

Gas Flows and Gas Prices in Europe: What is the Impact of Nord Stream 2

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Abstract: Natural gas plays an important role in Europe. It is a bridging technology for the transition of the electricity system and has also a significant potential to reduce CO₂ emission in the mobility and heating sectors. Nevertheless, Europe is strongly dependent on imports of natural gas. While it is expected that European gas demand declines in long-term, indigenous production in Europe also declines. Thus, European import dependency persists. An important supplier of natural gas is Russia. Even if Russia should increase its market share, there is still enough transport capacity existing to bring Russian gas to Europe. However, the pipeline Nord Stream 2 with an additional annual capacity of 55 billion cubic meters (bcm) is under construction. This pipeline probably starts operation in 2020 and has the potential to change gas flows in Europe significantly. Stadtwerke München GmbH (SWM) operate the worldwide gas market model WEGA to calculate gas flows and gas prices in daily resolution until 2040. This model is based on the commercial solution Pegasus from Pöyry Management Consulting. Public sources as well as commercial services are used by SWM to constantly update the dataset of WEGA. For plausibility checks, NBP, NCG and TTF future prices are also frequently calculated. To analyse the impact of Nord Stream 2 on European gas flows, different scenarios are calculated in WEGA. The following exemplary results of 2028 reveal that Nord Stream 2 has significant effects on European gas flows: Transit flows through Germany increase by 17 bcm in comparison to a scenario without Nord Stream 2. On the other hand, gas flows from Poland to Germany are reduced by 14 bcm due to Nord Stream 2. Other effects are reduced gas flows via Ukraine and a redirection of Norwegian gas (13 bcm) from Germany to other Northwest European countries. Furthermore, Nord Stream 2 has also an impact on European gas prices. In general, this pipeline has a moderate dampening effect, with gas prices in Western Europe falling slightly more than in Eastern Europe.

Keywords: WEGA, Nord Stream 2, pipelines, gas flows, gas price, gas market model

1 Introduction and Related Work

Natural gas plays an important role in energy supply and its fields of application are diverse: heat generation, hot water preparation, power generation and industrial applications. The world's largest growth potential among fossil fuels is attributed to the demand for natural gas. BP expects annual growth of 1.7 % worldwide by 2040 [1].

Gas demand in Europe is expected to fall by 2040, with some studies also forecasting relatively constant gas demand. At the same time, however, a significant decline in domestic production in Europe is to be expected, so that Europe will be even more dependent on gas imports in the long term. This additional import demand will be met primarily by Russian pipeline gas and LNG. [1], [7], [18], [26]

The Nord Stream 2 Baltic Sea pipeline would not be necessary considering only sufficient gas imports to Europe. The EU has enough pipelines and LNG terminals to import all the gas it needs [6]. There would also be alternatives to this pipeline from an economic point of view. The construction of Nord Stream 2 with a capacity of 55 bcm per year costs approximately 9.5 billion €. In comparison to this, the costs to renovate transit pipelines in Ukraine with a capacity of 160 bcm per year are expected to stand at 6 billion €, according to the European Political Strategy Centre [6]. But from a Russian perspective, the reasons for building Nord Stream 2 are strongly politically driven. Gazprom is aiming to minimize gas transit through Ukraine [23], and it is even possible to reduce it to zero [24]. This is intended to break the monopoly of Eastern European states for Russian transit gas, which is having a severe impact on Ukraine and Poland, among others. Nord Stream 2 leads to diminishing transit revenues for Ukraine and Poland [10]. It is also often argued that with Nord Stream 2 Russia is able to cut supply to specific Eastern European countries without hurting other consumers in Europe.

With two additional strings of Nord Stream 2 and two strings of Turkish Stream, there is a non-Ukrainian transit capacity of 205.9 bcm per year available for Russian gas exports to Europe [23]. However, Pirani and Yafimava [24] and Pirani [23] also introduce scenarios of higher Russian gas demand in Europe and a non-Ukrainian transit capacity, where transit flows through Ukraine are still required, especially from a seasonal point of view with a higher gas demand at peak times.

With the construction of Nord Stream 1 and the expansion of interconnection capacities west-east gas flows have increased and traditional east-west gas flows have decreased. This boosted gas-on-gas competition in Eastern Europe, where Russian gas from Nord Stream 1 competed with Russian gas from existing long-term contracts [22]. Goldthau [10] expects the same effect for gas prices if Nord Stream 2 comes online. He argues that Ukraine is moving from a situation where it gets high transit fees, but pays a high price for Russian gas to a situation where it gets small transit fees, but pays a cheaper price for Russian gas.

Kotek, Selei and Tóth [19] use the gas market model EGMM to calculate the impact of Nord Stream 2 on gas prices and competition in 2020. This model only focuses on 35 European countries and computes the equilibrium prices and gas flows in monthly resolution. The calculation for 2020

shows that gas prices in Western Europe are not affected by the construction of Nord Stream 2, but they increase in Eastern Europe. The authors conclude that Nord Stream 2 creates bottlenecks in gas flows from Western to Eastern Europe which result in lower available capacity for short term (spot) gas competition. Furthermore, it is assumed that LNG is relatively cheap and can push Russian gas out of the market if enough interconnection capacity would be available. The calculated overall welfare impact for Western and Eastern Europe of Nord Stream 2 is negative in 2020 (-2.1 billion €).

Hecking and Weiser [15] analyse the impact of Nord Stream 2 on European gas prices and gas flows by using the models COLUMBUS und TIGER. COLUMBUS is a long-term model for the global gas market and allows strategic behaviour of gas exporters. Investments into production capacities and infrastructure as well as marginal supply cost curves per country are a result of the model. In a second step the dispatching model TIGER is used with the results of COLUMBUS. The output of TIGER are gas flows and gas prices. Hecking and Weiser show that gas prices in all European countries are decreasing due to Nord Stream 2. In some countries prices are up to 32 % lower. This significant price effect is based on less imports of very expensive LNG to Europe if Nord Stream 2 will be built. The authors also show the cost curves of LNG in 2020, 2025 and 2030. If these cost curves would be lower, Nord Stream 2 would have a reduced price effect. It has to be noted that the study was commissioned by the Nord Stream 2 AG. Hecking and Weiser also calculate gas flows in scenarios with and without Nord Stream 2. It can be seen that gas flows from Norway are not significantly affected. Interestingly very high gas flows from Slovakia to Ukraine occur in all scenarios whereas no gas flows exist from Ukraine to Romania. The authors conclude that Nord Stream 2 has an overall welfare benefit of 7.9 to 24.4 billion €.

In another study from Kruse and Berkhahn [21], also commissioned by Nord Stream 2 AG, the economic benefit of Nord Stream 2 is calculated, but without a gas market model. According to the authors of this study the project adds 2.26 billion € in GDP and creates around 31,000 full-time equivalents over a period of five years.

All the above analyses have weaknesses: too rough a calculation of gas flows on a monthly basis, no consideration of global gas flows, exogenous specification of LNG imports in Europe and LNG prices that are too low or too high. Against this background, the question arises as to how the gas flows will change in Europe in the long-term through Nord Stream 2, and what price effects this will have for the individual European countries. These questions are the focus of our paper that is structured as follows: The WEGA gas market model is used to analyse gas prices and gas flows. This is explained in the following chapter. It also discusses the basic scenario used, in which Nord Stream 2 is included at 55 bcm per year. Chapter 3 then discusses the results compared to a scenario without Nord Stream 2. A summary of the main results then concludes our paper.

2 Gas Market Model WEGA and Base Case

SWM has been using the WEGA gas market model since 2013 to analyse global gas flows and gas prices until 2040. The consulting firm Pöyry Management Consulting (UK) Ltd. developed the model under the name PEGASUS [3], [25] and uses it for its own analyses and for the preparation of its own fee-based reports. To ensure that WEGA is up to date, SWM obtains an annual data update from Pöyry and modifies it with its own assumptions. For example, SWM has its own assumptions on the development of the oil price, exchange rates, marginal costs of storage facilities, gas demand or production volumes from individual sources. These modifications are based on SWM analyses, on publicly accessible sources or come from other commercial providers, some of which maintain their own gas market models. For this reason, the results of this work are not the view of PÖYRY, but of SWM within scenarios. Changes to the scenarios would lead to different results. For plausibility checks, NCG, NBP and TTF future prices are frequently calculated to make sure that WEGA is generating accurate market prices for the next years. In addition, results are discussed with experts of SWM and other companies.

Gas market models can be divided into two classes: On the one hand, models in which market power is exercised by the players and, on the other hand, models which operate with full competition. For an overview of gas market models, see the work of Chyong and Hobbs [2], Holz et al. [16] and the work of the Energy Modeling Forum [4]. The WEGA gas market model works with perfect foresight and full competition. Market power of individual players and investment decisions are fixed in scenarios. For example, the construction of the Nord Stream 2 Baltic Sea pipeline can be stored in WEGA. This assumes a scenario in which Russia deliberately creates overcapacities for the transport of natural gas in order to make it more difficult for other participants to enter the market. In any other scenario, additional price specifications from producers or a possible withholding of quantities can be assumed.

WEGA is a global gas market model. The mapping of global gas flows is important, as the increasing trade in liquefied natural gas (LNG) means that markets can no longer be viewed in isolation. According to BP, LNG will account for a larger share of global gas trade than pipeline gas in the long term [1]. While pipeline transport is linked to a fixed start and end point, LNG can be transported by ship from a liquefaction terminal to any regasification terminal in the world. Gas market models with a regional focus, which, for example, only consider North America or Europe and specify LNG flows, do not therefore reflect reality with sufficient accuracy.

With the help of different types at nodes and edges, the worldwide gas market is mapped in WEGA. A distinction is made between the nodes:

- Demand zone: These can be countries, regions or trading points. For example, NetConnect Germany (NCG) or Henry Hub (HH) in the USA are mapped as trading points in the model. Another example is the region Southeast Europe where some small countries with low gas demand are merged to a group. Each demand zone is assigned a daily gas demand until 2040.

- Local source: These gas fields represent own production within the demand zone. Production capacity, production costs and any production profiles during the year (e.g. seasonal production profiles at the Groningen gas field) are stored until 2040.
- Pipe source: In the model, gas fields are combined into larger groups in order to reduce the computing time. Gas fields have a capacity, production costs, and – if applicable – a production profile during the year and a minimum capacity. These data are given until 2040. One gas field in WEGA, for example, is the Yamal gas field in Russia.
- Pipe delivery point (DP): Pipelines are linked to a demand zone by means of a landing point. This landing point has a maximum capacity. An example is the landing station in Lubmin near Greifswald for the Nord Stream Baltic Sea pipeline.
- LNG source: This node is used to model LNG liquefaction terminals. They have a capacity, production costs, and possibly a production profile during the course of the year and a minimum capacity. The logic is identical to gas fields with pipeline connection. A distinction is made between gas fields with pipeline connection and gas fields with connection to LNG terminals in order to facilitate the evaluation of the results. Here an expansion path for the liquefaction capacity up to 2040 is specified in the model.
- LNG delivery point (DP): All worldwide import terminals are shown in the model. A possible expansion path for each demand zone is also stored here. Import terminals also have a capacity and costs.
- Gas storage: All gas storage facilities in Europe are modelled individually. They have an injection and withdrawal capacity as well as costs. Gas storage facilities in North America or China have been grouped together. Any extensions, new buildings or shutdowns are shown until 2040.
- Options for flexibility in demand zones (DS): These include price limits for the coal gas switch as well as for customers who can be switched off. There is also demand shedding to prevent the optimization problem from becoming insolvable. If load shedding occurs, the model is not sufficiently calibrated and must be readjusted.

There are many different edges for the connection between the nodes. Figure 1 shows the example of two demand zones. Between the demand zones, for example, there is an edge that represents an interconnector. It allows a gas flow in one direction. For an interconnector that allows gas flows in both directions, two edges are created. Figure 1 also shows that an LNG source (LNG liquefaction terminal) can be connected to several regasification terminals. Similarly, a source can have several pipelines and transport gas e.g. from Norway to Germany and the UK.

The model also contains a database of global gas supply contracts. A gas supply contract has a start date and an end date. It also includes flexibility options, take-or-pay clauses and an individual pricing formula. This price formula takes into account an oil price indexation, a hub indexation or a mixture of both. Any renegotiations of contracts can also be deposited. The model assumes a slow shift from oil price indexed contracts to hub indexed contracts or hybrid contracts [17].

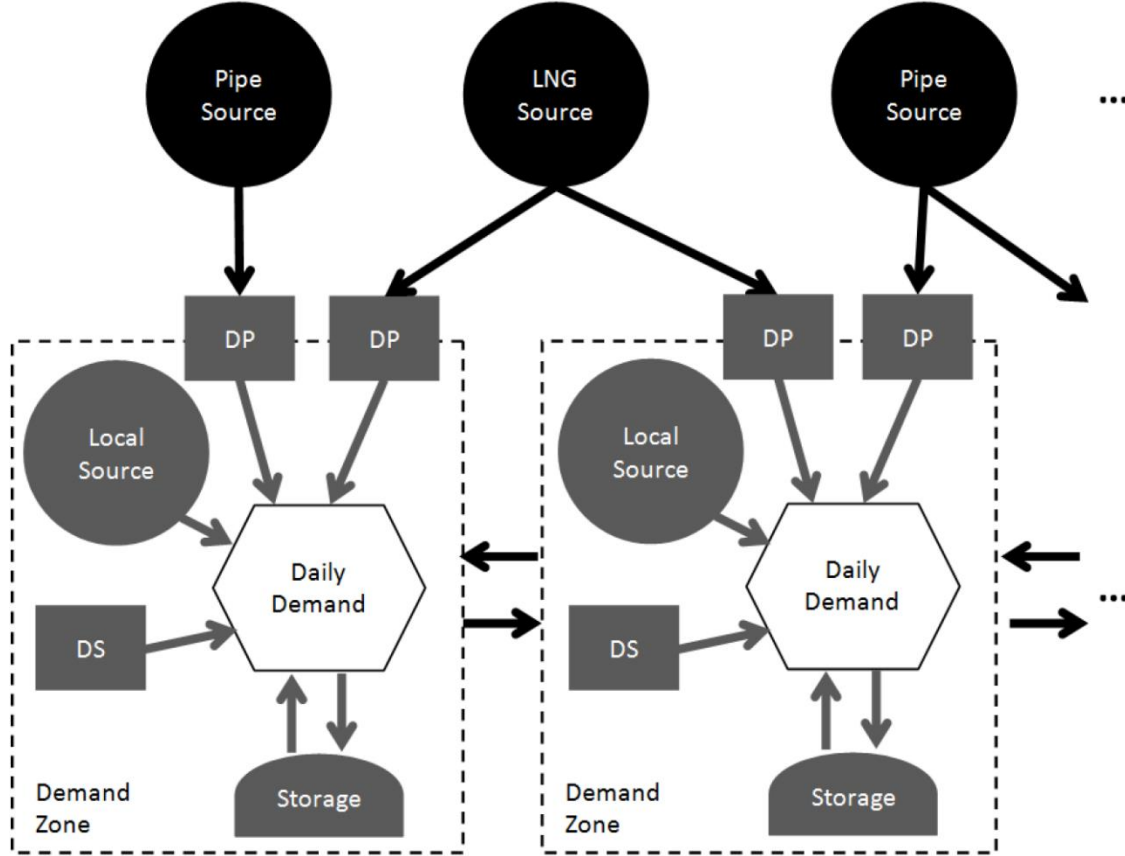


Figure 1: Example with two demand zones.

WEGA uses Linear Programming (LP) and was created in the Xpress Optimization Suite. A scenario until 2040 is calculated by WEGA on an RX600 with 1 TB RAM and 32 x 2 GHz in about 25 minutes. Each gas year is optimized separately by the model, whereby the gas year is broken down into individual days d . The goal of the optimization is to minimize the total cost C to cover the daily gas demand of a gas year (see Formula 1). The total costs consist of the daily production costs $CProd_d$, transport costs $CTransp_d$, storage costs $CStore_d$ and flexibility costs $CFlex_d$.

$$\text{Min } C = \sum_{d=1}^D (CProd_d + CTransp_d + CStore_d + CFlex_d) \quad (1)$$

There are numerous constraints to be met in minimising overall costs. A hard constraint is the coverage of the gas demand of each demand zone z on each day d (see Formula 2). In Formula 2, In means an inflow to the demand zone and Out means an outflow. The daily gas demand of a demand zone z is covered by inflows and outflows of the pipelines belonging to the demand zone, LNG regasification terminals ($LNGIn_{z,d}$) or LNG export terminals ($LNGOut_{z,d}$), interconnectors, storage facilities and flexibility options. There are also inflows from own production within the demand zone.

$$\begin{aligned}
 Demand_{z,d} = & PipelineIn_{z,d} - PipelineOut_{z,d} + \\
 & LNGIn_{z,d} - LNGOut_{z,d} + \\
 & InterconnectorIn_{z,d} - InterconnectorOut_{z,d} + \\
 & StorageIn_{z,d} - StorageOut_{z,d} + \\
 & FlexibilityIn_{z,d} + IndigenousProductionIn_{z,d} \quad \forall z \in Z, d \in D
 \end{aligned}
 \tag{2}$$

Other constraints refer to the previously mentioned properties of nodes, edges, and contracts. For example, the maximum capacity of a pipeline or LNG regasification terminal may not be exceeded. Contractual agreements arising from long-term supply contracts must also be observed.

The business intelligence software Tableau is integrated into the gas market model to visualize the large number of input data and results. Figure 2 shows a screenshot of WEGA. The number one marks the area in which new scenarios can be created or existing scenarios selected. Below this, predefined views of a scenario can be selected in the area with the number two, which are then displayed in the area with the number three. Input data can also be changed there.

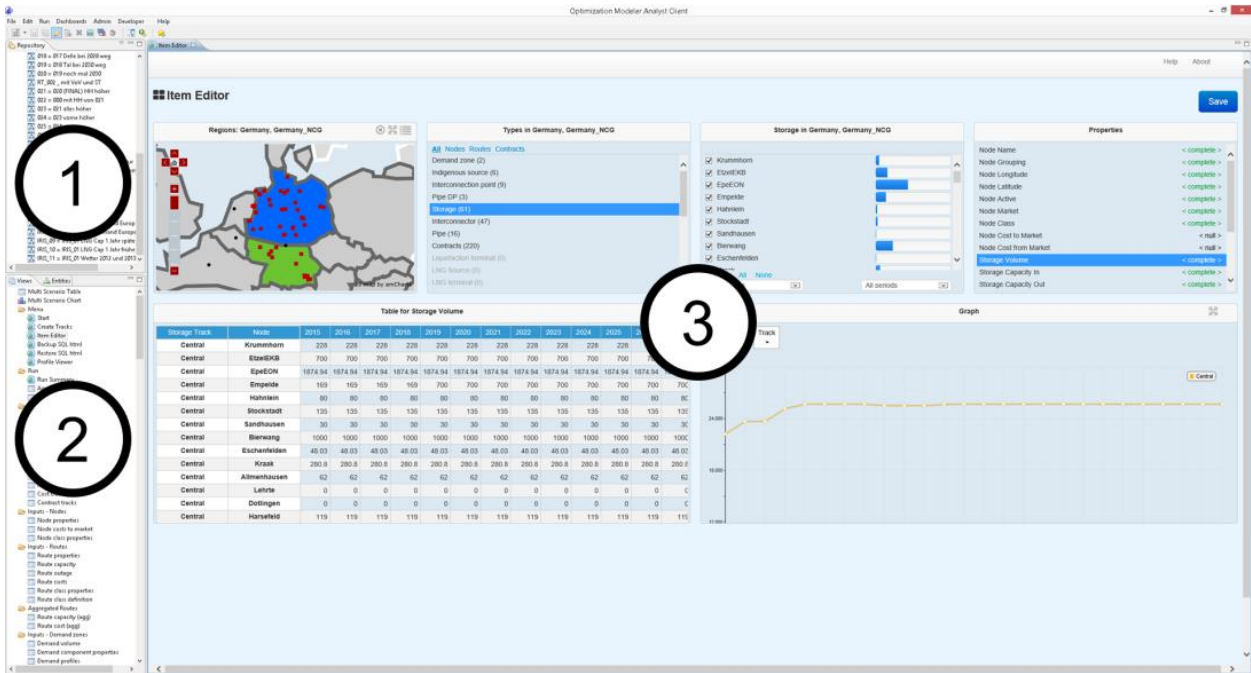


Figure 2: Screenshot of WEGA with data on gas storages in Germany

For the experiments of this work a base case in WEGA is generated, in which Nord Stream 2 is completed with 55 bcm per year. It is unlikely that Nord Stream 2 is operating at full capacity at the end of 2019 [23]. Thus, it is assumed for the base case that Nord Stream 2 starts operation

during 2020. It is also expected that Turkish Stream with 31.5 bcm per year and Trans Adriatic Pipeline (TAP) with 10 bcm per year will be built. Furthermore, it is assumed that the projects from the Ten-Year Network Development Plan (TYNDP) of ENTSOG [5] are built.

It is the intention of the EU to keep Ukraine a transit state for Russian gas [10], but the transit pipelines need to be refurbished [20]. Ukrainian transit pipelines are relatively old with some pipelines older than 50 years. At the moment only Urengoy-Pomary-Uzhgorod (UPU) pipeline with an annual capacity of 30 bcm is being refurbished. Financing for the other pipelines is not secured, so that their long-term operation is questionable. Therefore, transit flows of Russian gas through Ukraine are limited.

With regard to gas demand, the base case is grounded on the New Policies Scenario of the World Energy Outlook [18]. This results in a drop in demand for Europe of about 15 % between 2018 and 2040. In the same period, indigenous production in Europe falls to about 40 % of the 2018 level and production in Norway falls to 55 % of the 2018 level. Further information on WEGA and the model assumptions can be found in the papers [8], [9], [11], [12], [13] and [14].

3 Results and Discussion

To analyse the impact of Nord Stream 2 on gas prices and gas flows two scenarios are created: the base case from chapter 2 and an identical scenario but without Nord Stream 2. This chapter first discusses the gas flows with Nord Stream 2. As exemplary years for analysis of gas flows 2028 and 2035 are chosen. Figure 3 shows pipeline flows for 2028 in bcm and Figure 4 for 2035. 2028 was chosen as an exemplary year because this year all pipelines discussed today like Turkish Stream, TAP and TANAP will be built and also the second wave of LNG liquefaction terminals will be constructed. Moreover, 2028 is not too far in the future, which reduces the uncertainty regarding the multitude of model parameters. The year 2035 then allows an outlook on further developments in regular operation. The arrows in figures indicate gas flows in pipelines between two countries without showing exact pipeline routes.¹ Gas flows < 1 bcm per year were neglected. In addition, the values were rounded.

Figure 3 and Figure 4 show that the Russian gas is transported from Nord Stream 1 & 2 via OPAL and EUGAL to the Czech Republic, among other places, from where it is then transported to Slovakia and via the Gazelle to southern Germany. It can be seen in both Figures that transit flows via the Yamal-Europe route (transit from Northern Lights to Germany through Poland) are reduced to 6 bcm in 2028 and 2035. In 2017 and 2018 this route was nearly utilized at full capacity. In addition, the capacity of Nord Stream 2 will not be fully used, neither in 2028 nor in 2035 (96 bcm and 73 bcm respectively, instead of 110 bcm maximum capacity per year of Nord Stream 1 & 2). This

¹ Note: Albania, Bosnia and Herzegovina, Montenegro, Serbia and the Republic of North Macedonia are merged to one demand zone in Figures 3, 4, 5, and 6.

is due to falling gas demand in Europe in the base case of WEGA, more LNG imports and additional pipelines like Turkish Stream, TAP and TANAP. Moreover, the presented gas flows through Nord Stream 1 & 2 are annual values. On a seasonal level the utilization is much higher during the winter. In alternative scenarios, with higher European demand for gas, Nord Stream 2 and Yamal-Europe would be used to a correspondingly higher extent and gas flows through Ukraine would only increase as a last option.

As expected, gas flows from Russia via Ukraine are significantly reduced in Figure 3 and Figure 4 due to Nord Stream 2, Turkish Stream, more LNG imports and the slightly falling gas demand in Europe. In 2017 and 2018 the route via Ukraine had a utilization of more than 65 % (more than 80 bcm per year). Thus, Ukraine had a transport monopoly which will be repealed if Nord Stream 2 and Turkish Stream are online.

Especially Turkish Stream is the reason that the trans-Balkan route is not used to transport gas from Russia to Turkey via Ukraine, Romania and Bulgaria. The first string of Turkish Stream covers the gas demand in Turkey. The second string delivers gas from Russia to Turkey and via Bulgaria and Serbia also to Hungary. Without the second string gas flows via Ukraine would be 11 bcm per year higher (in all presented scenarios, with and without Nord Stream 2). Thus, an important role in reducing gas flows via Ukraine play Nord Stream 2 and also Turkish Stream.

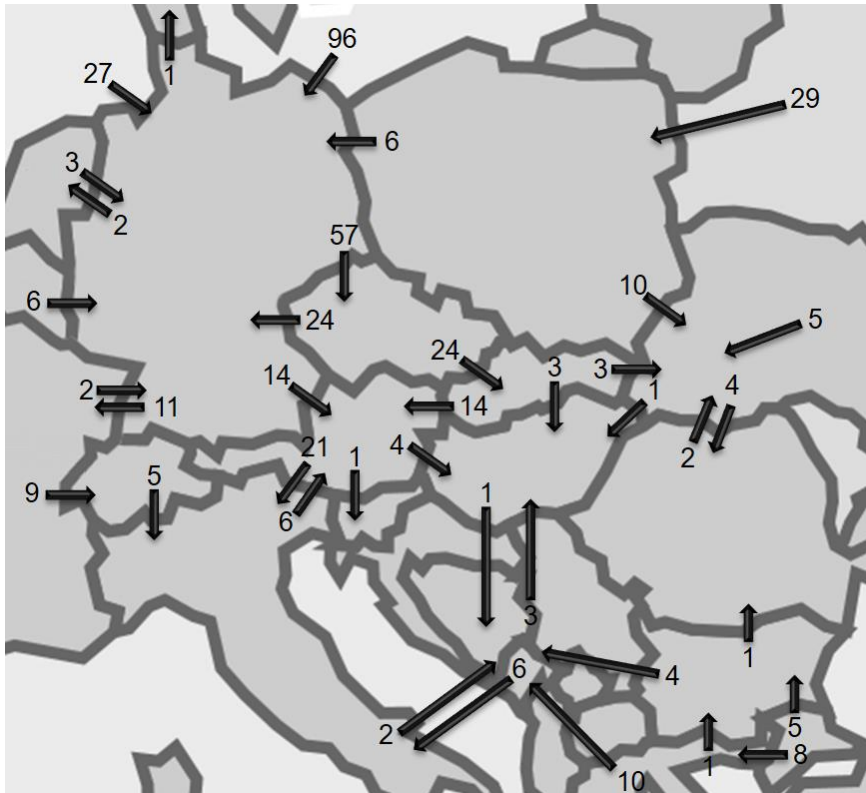


Figure 3: Pipeline flows in 2028 with Nord Stream 2 in bcm (only pipeline flows ≥ 1 bcm).

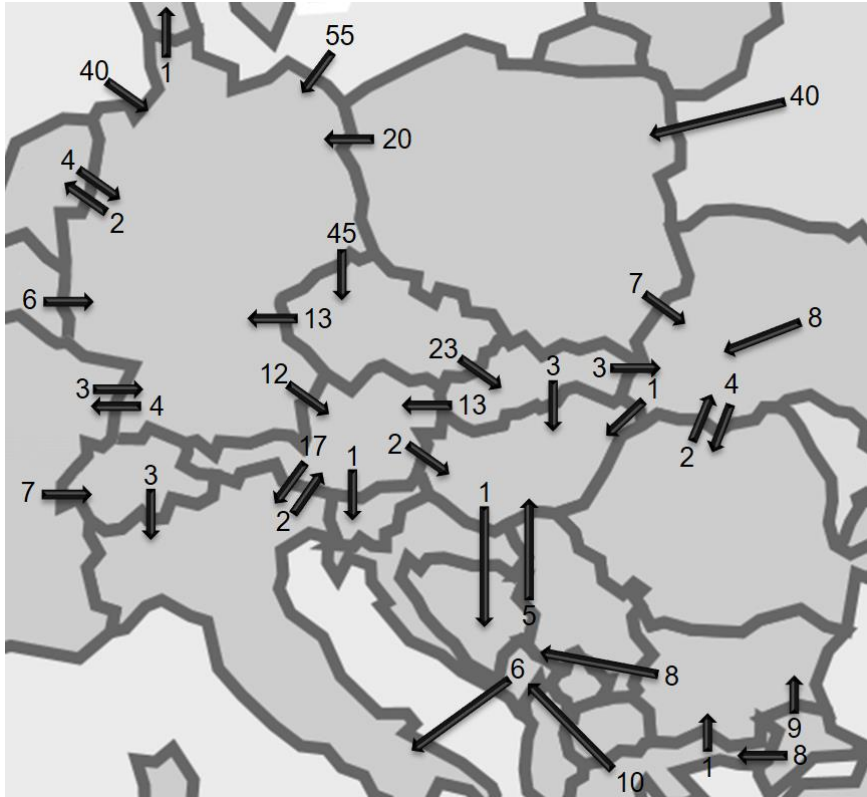


Figure 5: Pipeline flows in 2028 without Nord Stream 2 in bcm (only pipeline flows ≥ 1 bcm).

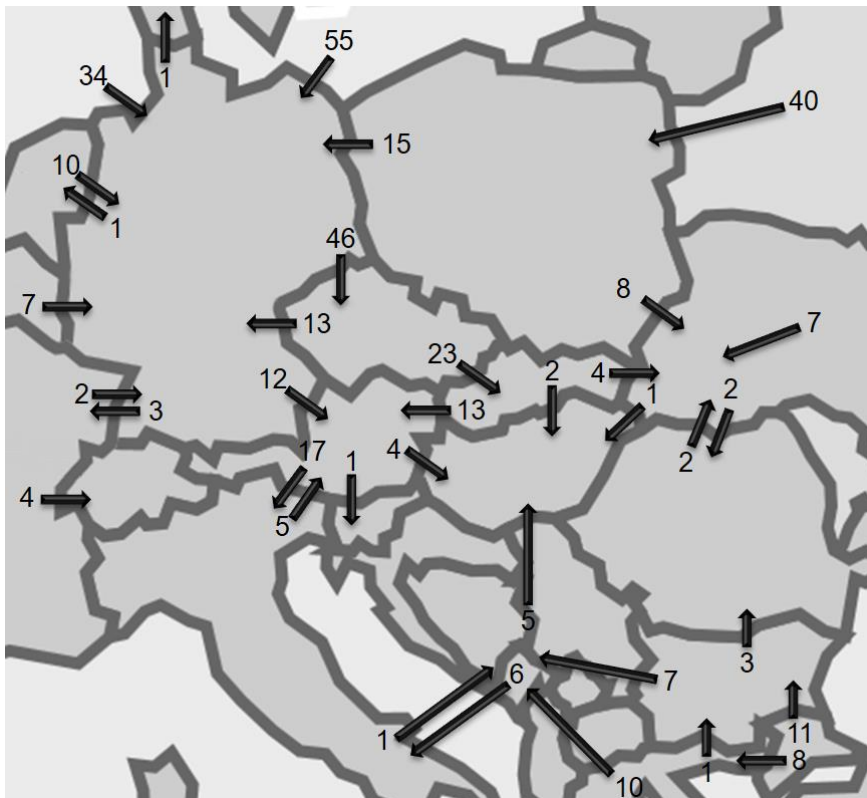


Figure 6: Pipeline flows in 2035 without Nord Stream 2 in bcm (only pipeline flows ≥ 1 bcm).

In total, Nord Stream 2 will make Germany a stronger transit country for gas. For example, Nord Stream 2 will increase German transit gas volumes by 17 bcm in 2028 and 8 bcm in 2035. On the other hand, transit flows from Poland to Germany decrease by 14 bcm in 2028 and 9 bcm in 2035.

Table 1 shows the price differences if Nord Stream 2 would not be built. These are average price differences in € per MWh over the period 2020 to 2040 as real values for the base year 2017. A positive value indicates that prices would increase in a scenario without Nord Stream 2. It can be seen that the price effect of Nord Stream 2 on wholesale prices is relatively low. In principle, Nord Stream 2 has a price dampening effect in all countries presented, which is also in line with Goldthau's expectations [10]. This contradicts the results of Kotek, Selei and Tóth [19], where no price effect can be observed in Western Europe, whereas Nord Stream 2 led to higher prices in Eastern Europe. Bottlenecks due to contracted gas flows from Nord Stream 2 are cited as the cause. However, bottlenecks exist in WEGA at worst on a seasonal level with peak demand in winter. This corresponds to Lang and Westphal [22] which constitute that the technical interconnection capacities exceed the contracted volumes. In contrast to the results in Table 1, Hecking and Weiser [15] see a much stronger price dampening effect if Nord Stream 2 was indeed built. This is mainly due to significantly higher price assumptions for LNG, which is displaced by the construction of Nord Stream 2.

United Kingdom	France	Netherlands	Germany	Czech Republic	Poland	Italy	Bulgaria	Romania
0.66	0.70	0.79	0.80	0.89	0.70	0.55	0.39	0.15

Table 1: Average price difference to a scenario without Nord Stream 2 on wholesale gas prices in €₂₀₁₇/MWh in the period of 2020 till 2040 (prices increase without Nord Stream 2).

4 Conclusion

This paper analyses the effects of Nord Stream 2 on European gas flows and gas prices. Differences to the results of other authors were found. The reasons for this are different assumptions about gas demand in Europe and the costs of LNG. Moreover, WEGA is very detailed and optimises worldwide gas flows in daily resolution.

In general, Nord Stream 2 has a slightly dampening effect on European gas prices, with gas prices in Western Europe falling slightly more than in Eastern Europe. In terms of gas flows, Germany plays a stronger role as a transit country for Russian gas through Nord Stream 2, while transit gas flows through Ukraine and Poland are declining significantly in the future. It can be concluded for Poland that on one hand revenues from transit fees are declining due to Nord Stream 2, but on the other hand wholesale gas prices are moderately reduced. Thus, consumers have to pay less for natural gas.

It was shown in the scenarios that even without Nord Stream 2, Russia would have avoided gas flows through Ukraine as much as possible, so that alternative routes such as Nord Stream 1, Yamal-Europe, Blue Stream and Turkish Stream would have priority. However, Russia's overall gas exports to Europe are 5 bcm per year higher in a scenario with Nord Stream 2.

In this paper also the effect of Turkish Stream was shown. Due to this pipeline, and especially the second string of this pipeline, gas flows via the trans-Balkan route are not used in the future to transport gas from Russia to Turkey via Ukraine, Romania and Bulgaria. Moreover, gas from the second string of Turkish Stream will reach Hungary via Serbia and Bulgaria.

Nord Stream 2 also has an impact on gas flows in Northwest Europe. For example, it displaces Norwegian gas from Germany. This does not mean that Norwegian gas is not needed and Norway will produce less gas in the future. These Norwegian volumes are needed and will be piped to Belgium, France and the UK where it displaces LNG.

Future investigations of gas prices and gas flows through Nord Stream 2 will focus, among other things, on sensitivities to changes in demand for natural gas, various price scenarios for LNG and Russia's price strategies.

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