new capacity (including LNG import terminals) is determined in the model on a least cost basis. In the model we simplify the cost structure of regasification by letting all model countries have equal costs, thus the destination of additional LNG is decided by distance and market conditions in general.

Pipeline costs are based on separate offshore and onshore unit costs and distance to market, while each LNG producer has a separate cost structure determined by production costs, liquefaction costs, shipping costs and regasification costs in the receiving countries. LNG export volumes other than Algerian LNG are presented as one sales unit in the results section since country specific import volumes are of more interest for our study than where the LNG comes from. In an assumed global LNG market, with a substantial share of short term trading, the source of the LNG will nevertheless be

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[1] The last constraint concerns gas fired electricity production in Norway, which is restricted in the model mainly due to national specific political barriers regarding environmental matters as Norway so far has relied solely on its clean hydro power resources.

highly speculative on a year-to-year basis. Thus the total LNG volume shifts in the model scenarios will be exogenously allocated to LNG suppliers according to their geographical location and assumed total export capacity in 2010.

3. Model scenario descriptions

We now present our assumptions for the four different supply scenarios. The motivation behind the scenarios is the uncertainties that are related to future Russian export capacities and the development of the LNG business towards 2010. We model a high supply case and a low supply case for both gas supply sources as well as combinations of low supply from Russia and high supply for the LNG sector and vice versa. For other major producing countries, including Algerian pipeline exports, production capacities are fixed at an assumed base level for 2010. We will elaborate on these base levels later.

Table 1 presents the variable input volume numbers, which form the basis of our four scenarios. The assumed high/low scenario volumes are displayed along with initial model transmission capacities and actual 2002 export volumes from the respective countries. The high and low scenario volume numbers are based on OME[2] (2002) natural gas export scenarios for Russian exports, the OSC[3] (2000) export scenarios for the LNG business and our own considerations.

Table 1: Exogenous gas supply scenarios and initial transmission capacities to the model countries (bcm[4])

	2010 production / export capacity	Initial transmission capacity to model countries	Actual 2002 production / export to model countries
Russia export	High: 125 Low: 91	86	73.5
Non Algeria LNG export	High: 53 Low: 27	44 Belgium (5.5) France (11.5) Spain (19.5) Italy (7.5)	11.7
Algeria LNG export	High: 29 Low: 23		21.6

Source: Various sources, BP Amoco (2003)

We see from table 1 that between the high supply and the low supply scenario there is a 66 bcm variation in natural gas exports headed for the model countries in 2010. This is roughly 17% of the total demand for natural gas in Western Europe in 2002. This volume variation is almost evenly divided between Russian supply and total LNG supply. Hence the two combinations of high and low

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[2] Observatoire Mediterraneen de L`Energie

[3] Ocean Shipping Consultants

supply create similar total volume numbers. This provides us with the options of analyzing the effects of changing either Russian or LNG supply while fixing the other at a high or low level as well as the effects of changing both Russian and LNG supplies with the total supply kept at an almost constant level. Thus we may investigate the importance of the supply source for European natural gas price levels and intra regional trade patterns.

Regarding scenario realism, we believe there is more support for a high Russian supply case than a high LNG supply case. A reason for this is that the potential growth in the LNG business is fragile and more dependent on world market factors and future unit cost reductions. Russia is well established as a major exporter of natural gas to Western Europe and several concrete plans for export expansions are currently being discussed. Thus, high Russian supply together with low LNG supply may in this paper be the most realistic scenario while the opposite scenario may be the least realistic one. However, the realism of each scenario will not be elaborated further in the discussions as we want to focus on the effects from radical changes in the natural gas supply situation for Western Europe in general.

Russian natural gas exports

As a baseline for new investments we assume that Russia operates a total annual transmission capacity of 86 bcm to the model countries. This is 12.5 bcm above actual exports to the same countries in 2002. In this baseline we assume that the aging transit capacity through Ukraine is kept at constant historical levels of around 110 bcm annually to Central and Western European countries, see Opitz and von Hirschhausen (2000). Of this volume a capacity of around 65 bcm is bound for the model countries, Germany and Austria respectively, which also act as transit countries for other West European countries. The residual initial annual capacity of 21 bcm (cf. table 1) goes to Finland (5 bcm) and to Germany through the Yamal-Europe pipeline transiting Belarus and Poland.

In the high supply scenario we assume that the Russian government manages to attract enough financial capital to meet its investment and export targets in 2010. This will most likely be as a result of a partial deregulation of the domestic gas sector combined with a splitting of Gazprom in separate production and transportation units. Particularly third party access to Russian domestic infrastructure and increased domestic end-user prices through deregulation will stimulate production from independent (domestic and foreign) producers and improve the financial ability to reach the huge investment level required. Alternatively Russia may further develop their relations with the gas producing CIS countries Turkmenistan and Kazakhstan. As Russia presently control both countries´

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[4] Billion cubic meters

export connections to western markets it may be more efficient to buy CIS gas as a replacement for expensive developments of new domestic gas fields in Western Siberia or the Barents region. Nevertheless, a major task for Russia is to maintain and develop pipeline capacities for its Western European markets.

In addition to the initial annual export capacity level of 86 bcm we assume another 39 bcm of Russian gas to be directed to the model countries in 2010. Thus the Russian high export scenario of 125 bcm is 12 bcm higher than a 2010 maximum scenario presented in OME (2002). Optional new capacity lines may be an expansion of the Yamal-Europe pipeline to Germany, a new direct sub-sea pipeline to Germany related to Barents Sea developments or direct pipelines to Italy via Balkan or Turkey. Particularly the Italy link may be more developed than earlier anticipated, e.g. in the OME study. In the high supply scenario we further assume political stability with respect to the Russian relationship with all transit countries, most importantly Ukraine, Belarus, Turkey and the Balkan countries.

In the low supply scenario we assume stagnation both in Russian supplies and LNG supplies to Western Europe. In this scenario we assume that Russia manages to raise exports only 5 bcm above the present level of transport capacity, and 34 bcm below the high supply capacity. Problems with the deregulation of domestic markets, political instability and disputes with transit countries may all cause the lack of investment that will slow down Russian natural gas exports.

LNG exports

The baseline LNG supply and import capacity totals 44 bcm per year, of which Spain and France hold the majority of the initial import capacity. Thus excess capacity in Western European LNG terminals reaches almost 11 bcm when compared with 2002 export levels. The initial capacity of LNG towards Europe reflects existing capacities and capacities in progress for the relevant model countries, see table 1. This means that all additional capacity above the initial 44 bcm requires investments in new regasification facilities.

In the high supply scenario we assume a significant growth in the LNG import volumes to Western Europe, particularly from new suppliers and distant sources. Of a potential global LNG production capacity of 300-350 bcm in 2010, we believe that a maximum of 82 bcm will be shipped to Western European markets. This is a 38 bcm increase from initial import capacity levels and nearly 50 bcm above the actual traded volume in 2002, of which a vast majority will come from distant sources. This is also a more optimistic scenario compared with the prospects presented in the OSC study as they assume a maximum LNG export of 72 bcm in 2010.

During the 1990´s the LNG business went through rapid change as unit capital costs for liquefaction fell by around 50% compared to earlier decades, accompanied by a radical improvement in safety standard. A significant fall in delivery prices for new LNG vessels in the late 1990´s has further contributed to make LNG more competitive in traditionally pipeline-based natural gas markets. In the high scenario we assume that this trend will continue towards 2010. Increased competition between producers of different technologies and scale advantages are believed to be the main drivers for further cost reductions in the liquefaction process, see Greaker and Sagen (2004a). For LNG vessels scale advantages, together with technology and productivity improvements, are expected to be crucial for further price reductions, see Greaker and Sagen (2004b). Furthermore, in the high supply scenario we expect LNG to be a commodity traded in a liquid global marketplace and that planned LNG production facilities in particularly Middle East countries, Nigeria and Egypt will reach the production phase before the end of the decade.

In the low supply scenario we assume that only a fraction of the LNG plants currently in the planning stages will come forward by 2010. In the model simulations we reduce the total supply of LNG to Western Europe by 32 bcm, to 50 bcm, compared with the high supply level, thus adding only 6 bcm to the initial LNG import capacity as shown in table 1. The volume gap between high and low LNG supplies is similar to the scenarios presented in the OSC study. The volume reduction is more or less evenly distributed on each LNG producer, which means that the new and small suppliers are expected to be relatively worse hit by a general slowdown in the LNG business than the big established ones, e.g. Algeria. Stagnating technological developments and cost reductions, lack of investments from the multinational oil companies and political turmoil may all cause a general slowdown in the currently fast growing LNG business. In addition we may experience a situation where LNG is attracted to other parts of the world at persistently higher prices.

Natural gas production in other countries

Norwegian production of natural gas is commonly expected to boost towards 2010 when new fields such as Ormen Lange, Kristin, Kvitebjorn and Snohvit reach their production phases. We assume a total base level production capacity of 100 bcm in 2010, which is roughly in line with both governmental targets and independent estimates, see OED (2003) and OME (2002). Norway already has in place potential annual pipeline capacity to export markets of around 90 bcm, of which roughly 50 bcm goes to Germany, splitting the rest in fairly similar volumes to France, Belgium and the UK, see OED (2003) and Statoil[5]. Current plans of building a direct pipeline to transport Ormen Lange gas to UK markets is thus not included in the model as this project has neither reached the construction phases nor final governmental approval, see Norsk Hydro[6].

The annual UK natural gas production level is expected to decline considerably towards 2010 due to sharply increasing costs of production from depleting fields. Wood MacKenzie (2001) estimates a base level UK natural gas production of around 70 bcm in 2010. We assume that the UK will have a resource base that allows for a maximum 90 bcm of production in 2010. Moreover, the UK cost function is calibrated with the intention that UK gas production will exceed 70 bcm at 2002 price levels. Natural gas production in the Netherlands is assumed to follow a constant volume level in line with the present national depletion policy. Current policy argues that small fields should be extracted first whenever feasible, while not exceeding a total depletion per annum above 3-4% of its reserves, see NAM (2001). The maximum level of Dutch natural gas supplies is set to 72 bcm in 2010, which is similar to the results of other studies, see Kingma et.al (2002). Export transmission capacities for the Netherlands and the UK will not be discussed further in this paper. In the model the majority of both countries´ pipeline capacity serves their respective domestic markets and will not have an influence on the results as long as there are excess capacities in both domestic and export pipelines. The UK is modeled with an initial annual import capacity of 20 bcm through the Interconnector[7], equal to today's capacity towards the continent, as new compressors will be installed between 2005 and 2008.

For Algerian pipelines, we assume fixed supply capacities in 2010 in all the scenarios. We assume that Algeria invests in additional annual pipeline capacities of 12 bcm, adding to the initial pipelines that in the model supply Italy and Spain with up to 27.5 bcm and 15.5 bcm respectively. There are presently talks of two new direct pipelines, one from Algeria to Italy via Sardinia and Corsica and one to Spain, bypassing Tunisia and Morocco as transit countries respectively. However, the destination of all new transport capacities is decided endogenously in the model through cost-benefit analysis.

Libya is the last gas exporting country that is modeled with a constant baseline export volume to Europe in all the scenarios. We assume Libya to have in place an 8 bcm per year sub sea direct pipeline to Italy by 2010.

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[5] http://www.statoil.com/STATOILCOM/SVG00990.nsf?opendatabase&lang=en&artid=75C210A3B645C1354125665D004AFF77

[6] http://www.hydro.com/en/press_room/news/archive/2004_01/ol_progress_en.html

[7] http://www.interconnector.com/Enhancement/Project.htm

4. Results and discussion

In this section we present the main model results of the four scenarios. In the discussions below we will see how different supply patterns will affect Western European natural gas markets in the medium term. Our purpose is to question the stability and level of European natural gas prices and trade patterns when gas supply changes substantially. Furthermore, it is important to note that the model provides long-run solutions, i.e. for every exogenous change in supply volumes between the scenarios the response by model countries are due to long term decision making, both regarding new investments in production facilities and infrastructure as well as adjustments on the demand side. Hence, in the short term, similar supply variations would give larger effects on natural gas producer prices than we show below.

In the discussions we will first elaborate on the supply side. Next we will go through the demand side, before analyzing possible changes in trade patterns and market structure between the scenarios. In the tables below, the letters H and L symbolize the high and low supply scenarios respectively, while the combinations HL and LH symbolize the middle scenarios where Russian natural gas production is represented by the first letter. To understand variations in natural gas prices, demand and trade patterns, it is important to compare these results with possible variations in electricity demand and trading. In view of the fact that the model deals with inter fuel substitution, we will thus investigate whether the model results support the common belief that the future growth in natural gas demand primarily will be driven by gas fired power generation.

Producer behavior

In a competitive market, supply and producer prices are closely linked together as a producer will increase its production to the point where marginal costs equal the price to the producer or a potential production capacity limit is reached. Similarly a gas pipeline owner will continue to transport natural gas to a third country to the point where its marginal costs of buying and transporting the gas equals their marginal sales income (i.e. the producer price in the third country) or the capacity of the pipeline is fully utilized. Table 2 and 3 show natural gas supply and natural gas producer prices respectively for each of the four supply scenarios, along with historical data for 2002, collected from BP Amoco (2003) and WGI (2002). From table 2 we see that changes in exogenous production explain most of the variation in total natural gas production. Compared with the 2002 production level of 270 bcm from model countries and 134 bcm in total imports from non model countries, we notice that total production in the model countries remain fairly stable at the end of the decade for all of the scenarios. Norwegian production growth and British cutbacks seem to be the main reason for this finding.

Moreover, this means that the overall growth in gas supply aimed for Western Europe towards 2010 has to come from external sources. The high and low supply scenarios give an increase in total production of 146 bcm and 86 bcm respectively compared with 2002 production levels. This makes the Western European import share rise from 33% in 2002 to almost 50% in the high supply scenario and over 40% in the low supply scenario. This is in line with the estimations provided by Eurogas (2003), who expects a 45% import share for Western Europe in 2010.

Table 2: Historical and model scenario natural gas production by 2010 (bcm per year)

	2002	H	L	HL	LH
Norway	65.4	98.0	98.4	98.1	98.1
The Netherlands	59.9	71.8	71.9	71.9	71.9
UK	103,1	76.5	79.0	77.5	77.4
Other endog production	40,9	33.7	36.2	34.7	34.4
Exogenous production	134	270.0	204.0	238.0	236.0
Total production	403.3	550.0	489.5	520.2	517.8

HL = Russia high and LNG low, LH = Russia low and LNG high.

We observe from table 2 that only UK of the big European natural gas producers is responding noticeably to swings in Russian and LNG exports. But even for the UK the difference between H and L is only 3%. A less steep supply cost curve in UK natural gas production, compared to Norway and the Netherlands in particular, forces UK to cut production slightly more when producer prices are falling. Both Norway and the Netherlands produce close to their capacity limit given in the model, hence the producer price variation has not a significant impact on their supply decisions. Consequently, in neither of the scenarios producer prices get so low as to be a major barrier for Norwegian and Dutch natural gas production. Table 3 displays, along with historical 2002 observations, variations in producer prices for key countries within the Western European region for all the scenarios, as well as variations in the average producer price covering all model countries.

Table 3: Natural gas producer prices for the model countries by 2010 (USD/Mbtu[8])

	2002*	H	L	HL	LH
Norway	2,52**	2,86	3,00	2,91	2,91
The Netherlands	2,83	2,97	3,15	3,02	3,01
UK	2,69	3,21	3,42	3,29	3,28
Germany	2,76	2,93	3,12	2,98	2,98
Finland	-	3,02	3,79	3,14	3,63
Belgium	3,40***	3,07	3,25	3,12	3,11
France	2,95	3,00	3,21	3,08	3,07
Austria	-	2,81	3,18	2,92	3,03
Italy	2,95	3,02	3,25	3,14	3,09
Spain	3,30	2,79	2,99	2,86	2,85
Average	3,05	3,05	3,27	3,13	3,13

HL = Russia high and LNG low, LH = Russia low and LNG high.

* Border price estimates. Source: World Gas Intelligence, various issues 2002.

** Average price to producer excluding average transport costs.

*** Excluding imports from UK.

We see that when both Russia and the LNG producers operate with low export volumes, the average producer price increases by 7.2 % to 3.3 USD/Mbtu compared with the high supply scenario. We also notice that when only Russia or the LNG-producers supply at high volumes the model gives identical average producer prices. Thus the average price of natural gas in Western Europe is only moderately affected by significant swings in aggregate supply and shows negligible response when we compare effects from relative changes in Russian gas exports only, with similar changes in LNG exports only.

Compared with the historical average EU border prices the last 15 years, we see from the model results that it is doubtful whether average EU natural gas producer prices will go markedly below these price levels in a fully liberalised 2010 marketplace. Only when the price of oil went close to or above USD 30/bbl in 2000, did we see Western European border prices go well above USD 3.0/Mbtu, see Favennec (2002). When we compare the results with the price on natural gas in the already completely deregulated UK market the picture is even clearer. The UK National Balance Point five year average price from 1998-2002 was 2.4 USD/Mbtu, see BP Amoco (2003). Hence, UK in

[8] Million British Thermal Units

particular is likely to experience increasing natural gas prices towards 2010, independent of the overall European supply situation.

For LNG deliveries, the average EU c.i.f.[9] five year average price from 1998-2002 was 3,0 USD/Mbtu, see BP Amoco (2003). If producer prices go well below 3.0 USD/Mbtu it is doubtful whether the European market will attract large volumes of LNG from distant sources, particularly the Middle East countries, as prices will approach total LNG-chain cost levels. Thus, for sufficiently low prices we may find a situation where distant LNG producers earn more money by selling their gas in Asian or American markets.

The producer price variations between our scenarios are relatively small compared with the assumed price variations presented in other studies, e.g. the IEA World Energy Outlook (2001). Both the IEA reference scenario and the low case scenario for the average European import price in 2010 is 2.5 USD/Mbtu, while in the high case scenario the price is 3.4 USD/Mbtu. In the IEA study however, prices are exogenously determined to investigate possible effects on global production of natural gas. Many of the arguments behind the IEA price scenarios are similar to the arguments that underlie the supply scenarios in this study. The main difference seems to be that IEA uses various assumptions about the oil price as the main driver for the price level of natural gas, while in our model the oil price is endogenously determined. Hence, in the IEA study the traditional oil price link is assumed to sustain and only the low price scenario seems to incorporate a high degree of gas-to-gas competition. Interestingly we observe that even the high supply price level in our fully liberalised market place is closer to the assumed IEA high price case than the low price case.

In our study, the level of the oil price is of less importance for the results. In an alternative simulation, not to be discussed further in this paper, we reduced the overall supply of oil significantly, which lead to radically higher oil prices. However, the effects on both natural gas prices and demand was only marginal. This is explained by only moderate substitution between oil and other energy goods in final demand and electricity production. Particularly in power generation, natural gas and coal seem to be the marginal sources of energy input. Low cross-price elasticities make the demand for- and price of oil only marginally affected by radical changes in gas supply volumes.

Despite small differences in average prices between the scenarios, table 3 shows some significant country-specific differences in the price responsiveness to supply changes. The model results show

[9] Cost included freight.

that Italy, Austria, Switzerland[10] and Finland in particular differ from the other countries when it comes to price changes between the scenarios. In most other countries producer prices increase moderately below average, with Norway having the lowest price increase (4.9 %).

It is, however, when we compare the medium scenarios that we see the most interesting differences in price changes between the model countries. High Russian export volumes coupled with low LNG exports give, with Austria, Finland and Italy as the only exceptions, negligible price reductions when compared with the vice versa scenario. In Austria and Finland prices actually increase by 3.7 and 15.7 % respectively. In general, relative changes in LNG export volumes seem to have the strongest effects on natural gas producer prices in most countries and Italy in particular, although these effects are modest. On the contrary, Austria and Finland in particular are by far most influenced by changes in Russian exports.

To find the rationale behind these findings we think it is relevant to separate supply driven effects from the demand driven effects. Some countries, in particular Finland because of their geographical closeness to Russian export pipelines, are very dependent on one single source of natural gas. Hence, when Russia has problems with their natural gas deliveries, Finland has to find other and more expensive sources of gas when there are no alternative energy sources available. Likewise, Austria seems to be more dependent on Russian gas because of their relative closeness to Russian pipelines compared with LNG terminals or other major pipelines. To attract gas towards domestic markets the choice is between building pipelines from neighbor countries or, for countries with a coastline, to invest in LNG import facilities and compete for the given amount of LNG exports. Alternatively, if the gas is used for power generation it may be an option to invest in power transmission lines for electricity imports or use alternative inputs in domestic power production. In the case of Finland we will see that imports of LNG are the optimal solution when Russian exports fall short. Thus the increase in producer prices in Finland according to table 4 is supply driven in the sense that imports are more expensive due to long distance trading. Demand driven effects are here primarily connected to the substitutability of natural gas when gas prices rise. Particularly the possibilities of inter-fuel substitution in domestic power generation or access to cheap electricity imports are expected to be vital for a single country's ability to handle increasing natural gas prices[11]. Thus we expect countries

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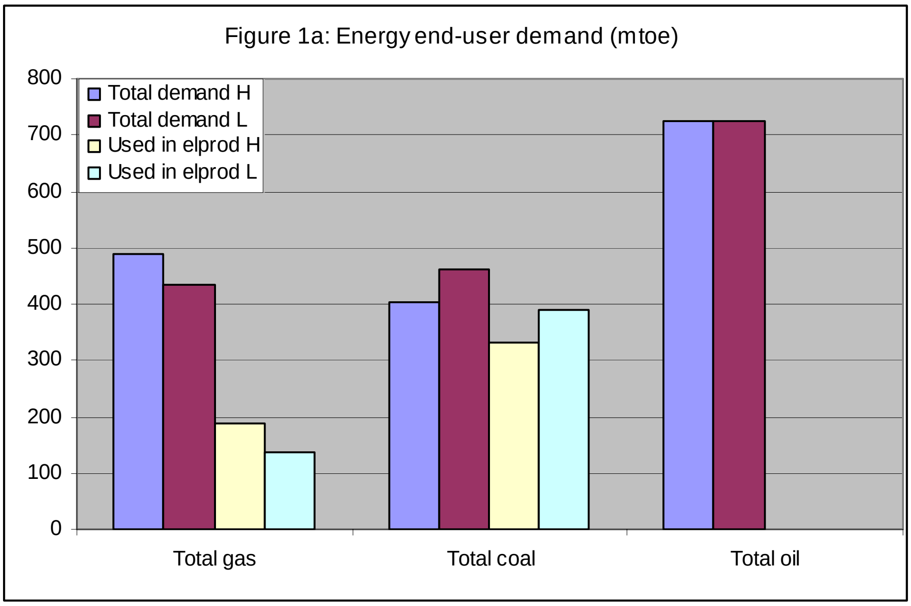
[10] Switzerland is omitted from table 2, 3 and most of the discussion below as it's national market is small and it's reaction pattern for all the relevant variables is close to and a direct cause of changes in Austria for all the scenarios.

[11] Finland has announced plans to build a large nuclear power production facility with start-up in 2009. This is not taken care of in our study, however, as we exclude all new nuclear power capacity in our model simulations. Still this is interesting as Finland seems to be vulnerable for changes in gas supplies in the future.

that lack this capability to be worse hit by negative supply shocks even in the long term, as they have to pay more to secure their needs of gas. Conversely we also expect countries with the ability to switch to gas, or where the marginal input in power generation is already gas, to gain more from positive supply shocks in a competitive market and thus increased gas to gas competition.

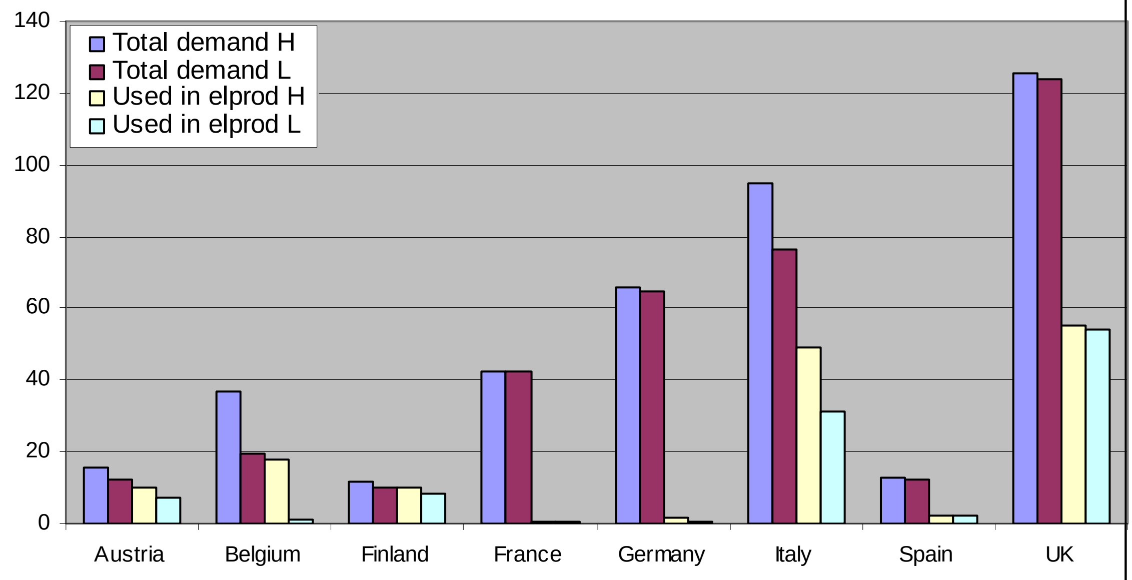
End-user behaviour

In this section we will elaborate on the demand side of the model results. We will in particular focus on changes in natural gas demand- and end-user price changes between the high and low supply scenarios. We also discuss changes in electricity end-user prices between countries, mainly to elaborate on the relationship between power generation and natural gas demand. Figure 1(a,b) displays aggregate volume- and country-specific changes in low supply scenario end-user demand with the high supply scenario as the reference[12]. As we compare natural gas demand with other energy goods demand volumes is in mtoe[13].



[12] Tables displaying the medium scenario results are in the appendix.
[13] Million tons of oil equivalents.

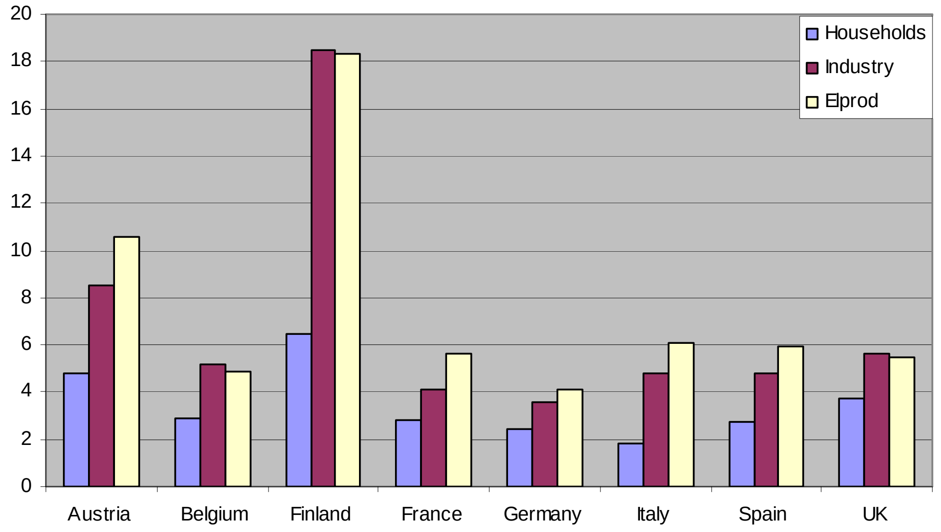
Figure 1b: Natural gas end-user demand (mtoe)

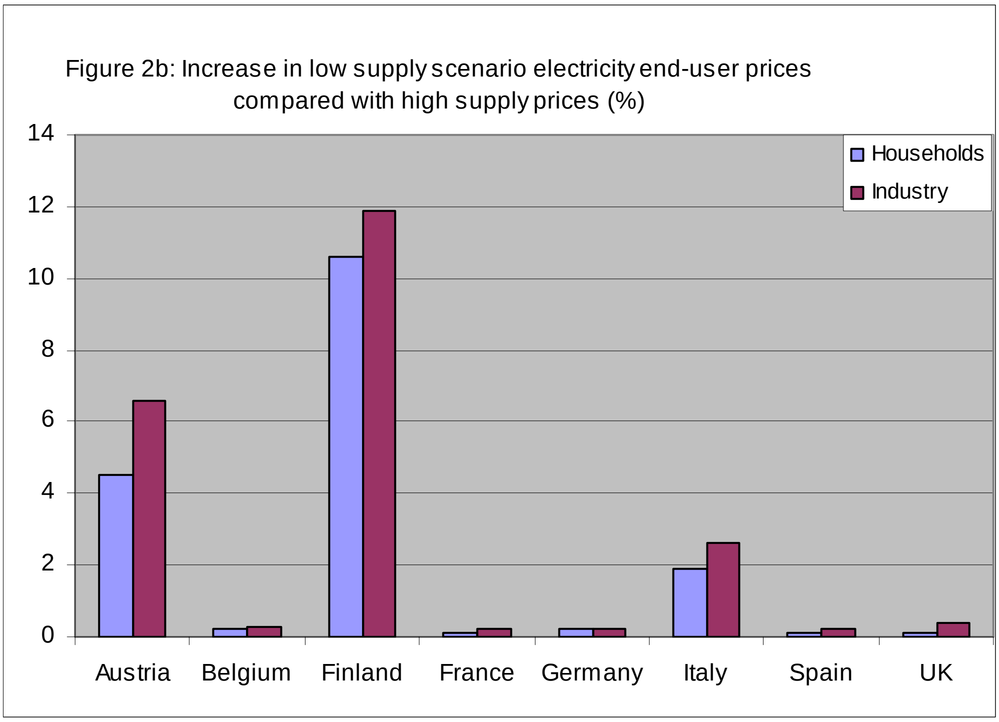


From figure 1(a) we notice that compared with the 2002 natural gas demand of roughly 350 mtoe, total demand in Western Europe increases significantly in all scenarios for 2010. The growth is primarily driven by UK and Italy, where demand for gas grows in all sectors with power generation occupying most of the volume. In the high supply scenario, Finland, Belgium and Austria also increase their total gas demand from current levels considerably. However, these countries primarily use their growth in natural gas demand for power generation only. For the rest of the countries in Western Europe the growth in natural gas demand is modest, or even negative for the case of Germany and Spain, when compared with current levels. With its relatively cheap access to domestic coal and the nuclear power phase-out in progress, particularly Germany will increase its reliance on coal as the primary fuel for power generation. Compared with the model base year, 1996, Germany has only 14% of its gas fired power production left in 2010 and no new generators will be built. This may be a controversial result as particularly environmental goals encourage the opposite development pattern. However, it may be vital for the results that our study does not include any emission restrictions towards 2010. The overall share of natural gas in power generation is at a highest 39% in the high supply scenario. This is well below the EU expectations of a natural gas share in power production above 45% by 2010, see EU (2000c). This difference is even bigger in the lower gas supply scenarios as the natural gas demand respond to producer price increases.

The obvious finding from figure 1(a,b) is that power generation is the swing sector when the supply of natural gas changes between the scenarios. Practically all of the reduction in natural gas demand corresponds to reduced gas fired power generation. Hence, as end-user prices of natural gas follow changes in producer prices, more countries use coal as the marginal input in power generation when gas prices rise. Consequently, as figure 1(a) shows, the total demand for coal is roughly inversely proportional to changes in natural gas demand. As a result the demand for- and the price of electricity, is basically unchanged on an aggregate level. There are however some interesting country-specific differences in both electricity- and natural gas end-user price changes, as shown in figure 2(a,b) below.

Figure 2a: Increase in low supply scenario gas end-user prices compared with high supply prices (%)





In Austria and Finland in particular, electricity end-user prices increase considerably more than in other countries when the supply of gas from Russia tightens. This is a direct result of these countries´ dependence on both Russian gas deliveries and gas fired power generation. As their marginal input fuel in power generation is gas, even after the gas price increase, this price increase is passed on to electricity prices through gas fired electricity production. On the contrary, e.g. Belgium has multiple natural gas import sources and also substitutes coal for gas in power generation when gas prices rise. Consequently Belgian end-user prices increase below average when gas supplies drop. In the high supply scenario, much of the electricity produced from gas in Belgium is exported to Germany. In the low supply scenario Belgium reduces this export and the electricity is replaced by German coal power production. Italy also reduces its demand for natural gas in power production in the low supply scenario and replaces its domestic power production with electricity imports from France. Consequently, in the low supply scenario, France increases its demand for coal used in power generation with almost 25% to serve Italian energy needs. However, Italy has good access to both LNG deliveries and Russian pipelines. Hence, Italian energy prices and the level of gas fired power generation remain fairly stable as long as either Russia or the LNG producers supply at high volumes. In table 4 we investigate to what extent the natural gas trade patterns changes when both the Russian and the LNG export levels drop compared to the high supply scenario[14].

[14] For the medium scenarios trade patterns and table explanations, see the appendix.

Table 4: Trade patterns for the high and low supply scenarios (bcm, from - to)

	Belgium		Nordic		France		Germany		Italy		Spain		UK		Austria + Switzerland		Total	
	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
Russia			12.8	6.8			58.5	58.5	3.6						47.5	23.8	122.4	89.1
LNG	5.4	5.4		4.1	15.6	12.7			28.6	8.6	19.6	18.8	12.7	0.7			82.0	50.3
Algeria pipe									26.3	38.8	28.1	15.6					54.4	54.4
Norway	12.7	12.7		0.1	16.3	16.3	51.2	51.5					11.7	11.7			91.9	92.3
Belgium													19.5	29.6			19.5	29.6
France	12.0												19.8	16.9			31.8	16.9
Germany	17.8	18.2	17.6	15.3	9.8	9.8				3.8					1.6	3.6	46.8	50.7
Spain					35.3	22.6											35.3	22.6
Austria							2.7		21.7	11.1					6.0		30.4	11.1
Netherland + other	12.5	15.4	1.5	1.5					8.0	8.0							22.0	24.9
Total	60.4	51.7	31.9	27.8	77.0	61.4	112.4	110.0	88.2	70.3	47.7	34.4	63.7	58.9	55.1	27.4	536.4	441.9

HL = Russia high and LNG low, LH = Russia low and LNG high.

Compared with current natural gas trade patterns, table 4 shows some noteworthy developments. First of all, from a producer's perspective, Norway turns out to be the only major exporter of natural gas within Western Europe. The Netherlands with their low production profile and expected growth in demand only exports moderate volumes to Belgium in each scenario, while the UK develops a net import of around 60 bcm in 2010. This huge need for UK natural gas imports forces UK to develop their pipeline connections to the continent and invest in new LNG terminals. Although not shown in the tables we also notice that even for the highest UK gas prices in the low supply scenario there are no investments in additional electricity import capacity from the continent. Hence we conclude that it is more cost efficient to produce electricity in UK from imported gas than to import the electricity directly from another country. Both Belgium through the existing "Interconnector" and France through new pipeline investments seem to be important transit countries for gas towards the British market in 2010. We assume that a significant part of the "French" gas will come from Algeria through Spain.

We further observe that UK will import significant volumes of LNG in most scenarios. Hence the proposed LNG terminals at the Isle of Grain and at Milford Haven in Wales may well be a reality.

The only exception is when both Russian and LNG exports drop, and particularly LNG is attracted to southern Europe. In this case the Zeebrugge-Bacton Interconnector is developed to handle yearly gas flows of around 30 bcm. Interestingly we also notice that Norway chooses not to build additional export capacities towards UK. This finding is in sharp contrast to the current Norwegian plans of building a 20-25 bcm direct pipeline related to the Ormen Lange gas field in the Norwegian Sea. The model results show that the optimal solution for Norway is to utilize their existing pipeline capacity towards their current trade partners and Germany in particular. However, as UK gas production declines, considerable spare pipeline capacities from their North Sea fields will be available for Norway's nearby fields. This may be a cost effective solution to additional UK imports of Norwegian gas and would probably alter the model results as this export option is not implemented in the model setup. However, dilemmas of difference in national taxations and pipeline owner rights are examples of obstacles for cross-border pipeline cooperation, see Pilot-Konkraft (2002).

As mentioned earlier we see that Finland chooses to import LNG when Russian exports are stagnating. This means that LNG imports will be a more cost effective solution to Finnish energy needs than both new gas pipeline- and power transmission investments from other nearby countries[15]. Germany, with its massive existing infrastructure network, will probably be a major and stable transit country for both Norwegian and Russian gas in the foreseeable future.

In the south of Europe we see that variations in both Russian and LNG exports cause major changes in the trade pattern for natural gas. With its fast growing domestic gas market and multiple sources of supply, Italy is the center of the shifts in trade patterns between the scenarios. Hence, when the level of both Russian and LNG exports are high, both parties develop huge additional capacities towards Italy with Austria as the major transit country for Russian gas. Russia also develops a direct pipeline capacity to Italy which reaches nearly 10 bcm when the supply of LNG is low. In the high supply scenario Algeria will direct all its new pipeline investments to the Spanish border, heading for markets further north. However, when either Russia or the LNG producers or both fail to reach their high supply stages, Algeria will choose the Italian market for their additional gas supplies. Thus it seems to be a race for Italian market shares towards 2010, and we may find that the gas exporter which arrives first in the market will turn out to be the winner. A high supply scenario with additional Algerian investments towards Italy already in place would probably force both Russian gas and LNG to other markets. There is also a certain danger that major strategic investments in new gas infrastructure will

[15] Again, we exclude future plans of Finnish nuclear power production from our model simulations.

cause substantial excess import capacity towards Italy. However, in our model this is not an optimal solution as investments are made through strict cost-benefit evaluations without any forward looking behavior.

Generally we see that changes in natural gas supplies from either Russia or the LNG producers cause major changes in trade patterns for primarily Italy and the UK. Between the medium scenarios only Italy experience dramatic changes in trade pattern as they switch between Russian gas and LNG. Russia, with its ability to reach both northern and southern European gas markets, seems to prevent an extensive north-south trade through central Europe in the medium scenarios.

5. Conclusion

The results from our study show that in a liberalised marketplace it is highly unlikely that Western Europe will experience average natural gas producer prices below 3.0 USD/Mbtu towards 2010, a price which is well above average historical levels. Even in an optimistic supply scenario for both Russian pipeline exports and LNG, average prices stay above 3.0 USD/Mbtu, however there are some country specific differences. For prices below 3.0 USD/Mbtu it is nevertheless highly uncertain that LNG from distant sources will flow to Europe in large volumes due to the relatively high cost-of-service in the LNG chain.

The changes in average natural gas producer prices are modest despite large changes in overall gas supply volumes. The main reason behind this finding may be that the total use of natural gas in power generation in 2010 is well below EU expectations. Coal is still the marginal input source in power generation for most Western European countries; hence the influence of gas-to-gas competition in reducing gas prices is not satisfactory utilized in an EU setting. We see that the most prominent country specific differences in both end-user- and producer price changes are a consequence of relying on gas in power generation combined with changes in natural gas trade patterns after supply shocks. The vulnerability of weakened security of supply may therefore be large if Western Europe becomes too dependent on natural gas, particularly in power generation.

As UK gas resources decline and the Netherlands continue their moderate production profile, Norway becomes the leading producer and the only major exporter of natural gas within Western Europe in 2010. This feature, combined with a total natural gas demand close to 500 mtoe at highest, make the Western European import share rise from 33% in 2002 to almost 50% in 2010. In a longer term, particularly if natural gas grows as a marginal input in power generation, the import dependency may even be substantially higher.

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Appendix:

Key results from model simulations

Table A1: Differences in end-user demand compared with high supply scenario (mtoe)

	H		L		HL		LH	
	Total demand	Used in elprod	Total demand	Used in elprod	Total demand	Used in elprod	Total demand	Used in elprod
Austria gas	15.4	10.2	-3.2	-3.1	-1.6	-1.6	-2.2	-2.2
Belgium gas	36.6	18.1	-17.1	-17.0	-16.7	-16.6	-16.7	-16.6
Finland gas	11.6	9.8	-1.8	-1.7	-0.5	-0.5	-1.7	-1.6
France gas	42.5	0.7	-0.3	-0.0	-0.1	-0.0	-0.1	-0.0
Germany gas	66.0	1.6	-1.5	-1.0	-0.4	-0.3	-0.4	-0.2
Italy gas	95.0	49.3	-18.5	-18.3	-1.3	-1.2	-0.5	-0.4
Spain gas	12.7	2.5	-0.2	-0.0	-0.1	-0.0	-0.1	-0.0
UK gas	125.7	55.3	-1.9	-1.0	-0.7	-0.4	-0.4	-0.3
Total gas	487.5	188.0	-52.8	-50.0	-26.1	-25.1	-27.7	-26.7
Total coal	404.3	333.2	56.9	56.9	28.9	28.9	30.6	30.6
Total oil	724.4	0.7	-0.2	0.7	-0.1	0.7	-0.1	0.7
Total electricity	301.4	0.8	-0.6	0.5	-0.3	0.2	-0.4	0.1

HL = Russia high and LNG low, LH = Russia low and LNG high.

Table A2: Changes in end user prises compared to the high supply scenario

	L			HL			LH		
	House-holds	Industry	Elprod.	House-holds	Industry	Elprod.	House-holds	Industry	Elprod.
Austria gas	4.8	8.5	10.6	1.4	2.6	3.2	2.8	5.2	6.2
Austria el	4.5	6.6	-	1.2	1.8	-	2.6	3.8	-
Belgium gas	2.9	5.2	4.9	0.8	1.5	1.4	0.7	1.3	1.2
Belgium el	0.2	0.3	-	0.1	0.2	-	0.1	0.2	-
Finland gas	6.5	18.5	18.3	1.0	2.8	2.7	5.2	15.0	14.8
Finland el	10.6	11.9	-	1.6	1.8	-	8.6	9.7	-
France gas	2.8	4.1	5.6	1.0	1.5	2.1	0.9	1.4	1.9
France el	0.1	0.2	0.3	0.1	0.1	0.2	0.1	0.1	0.2
Germany gas	2.4	3.6	4.1	0.7	1.0	1.2	0.6	0.9	1.0
Germany el	0.2	0.2	-	0.1	0.1	-	0.1	0.1	-
Italy gas	1.8	4.8	6.1	0.9	2.4	3.0	0.5	1.5	1.9
Italy el	1.9	2.6	-	0.9	1.3	-	0.6	0.8	-
Spain gas	2.7	4.8	5.9	1.0	1.8	2.2	0.9	1.6	1.9
Spain el	0.1	0.2	-	0.1	0.1	-	0.1	0.1	-
UK gas	3.7	5.6	5.5	1.3	2.1	2.0	1.2	1.9	1.8
UK el	0.1	0.4	-	0.1	0.2	-	0.1	0.2	-
Average gas	2.8	4.8	7.2	1.0	1.7	2.5	0.8	1.6	2.9
Average el	1.3	1.9	-	0.5	0.7	-	0.6	0.9	-

HL = Russia high and LNG low, LH = Russia low and LNG high.

Table A3: Trade patterns for the medium supply scenarios (bcm, from - to)

	Belgium		Nordic		France		Germany		Italy		Spain		UK		Austria + Switzerland		Total	
	HL	LH	HL	LH	HL	LH	HL	LH	HL	LH	HL	LH	HL	LH	HL	LH	HL	LH
Russia			12.3	6.7			58.5	58.5	9.1						42.5	23.8	122.4	89.0
LNG	5.4	5.4		4.2	12.7	12.7			8.6	31.6	18.8	19.6	4.9	8.5			50.4	82.0
Algeria pipe									38.8	38.2	15.6	16.3					54.4	54.5
Norway	12.7	12.7		0.1	16.3	16.3	51.3	51.3					11.7	11.7			92.0	92.1
Belgium													28.9	24.0			28.9	24.0
France													16.5	17.8			16.5	17.8
Germany	18.2	13.3	16.3	18.5	9.8	9.8				3.8					1.6	3.3	45.9	48.7
Spain					22.4	23.8											22.4	23.8
Austria							0.9		21.7	9.7					4.7		27.3	9.7
Netherland + other	15.2	15.2	1.5	1.5					8.0	8.0							24.7	24.7
Total	51.5	46.6	30.1	31.0	60.2	61.6	110.7	109.8	86.2	91.3	34.4	35.9	62.0	62.0	48.8	27.1	484.0	466.3

HL = Russia high and LNG low, LH = Russia low and LNG high.

In the last column from the left in table A3, we see the total volume of gas flowing from each respective country to its trade partners in each scenario. Hence for the producing countries, total volumes in the tables express the actual amount of gas traded. The difference from Russian supply volumes are thus loss during transport, while for Norway the difference also corresponds to domestic use. The bottom row displays the total amount of gas flowing to each respective country in each scenario. The row labeled "Netherlands + other" also includes Denmark with exports to Sweden, and Libya with exports to Italy. In the column "Austria + Switzerland", Austria takes the entire amount of gas from Russia and most of the volume from Germany in all scenarios. In the column labeled "Nordic", Finland takes the entire amount of both Russian and LNG exports, Denmark imports a negligible amount from Norway and Germany, while Swedish power production occupies most of the gas going from Germany to the "Nordic" countries in the tables.

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