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Perspectives of the European Natural Gas Markets until 2025

Franziska Holz, Christian von Hirschhausen, Claudia Kemfert

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Perspectives of the European Natural Gas Markets until 2025

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Abstract

We apply the EMF 23 study design to simulate the effects of the reference case and the scenarios to European natural gas supplies to 2025. We use GASMOD, a strategic several-layer model of European gas supply, consisting of upstream natural gas producers, traders in each consuming European country (or region), and final demand. Our model results suggest rather modest changes in the overall supply situation of natural gas to Europe, indicating that current worries about energy supply security issues may be overrated. LNG will likely increase its share of European natural gas imports in the future, Russia will not dominate the European imports (~ share of 1/3), the Middle East will continue to be a rather modest supplier, the UK is successfully converting from being a natural gas exporter to become a transit node for LNG towards continental Europe, and congested pipeline infrastructure, and in some cases LNG terminals, will remain a feature of the European gas markets, but less than in the current situation.

Keywords: natural gas, Europe, modeling, LNG, supply security

JEL Codes: L95, L13, F14

1 Introduction: The European Natural Gas Market

The European natural gas market lends itself particularly to the EMF 23 study design. It is in the middle of a deep structural change that comprises both, restructuring and vertical unbundling, as well as changing supply relations. Contrary to the reform process in the U.S., restructuring in continental Europe has only started seriously with the second European Gas Directive (2003/55/EC, so-called "Acceleration Directive") whereas the UK had started the reform of its natural gas sector in the early 1990s already. In continental Europe, a small number of players still dominate the national wholesale markets; vertical unbundling is pursued by most member states, though with varying degrees of success. The individual countries are poorly interconnected, and the limited access to pipeline capacity prevents liquid hubs from emerging.

The second aspect, supply structures, also plays an important role in the energy policy debate, and it is the focus of this paper. Europe is a relatively mature pipeline market, with a significant increase in LNG regasification capacity and imports over the last years (IEA (2004, 2007). In the next decades, the demand for natural gas is generally expected to rise, albeit with some uncertainty on the extent given new developments that may reduce the relative benefit of gas in environmental or cost terms (e.g. in competition with coal with CCS for power production). In institutional terms, European gas supplies are also undergoing the global trend from long-term contracts towards shorter-term trading and a more important role for spot markets. "Energy supply security" is a particularly sensitive issue in European gas, in particular with a view to the dominant supplier, Russia.

The issues mentioned have been covered in previous literature. Thus, several models have indicated that market power is indeed an issue in the European natural gas market, amongst them Boots et al. (2004), Egging and Gabriel (2006), and Egging et al. (2008). Smeers (2008) summarized and discussed the papers that develop strategic models of European gas supply. Hubert and Ikonnikova (2003) and Hubert and Suleymanova (2006) have focused on the specific role of Russia as a supplier to Europe, and the strategic role of transit countries such as Ukraine or Poland. OME (2001, 2005) have provided in-depth figures of potential prices and quantities of gas supply options for the EU. Stern (2007) provides a balanced discussion of the true "supply security" issues.

In this paper, we report simulation results for European natural gas supplies to 2025, following the EMF 23 study design (EMF, 2007). We apply a strategic model of European gas supply, called GASMOD, that was developed in the early phase of the EMF 23 study, and then slightly adopted to suit the requirements of the EMF 23 study design. The GASMOD model is described in detail in Holz et al. (2008), and therefore will not be presented in detail in this paper. Instead, we focus on the results of GASMOD with regard to the EMF 23 Reference case, and most of the EMF 23 scenarios (see EMF, 2007, p. 30). The next section provides a non-technical model description and discusses data sources and assumptions. Section 3 then summarizes the model results for the EMF Reference case, and five scenarios: higher demand growth, Russian exports constrained, Middle East exports constrained, Middle East & Russian exports constrained, and liquefaction constrained. We put particular emphasis on the future role of Russia, potential alternative supply sources, and model results for the UK market in transition.

In general, our results suggest rather modest changes in the overall supply situation of natural gas to Europe. This also indicates that current worries about energy supply security issues may be overrated:

- LNG will likely increase its share of European natural gas imports in the future, but stay relatively stable beyond 2015;
- Russia will continue to play an important role as a supplier to Europe (~ 1/3 of imports), but it will not play the dominant role that many studies (and politicians) suggest it might play;
- In the time frame of our analysis (2025), the Middle East will continue to be a rather modest supplier, and its exports are more likely to be directed to the Asian and the North American markets;
- The UK is in the process of successfully converting from being a natural gas exporter to become an importer and a transit node for LNG towards continental Europe;
- Congested pipeline infrastructure, and in some cases LNG terminals, will remain a feature of the European gas markets, but less than in the current situation;
- The diversification of natural gas supplies, already observed in this decade, should continue and contribute to supply security.

2 The GASMOD Model: Model Description and Data Specification

The model used is a modified version of the static GASMOD model. It corresponds to the description by Holz et al. (2008), except for the regional and technology aggregation (pipeline vs. LNG), the demand function, the time frame and the market power assumptions for certain countries.

GASMOD is a model of the European natural gas trade on a yearly basis.[1] It is programmed in GAMS in the mixed complementarity format and solved using the PATH solver (Ferris and Munson, 2000). We include data for all relevant exporters to Europe, which can supply pipeline gas and/or LNG (Table 1). An exporter can use both technologies simultaneously, but each technology is modeled as a separate player, contrary to Holz et al. (2008) where both technologies were aggregated to one player per country. The importing market in Europe is represented by a disaggregated representation of continental Europe, assuming one wholesale company (marketer) per country that can import from both technologies. Figure 1 shows the structure of the model, exemplified by two exporters (Russia by pipeline and Algeria by LNG) and two European markets (Germany and France), with imports and wholesale trade between each other. European importers are detailed in Table 1 with their import technologies in 2025. In addition, we include the possibility for endogenous domestic production in all

[1] Given the focus on yearly trade volumes, we do not include storage which would provide seasonal swing supplies, neither do we include reserve optimization.

European countries. Final consumption is aggregated to total demand of all sectors in each importing country. We model the trade relations in bilateral pairs of exporters-importers, or marketers-final markets,[2] and use aggregated and calibrated capacity bounds for each pair and technology.

Region	Country	Export/Import Technology in 2025
Exporters		
Europe	United Kingdom	Pipeline
	Netherlands	Pipeline
	Norway	pipeline and LNG
	Russia	pipeline and LNG[3]
North Africa	Algeria	pipeline and LNG
	Libya	pipeline and LNG
	Egypt	pipeline and LNG
Middle East	Iran	pipeline and LNG
	Iraq	Pipeline
	"Middle East" (Qatar, UAE, Oman, Yemen)	LNG
Overseas	Nigeria/West Africa	LNG
	Trinidad	LNG
	Venezuela	LNG
Importers		
West Europe	United Kingdom	pipeline and LNG
	Netherlands	pipeline and LNG
	Spain and Portugal	pipeline and LNG
	France	pipeline and LNG
	Italy and Switzerlands	pipeline and LNG
	Belgium and Luxemburg	pipeline and LNG
	Germany	pipeline and LNG
	Denmark	Pipeline
	Sweden and Finland	Pipeline
	Austria	Pipeline
	Greece	pipeline and LNG
Eastern Europe	Poland	pipeline and LNG
	Hungary, Czech and Slovak Rep.	Pipeline
	"Balkan" (former Yugoslavia and Albania)	pipeline and LNG
	Romania and Bulgaria	Pipeline
	"Baltic region" (Estonia, Latvia, Lithuania)	Pipeline
	Turkey	pipeline and LNG

Table 1: Countries included in the GASMOD model, with possible export/import technologies by 2025

GASMOD is a game-theoretic partial equilibrium model of the European natural gas market. Exports to Europe and wholesale trade within Europe are represented as successive markets in a two-stage structure. Market power can be assumed in both market stages, thereby leading to double marginalization of the final customers. We assume market power to be exerted in a Cournot framework. A Cournot market model typically yields higher prices than the perfect competition model

[2] Note that the pairs are not limited to adjacent countries.
[3] This refers to the Shtokman LNG project and does not include the Sakhalin LNG project in the Pacific because it can be considered as relatively too expensive to supply to the European market.

(or Bertrand models), thereby giving an incentive to more (higher cost) players to participate in the market. The results of this equilibrium model correspond to the Nash equilibrium of the Cournot game in each market stage. The model results must therefore be interpreted as long-term market equilibrium that does not reflect the short-term adaptation path to the equilibria. Hence, this model type is also not appropriate to simulate short-term market shocks.

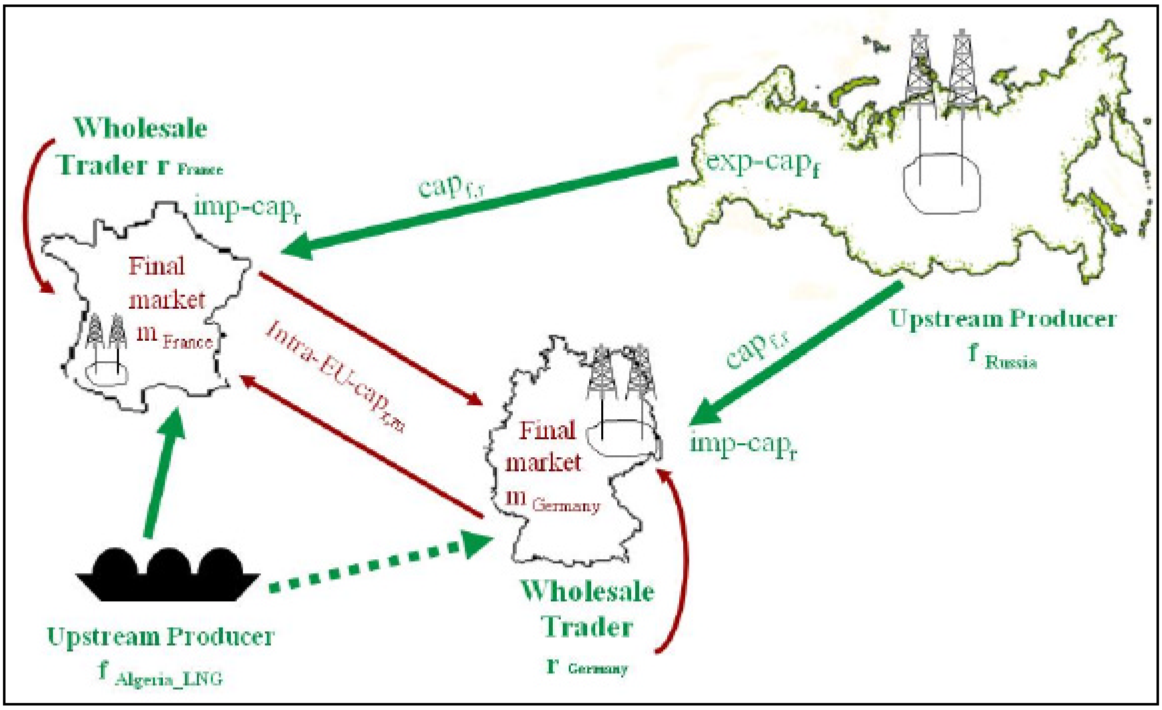

Figure 1: Stylized representation of the GASMOD model setup

In Holz et al. (2008) we consider three stylized cases of market power in each market stage in order to assess the most realistic scenario for the current European gas market: Cournot competition in both market stages, perfect competition in both market stages, and EU liberalization (Cournot competition in export market, and perfect competition in the wholesale market). In line with the market observation we identify the successive Cournot market model as the most realistic representation, but with exceptions for certain countries where the double marginalization structure leads to very high prices and low imports or consumption. Hence, in the GASMOD version used for the EMF simulations, we use a successive Cournot model with a competitive fringe in the export market, and the assumption of perfect competition for certain final markets. On the production market, next to the Cournot players, we assume the small players to be the competitive fringe (Libya, Egypt, Iran, Iraq, Nigeria, Trinidad, and Venezuela, and all domestic European producers except the UK and the Netherlands). On the wholesale market level in Europe, we assume the following markets to be competitive: in the UK, Denmark, Sweden/Finland, Romania/Bulgaria, the Baltic countries, and Turkey.[4]

[4] In reality, these countries, except for the UK, do not have competitive but monopolistic market structures with generally only one player supplying the final market due to missing interconnection infrastructure with other countries. However, the downstream monopoly leads to very high prices in the model results that are not reflected in the real-world data. We therefore decided to assume perfect competition for these countries that have little impact on the overall European market.

In this paper, we apply the method of comparative static simulations for the time period 2003 – 2025. We simulate the years 2003, 2010 and continue in five-year steps up to 2025. For each year, we adapt the data input, namely the reference demand and import volumes and prices, the production and transport capacities and costs. In the absence of founded knowledge about the future market structure, we assume the same market structure prevailing in all model periods.

In particular, as agreed within the EMF group and based on EIA (2005) projections, we assume the reference demand volumes (needed to specify the demand function) to increase by 1.8% p.a. in Western Europe and by 2.2 % p.a. in Eastern Europe. The increase of the reference prices (that are also included in the demand function) is based on projections by the European Commission (European Commission, 2003) with an annual growth rate of 0.8% until 2010, of 2.06% between 2010 and 2020, and 1.25% between 2020 and 2025.[5] The production and transport cost data are based on OME (2001) for 2003 and OME (2005) for all other periods. They mainly include a cost reduction over time of LNG supplies relative to pipeline supplies to Europe.

	2003	**2010**	**2015**	**2020**	**2025**
UK	120	78	51	24	20
Netherlands	80	80	80	80	80
Norway Pipe	86	119	119	119	119
Norway LNG	0	6	11	11	11
Russia Pipe	172	186	186	196	196
Russia LNG	0	0	0	6	11
Algeria Pipe	35	53	53	61	61
Algeria LNG	28	38	38	38	43
Libya Pipe	8	8	8	16	24
Libya LNG	1	4	4	9	14
Egypt	12	23	28	28	28
Iran Pipe	10	10	14	20	20
Iran LNG	0	0	24	36	36
Iraq	0	0	0	10	20
Middle East	36	103	111	120	120
Nigeria	13	34	67	98	98
Trinidad	19	23	37	47	47
Venezuela	0	0	0	0	11
Total Pipe	511	534	511	526	540
Total LNG	108	232	321	393	419

Table 2: Assumed export capacities for 2003 to 2025, in bcm per year

Export and transport capacities are included based on available project data up to 2006, and are reported in Table 2. We adopt a rather conservative approach for those projects that are suggested but

[5] Note that as we go to print, current natural gas prices have increased significantly and price forecasts are heterogeneous as rarely before. Also, higher prices are likely to reduce demand in the long run. Nonetheless, to assure consistency we stick to the scenarios as defined by the EMF 23 group.

not yet constructed and do not include any projects beyond those known by 2006. Hence, we assume little increase in export capacities to Europe after 2020. This is consistent with the assumption that the mature European market will experience a slower demand growth after 2020 because demand substitutions in favor of natural gas will have taken place by then (e.g., in power generation).

3 Results for the EMF Scenarios to 2025

3.1 Scenario Overview

We simulated the following scenarios with the GASMOD model: EMF reference scenario (with data as described above), a slightly higher demand growth scenario, constraint on Russian exports to Europe, constraint on Middle East exports to Europe, and constraint on liquefaction capacity. Those cases were agreed upon in the EMF group and are described in EMF (2007).

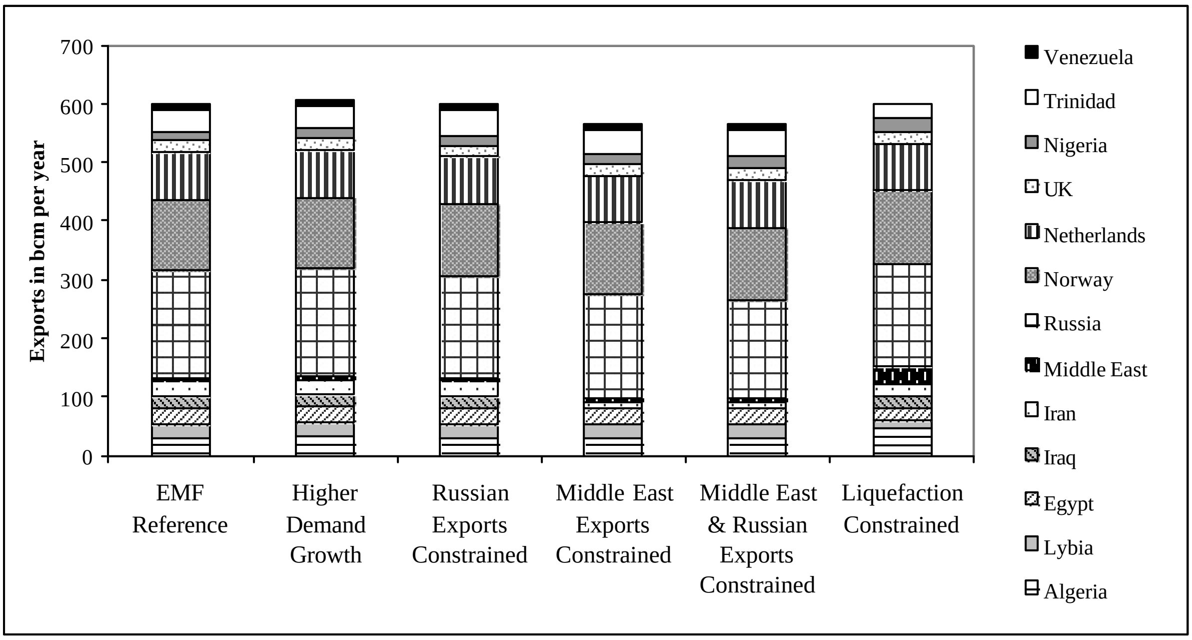

Figure 2: Model results of exports to Europe by exporting country in 2025 for all EMF scenarios (in bcm per year)

Figure 2 shows the GASMOD results of all scenarios for the last model year (2025). As underlined in EMF (2007), the European natural gas market demonstrates a lot of resilience and the overall export picture seems to be similar between the scenarios. In particular, Europe will rely to a larger extent on imports than today with only about a sixth from the large domestic producers Netherlands and the UK. Russia will continue to have an important albeit not dominant role as supplier to Europe with less than a third of European imports in all scenarios.[6] On the other hand, the Middle East with its LNG exporters Qatar, UAE, Oman and Yemen will play only a limited role because other LNG producers

[6] While one third of European imports from Russia may seem high, this is considerably lower than earlier forecasts. For example, EC (2001) expected over 60% of the European imports coming from Russia.

(Norway, Nigeria and West Africa, Caribbean with Trinidad and Venezuela) can supply Europe at lower costs. In total, LNG will have a share of about 25 % of all imports. This share will be more than double the current share of LNG in European imports (10% in 2003) and it implies more than a tripling of the LNG volumes. The relatively large number of potential LNG suppliers to Europe will allow for a more diversified picture than was prevailing in Europe in the last decades, and thereby improving the European supply security.

Figure 3 shows the evolution of natural gas exports to Europe over time. Consistent with the assumption of a growing reference demand, we find growing exports to Europe. Some exporters can increase their share in the European import portfolio due to new build and expanded export capacity, especially LNG producers such as Venezuela (assumed to be starting in the early 2020s), Iran (starting in 2015; OME, 2005), as well as Nigeria and Trinidad & Tobago (strong expansions planned in the next years). This increase in liquefaction capacity will be matched by an increase in regasification capacity in Europe, as detailed in DIW (2006). Figure 4 illustrates that the increased share of LNG mainly substitutes pipeline supplies from other suppliers than Russia, especially the falling UK production.

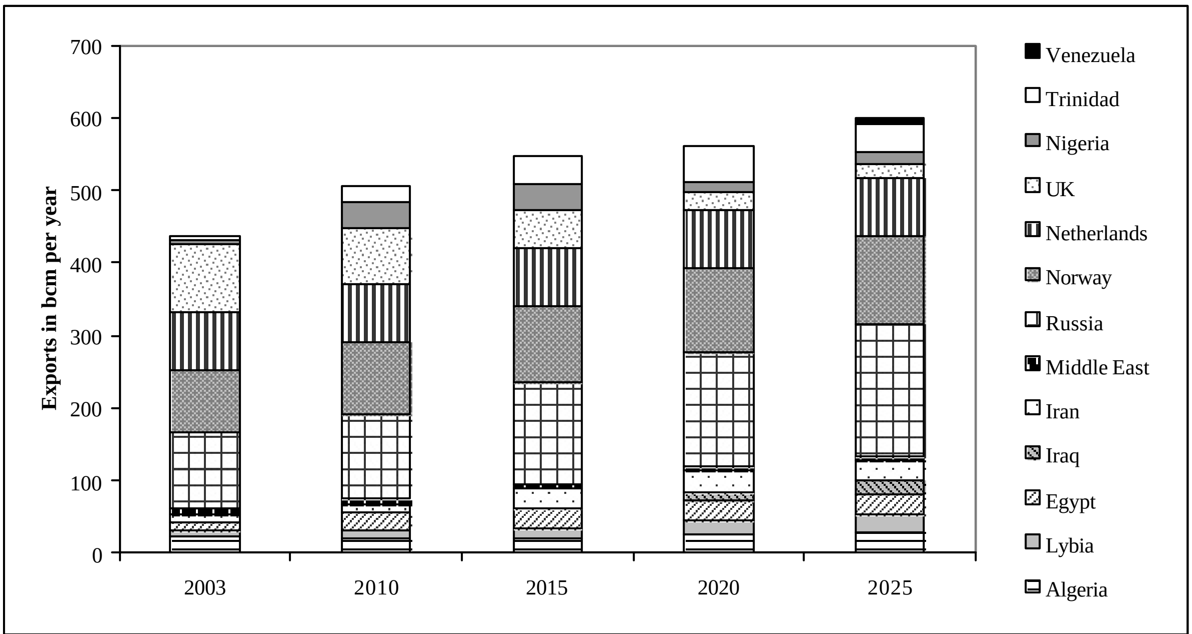

Figure 3: Model results exports in each model year, EMF reference scenario (in bcm per year)

3.2 The Role of Russia

Russia will continue to supply about one third of the European natural gas imports, without, however, hitting any export capacity constraint to Europe (Holz, 2007).[7] Hence, the EMF scenario of

[7] This suggests, among other things, that the much debated *Nordstream* pipeline from St. Petersburg through the Baltic Sea into Germany lacks an economic justification. Note that we calculated a long-term equilibrium, but not short-term interruption scenarios. Hubert and Ikonnikova (2003) and Hubert and Suleymanova (2006) provide a game-theoretic analysis of the *Nordstream* project that is based on its strategic value.

"Constrained Russian Exports" that consists of limiting the Russian export infrastructure for all future periods to the existing capacity in 2005 (180 bcm of pipeline capacity) has almost no effect in the model results. The only impact can be found in later periods, when the planned LNG terminal of the Shtokman field, is excluded in this scenario and its small LNG volumes are supplied by other LNG exporters than in the reference scenario.

Russia's important position is mainly due to the large volumes exported to some West European countries (Germany, Italy) and especially the strong dependence of Central and Eastern Europe on Russian natural gas supplies. All Eastern European countries have dependency rates on Russia of above 50 % (e.g., Czech Republic and Hungary for 75 %, Poland for 67 % of their imports); several rely on Russia for all of their natural gas imports today (Bulgaria, Baltic countries, Slovakia) (BP, 2008). The relative proximity to Russia and the existing pipeline infrastructure create a lock-in position for Eastern Europe and only few infrastructure projects are in the discussion to reduce the dependency on Russia. In addition to some projects (with relatively small volumes) of reverse flows from Western Europe (Germany, Austria), much hope lies on the *Nabucco* project with supplies from Iran and possibly some Caspian countries. Given the current financial and political obstacles to this project, we have not included it in our data set.

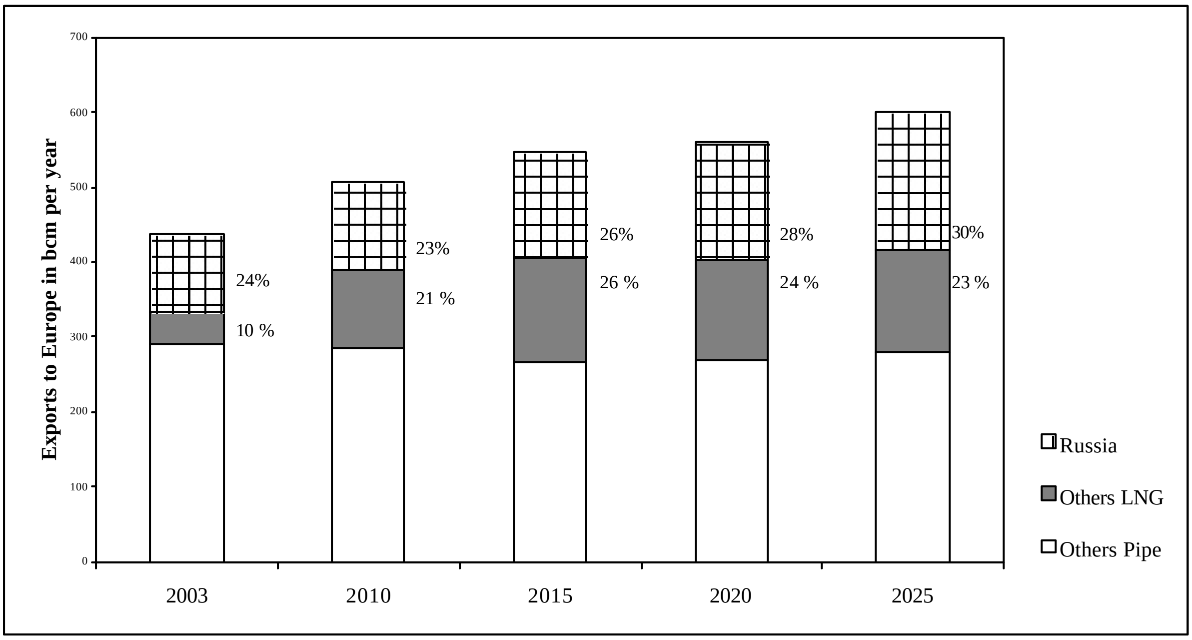

Figure 4: Shares of European imports from Russia, other pipeline and LNG in reference scenario results (in bcm per year)

3.3 The LNG Market (Liquefaction Constraint Scenario)

The West European countries are (geographically) in a more comfortable position than Eastern Europe because they can rely on a larger number of pipeline exporters (e.g. Norway, Algeria) and many have a seashore line that allows for access to the international LNG market. In addition to the "traditional" LNG importers of the 1990s and before (France, Italy, Spain, Belgium, Turkey), the 2000s have seen

Portugal, Greece and the UK entering the LNG market with new build regasification terminals. Plans for more LNG terminals have been advanced for all of the existing importers and for potential new importers such as the Netherlands and Germany (likely in the 2010-2015 period), Poland, Croatia and Ireland (less likely to be realized soon). Many of the LNG expansion/construction plans are for the period until 2015. In Figure 4 we saw that the LNG share in European imports increases until 2015 when it reaches a plateau of approximately 25 % where it remains stable for the next periods.

Only in the scenario of "constrained liquefaction", the Middle East LNG exporters (Qatar, United Arab Emirates, Oman) can supply a significant share of European LNG imports. The scenario is defined as limitation of liquefaction capacity to those projects that were already in operation or under construction at the end of 2005 (EMF, 2007). Hence, new entrants on the (Atlantic) LNG supply market, such as Russia, Venezuela and Iran do not start supplying LNG in all periods. Instead, existing LNG exporters, especially those with large capacities, will replace the lacking LNG volumes albeit at higher costs and hence with somewhat lower volumes (negative price effect on the import demand function).

	2010	**2015**	**2020**	**2025**
Norway	0.1 (+1 %)	*-1.9* *(-24 %)*	*-1.4* *(-19 %)*	2.9 (+96 %)
Russia	0	0	*-6.0* *(-100 %)*	*-10.3* *(-100 %)*
Algeria	4.1 (+57 %)	10.7 (+166 %)	13.6 (+227 %)	14.2 (+222 %)
Libya	0	0	*-5.0* *(-56 %)*	*-10.0* *(-71 %)*
Egypt	0	*-4.6* *(-16 %)*	*-4.6* *(-16 %)*	*-4.6* *(-16 %)*
Iran	0	*-14.5* *(-100 %)*	*-11.0* *(-100 %)*	*-5.9* *(-100 %)*
Middle East	5.7 (+68 %)	19.5 (+327 %)	21.6 (+375 %)	24.4 (+445 %)
Nigeria	*-11.0* *(-32 %)*	*-13.5* *(-37 %)*	8.5 (+58 %)	6.9 (+42 %)
Trinidad	0	*-14.1* *(-38 %)*	*-23.7* *(-50 %)*	*-14.6* *(-39 %)*
Venezuela	0	0	0	*-9.2* *(-100 %)*

Table 3: Difference of LNG exports in „Liquefaction Constraint Scenario" compared to EMF Reference Scenario, in bcm per year (percentage)

The Middle East with liquefaction capacities of 36 bcm in 2003 and about 20 bcm more under construction in 2005 obtains an increased market share in Europe in this scenario. Other LNG exporters that benefit from the restricted liquefaction capacity increase are Algeria and Norway and Nigeria in later periods (highlighted in Table 3). In the reference scenario, a large part of their LNG exports does not go to the European market but is available for the North American and Pacific (East Asian) market (not included in the GASMOD model). The scenario of constrained liquefaction capacity also highlights which LNG exporters are the preferred suppliers to the European markets in the reference case, namely those where the expected capacity expansion over the periods results in large export volumes and hence in large losses in the "Liquefaction Constraint Scenario" compared to the "EMF Reference Scenario". Table 3 reports that these are mainly Trinidad & Tobago, Egypt and Libya. The cost decrease of LNG compared to pipeline exports plays a major role in explaining the high future export potential.

3.4 Results for the United Kingdom

The United Kingdom is the natural gas market in Europe where several developments that are characteristic for the entire European market take place "in a nutshell". First, the UK market has already undergone a liberalization process to a competitive wholesale market that the European Commission still struggles to achieve on the European Continent. Moreover, the UK market does not only experience a strong decline in domestic production over the course of the analyzed period (assumed to fall to about 1/6th of its 2003 level in 2025) but also has the strategy to meet (parts of) the increasing need for imports with LNG. Similarly, decreasing domestic production and increasing (LNG) imports can be observed in Europe as a whole.

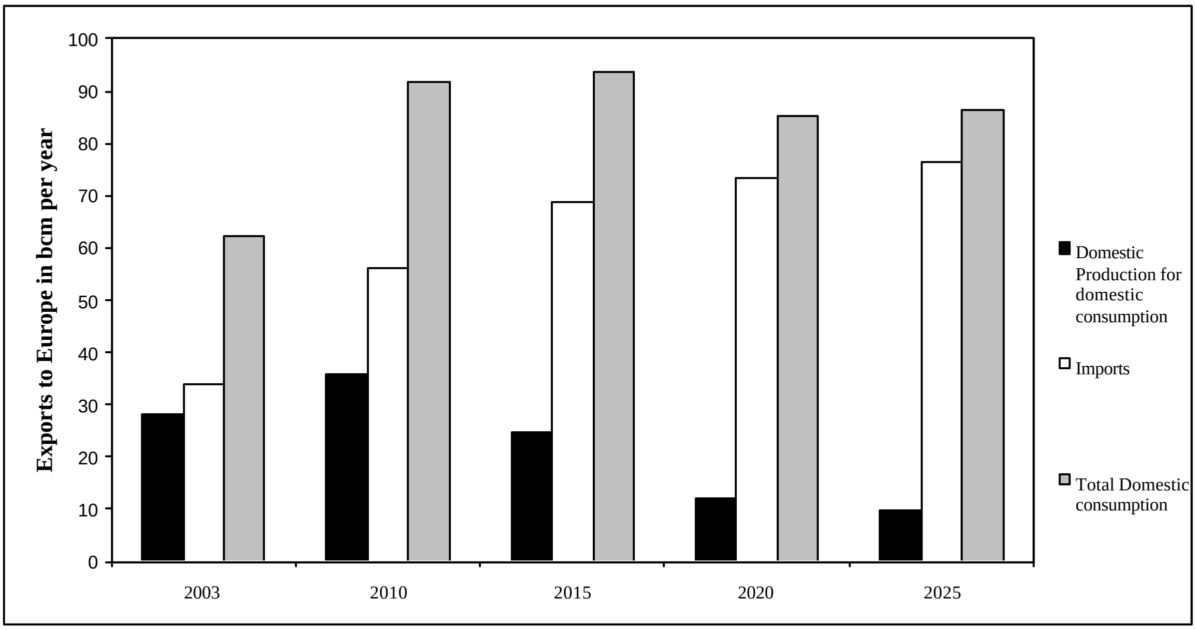

Figure 5: Model results for the UK market (consumption, imports, production for domestic consumption, exclusive exports)

The UK started to develop LNG regasification projects in the early 2000s and has three operating terminals in 2008 (Milford Haven, Isle of Grain, and an Excelerate vessel in Teesside). There are expansion plans for these terminals and construction plans for three or so more regasification ports in the next decade. In total, the UK will have more than 40 bcm per year of LNG import capacity by 2015. Together with an increased pipeline import volume from Norway and the Continent (Belgium and the Netherlands), this will compensate for the decline in domestic production. Figure 5 shows that the UK can potentially keep its natural gas consumption level stable, thanks to the increased import capacities. The competitive wholesale market with lower prices than on the monopolistic market further enables the UK consumers to maintain their consumption levels.

3.5 Infrastructure Bottlenecks in Europe

Several of the trade flows that result from our modeling exercise are constrained by the assumed infrastructure capacities. This is particularly important for all intra-European pipeline flows. Figure 6 shows a stylized map with the congested border capacities between the countries in West and Central Europe. Our model data set is based on the assumption that the current European market structure will persist until 2025, with predominantly monopolistic, generally vertically integrated (between wholesale trade and shipping, incl. pipeline ownership) natural gas companies. This market structure has shaped the existing infrastructure situation in Europe with insufficient liquid interconnection between European countries. The monopolistic wholesale companies that are also the owners of the network have no incentive to invest in cross-border capacities because that would give market access to competitors from abroad.

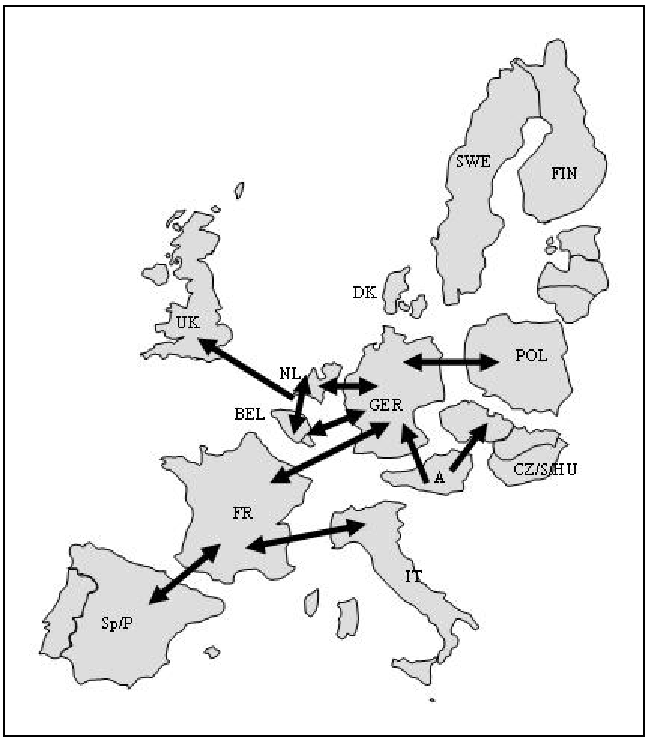

Figure 6: Pipeline bottlenecks in West and Central Europe in 2015

4 Conclusions

In this paper, we have presented the reference case simulation and scenario calculations of the EMF 23 study design, focusing on the supply and demand situation in Europe. We applied GASMOD, a strategic model of European gas supply. In general, we find that Europe is likely to increase its supply security through diversification: the number of suppliers increases over time, and the role of Russia stays within a reasonable range, with about 1/3 of total imports. We also find that infrastructure availability remains a critical issue, mainly for pipelines. This supports polic ies in favor of higher incentives for infrastructure investments.

The success story of the UK can be seen as a “role model” for the future of European gas supplies. From being a net exporter, the UK has transformed into a gas importing country, without putting supply security at risk. A competitive industry structure and appropriate network regulation and investment incentives have favored this transition. Our model results suggest that Europe need not to be overly worried about increased import dependence, provided that the institutional framework is adopted accordingly.

Last but not least, let us point out some critical points in the analysis: Demand forecasts are uncertain because of gas price changes, but also because of climate protection policy and the need for low-carbon technology at scale. Also, our results depend upon the choice of model parameters (e.g. elasticities) and assumptions about new infrastructure to be built. Upcoming research should move from a comparative static analysis to a dynamic model with endogenous investment decisions.

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