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From Russia with gas: an analysis of the Nord Stream pipeline's impact on the European Gas Transmission System with the TIGER-Model

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From Russia with Gas
An analysis of the Nord Stream pipeline's impact on the European Gas
Transmission System with the Tiger-Model

by

Stefan Lochner and David Bothe

September 2007

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From Russia With Gas

An analysis of the Nord Stream pipeline's impact on the European Gas Transmission System with the TIGER-Model

Stefan Lochner and David Bothe*

September 2007

Abstract

Europe's increasing import dependency in natural gas facilitates a number of new infrastructure projects. However, up to now it has always been difficult to assess the full impact of these projects as interdependencies within the whole European gas infrastructure system were hard to predict. We present a model that allows such forecasts and therefore an integrated analysis of new pipeline, storage or LNG terminal investments with a high resolution of time and space. To demonstrate the model's capabilities, we examine the effects of the Russian-German Nord Stream (Baltic Sea) import pipeline with respect to its impact on Europe's infrastructure system, especially volume flows within the grid and the utilization of import pipelines with the respective effect on Europe's gas supply mix. We analyse a scenario where Russian exports are allowed to increase alongside the capacity increase and one where they are not. It is shown that although bottlenecks within the European transmission grid are not yet a problem, transit capacity in Central Europe will soon be an issue. In both scenarios, Nord Stream exhibits a cannibalization effect on the traditional Russian export routes - at least in the short run. The increased arrival of Russian gas in Northern Germany however will have a sustained impact on the roles of the other import pipelines, investments in alternative import infrastructure and gas flows in Western Europe in general.

JEL: Q41, C61, N74, L95

Keywords: Natural gas, European gas market, gas infrastructure, modeling

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1 Introduction

Over the next ten years European gas supply faces two major challenges. Firstly, gas demand is projected to rise - depending on the study increases between ten and 40 percent are forecasted. Secondly, European production is declining - especially in the EU's major gas producing countries, the UK and the Netherlands - and is expected to further decline by at least 20 (Netherlands) and 50 percent (UK) until 2020¹. Consequently, gas imports will have to rise. This in turn is associated with increased transport infrastructure investments - mainly in LNG regasification terminals and import pipelines but also in gas storages. However, such investments cannot be evaluated on their own as they affect the system as a whole. Thus, a new investment at some place may lead to inefficiencies or bottlenecks at some other place within the European gas transmission system. To anticipate those through an integrated analysis of the European gas infrastructure, the Cologne Institute of Energy Economics developed its TIGER model.

In this paper, we apply the model to demonstrate the effects of a new pipeline with a focus on its impact on existing import pipelines with respect to utilization, a possibly changing supply structure and gas flows within the whole of Europe. As an example, we chose the Nord Stream pipeline project as it is currently one of Europe's biggest and most controversial politically. The following section provides a brief introduction to the Nord Stream pipeline, sections 3 and 4 present the TIGER model used for the analysis, its parameterization and a validation with historic data. Our results are presented in section 5, section 6 offers some concluding remarks.

2 The Nord Stream Pipeline Project

What is now to become the Nord Stream pipeline was launched as a joint venture between Gazprom and Finnish energy company Neste Oil (which was later merged into Fortum Oyi) in 1997. The German project partner was Ruhrgas (later acquired by E.ON). Following the exit of the Finnish company, Gazprom, E.ON and BASF agreed to the construction of the pipeline in September 2005. For construction and operation of the pipeline, the new North European Gas Pipeline Company with headquarters in Switzerland was established. As for today, each of the German firms owns 24.5 percent of the joint venture through their subsidiaries E.ON Ruhrgas and Wintershall (BASF), the 51 percent majority is owned by Gazprom². In October 2006, the North European Gas Pipeline Company was officially renamed as Nord Stream.

The 1,196 kilometer long offshore section of the pipeline, which is expected to cost

¹From 2006 levels, see Gas Strategies (2007).

²According to an October 2006 Memorandum of Understanding between Gazprom and Gasunie, the Dutch company will receive a 9 percent stake in Nord Stream reducing both Wintershall and E.ON's stakes to 20 percent each (Gas Matters, 2006, p. 31). However, the deal has not yet been completed.

between 5 and 6 billion Euro, will run from Russian Vyborg to Lubmin near Greifswald in Germany. Consisting of initially one line (a second one is planned to be constructed later) with a diameter of 48 inches (1220mm) and operated with a pressure of 220 bar, Nord Stream will have a capacity of 27.5 billion cubic meters (bcm) per year. Construction of the offshore section is supposed to start in 2008, operation of the pipeline by 2010. The construction of the Russian onshore section has begun in 2005 and will link Vyborg to the Russian pipeline grid. In the long-term, gas supplies for the Nord Stream pipeline are supposed to come from gas fields on the Yamal peninsula. On the German side, two onshore connections are planned. A southern link (called OPAL) constructed and operated by Wingas will connect Nord Stream with the company's JAGAL and STEGAL pipelines in Kienbaum and Olbernau (Czech border). A western link (NEL) built by E.ON will connect the project to that company's grid in Achim south of Hamburg.³ Gas flows through the pipeline contracted so far include 9 bcm/year going to Wingas, 4 to E.ON, 2.5 to EdF and 1 bcm destined for the Danish energy company DONG Energy⁴.

The political controversy of the project stems from the fact that it allows direct gas supply from Russia to Western Europe bypassing all current transit countries. These transit countries, mainly Belarus, Ukraine, Poland and Slovakia, usually solely depend on Russia for their gas imports. Their fear is that Russia may use this dependency to attempt to exert political influence in these countries. Today this is hampered by their role as transit countries: turning off gas supply is not a viable option for Russia as such a move would also stop Russian gas supplies to Western Europe and thereby seriously damage the country's reputation as a reliable gas supplier to the West. Morbée and Proost (2007) have shown that this is not a profitable long-term strategy for Russia. After the completion of Nord Stream, Russia may be in a better position to keep up gas supplies to the West while threatening transit countries to cut off supplies at the same time. However, we believe that such a threat would be limited. With a capacity of Nord Stream of 27.5 bcm per year initially (later maybe 55 bcm), the direct route cannot compensate for the gas transports through the transit countries in excess of 120 bcm in 2005. The fear of a cut-off should be greatest in Poland which merely transits about 30 bcm per year to Germany (Gas Strategies, 2007). For the other countries, especially Slovakia and Ukraine which transit more than 100 bcm annually, Russia's position to threaten should not be significantly different from today.

3 Model and Database

In order to enable an integrated assessment of the different infrastructure components (pipeline, storages, terminals) and their interaction with regards to a comprehensive

³For further background on the project, see Nord Stream (2007).

⁴See Wingas (2005), Gazprom (2006a, 2006b) and Gaz de France (2006).

analysis of the supply situation we apply the TIGER model developed by the Cologne Institute of Energy Economics. Existing gas supply models⁵ focus on issues like the overall supply situation or the supply mix; the necessary infrastructure is only taken into account on an aggregate level. TIGER (Transport Infrastructure for Gas with Enhanced Resolution) is a dispatch model optimizing natural gas supply to all European countries subject to the available infrastructure on a very detailed level. The latter is stored in the institute’s European Database of Gas Infrastructure called EDGIS⁶.

The EDGIS database contains the following elements:

- the European transmission grid⁷ consisting of pipelines/networks run by more 50 transmission system operators and the respective interconnector capacities between the networks, which in total equates to
- more than 500 nodes and more than 650 pipeline sections (including pipeline projects being planned or under construction) with their individual characteristics (diameter, pressure, capacity, length, owner),
- gas production in Europe and neighboring countries (i.e. Algeria) aggregated to 17 production regions,
- non-European production from 4 regions which enter the system at its border points or through Liquefied Natural Gas (LNG) import terminals,
- 147 gas storage facilities and 20 soon-to-be completed storage projects with individual working gas volumes and injection and withdrawal rates (which are a function of actual storage volume and storage type),
- 24 LNG terminals and terminal projects with individual import, LNG storage and regasification capacities,
- monthly European gas demand broken down into 53 demand regions and assigned to individual nodes
- and 58 demand profiles distinguished by country and sector to allow for characteristic demand cycles in each demand region and different demand growth paths in the sectors (i.e. power generation and domestic consumers).

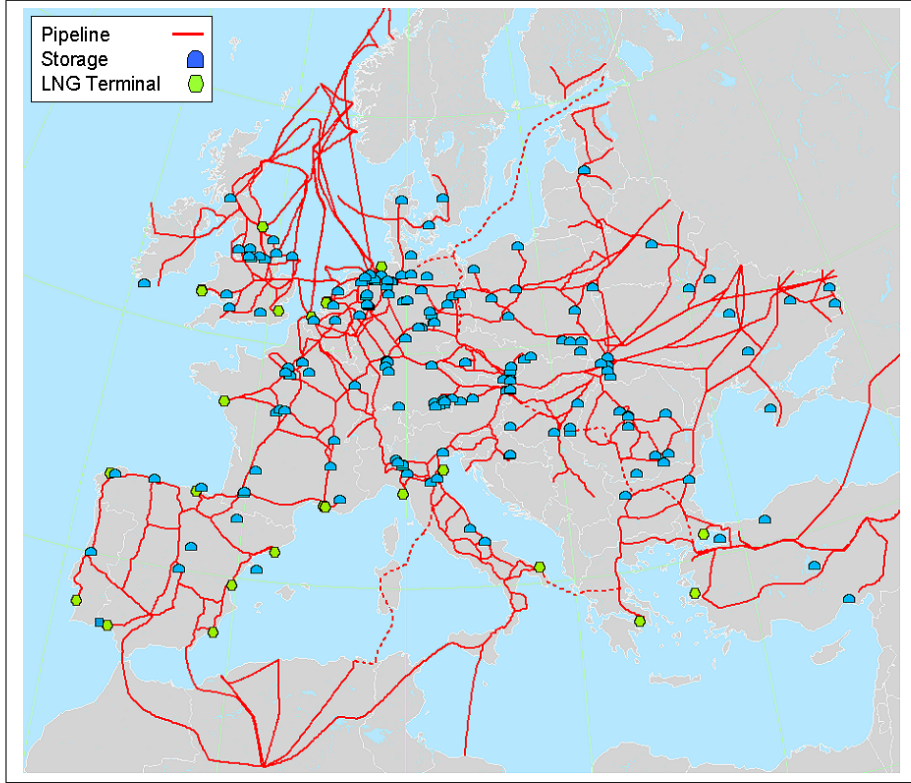
In order to provide an easy overview on parameters and to enable a comprehensive visualization, all infrastructure elements are geocoded and can therefore be included in automatically generated maps. All EDGIS infrastructure elements encompassed in TIGER are illustrated in figure 1.

⁵For example, see Perner (2002) and Seeliger (2006).

⁶EDGIS is owned and maintained by the Cologne Institute of Energy Economics (EWI).

⁷Including neighboring regions such as Turkey and Algeria.

Figure 1: European gas infrastructure



TIGER is a dispatch model optimizing natural gas supply to the European market. As a linear model, it minimizes the total cost of gas supply over the 10 year time period it models on a monthly base. Total costs comprise of transport, storage and production costs. The reason for exogenously including region-specific production costs is to allow the model to choose the cost minimal supply mix for Europe subject to the gas transmission system instead of pre-specifying the mix of supply countries. The transport and storage cost components only consist of operating cost. In a dispatch model, only existing infrastructure or exogenous additions are used, capital costs do not need to be taken into account.

To realistically model the European natural gas market, the cost minimization is subject to the following constraints.

Production constraint : For each month, production in a production region cannot exceed the maximum monthly production capacities in the specific region (exogenously given).

Input-output balance : At each of the 500+ nodes in the system, inflows and outflows have to be balanced in each period. Inflows consist of gas transports to the respective node from other nodes and, if applicable, production at the node or flows out of storages

or regasification terminals; outflows equal flows to other nodes or into storages as well as demand at the specific node.

Storage constraint : The volume of gas in a storage equals its volume in the previous period plus injections and minus withdrawals from the storage and minus compressor consumption (only in the case of withdrawal or injection taking place).

Supply constraint : The total volume of gas supplied to nodes within a demand region has to equal total demand in that region for each time period.

Capacity constraints ensuring that gas supply is subject to the characteristics of the European gas infrastructure system apply for all the elements. These constraints are posed by pipeline capacities, maximum storage volumes and injection and withdrawal rates (the latter two being functions of the storage volume) and LNG import, storage and regasification capacities.

4 Model Parameterization and Historical Validation

This section describes the parameterization of the model for our analysis. To run a simulation of the impact of the Nord Stream pipeline on the utilization of the European gas transport infrastructure, we chose to model the 2005 to 2014 period. This allows us to (a) observe the impact of Nord Stream line 1 going into service in late 2010 and (b) verify the model results for the year 2005 with derived 2005 data.

Parameterization

Parameterization includes three main elements: production, consumption and infrastructure. A framework for all three categories is given by the EDGIS database described in section 3.

For consumption data, we have to select a demand forecast. We chose the Gas Strategies (2007) Central demand case prognosis for two reasons. First, it is a good average of all published forecasts for European gas demand in the next ten years⁸. Second, not just aggregated by country forecasts but detailed prognosis for different sectors in each country are available. This allows us to make full use of the TIGER models capabilities.

Production needs to be further specified by determining available volumes and either production costs or natural gas prices. For this simulation, we set production capacities and costs according to the current reference run of the European supply forecast-model EUGAS⁹. Production capacities are taken from the results of EUGAS, costs as

⁸See Lochner/Bothe/Lienert (2007).

⁹See Perner (2002) with updated parameterization and also Seeliger (2006).

specified in the model’s assumptions. For production regions not modeled in detail in EUGAS, we use Gas Strategies’ (2007) production forecast for the model period and set production costs according to similar production areas. Some adjustments are made to take declining reserves into account (specifically in the UK and the Netherlands). In such cases a mark-up over variable production costs for these gas fields is assumed to model the higher value of the remaining gas.

Regarding infrastructure parameterization, the model relies on the EDGIS database. Therefore, all current infrastructure elements (pipelines, LNG terminals, storages) are considered truthfully. For new infrastructure projects, we make conservative assumptions to mirror observed past differences between initially projected and actual completion dates. For example, we assume the Algeria-Sardinia-Italy pipeline (Galsi) and the Italy-Greece-Interconnector not to be available before 2012 and the first construction phase of Nabucco not before late 2013 (although it is debatable whether that is a conservative or rather an optimistic assumption). An expansion of the Yamal pipeline or the construction of a Baltic-Gas-Interconnector between Germany and Sweden/Denmark are not considered as we do not deem them as likely to happen until 2014. Nord Stream and the two German onshore connections are assumed to enter service in October 2010.

Model Validation

To validate the results of our simulation, we aggregate cross-border flows for the year 2005 and compare them with actual flows derived from available data from Cedigaz (2006) and Gas Strategies (2007). Focusing on aggregate flows makes sense as a cost-minimization model which does not take long-term take-or-pay contracts into account will always chose the optimal dispatch, i.e. anticipating swaps and avoiding inefficient gas flows. Therefore, observations made in import and export statistics like simultaneous Norwegian gas flows to Austria and Russian exports to Germany via Austria¹⁰ will not be matched in our simulation. Instead, some form of swap will take place in either Austria or Germany (due to numerous border points) resulting in a net-flow from Austria to Germany. This may indeed match real gas flows more realistically than the available statistics. However, gas flows may not always be as clear as in the case of Austria where Russian gas will always be imported through Baumgarten. For example, consider the Benelux countries where Norwegian gas may reach Belgium via France, the Netherlands or Germany or directly through the Zeepipe offshore pipeline. However, some gas volumes on the latter route may actually be destined for France or the Netherlands making it difficult to assess where gas from which fields actually ends up. Therefore, we focus our validation on the major natural gas import routes into the European Union and transit countries where gas flows mainly in one direction making it easier to track (i.e. the example of Austria mentioned above).

¹⁰See Cedigaz (2006).

Results of our simulation compared with adjusted Cedigaz (2006) figures are presented in table 1.

Table 1: Estimated actual vs. projected 2005 gas flows in bcm with production cost parameterization

Imports from / to	LNG		Russian gas*		Norway		Algeria**	
	real	proj.	real	proj.	real	proj.	real	proj.
EU 25	47.6	45.0	132.0	143.1	80.9	79.2	34.7	34.5
France	12.8	12.5	11.5	12.1	16.2	17.7		
Germany			51.0	63.2	36.3	34.7		
Austria			56.0	56.6				
Benelux	3.0	1.5			14.6	13.8		
UK	0.5	2.4			13.0	13.0		
Italy	2.5	1.5	23.3	33.1			25.2	25.0
Spain	21.8	24.6					9.5	9.5

* Via Russian gas transit countries; ** Pipeline imports only

The only major deviations on an absolute level between our projection and the estimated actual volumes can be detected for Russian pipeline imports to Germany and Italy. These may be determined by our assumption for Dutch gas production costs plus mark-up (see previous paragraph). Therefore, Dutch gas is less competitive and exported to a lesser extend to both Germany and further on to Italy. Consequently, projected flows differ from actual flows for 2005; however, we believe this to be a more realistic scenario for long-run considerations where we expect gas production from the Netherlands to be at least partially replaced by Russian imports. The general picture presented by our validation however shows actual gas flows are relatively well reflected by gas flows in the TIGER model.

An alternative parameterization with gas price instead of production costs yields even better results in a historical validation¹¹. However, due to the difficulties associated with estimating future prices we stay with the production cost parameterization for the purpose of this paper. Nevertheless, the results of the price validation are reported in table 2.

¹¹Prices were derived from average EU-15 border prices between 2001 and 2005. Where there is more than one border price for one producer country (i.e. Russian gas has different border prices for imports to Italy and Germany, a weighted average was applied).

Table 2: Estimated actual vs. projected 2005 gas flows in bcm with gas price parameterization

Imports from / to	LNG		Russian gas*		Norway		Algeria**	
	real	proj.	real	proj.	real	proj.	real	proj.
EU 25	47.6	46.9	132.0	126.7	80.9	79.4	34.7	35.5
France	12.8	12.7	11.5	9.0	16.2	17.7		
Germany			51.0	49.0	36.3	36.1		
Austria			49.0	49.0				
Benelux	3.0	2.0			14.6	13.5		
UK	0.5	1.5			13.0	12.1		
Italy	2.5	3.4	23.3	28.0			25.2	27.0
Spain	21.8	24.1					9.5	8.5

* Via Russian gas transit countries; ** Pipeline imports only

5 Results

To demonstrate the capabilities of the TIGER model for analyses of infrastructure projects, it is applied to assess the impact of the Nord Stream pipeline on the European gas transmission system. Therefore, we conducted the following simulations. For later comparisons we first perform a reference run with the assumption that the Nord Stream pipeline project is not realized (scenario R (for reference)). According to Nord Stream (2007), the first line of the offshore pipeline will enter service in 2010, presumably in the second half of that year. Therefore, from 2010 onwards we can imagine two scenarios, both of them assuming that one line of the Nord Stream pipeline with a capacity of 27.5 bcm/year is built and that the two connections to the German grid, OPAL and NEL, are available at the same time. In the first scenario (no. 1), Russia will increase its exports to make use of the new export capacities. However, it might be doubted that Russia will be able to do so due to a bottleneck in gas production¹². Therefore, scenario 2 assumes that despite the new pipeline, Russian exports to the EU will not change compared to the reference run. The motivation for Nord Stream in such a scenario might be to partially bypass today's transit countries.

¹²The authors of this paper agree with opinions expressed in the literature that high domestic Russian gas demand (because of low regulated prices), uncertainty about supplies from other former CIS countries, declining production in existing Russian gas fields and insufficient investments in new fields may lead to a shortage in gas supply prohibiting an increase in exports to the EU until 2015 (see Stern (2005)).

Scenario 1

As the pipeline may have entered service by late 2010, we will focus our comparison on its first year of full service, namely 2011. Compared to the reference run, Russian import capacities to Western Europe will then have increased by 27.5 bcm. Table 4 on page 13 shows how this capacity increase affects total imports into the EU in scenario 1.

Comparing scenarios R and 1 we observe two things. Firstly, total Russian imports are about 18 bcm higher, thus at that time only about 65 percent of the capacity increase will actually translate into increased imports compared to a scenario without Nord Stream. Secondly, LNG imports will suffer due to the increased availability of cheaper Russian gas.

The second issue to analyse should be how the gas dispatch within Europe is affected by the new import route. The graphical illustration of the results produced by the TIGER model is displayed in figure 2. The map visualizes changes in volume flows between scenarios R and 1. Pipelines or pipeline sections with higher flows in scenario R are coloured in green, routes with higher flows in scenario 1 are red¹³. The magnitude of the absolute volume change is implied by the line thickness (the thicker the line, the higher the absolute change).

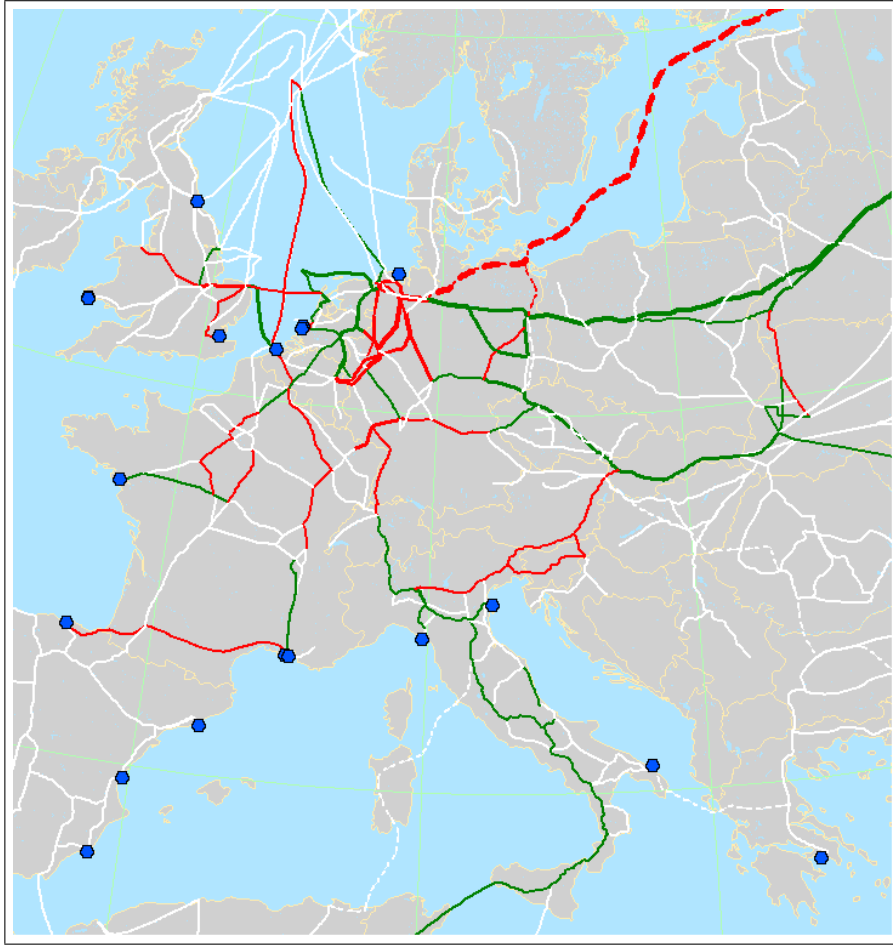
The following effects of Nord Stream on the European transmission grid become evident. First, Nord Stream at least partially cannibalizes imports on the other Russian import pipelines, Yamal (through Belarus and Poland) and Transgas (Ukraine, Slovakia). Secondly, due to the increased arrival of Russian gas in North-Western Germany through the E.ON link to the Nord Stream pipeline, the model chooses to reduce Norwegian imports through Europipe 1. Instead, the same gas is exported to Belgium via increased flows through the Zeepipe pipeline in the scenario with Nord Stream. For the same reason (more Russian gas in Germany), less Dutch gas is required in Germany. This gas is exported to the UK via the BBL interconnector.

In addition to these findings, the high resolution of the TIGER model allows us to look at individual pipelines on a more detailed level.

Investigating why only 65 percent of the import capacity increase for Russian gas actually translates into Russian gas imports, we therefore focus on the East-to-West transit pipelines in central Europe, the NETRA, STEGAL and MEGAL pipelines in Germany and the Austrian TAG to Italy. A comparison of the average annual and peak utilization of these pipelines in scenario R and 1 is presented in table 3 (page 11). Although the figures show that the East-West transit significantly increases in scenario 1, transport volumes on an annual level are not yet restricted by capacity except on the route to Italy. Instead, what restricts transits rather seems to be the

¹³Only differences in excess of 1 bcm (per year) are coloured, pipelines with unchanged or only slightly changed flows remain white.

Figure 2: Differences in flows between scenario R and 1 for the year 2011



border points (or the pipeline sections behind the borders) to the neighboring countries in the West. (The utilizations of the three German borderpoints to the West are also displayed in table 3). Furthermore, the difference between average and peak utilization for the borderpoints and pipelines implies that a less structured supply of natural gas imports is not economically viable under the physical constraints of the systems and the assumptions of the model.

Considering the utilization of storages shows that, in 2011, 84 percent of available working gas volume (WGV) is used for seasonal load balancing¹⁴ (see figure 3 for exemplary results on selected underground gas storages in Germany). In the light of the debate on the necessity of more gas storage in Europe, it can therefore be concluded that, without new storages, additional flexibility would have to be obtained through further structuring import quantities, which consequently leads to a lower average utilization of import routes. However, the analyses with TIGER also show that the value of an additional storage largely depends on its location due to grid characteristics and differing demand levels between different regions. Additional storages therefore do not necessarily disburden the system or increase security of supply but have to be

¹⁴Fill level as of October 1.

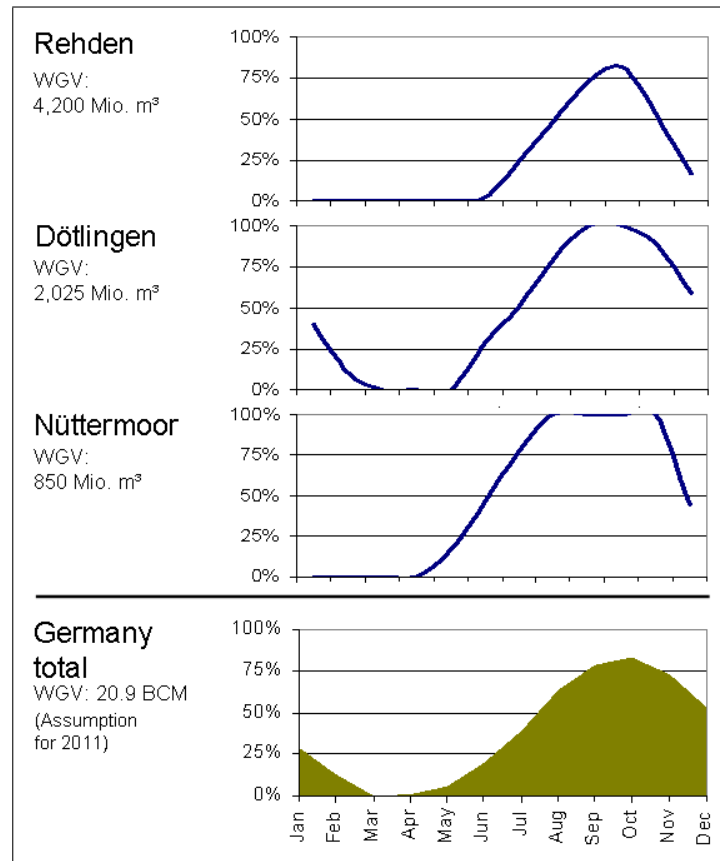
Table 3: Utilization of capacities of selected borderpoints and pipelines in 2011

Pipeline / Borderpoint	Scenario R		Scenario 1	
	Average	Peak	Average	Peak
NETRA*	9.6 %	32.3 %	88.7 %	100.0 %
STEGAL	92.4 %	100.0 %	80.2 %	100.0 %
MEGAL	49.5 %	60.2 %	53.6 %	58.3 %
TAG	97.3 %	100.0 %	100.0 %	100.0 %
Obergailbach (FR)	77.3 %	99.0 %	92.7 %	100.0 %
Eynatten (BE)**	27.2 %	59.1 %	70.7 %	100.0 %
Emden (NL)**	25.0 %	100.0 %	100.0 %	100.0 %

*Section West of Achim; **Flows out of Germany only.

evaluated in the context of the whole gas transmission system as well.

Figure 3: 2011 storage levels for selected German storages



Returning to the effect of Nord Stream in scenario 1 and regarding the impact on the traditional transit pipelines (Transgas and Yamal), it is evident that these differ in scope and manner. While Yamal experiences a cannibalization effect leading to a decrease in transported volumes, such an effect is less relevant for Transgas. Instead, the purpose of Transgas seems to change with the beginning of operations of Nord Stream. Due to the increased arrival of Russian gas in Northern Germany through the new pipeline, Transgas can be increasingly used to supply Italy and France. In figure

2, it is visible that those volumes on the pipeline still reaching Germany are consumed to a lesser extent in Germany but instead transited in higher quantities to France on the MEGAL pipeline (flows on that pipeline increase as seen in table 3). Transgas transits through Austria to Germany seem unaffected and transits destined for Italy are also higher in the Nord Stream scenario. A more detailed comparison providing transported volumes and utilization of the import routes is presented in figures 4a and 4b¹⁵.

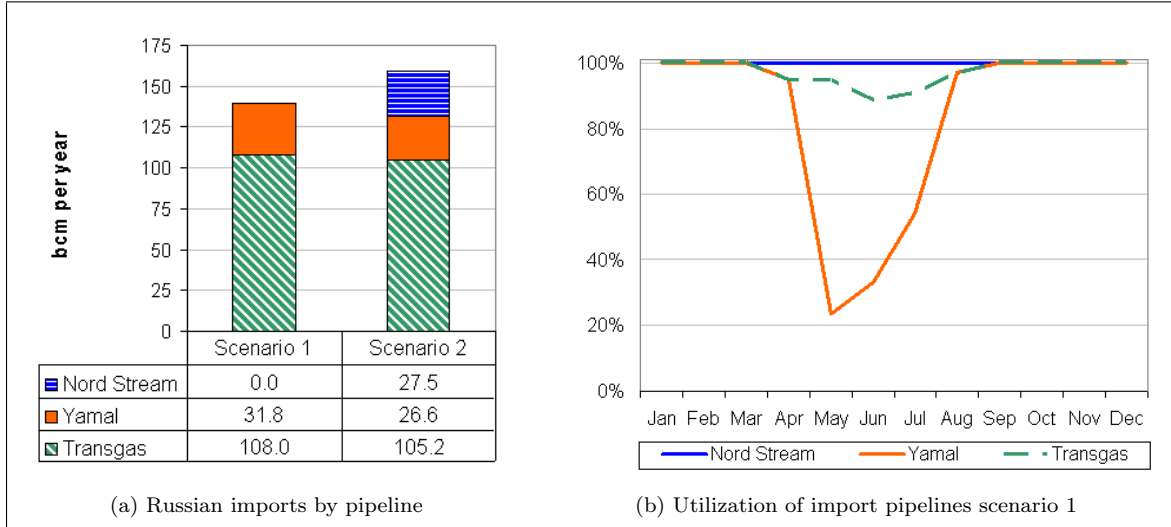


Figure 4: Nord Stream's impact on Russian import pipelines in 2011 (scenario 1)

For the German onshore links connecting Nord Stream to the grid, NEL and OPAL, it can be said that while both are used, capacity is only fully utilized on the Western NEL. The overcapacities resulting from the fact that the sum of the capacities of the two links is higher than Nord Stream's capacity will therefore be more of a problem for OPAL according to TIGER. Two further minor observations from figure 2 in scenario 1 are higher gas flows to Switzerland via Germany (due to the increased availability of Russian gas in the North of the country) and lower gas imports from Algeria. This is caused by the increased arrival of Russian gas in Northern Italy compared to scenario R and by the decreased need of supplying Switzerland with gas from the South in the winter months for the aforementioned reason.

Under our scenario 1 assumptions allowing Russia to increase its exports in line with transport capacity, we find that for later periods, i.e. for 2014 before the second Nord Stream line enters service, that the cannibalization effect has disappeared due to increased demand in central Europe giving Russia the opportunity to sell additional gas. By that year, utilizations of Yamal and Transgas have recovered to levels before the start of Nord Stream (100 and 99 percent respectively). The analysis however also shows that - as already observable in 2011 - capacity for transports further into Western Europe is limited. Consequently, the shift of Norwegian gas flows further to

¹⁵The data is provided for the EU-27 entry points of the pipelines in Germany, Poland and Slovakia respectively.

the West intensifies. Liquefied natural gas, which in absence of Nord Stream would have covered demand increases in Europe, is still required less compared to scenario R.

Table 4: Comparison of import quantities scenarios R, 1 and 2 for 2011

	Scenario R [bcm/year]	Scenario 1 [bcm/year]	Scenario 2 [bcm/year]
Russia	166.3	184.2	166.3
Algeria	42.8	41.7	43.3
Norway	88.3	88.3	88.3
Libya	7.9	7.9	7.9
LNG imports	97.6	86.9	98.1

Column sum differences result from marginal changes in EU-27 production. The constant values for Norway are determined by limited production capacity, for Libya by pipeline export capacity.

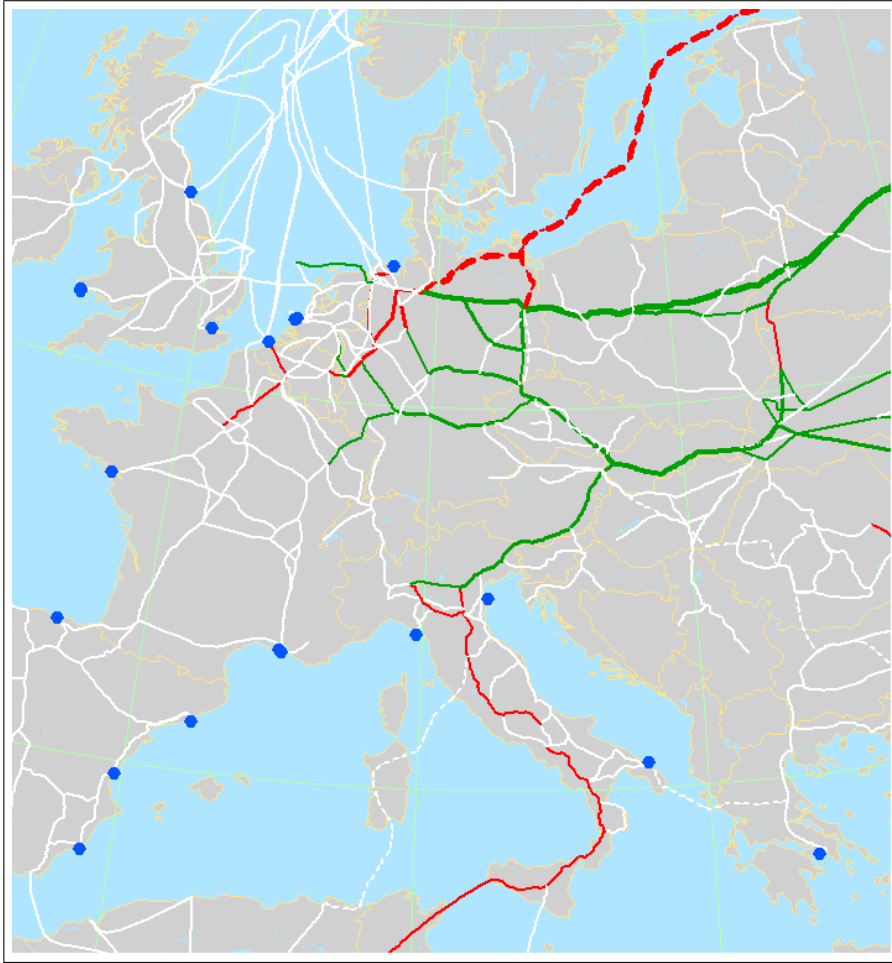
Scenario 2

Under the assumptions of scenario 2, results differ significantly from the previous simulation. Here it is assumed that due to limited production capacities the Russian export monopolist is not able to increase supply to the EU when transport capacity increases. Therefore, we fix Russian production at the reference run levels. The transport capacity increase in this scenario should be interpreted as a commitment by Gazprom with the aim to discourage European diversification of supply efforts and lessen the dependency on the transit countries. Advantages which would make the project still profitable are Russia's improved bargaining power compared to the transit countries and saved transit fees.

The results of the scenario 2 vs. R comparison are depicted in figure 5 in the same fashion as the scenario 1 vs. R comparison (figure 2).

The main commonality with the previous analysis is the cannibalization effect Nord Stream exhibits on the other Russian import pipelines. It is much stronger in scenario 2. The effects of Nord Stream for North-Western Europe almost disappear. Most supplies are simply rerouted from Yamal and to a lesser extend Transgas to Nord Stream. Gas flows from Norway are not affected in this scenario. Regarding LNG, the situation is different from the scenario 1. While LNG imports to the Benelux countries still suffer due to the arrival of Russian gas in Northern Germany, LNG in Italy actually benefits from Nord Stream. And so does Algerian pipeline gas. As transits on the Transgas pipeline, a large part of which is going to Italy, fall due to the use of Nord Stream and limited Russian exports, the missing gas in Northern Italy is replaced by LNG and Algerian pipeline imports. (In a competitive market without long-term contracts, Russia would chose to supply the closer German market instead of exporting further South to Italy.) For the differing import quantities compared to scenarios R and 1, refer again to table 4.

Figure 5: Differences in flows between scenario R and 2 for the year 2011



Discussion of Results

The informative value of such model results mainly depends on two factors: the quality of the model parameterization - which can be increased constantly through research - and the underlying logic of the model. For the latter factor, the question is whether or not a linear optimization model with the respective assumptions of perfect competition is able to make predictions for a market characterized by long-term contracts and oligopolistic structures. To comment on that, one has to distinguish between economic and real gas flows: of course in reality there are gas flows determined by long-term contracts which are not represented accurately with the cost minimization approach of the model. Dutch exports via the German TENP pipeline to Switzerland and Italy are an example. However, economically contracted flows are even in reality not necessarily equal to physical gas flows but are swapped somewhere along the way. An example would be Norwegian export contracts with Spain. The results of the model anticipate such swaps and focus on the residual gas flows. The validation presented in section 4 shows that these physical gas flows are reproduced accurately by the TIGER model and therefore constitute a reliable benchmark for scenario analyses like the ones presented

in this paper.

6 Conclusion

The simulations in this paper have shown that the effects of new pipeline projects - or infrastructure projects in general - are complex due to interdependencies within the system which affect a number of other infrastructure elements as well. The TIGER model which is presented in this paper seems a suitable tool to do so.

Regarding the Nord Stream pipeline, we demonstrate that, putting political motivations concerning the bypass of transit countries aside and assuming sufficient production capacity in Russia, the country is put in a position to increase its exports to Europe by using the existing infrastructure. However, East-to-West transit capacities in central Europe are limited causing Norwegian gas exports to be pushed further to the West by the Russian gas. Less LNG is required in Europe leading to a fall in the utilization of LNG import terminals. Under the assumption of constant Russian exports, Nord Stream mainly leads to a cannibalization of transport volumes on the traditional transit pipelines.

The analyses in this paper have demonstrated the features of a detailed dispatch model as compared to more aggregated gas supply models. While the fundamental message does not change significantly, it is evident that it requires a model like TIGER with a high resolution of time and space to evaluate the specific effects of forecasted demand and supply scenarios on the infrastructure. The model thereby allows detailed surveys all the way down to single pipeline sections, storages and LNG terminals.

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