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Forecasting European Gas Supply
Selected results from EUGAS model and historical verification*

by

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Abstract:

The common application of EUGAS, a long-term, dynamic, interregional linear optimization model, is the projection of European natural gas supply up to 2030. Based on current expectations regarding future demand, supply costs and reserves, the model results comprise production and transport volumes, changes in infrastructure and marginal costs of supply, covering the EU-25 plus the main non-EU supply countries. In the reference run a significant increase in Middle Eastern gas is projected while generally a growing share of volume will be imported via LNG. In order to assess validity of these projections a model run was conducted re-simulating the evolution of European gas market from 1960-2000. While the general results are predominantly in line with the historical development, one of the main findings is that the current strong position of FSU-gas in Western Europe contradicts cost minimal calculation.

Keywords: Natural Gas, European gas market, Modelling

JEL-classification: Q41, C61, N74, L95

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1 Introduction

Natural gas is projected to be the fastest growing conventional energy source in the next decades.[1] Due to limited resources in the member countries of the EU-25, a huge increase in demand implies a greater need for external gas supplies. In this paper we first present the model structure and some main parameters of the linear optimization model EUGAS which allows a quantitative forecast of the European gas market for the next 30 years. We also present some assumptions and selected results of a so called reference case.

Frequently concerns are raised concerning the validity of such model based predictions. The necessarily simplified projections in the model-world lead to doubts regarding the relevance of the gained results in real. To meet these objections we developed a test run for historical periods. Some empirical and model technical problems are discussed as well as some results in the last part of our paper.

2 The EUGAS-Model

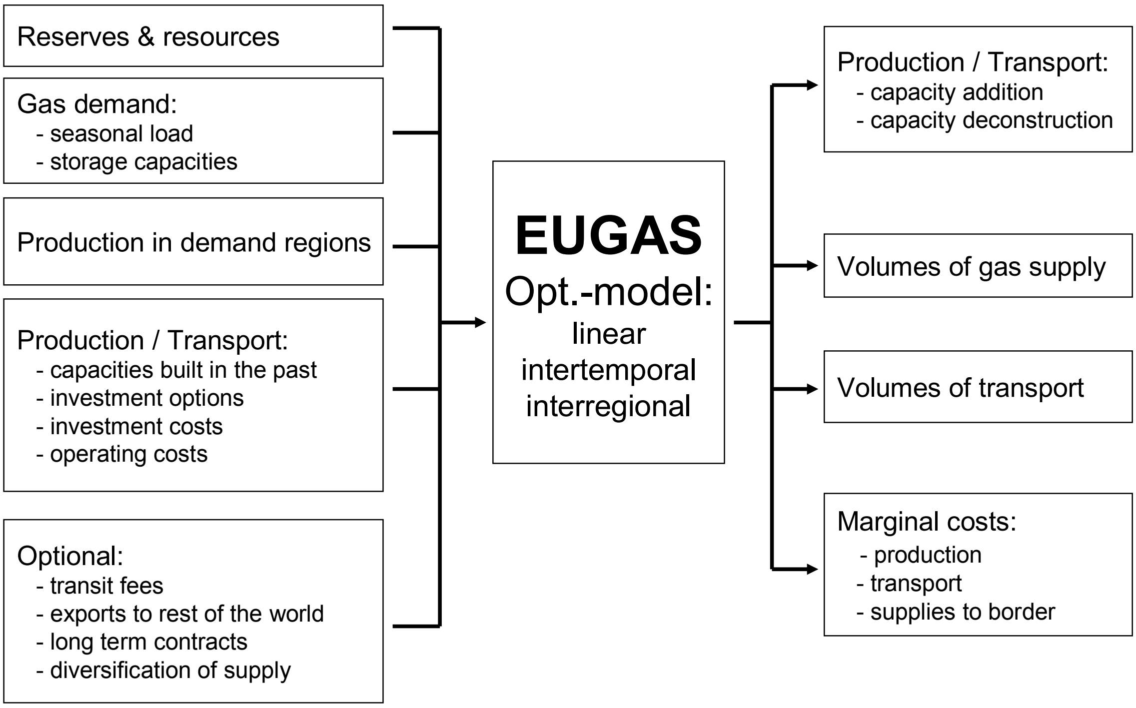
The model EUGAS is a simulation tool to analyse the future European natural gas supply quantitatively. It is structured as a long-term, dynamic, interregional optimization model. The objective and the restrictions of the model are linear (linear program). EUGAS provides forecasts until 2030 in five-years-steps, beginning with 2005, followed by 2010 and so on.

The model optimises future European natural gas supplies provided that European gas demand is satisfied at minimum costs (objective of the optimization). The logic of the model algorithm is that of a perfectly informed central decision taker who optimises overall social welfare. By applying this approach, the market results of perfect competition are reproduced. Though the European gas market is currently dominated by an oligopoly of some major gas producers, the market can be expected to become more competitive in the coming years because of the European gas market liberalization and the emergence of new supplies from upcoming gas producing countries (e.g. Nigeria, Egypt).

The main parameters, which impact the model results, are gas demand, supply costs and gas reserves. Further on, existing production and transportation capacities partly predetermine the gas flows especially during the first time periods (until year 2010), since past investments in gas facilities are irreversible and therefore regarded as sunk costs. Some other important input

[1] See IEA (2004a).

Figure 1. Inputs and outputs of EUGAS



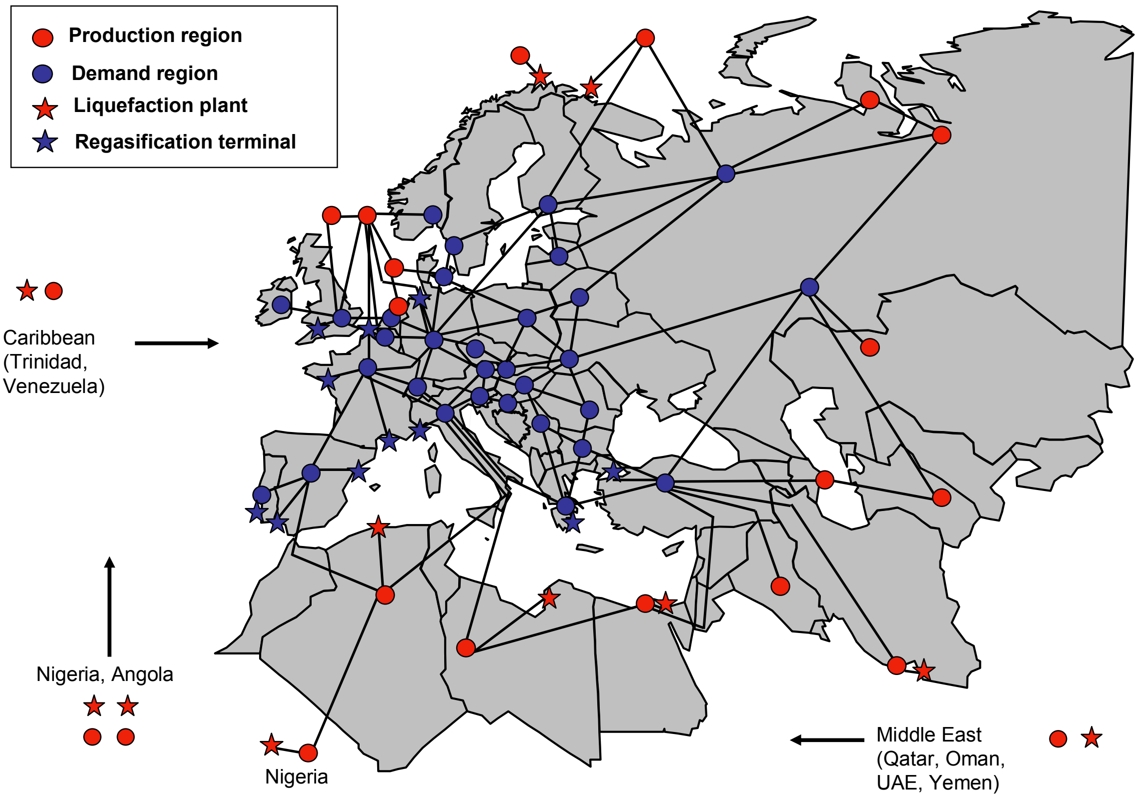
parameters are existing long term contracts, transit fees and ambitions of some countries to diversify the origin of imports.

EUGAS calculates a bundle of detailed model results of which gas production and transport flows are the most important. Additional to produced and transported volumes (and therefore additional capacities needed) the model generates marginal costs for gas flows from production region to each demand country where gas imports from the specific supplier arrive. Figure 1 gives an overview over the main model inputs and outputs.[2]

European gas demand is satisfied by both, intra-European production and gas sources from outside Europe. Gas production comprises exploration, production, storage and processing close to the gas fields. The model optimises the extension and decommissioning of production capacities as well as annual production quantities in the most important producing countries. In EUGAS, the main intra-European gas producing countries comprise Denmark, the

[2] For more detailed information on EUGAS see Perner (2002) and Perner/Seeliger (2004).

Figure 2. Regional coverage of EUGAS



Netherlands, Norway and the United Kingdom.[3] Main non-European producing countries are some states of the former Soviet Union (Russia, Azerbaijan, Kazakhstan and Turkmenistan), Algeria and other African states (Angola, Libya, Egypt and Nigeria), and the Middle East (Iran, Iraq, Qatar, Oman, United Arabic Emirates and Yemen). The Caribbean states Trinidad & Tobago and Venezuela are taken into account, too.

Figure 2 illustrates the regional coverage of EUGAS as well as all existing and possible infrastructure elements, especially LNG import and export locations and pipeline connections.

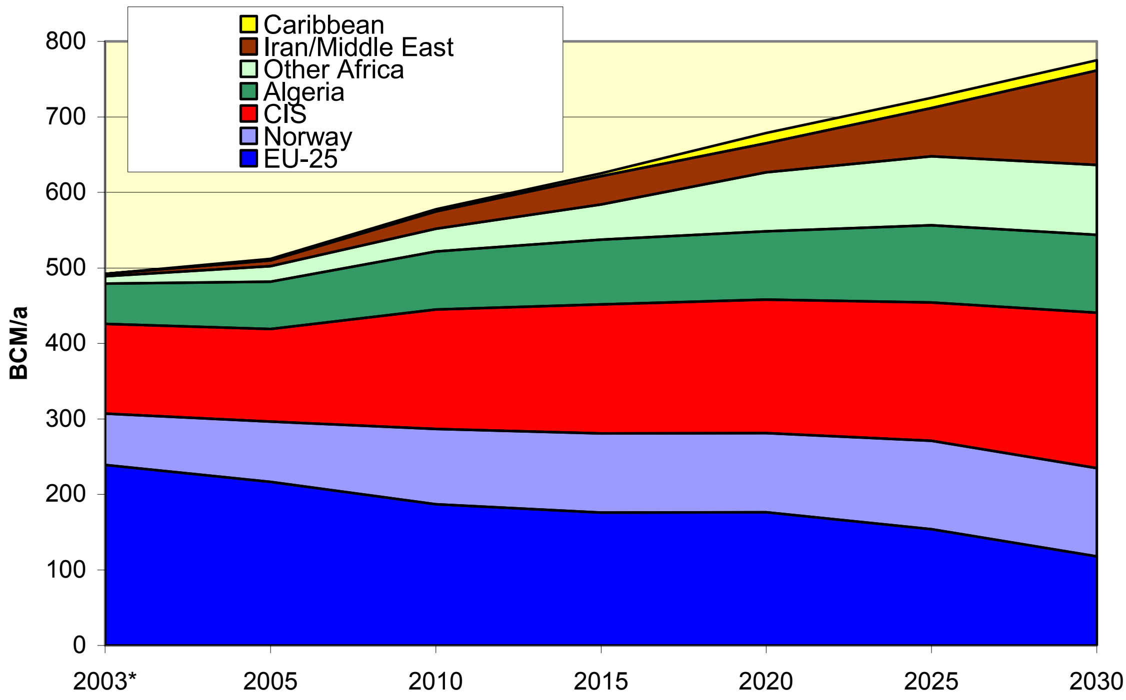
3 Reference Case

3.1 Main Assumptions

Following model results bases on a so called reference run. A pure cost minimization approach which only refers to basic economic facts produces political unrealistic results. In

[3] Natural gas production of less important European gas producing countries (e.g. Germany, Italy, Romania) is exogenously given to the model. These are countries with relatively low gas resources having only local impacts on gas supply. In these cases, gas output is subtracted from domestic demand.

Figure 3. Supply mix of EU-25, 2003 and model results for periods 2005 to 2030



order to gain useable projections therefore the following additional assumptions were included in the reference case:

- existing long-term Take-or-Pay contracts,
- ambitions to diversify import sources in most European countries,
- transit fees for some pipeline routes (e.g. Ukraine, Belarus) and Suez channel,
- exports to regions out of EUGAS-coverage (e.g. LNG from Middle East to Asia),
- political, environmental and logistical constraints.

Reserves and resource assumptions base on several published standard publication, like BGR, BP, Cedigaz, Exxon Mobil, Oil & Gas Journal and USGS.[4] Demand forecasts base mainly on actual publications of the EU Commission, with additional references to EIA and IEA.[5]

3.2 Future Supply Mix of EU-25

Based on above mentioned assumptions, natural gas demand increases significantly during the next decades. In contrast, indigenous production declines until 2030 to a half of produced

[4] BGR (2003), BP (2005), Cedigaz (2004), Exxon Mobil (2005), O&GJ (2004) and USGS (2000).

[5] EU (2003), EIA (2004) and IEA (2004a).

volumes in 2003, of which most will still be extracted from British North Sea and Dutch on- and offshore fields. Therefore steadily growing imports from countries outside the EU are needed. Figure 3 shows the development of the EU-25 supply mix during the forecast period.

Russia remains the most important supplier for Europe, increasing both absolute volumes and relative market share. Together with minor exports from Turkmenistan and Azerbaijan, CIS members achieve a share of about 27% in EU-25 supply mix. Also Norway and Algeria can secure their strong position and reach market shares of 15% and 13%.

In 2003 other producing countries exported only small volumes (around 3% in total supply) to EU-25. Until 2030 EUGAS forecasts a rise to 30% in EU-25 supply. While Caribbean countries Trinidad & Tobago and Venezuela remain minor exporters to Europe, African and Middle East producers become increasingly essential to satisfy European demand. Libya turns after Algeria into second-most-important African gas trading partner (about 6%), followed by Nigeria (4%) and Egypt (2%). The latter exports greater volumes to regions out of EUGAS coverage, especially to the US.

Middle East producers show the greatest increase in market-share. Thereby Iran accounts for more than half of the total 16% share. Exports from South Pars are reaching Europe both via several new built LNG terminals as well as by increased pipeline capacities passing Turkey and several Balkan states. The remaining volumes are delivered by LNG from Qatar, Oman, UAE and Yemen.

3.3 Development of Transport Infrastructure

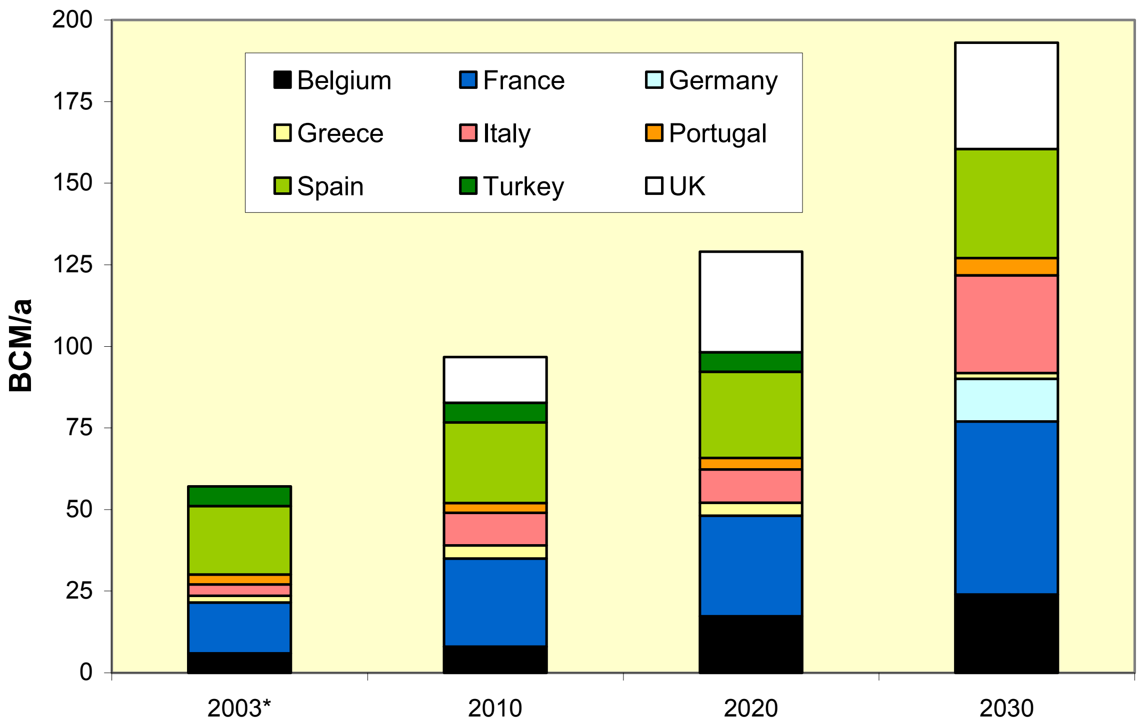
Following the increasing demand in external gas supplies, European import capacities have to be boosted during the next decades.

As shown in Figure 4 LNG import capacity is about to triple until model period 2030 compared to initial capacities in 2003. Nearly all LNG opportunities offered by EUGAS model design are getting realised. Only Turkey and Greece deconstructs LNG capacities in the last model periods due to large new build pipeline capacities from Iran and Azerbaijan which are more cost efficient alternatives for the two countries.

While most major transport pipelines will be expanded still additional new export channels are required to cover total European demand (Figure 5).

Worth to mention is the comparatively late realization of two actual discussed projects, namely the Baltic Sea Pipeline and Nabucco. Both projects are likely to get started by about

Figure 4. Development of LNG regasifications in Europe, 2003 and selected periods



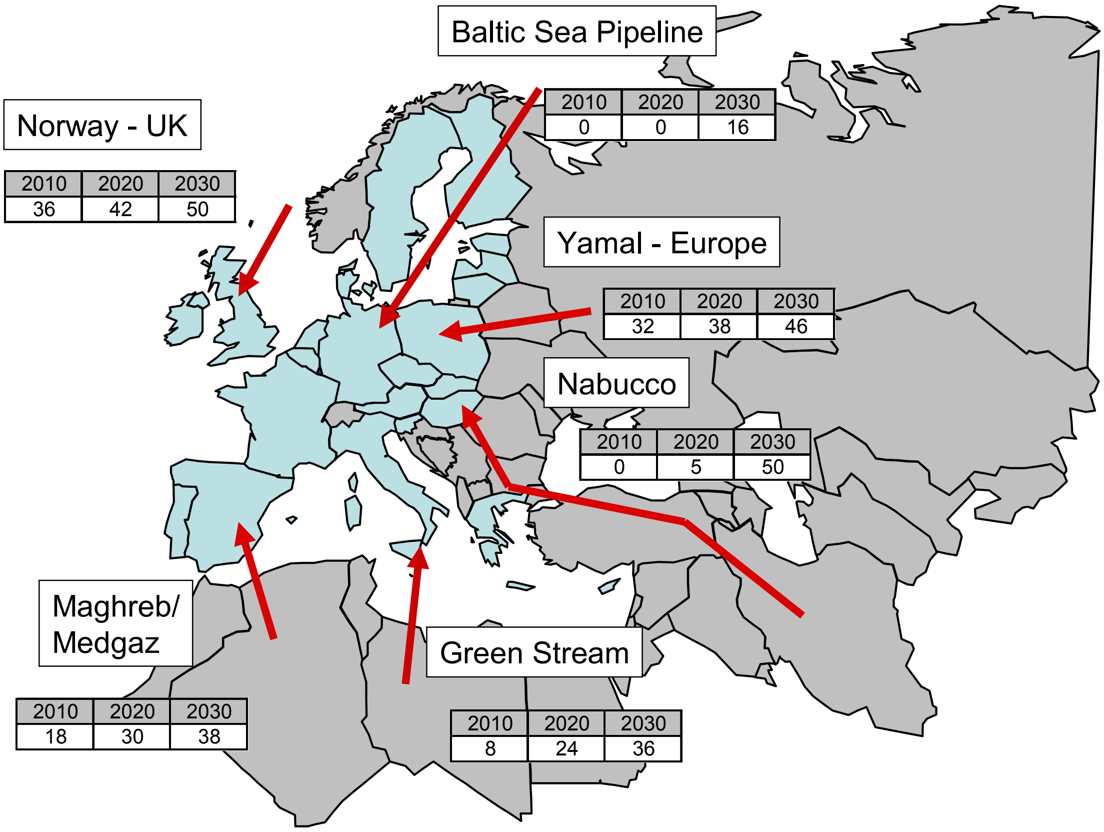
2010 but in EUGAS reference case several existing pipelines are preferred to become expanded rather than building these new routes. So Nabucco becomes operational in 2020 with only small capacity before being expanded by 2025, while Baltic Sea starts in 2025 with gas from Western Siberia. A link to the Barents Sea fields is not accomplished until 2030.

4 Historical verification

4.1 Approach

Such projections are often met with scepticism. The necessarily simplified projections in the model-world lead to doubts regarding the relevance of the gained results. Therefore any possibility to assess the quality and relevance of modelling-results should be welcomed. Since today it can already be looked back on several decades of evolution in the European gas market, the idea arose to relate these available experiences in the market with the results of a cost-minimization prediction as outlined above. Therefore a EUGAS test run (labelled from now on $EUGAS_{1965}$ in distinction to the up-to-date run $EUGAS_{2005}$) covering the periods 1970-2000 was developed. Based on originally available information and data the development of the European gas supply in the past decades was re-simulated in order to gain evidences regarding the robustness of the model's outcome and their comparability to real-world development.

Figure 5. Capacities of selected pipeline projects (model results)



In the next paragraph we will first briefly outline the evolution of European gas supply, followed by a discussion, to which extend these developments were in line with the projections of $EUGAS_{1965}$.

4.2 Evolution of European gas market

The beginning of the first significant cross-border deliveries in the 1960s can be regarded as the beginning of a European gas market. The 1959 discovered Groningen field served at this time as a monopoly-supplier to seven West European countries while in a few additional countries natural gas was used on a small scale based on domestic production. Already in this early stage of the market the LNG technology was applied to diversify gas-supply and access outer-European sources: Starting with UK's Canway Island terminal in 1964 and followed by the construction of regasification plants in France, Italy and Spain until the end of the decade Algerian and later Libyan gas reach a growing share of European supply.

European gas demand was boosted by the oil crisis in 1973 which initiated a growing trend to substitute oil with gas in the heating as well as in the electricity sector. In consequence the number of importing countries in Western Europe rose to eleven during the 1970s. This trend was brought forward through additional successful explorations in the North Sea, mainly on Norwegian and British territories but also in Danish and Dutch waters. While the British fields solely met domestic demand, Norway situated itself as export country through the construction of two offshore pipelines (Norpipe and Frigg) and supplied gas to the UK and the European mainland. Till this day Norway shows only minor domestic gas demand, mostly due to the huge potential in hydropower.

In the beginning of the 1970s another important player entered the (Western-) European gas market: Having been a supplier to Central Europe after the completion of the Brotherhood pipeline in 1967, the former Soviet Union at this time started delivery of its Wolga-Ural-gas to Western Europe through the completion of the Transgaz Pipeline through Czechoslovakia.

In the 1980s the development of the European gas market showed a continuing growth in demand, which required the extension in existing import capacities: Algeria enlarged its LNG capacities in order to supply more import terminals, which were build in Belgium, France and Spain. In addition the country was linked to the European pipeline-system via the Transmed-offshore pipeline. Despite the cold war the Soviet Union rose to one of Europe's main supplier of natural gas by finalising projects such as the exploitation of the Western Siberia fields and the further construction of major transmission lines (Progess, Norther-Light-Extension, etc.).

Through these developments the initial dominant position of the Netherlands faded. But due to its proximity to the main consumers and favourable production conditions at the Groningen field the Netherlands hold till this day an important role as swing-supplier. During the 1990s the last remaining EU-members (except for Malta and Cyprus) Ireland, Portugal and Greece were connected to the European gas-grid. Therefore – and due to the general increase in demand – a growing need to build new transport capacities evolved. Mainly Algeria and Norway secured their dominant position as supplier through the construction of additional pipelines (Transmed extension, Maghreb-Europe, Zeepipe, Europipe I, Norfra).

The release of the EU-gas directive in the year 1998 marks a corner stone in the development of the natural gas market. Although the following political process mainly dealt with market structures and liberalization the next years showed also important changes on the supply side. They were significantly driven by growing ambitions to diversify import sources in most European countries. As a result more remote countries such as Trinidad & Tobago, Nigeria, Qatar, Oman, the UAE (all via LNG) and Iran (via Pipeline to Turkey) started exporting to Europe. Despite these new market entrances the major volumes were still supplied from the established exporters Algeria, Russia and Norway. Consequently additions to the transport capacities from these countries were completed in the past years, e.g. the Yamal-Europe and the Europipe II. Parallel to these pipeline projects also LNG regasification capacities were enlarged by projects in Greece, Portugal and Spain. The construction of the Bacton-Zeebrugge Interconnector in 1998 turned UK to the third EU-net-exporter (beside the Netherlands and Denmark) of natural gas, although this position will only last for a short time given the declining UK production.

4.3 Parameterization

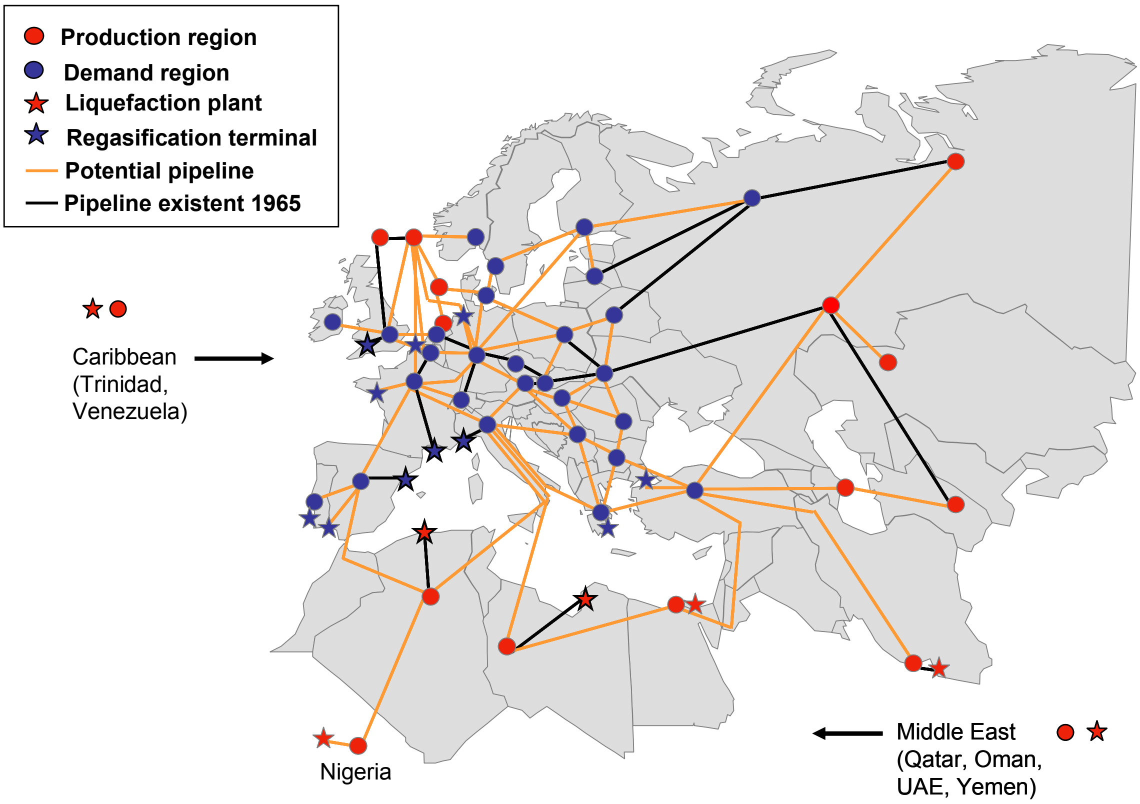
In order to be able to analyse, to which extend this evolution of the European gas market during the last three decades of the past century would be inline with a 1965 based projection, the first step was to "turn back" EUGAS' parameterization to the fundamental data of this time. Although this approach might appear straight forward, there is one particular difference to the current application: Today exogenous data – such as development of demand or resource potentials – are fed into EUGAS based on current available outlooks and prediction. Turning back EUGAS would therefore mean to also use past outlooks of expected demand and resource basis. Unfortunately due to the early stage of market development such outlooks and statistics were not available to a comparable extend as today and in addition were quite inconsistent. Hence we decided to differ in this aspect from the analogy of the current EUGAS implementation and referred to observed historical market data as input parameters. Still this issue has to be kept in mind when comparing real market development with the results of the model run.

In the following paragraphs we now will briefly discuss the major parameters:

4.3.1 Regional coverage and granularity/resolution, Infrastructure

As outlined in the preceding history, the European gas-supply sphere was significantly smaller than today. These differences were met by eliminating several production regions (Norwegian/Russian Barents Sea, Russian Yamal fields, Angola and Iraq) from the model. In exchange we had to include the Russian Wolga/Ural fields, where production has declined in the last years but was a significant production region in the past. In line with the removal of these production-nodes also potential LNG liquefaction locations have been eliminated (Murmansk, Melkoya, Luanda). In order to preserve the models integrity we also had to account for different political borderlines of supply countries, which mainly affected the countries of the former USSR.

Figure 6. EUGAS$_{1965}$ regional model structure



Infrastructure built before start of optimization periods have a significant cost advantage since in EUGAS their investments are treated as sunk costs. In a developed gas world as it is today this approach somehow reflect the realistic persistence of already taken development paths. But in an early-stage market such significant cost-advantages have to be assessed carefully. On the transport sector we therefore only predefined these projects which in fact were existent in 1965. Regarding the installed production capacities on the fields we referred to the published production volumes in 1971. Figure 6 outlines the EUGAS$_{1965}$ regional model structure after these adaptations.

4.3.2 Resources and Demand

One of the most crucial external parameters to the EUGAS-model is the exogenous defined demand in the forecast periods. As discussed above we based the data on the real observed demand in the years 1970-2000. Since the net-demand also depends on the domestic production in the demand regions, the same applies to the data of domestic production. All data were based on published information (e.g. BP, IEA). More challenging was the estimation of resources and in particular the development over time for different fields. Although sporadic information for individual fields was available and the current estimations together with data regarding the cumulated production gave some idea, in some cases – in particular for different Soviet production regions – distribution of the total amount had to be guessed.

4.3.3 Costs / technological progress

Also subject to a detailed assessment were several cost parameters related to field production, transportation, infrastructure building, etc. Obviously only rare information are available to estimate the 1965 cost parameters. But when referring to today costs several opposing trends have to be accounted for: inflation has to be considered but also the fact, that the current cost-levels include more than 30 additional years of technical progress. On the other hand in many regions the most accessible gas deposits are already in a mature production stage or depleted, which tend to increase the average cost level.

Since cost parameters in EUGAS are not static but instead are assumed to fall over time due to technological progress, assumptions regarding these trends have to be made. Since it can be assumed, that in the early stage of the natural gas market technological progress led to significant greater cost reduction effects (steeper section of the learning curve), the cost-reducing parameters for the different technologies (liquefaction, regasification, pipeline, production, …) were increased compared to the $EUGAS_{2005}$-run.

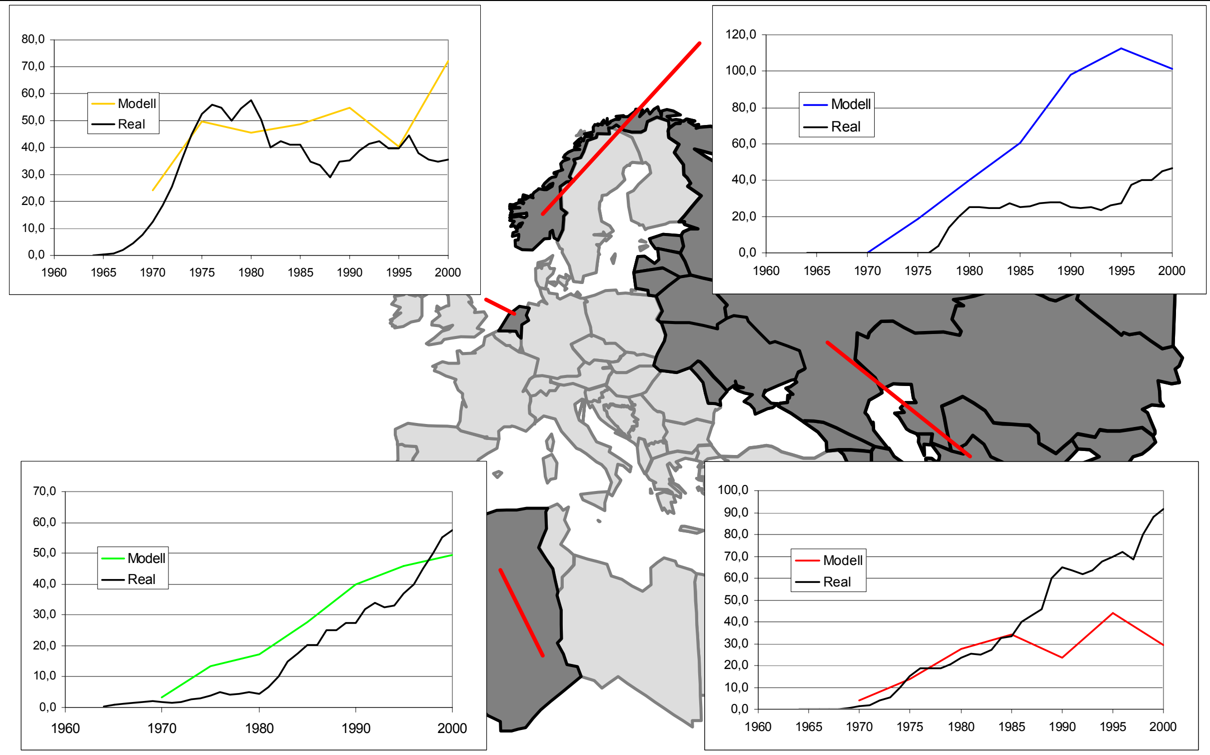
4.4 Results

With regards to the general intention of this experiment the aim was not to try to come as close to reality as possible with the model results, but instead to assess how model runs with only minor manually interfering (such as bounds or exogenous supply agreements) would compare to real-world evolution. As will be seen in the following paragraph, where the results under pure cost minimization aspects will be presented, nevertheless some additional restrictions have to be included in order to enable a meaningful comparison between reality and projection. A corresponding model-run will therefore be presented afterwards.

4.4.1 First run

The first run was solely based on the above discussed parameterization without any additional adjustments. As only exception we included a production cap for the Netherlands. Given the unique advantage of the large, low-cost Groningen field situated next to the main consumers otherwise pure cost minimization would lead to unrealistic high production rates. To at least

Figure 7. Export volumes for selected supply countries, EUGAS$_{1965}$ results vs. empirical data – FIRST RUN



rudimentary account for a realistic long-term policy the maximum production at Groningen therefore had to be limited.

To gain a quick overview regarding the proportion between model-results and reality we plotted the total volumes of four main supply-countries as predicted by EUGAS$_{1965}$ against available empirical data.[6] Figure 7 therefore already displays the main findings of this first run: The restrictions to the Dutch fields are compensated under cost minimization with additional imports from Norway, whose North Sea fields hold a strategic position close to the UK grid and in reasonable distance to continental Europe. This strong position of the Norwegian fields in contrast weakens the relevance of Russia (respectively the USSR), which shows significant lower shipments than in reality. Accordingly Germany's demand in this run is nearly exclusively met by Dutch and Norwegian gas.

4.4.2 Required adjustments

Therefore not surprisingly this first result lead to the finding, that the evolution of European gas supply does not solely reflect the most cost effective alternative but also mirrors at least

[6] Own calculations based on Cedigaz (2004), IEA (2004b) and BP (2005).

some political decisions. In particular the observable strong position of Russian gas can hardly be explained from a pure economic point of view due to its burden of long transport-distances. The evolution of the European gas market has obviously also been affected by political issues in the past decades, namely the segmentation due to the "iron curtain". The construction of westward transport capacities for Russian gas therefore was partly political motivated in order to supply members of the Warsaw pact. Infrastructure-investments – and in the end consequently transport cost – certainly benefited from this political support, and therefore are not on a level playing field with Western European projects. In the following model run this aspect was accounted for by a lowered cost structure for Russian gas.

In addition a few additional "political aspects" have been introduced into the model. One of these was a growing need of supply-diversification for the main demand regions. As the European gas sector evolved, a complete dependency on a single supplier became increasingly more unacceptable for several countries and consequently efforts were raised to diversify supply. Since the EUGAS model has the ability to account for these considerations, this feature was increasingly activated in the later model periods for selected countries such as Germany, Spain, France and Italy.

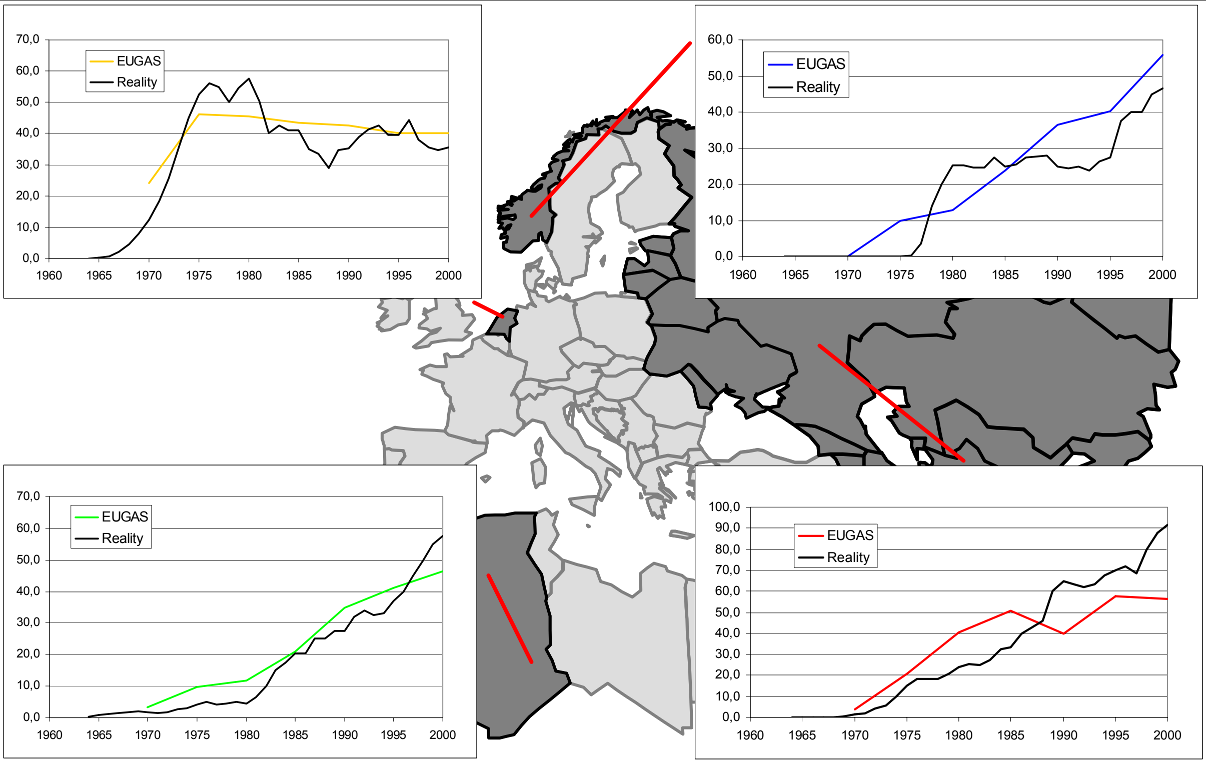
As already discussed in the context of the Netherlands it has to be accounted for different political demands to a sustainable development in the cost minimal production regions, particularly Norway and Denmark. The early exploitation of these cheap and close resources is advantageous with regards to a minimization of total supply costs for Europe as a whole, but of course contradicts national interests of a long-lasting economic development. To reflect these aspects additional moderate production caps were introduced into EUGAS_{1965}.

4.4.3 Selected Results

After including these additional aspects as exogenous requirements, the cost minimal evolution of the European gas market is outlined as displayed in Figure 8.

Obviously the additional assumptions brought the results closer to the reality. But still one of the main findings is that in the past Soviet gas under cost aspects is hardly competitive to alternative sources in Western European demand regions. For example figure 9 illustrates that in the model run FSU-exports to Germany amount only to around 10 BCM at the end of the century, roughly one third of the real supply. No FSU-gas at all is delivered to France, Italy (in the last decade) and Turkey, which today obtain significant shares of their import from Russia. Apart from that in all other countries the EUGAS_{1965} prediction for the FSU-

Figure 8. Export volumes for selected supply countries, EUGAS$_{1965}$ results vs. empirical data – ADJUSTED RUN

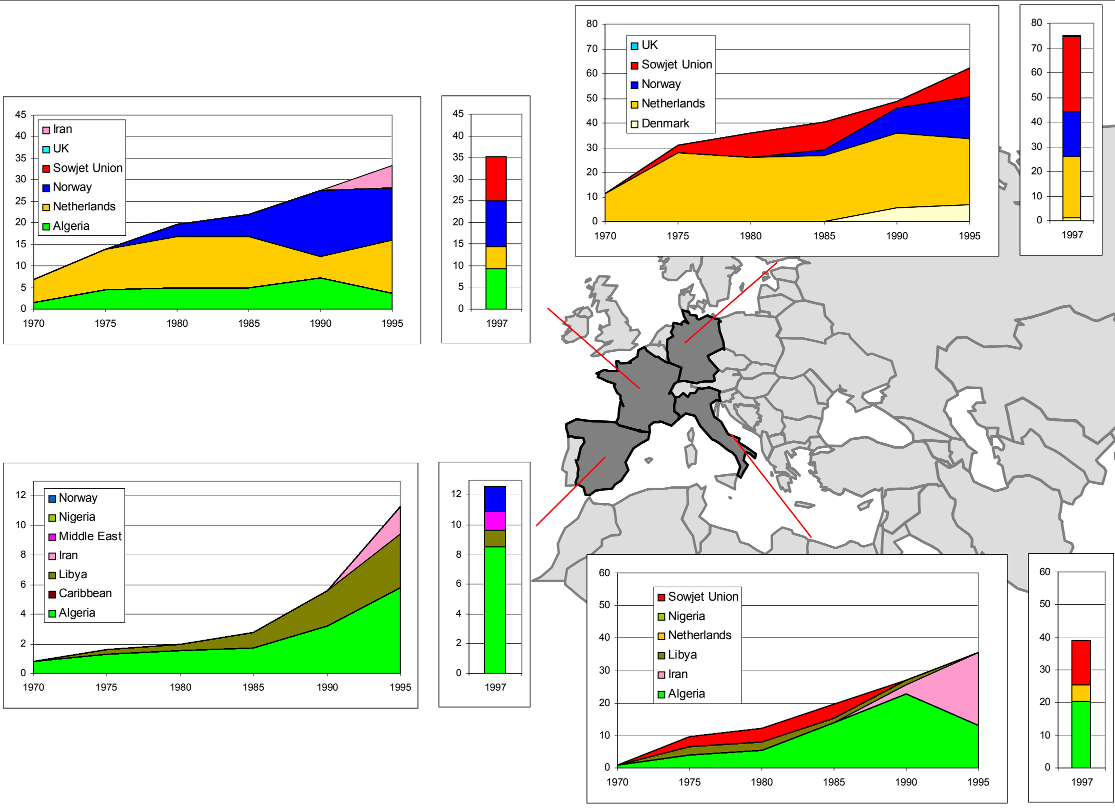


originated imports in the year 2000 reflects the real observable situation – which is not very surprising given the geographically locations of these mostly eastern countries. But one noteworthy result certainly is the finding that even considering politically motivated cost advantages due to the long transport routes Russian gas cannot compete with alternative sources in Western European countries.

While the share of LNG-gas in total European imports does not differ much between EUGAS$_{1965}$ forecasts and reality in 2000, the projections show significant differences on a per-country-level. So Algerian LNG loses shares in Spanish gas market due to an earlier construction of the pipeline link between the two countries. In the case of Italy the model results differ to the opposite direction: Although the Transmed-Pipeline is built, capacities at La Spezia are extended at the same time, which leads to a significantly greater share of LNG in Italian imports. These capacities are partly required to compensate for the already discussed lack of Russian gas in Western Europe, but are also crowding out additional pipeline capacities.

Similar effects of an abandoned pipeline project due to increased LNG development can be observed in the projections for the UK import capacities. In line with the historical experiences capacities at the Canway Island LNG terminal – although exogenous defined to

Figure 9. EUGAS$_{1965}$ import mix 1965-1995 and empirical data 1997



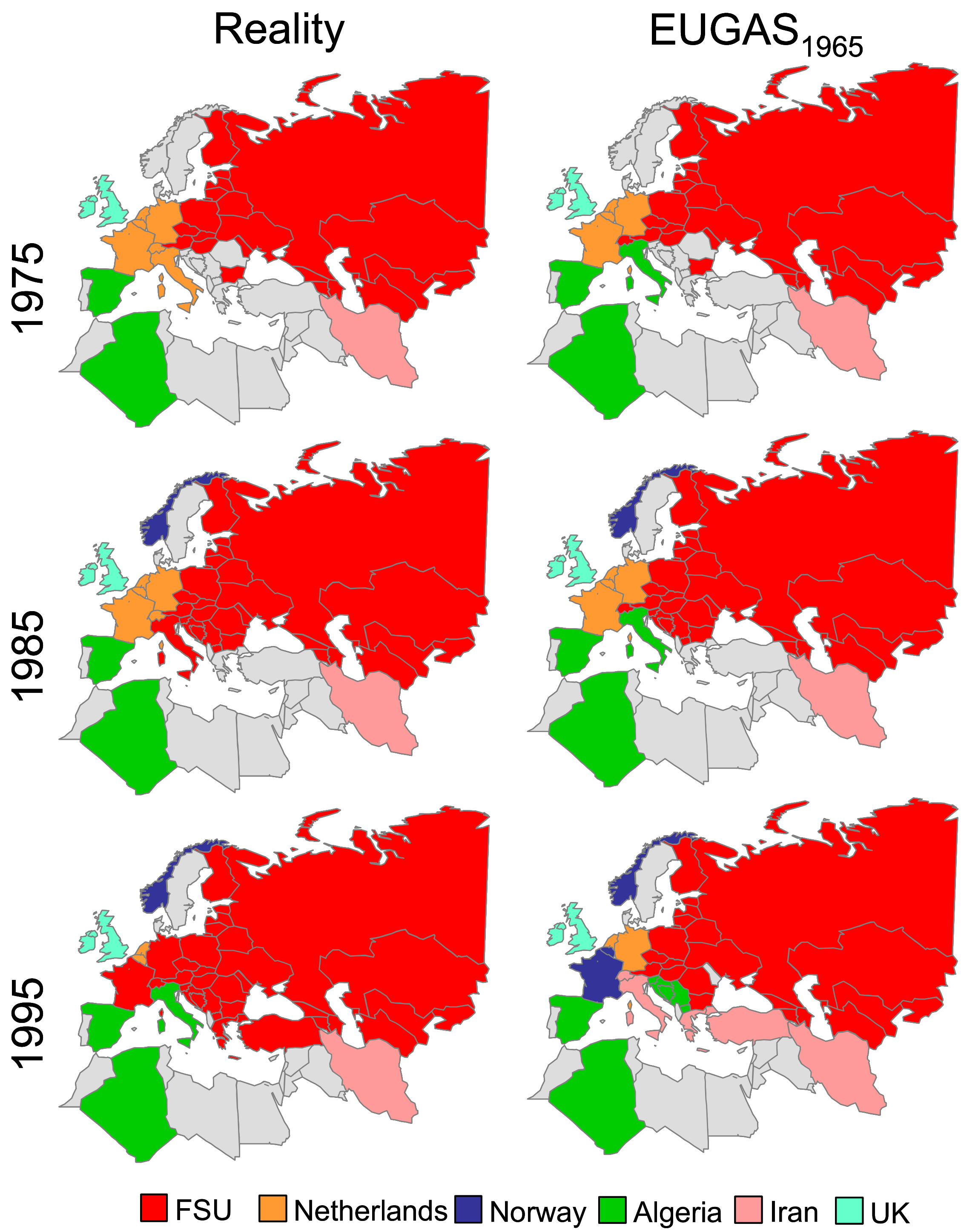
the model early – is not utilized in the first decades. Nevertheless LNG capacities are getting extended in major steps during the 1990s, while on the other side the Belgium-UK Interconnector is not built due to cost considerations.

Clearly the model results open a large field for interpretation and analysis down to a per-country analysis. But given the introductorily outlined problems securing valid historical parameters interpretation of the gained results has to be careful. Therefore we so far restricted the analysis to the identification of these trends on a general level.

4.5 Interpretation

The above presented results demonstrate that in principle a cost-minimizing optimization model is able to explain the major trends in the evolution of European gas market, if certain restrictions such as (political) production caps and diversification of imports are included. Thereby these deviations from pure cost minimization are completely in line with reasonable assumptions, such as a long-term field policy or growing attempts of supply diversification. Despite this general demonstration of applicability and the expectable minor variations due to imperfect parameterization, there are some deviations in the projections, where additional explanations have to be applied.

Figure 10. Main import-sources



The perhaps most important finding is that the strong position of Russian gas in Western Europe countries is hard to explain on a pure cost base, as the comparison in figure 10 demonstrates Transport distances are too long to be able to compete with closer sources such as Norway (in Northern and Western Europe) or Algeria (in Southern Europe), even if the higher transport costs are moderated by lower production costs. As discussed above, the current dominant position of FSU gas in these regions therefore has to be explained with political reasons. Taken Germany as an example, the supply of the former GDR through the East European gas-grid certainly had been more costly than imports from Norway or the Netherlands by a link with the West-German network. But clearly the political circumstances favoured the first alternative. Therefore the 2000 supply mix of Germany does not evolve from pure economic consideration but reflects until today the political based decisions of the past. Similar conclusion can be drawn for Western Europe as a whole.

Such political considerations are one reason for non-cost-minimal developments in the past. One other main source of variation was the lack of perfect foresight in the past. Particular in the early evolutionary stages of the European gas market, expectations and outlooks on which investment decisions had to be made varied on a wide range and contained a great deal of uncertainty. Therefore assumptions had to be made regarding important factors such as the available reserves and resources – a figure which has changed substantially in the past decades – or the cost development due to technological advance. Therefore an ex-post examination based on real observed information is clearly in an advantageous position and the analysis of differences has to account for the limited available data in the past.

And finally we have to consider the possibility, that decisions were met, which clearly were not cost minimal – either due to market power and / or strategic considerations. Nevertheless on the rough level of our so far analysis no significant indication could be found. Given the small amount of valid information available and the general necessary simplifications in a model world, we are therefore indeed quite satisfied with the degree of explanatory power of the $EUGAS_{1965}$ model runs. Certainly a more detailed parameterization and analysis would be desirable and clearly lead to deeper and more substantiated results. But already on this less detailed level we do hope the results can serve as a stimulus to other modellers, to apply their tools to historical data.

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