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IMPACTS OF NORD STREAM 2 ON THE EU NATURAL GAS MARKET

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EXECUTIVE SUMMARY

This study focuses on the impacts of the offshore pipeline Nord Stream 2 on European Union (EU) natural gas markets. Gas flows, gas prices and welfare in the EU gas market are the focus of the analysis. Since the impact of Nord Stream 2 crucially depends on the competition between Russian gas and LNG, supply functions for LNG are derived using the global gas market model COLUMBUS. The supply functions model the cost of supplying gas to the market, taking account of, for example, the cost of additional investment in liquefaction capacity to meet higher demand as well as competing demand for LNG. Those functions are then fed into the European infrastructure model TIGER which models how gas is traded within the European markets based on available and planned infrastructure and the cost of using that infrastructure. The unique advantage of coupling both models is that the influence of global gas market fundamentals on European gas markets and restrictions arising from a detailed representation of the European gas infrastructure are both considered. As a result, the study shows not only the impacts on consumers at an EU level, but also on a country by country level.

Two global LNG demand scenarios are used: "Low" where Asian LNG demand is 5% lower than the IEA forecasts for global gas demand (New Policies Scenario in IEA (2016)), and "High" where Asian LNG demand is 20% higher than the IEA forecasts. The cost of LNG to the EU is higher in the "High" demand scenario because the overall supply demand balance for LNG is tighter, leading to a higher market price for LNG. Within this study, LNG is assumed to be the price setting supply in the EU.

The study looks at two different scenarios for the availability of major import infrastructure: Nord Stream 2 being available compared to Nord Stream 2 being unavailable. All other import infrastructure is available in all scenarios (e.g. Yamal, Norwegian and North African pipelines). 30 bcm of Ukrainian transit capacity is assumed, based on the capacity of the Urengoy–Pomary–Uzhgorod (UPU) pipeline, which is the only transit pipeline of the old Ukrainian system which is being refurbished (with the aid of emergency loans by the European Investment Bank and the European Bank for Reconstruction and Development).

For intra-EU infrastructure, PCI projects with FID according to the TYNDP 2017 have been assumed, including capacity increases as a result of the PRISMA capacity auction from March 6th 2017 and infrastructure that is included in the scenario framework of the German TSOs for 2018.

The main findings of the study are:

- If Nord Stream 2 is available, less LNG needs to be imported into the EU, leading to lower import prices for LNG. As LNG is the marginal source of supply in the EU, this decreases gas prices in the EU. All countries benefit from the impact of Nord Stream 2 including Central and South Eastern Europe in both Low and High Global LNG Demand scenarios.
- In the Low Global LNG Demand scenario, EU wholesale gas prices will be up to 13% lower in 2020 if Nord Stream 2 is available, compared to a scenario without Nord Stream 2. Consumers in the EU-28 countries enjoy a total welfare benefit of 7.9 billion €.
- In the High Global LNG Demand scenario in 2020, the EU-28 consumers enjoy a total welfare benefit of 24.4 billion € compared to a situation in which Nord Stream 2 is unavailable. EU gas wholesale prices will be up to 32% lower in 2020 compared to a scenario where Nord Stream 2 is not available.

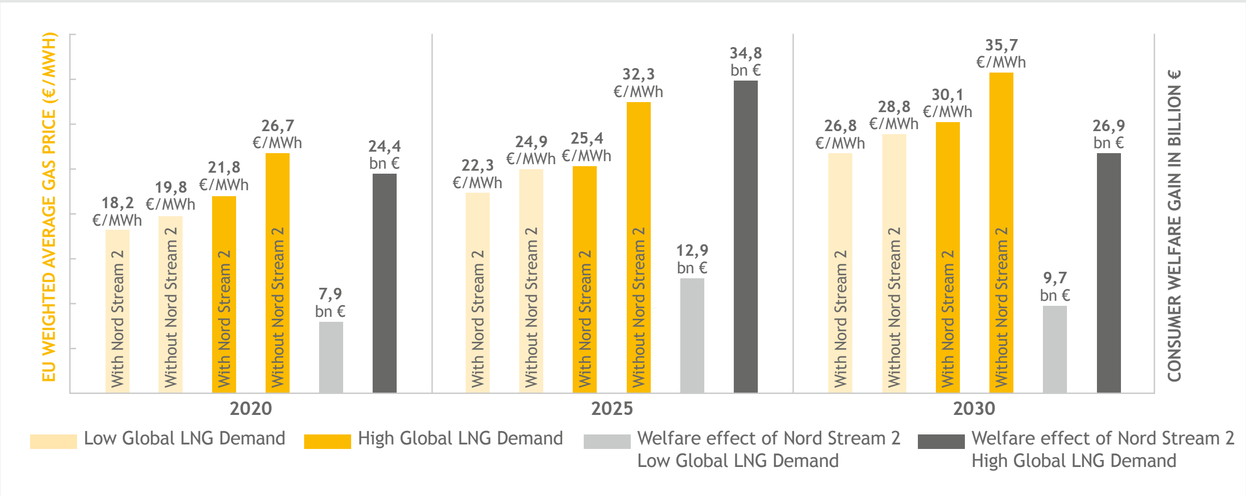


FIGURE A: IMPACT OF NORD STREAM 2 ON EU-28 PRICE LEVELS AND CONSUMER WELFARE
(Source: ewi ER&S – TIGER model)

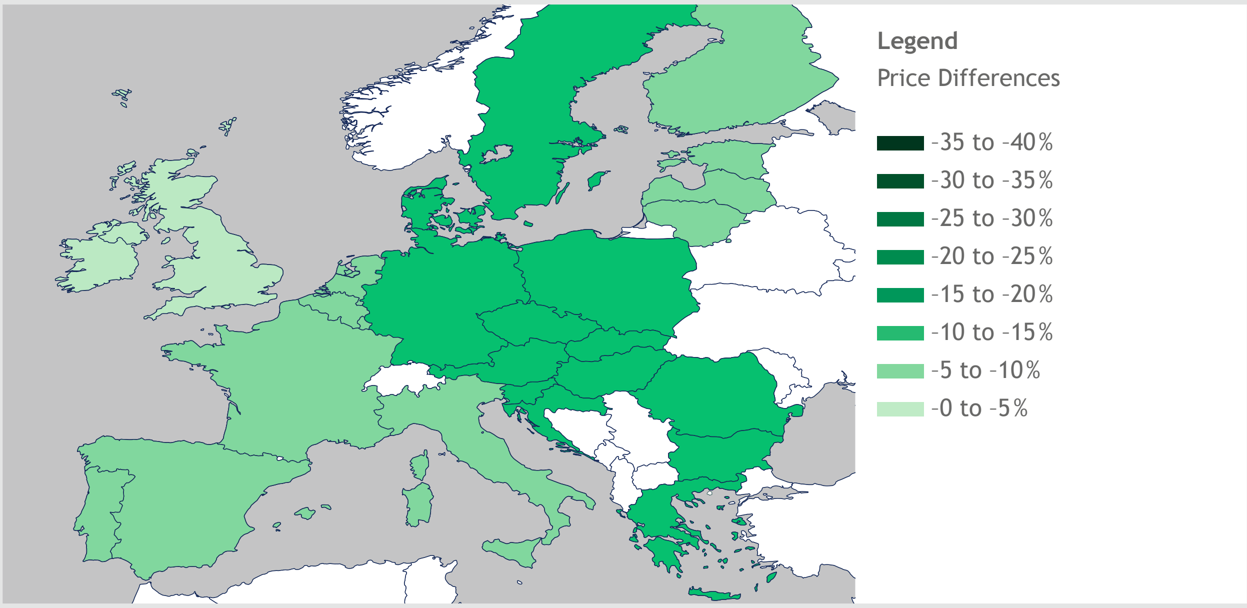


FIGURE B: BENEFICIAL IMPACT OF NORD STREAM 2 ON PRICE LEVELS COMPARED TO SCENARIO WITHOUT NORD STREAM 2 (LOW GLOBAL LNG DEMAND)
(Source: ewi ER&S – TIGER model)

1. INTRODUCTION

In recent years, the natural gas markets of the European Union (EU) have been characterized by increasing market integration. Especially in North Western Europe, gas hubs function as a pool in which increased interconnection and ongoing infrastructure expansion creates further aligned and correlated prices between individual markets (ACER, 2016). Integration is expected to increase as further infrastructure projects are constructed. Infrastructure extensions can be realized by a planning process of the TSOs (Ten-Year-Network-Development-Plan), or market based via capacity auctions and the open seasons system implemented by the EU Network Code (NC CAM). In addition the Security of Supply Regulation requires EU Member States to invest in greater interconnection with neighbouring markets (EU, 2010). Increasing market integration is in line with the Energy Union Strategy of the EU that aims on affordable prices for consumers, security of supply and sustainability (COM 2015 80).

Indigenous gas production in the EU is expected to decline between 2020 and 2030, whereas the demand is decreasing only slightly (cf. Figure 1)[1]. As gas imports from Norway and North Africa are also expected to decline in the near future (see e. g. Prognos (2017), Hecking et al. (2016)) the resulting future supply gap for natural gas will be filled by a combination of LNG imports and additional Russian pipeline imports.

Nord Stream 2, a planned offshore pipeline running from Russia via the Baltic Sea to northern Germany where it connects to the well-integrated European pipeline grid, offers additional import options for Russian gas. The availability of Nord Stream 2 and the price of future LNG imports are two crucial factors for the future development of the EU gas markets. Against this background, this study analyzes the impact of Nord Stream 2 on EU gas markets under two different global LNG demand scenarios.

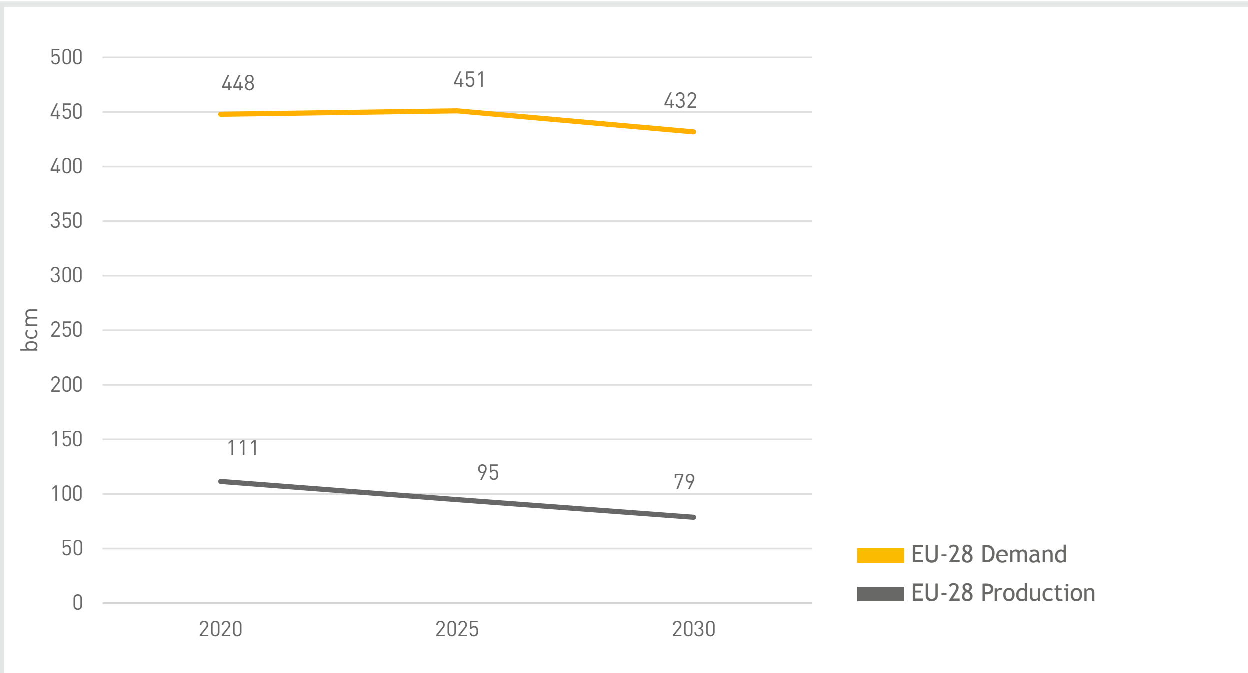
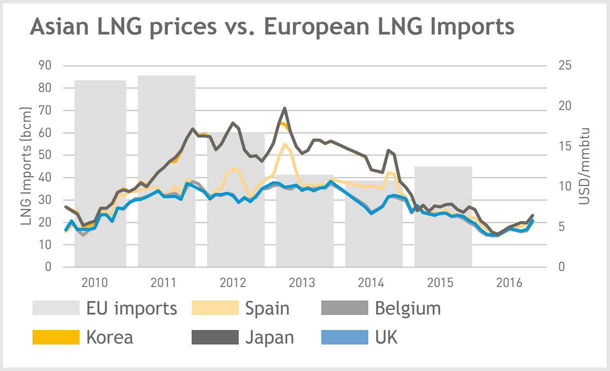
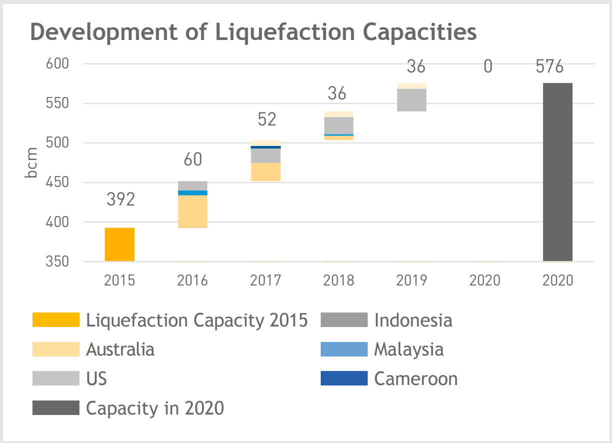


FIGURE 1: SUPPLY GAP FOR EU-28 GAS MARKETS
(Source: Prognos (2017), European Commission (2016))

1 Volumes of gas are measured in billion cubic meters in this study. They are normalized with a gross calorific value of 11.1 TWh/bcm at 0 °C.





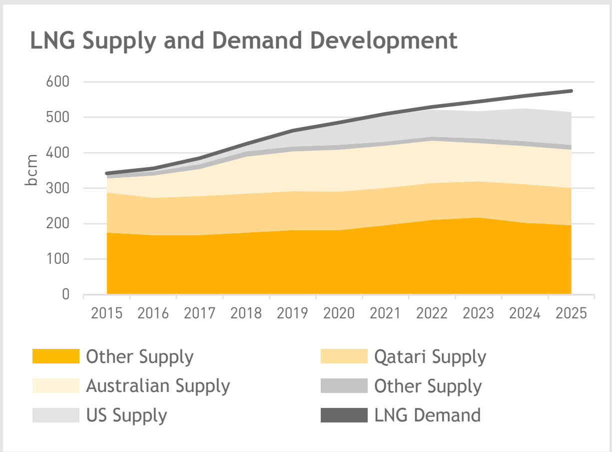


FIGURE 2: GLOBAL LNG DYNAMICS
(Source: International Gas Union and Federal Energy Regulatory Commission (2010–2016), International Gas Union (2016))

Methodologically, a combination of the COLUMBUS model for the global gas market and the European gas infrastructure model TIGER is applied in this analysis. The investigation focuses on 2020, which is the scheduled first full year of operation for Nord Stream 2, as well as on 2025 and 2030.

The LNG market is characterized by global market dynamics. Europe is usually seen as a market of last resort. Since Asian gas markets (e. g. Korea, Japan) have no pipeline import options, those countries depend on LNG and have paid high prices in the past to ensure sufficient supply. In a tight market, they attract more LNG with higher prices which leads to lower European LNG imports. This was observed for example after the Fukushima accident (top diagram of Figure 2) in the years after 2011. Furthermore, the LNG market is a cyclical market. Many liquefaction projects will come on stream in the near future as a reaction to high prices in the early 2010s. However, since LNG prices have decreased after 2014, fewer new investment decisions have been taken (middle diagram of Figure 2). So far no additional liquefaction capacity is planned for the year 2020. Hence, LNG supplies will plateau in 2020s. Depending on the development of demand, LNG demand could outpace supply leading again to higher prices (bottom diagram of Figure 2).

In order to address this uncertainty about the future development of LNG markets, two scenarios for LNG demand are considered in a simulation with the TIGER model: High Global LNG Demand resulting in a tight supply demand balance for LNG and therefore comparably high import costs for LNG in the EU, and Low Global LNG Demand with abundant LNG supply and hence lower LNG prices. The study assumes that LNG is the market price setter for natural gas prices within the EU.

In all scenarios, infrastructure downstream of the Nord Stream 2 pipeline (EUGAL as well as the connections between Germany and Poland, Czech Republic and the Netherlands, and the connection between Czech Republic and Slovakia) are included in the modelling. The results indicate that gas prices are significantly reduced in all EU-28 countries, if Nord Stream 2 can be used.

The structure of the study is as follows: After introducing the methodology (Section 2), the assumptions and the scenario design are discussed (Section 3). Then, the model results are presented (Section 4). Section 5 concludes this study.

2. METHODOLOGY: SUPPLY FUNCTION APPROACH

In this study, supply functions[1] of LNG to Europe[2] are derived with the global gas market model COLUMBUS that then are used as an input for the European gas infrastructure model TIGER (see Appendix for detailed descriptions for the TIGER and COLUMBUS models). The advantage of coupling both models is that the influence of global gas market fundamentals on European gas markets as well as restrictions arising from a detailed representation of the European gas infrastructure are both considered in this innovative approach.

In the COLUMBUS model, a case with moderately Low Global LNG Demand and with High Global LNG Demand is simulated. High (respectively low) Global LNG Demand implies high (respectively low) Asian LNG import demand and hence higher (respectively lower) price levels for European LNG imports.

The demand assumptions in the COLUMBUS model are based on the International Energy Agency's (IEA) forecasts contained in the Medium Term Gas Report and World Energy Outlook (IEA 2016a / 2016b). For the High Global LNG Demand scenario, it is assumed that the Asian demand is 20% higher compared to the IEA's trajectory. In the Low Global LNG Demand scenario, a 5% lower Asian demand level compared to IEA's scenario is considered. With fixed Asian demand, the European demand level for LNG is varied over a wide range in the COLUMBUS model, reflecting the availability of pipeline imports into Europe. This results in different LNG import volumes and import prices (net of regasification costs). Based on this, a supply function for LNG to European harbours is derived. Figure 3 shows the LNG supply functions for low and High Global LNG Demand in the years 2020, 2025 and 2030.

The supply functions for LNG illustrate the price Europe would have to pay to attract incremental volumes of LNG. Take-or-pay levels of contracts are treated as must-run flows, i.e. gas contracted under take-or-pay contracts will flow regardless of the market price as buyers have to pay for the gas even if they do not take it. Re-exports of LNG are not considered, since more LNG than the contracted volume is expected to be imported in 2020 and DES (delivery ex ship) conditions for LNG are expected to be phased out in future. Additionally, the effect of LNG re-exports on the simulation results is negligible, because they do not impact the global balance of supply and demand for LNG.

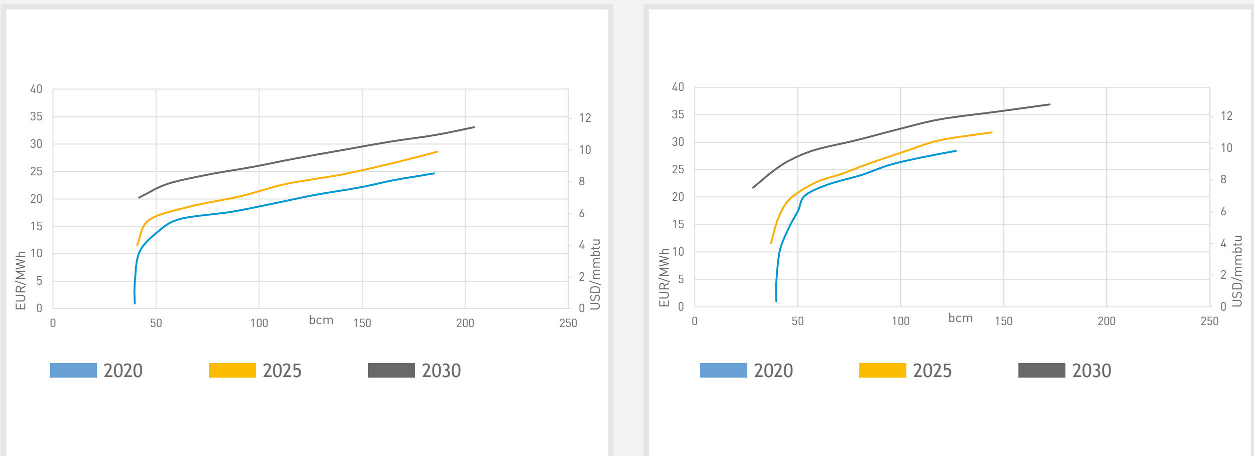


FIGURE 3: LNG SUPPLY FUNCTIONS FOR LOW GLOBAL LNG DEMAND (TOP) AND HIGH GLOBAL LND DEMAND (BOTTOM), EXCHANGE RATE: 1.18 €/USD (Source: ewi ER&S – COLUMBUS model)

1 Supply functions should not be considered as supply cost curves. Supply functions take reactions of other market participants into account, whereas supply costs are the costs of supplying irrespective of the behavior of other market participants.
2 In this context, Europe means geographical Europe including Turkey, which is also covered by the TIGER model. However, the results shown in this study are for the EU only.

The COLUMBUS model takes into account the final investment decisions for certain liquefaction plants in the USA, Australia and the Russian Yamal Peninsula based on their current reported project status. These projects are sufficient to meet the modelled demand in 2020. After 2020, however, investments in new liquefaction plants are included in the model, if High Global LNG Demand is assumed, to enable supply and demand for LNG to balance. Hence, the triggering of these additional investments leads to comparably high equilibrium price levels on the LNG market in 2030.

The supply functions for LNG alone determine the general magnitude of the price effect of Nord Stream 2. For example in a simplified calculation to highlight the mechanism, as illustrated in Figure 4, one could expect that approximately 50 bcm of additional LNG would be imported to Europe if Nord Stream 2 is not available.

Those additional imports lead to price increases for LNG globally and therefore also in Europe. This price increase is stronger in a situation with scarce global LNG supply. However, a detailed analysis with the TIGER model, taking into account infrastructure restrictions and flows between EU countries, is required to understand the impact on specific countries and the country specific volumes of LNG that would need to be imported into Europe in case Nord Stream 2 is not available.

The study assumes that LNG supplies determine the price levels in all EU countries, as the marginal source of supply to the EU markets.[1] The price of Russian gas is determined by the price of LNG plus transportation costs from the closest LNG terminal compared to the cost of bringing Russian gas to this point. Such an approach implies that Russian pricing is determined by the cost of alternative supplies.

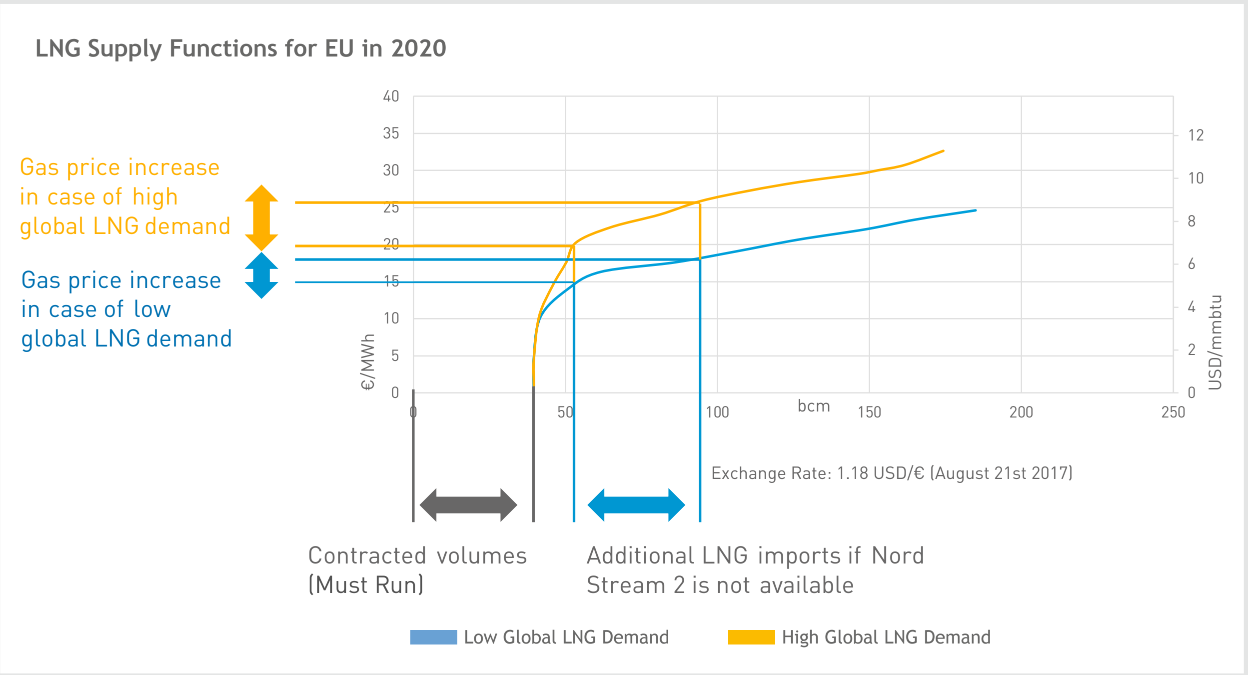


FIGURE 4: SHIFT IN LNG SUPPLY FUNCTION DUE TO ADDITIONAL LNG IMPORTS
(Source: ewi ER&S – COLUMBUS model)

1 The Russian marginal supply costs are usually assumed to be below the marginal supply costs of LNG (Henderson, Mitrova (2015)).

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3. ASSUMPTIONS AND SCENARIO DESIGN

Inputs for the TIGER model are demand, supply and the current state as well as planned development of gas infrastructure. The demand assumptions for the EU are based on the Prognos report "Current Status and Perspectives of the European Gas Balance" (Prognos 2017).[1] Assumptions on supply availability for both indigenous EU production and other sources of imports (e. g. from Norway, Algeria etc.) are also based on the Prognos report. The infrastructure is modelled in line with ENTSO-G's Ten Year Network Development Plan (ENTSO-G (2016a)) and its European Natural Gas Network map (ENTSO-G (2016b)). All projects with the status "Final Investment Decision" (FID) are included in the model. Additionally, selected non-FID projects that are supported by the European Commission are included, e.g. the EASTRING project and the Baltic Connector which are both Projects of Common Interest (PCI).

The EASTRING project is considered over competing projects in South Eastern Europe in parts due to the fact that we assess its likelihood of implementation higher than that of competing projects. This is based on the fact that the German Scenario Framework for 2018 (FNB (2017)) considers it (as the only project not having FID) when discussing import options for gas to Germany and the fact that the competing BRUA pipeline has had recent setbacks.[2]

Furthermore, the realization of one line of Turkish Stream (16 bcm/a) is modelled.[3] It is assumed that the restrictions on the use of OPAL are lifted so that up to 100% of its capacity can be used. Transportation tariffs between gas market areas are based on the Agency for Cooperation of Energy Regulators Market Monitoring Report 2015 (ACER 2016) and kept constant throughout the modelling period.[4] For pipeline transportation within Russia, a distance based approach is used resulting in higher transportation costs from the production sites in Siberia to the border between Russia and Ukraine than to the Nord Stream 2 pipeline starting point at the Gulf of Finland. The Nord Stream 2 tariff is based on Henderson, Mitrova (2015). For Ukraine, the tariffs are based on the Ukrainian regulator's announcement reported in Interfax (2015).

It is assumed that the Nord Stream 2 pipeline becomes operational by 2020 with a capacity of 57 bcm/a[5]. Additionally, it is assumed that the connecting infrastructure downstream of Nord Stream 2 is constructed, i. e. EUGAL as well as the connections to countries neighboring Germany based on the capacity auction results from PRISMA on March 6th 2017. As a result of this capacity auction, an upgrade of the existing pipeline between Hora Svaté Kateřiny and Lanžhot is assumed in the Czech Republic connecting to the infrastructure in Slovakia that runs to Baumgarten in Austria. Additionally, an upgrade of the NEL pipeline is necessary in order to enable additional export options to the Netherlands. Table 1 gives an overview of the auction results. Figure 5 shows the state of the infrastructure in 2020 including key projects such as EUGAL, TAP, and Eastring etc. In the appendix, a detailed list of the assumed infrastructure extensions is included (cf. Table 7 and Table 8).

	Capacity (bcm/a)
Nord Stream 2 to Gaspool	57.0
Gaspool to Czech Republic	37.0
Gaspool to Poland	4.3
Gaspool to Netherlands	8.5

TABLE 1: AUCTION RESULTS FOR CAPACITY ADDITIONS, MARCH 6TH 2017 (Own derivations based on: https://corporate.prisma-capacity.eu/)

1 The demand of non-EU countries is based on (ENTSO-G (2016a)).
2 https://www.icis.com/resources/news/2017/07/21/10126487/brua-gas-pipeline-at-risk-after-surprise-move-by-hungary/
3 While creating the report, it was not foreseeable if one or two strings of Turk Stream would be realized. In the supplementary documentation Prognos (2017) discusses the potential risks for the construction of a second Stream of Turk Stream and assesses its likelihood of timely implementation as slightly lower.
4 A steady flow is assumed. If the tariff between two market areas would be 365 €/MWh/day/year, the cost would be 1/365*365 = 1 €/MWh.
5 In the TIGER model, bcm are normalized with a gross calorific value of 11.1 TWh/bcm at 0 °C, Additionally, full pipeline utilization is assumed in order to derive capacities. The official capacity of the Nord Stream 2 pipeline is 55 bcm/a based on a load factor of 0.9 and Russian standard volume units (at 20 °C instead of 0 °C) and a pressure of 1 atm.

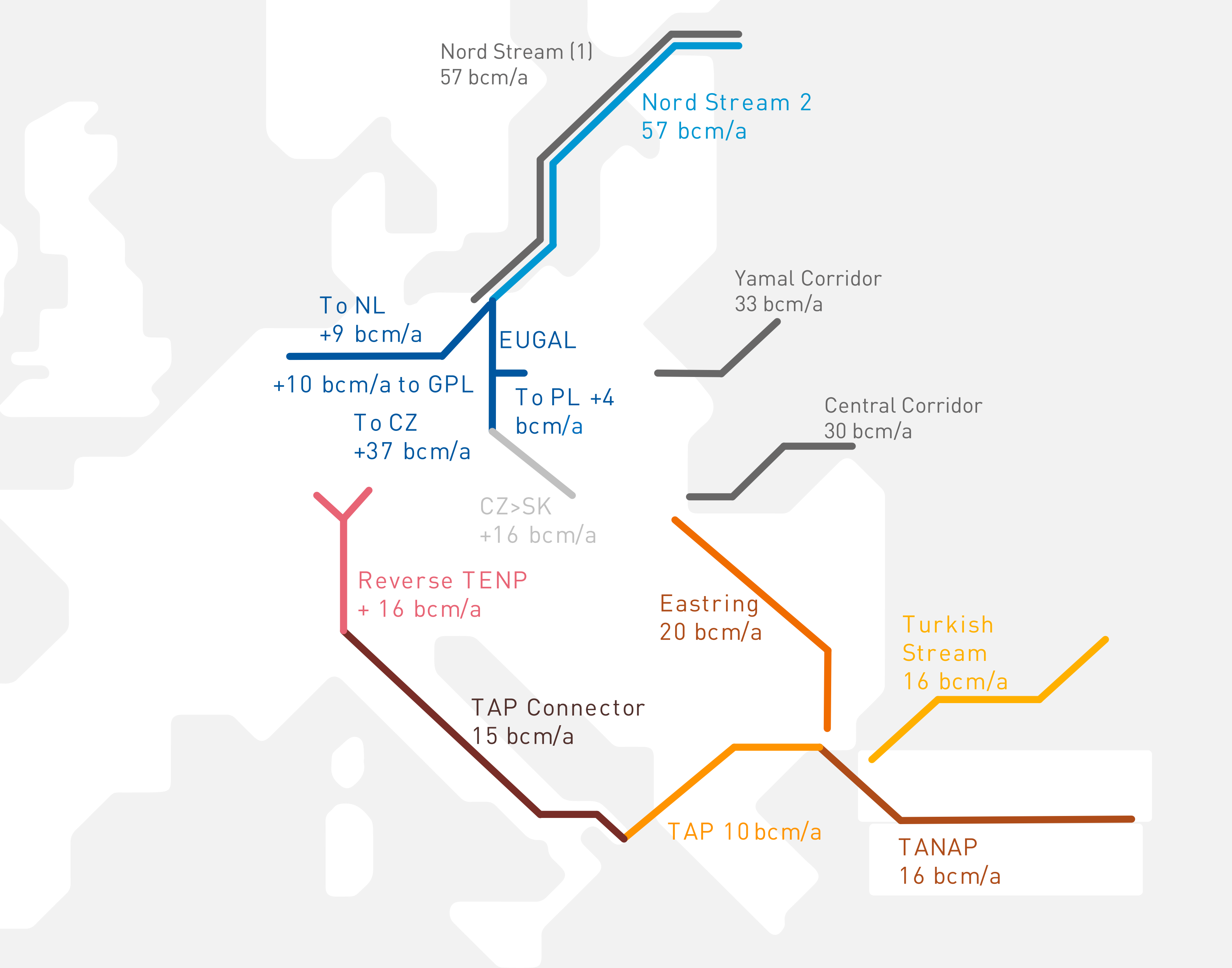


FIGURE 5: ASSUMED MAJOR CAPACITY INCREASES UNTIL 2020
(Source: ewi ER&S – TIGER model)

The Ukrainian transit pipelines are up to 50 years old in the scenarios' timeframes and require refurbishment. Currently only the Urengoy-Pomary-Uzhgorod (UPU) pipeline (with a capacity of approximately 30 bcm/a) is being refurbished[1], whereas it is unlikely that any other major segments of the Ukrainian transmission system will be modernized soon due to a lack of financing (KPMG, 2017). This is in line with statements made by the management of Ukrtransgaz regarding decommissioning of parts of their transit system.[2] Therefore, the study uses a conservative approach to the availability of transport capacity through Ukraine, in line with publically available estimates of what part of the transit system can be considered sustainably available by EU standards by 2020 (KPMG, 2017). In total 4 scenarios are simulated in the TIGER model that can be seen in Table 2.

	Low Global LNG Demand	High Global LNG Demand
Nord Stream 2 **available**	Scenario **A1**	Scenario **B1**
Nord Stream 2 **not available**	Scenario **A2**	Scenario **B2**

TABLE 2: OVERVIEW OF SCENARIO SETTING

1 The European Bank for Reconstruction and Development (EBRD) finances an emergency upgrade and modernization project: http://www.ebrd.com/work-with-us/projects/psd/nak-naftogaz-emergency-pipeline-upgrade-and-modernisation.html
Additionally, Ukrtransgaz' last report to the energy community shows only activity on repairing the UPU line, but little to no other main pipeline refurbishment activity, cf.: https://www.energy-community.org/portal/page/portal/ENC_HOME/DOCS/1676177/0633975ABAE57B9CE053C92FA8C06338.PDF

2 https://www.unian.info/economics/1519579-reuters-ukraine-may-decommission-part-of-gas-network-on-lower-russian-supplies.html

4. RESULTS

4.1 Low Global LNG Demand (Scenario A)

Figure 6 shows the European gas flows and LNG imports in the scenario A1 (Nord Stream 2 available). Figure 7 is the analogous diagram for scenario A2 (Nord Stream 2 not available).[1] In scenario A1, approximately 88 bcm are shipped via Nord Stream 1 and 2 to Germany[2] in 2020 while still 30 bcm of Ukrainian transits occur. In scenario A2, the full capacity of Nord Stream 1 is used while again 30 bcm/a Ukrainian transits occur. If Nord Stream 2 is not used, more LNG is imported in the EU-28 (88 bcm in 2020) compared to scenario A1 (66 bcm LNG imports in 2020). Additionally, the North African imports to the EU are higher in scenario A2 (35 bcm in 2020) than in scenario A1 (32 bcm in 2020). The Norwegian imports are unchanged (at approximately 108 bcm in 2020) in both scenarios. Hence, among the various supply sources mainly LNG imports are reduced if Nord Stream 2 is available.

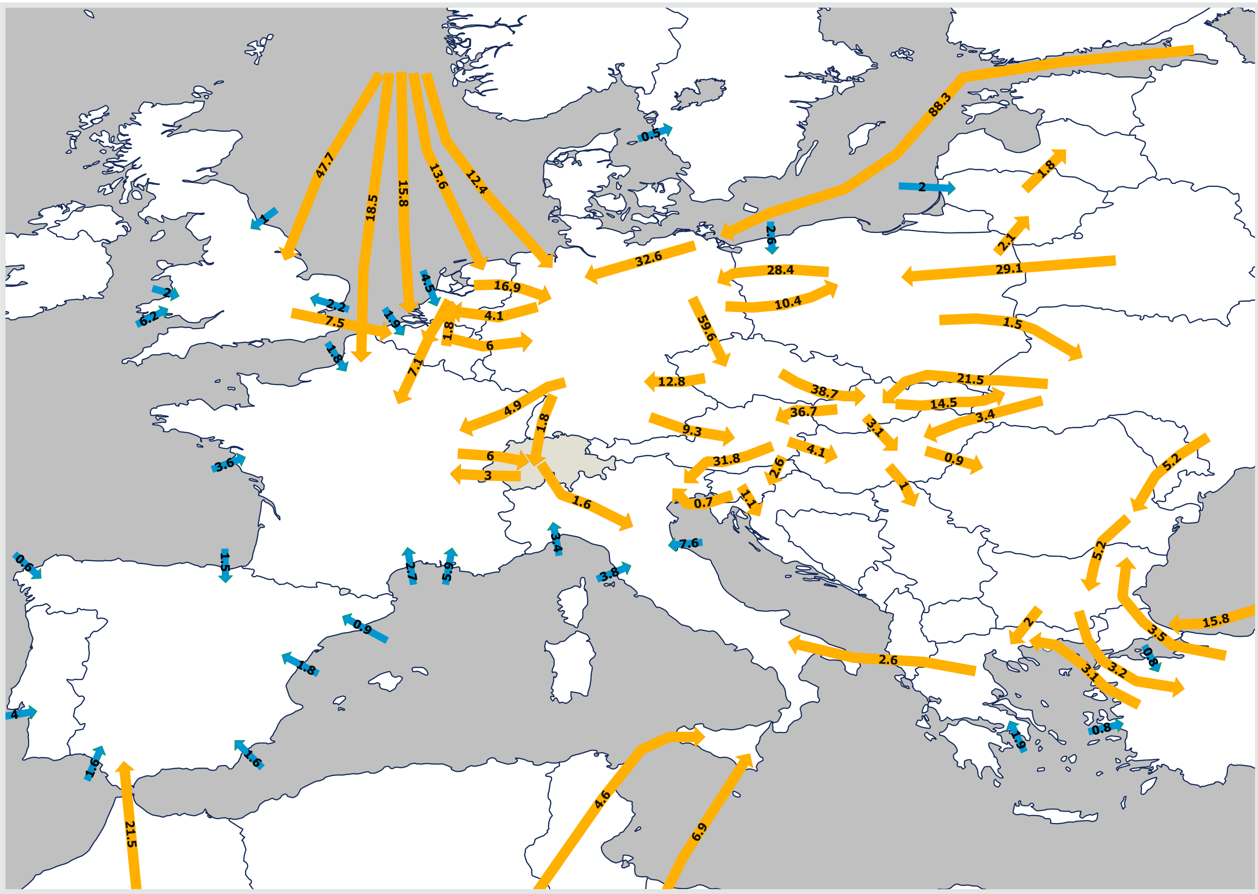


FIGURE 6: MODELLED PIPELINE AND LNG FLOWS IN 2020 IN SCENARIO A1 (LOW GLOBAL LNG DEMAND, WITH NORD STREAM 2)
(Source: ewi ER&S – TIGER model)

1 Note that where flows in both directions between countries are shown (e.g. between Poland and Germany), this is because of contractual obligations and due to different flows at different times of the year.

2 The TIGER model does not explicitly distinguish flows via Nord Stream 1 and Nord Stream 2. Since pipelines will not always be operated at full capacity, it is unlikely that Nord Stream 1 would be fully used while Nord Stream 2 would only be used by 31 bcm/a. Instead, a more even distribution of flows among the pipeline is likely.

Within Europe, more flows from West to East take place in scenario A1 compared to A2. At the interconnection between Czech Republic and Slovakia, 39 bcm are transitted from the Czech Republic to Slovakia in scenario A1. This implies that the West-East capacities in Lanžhot (including the additional 16 bcm/a from the PRISMA auction) are fully used in 2020.[1]

Interestingly, the flow direction of the Gas Interconnection Poland–Lithuania (GIPL) is changed between scenario A1 and scenario A2. Whereas GIPL is used in the direction from Poland to Lithuania in scenario A1, the flow direction is reversed when Nord Stream 2 is unavailable.

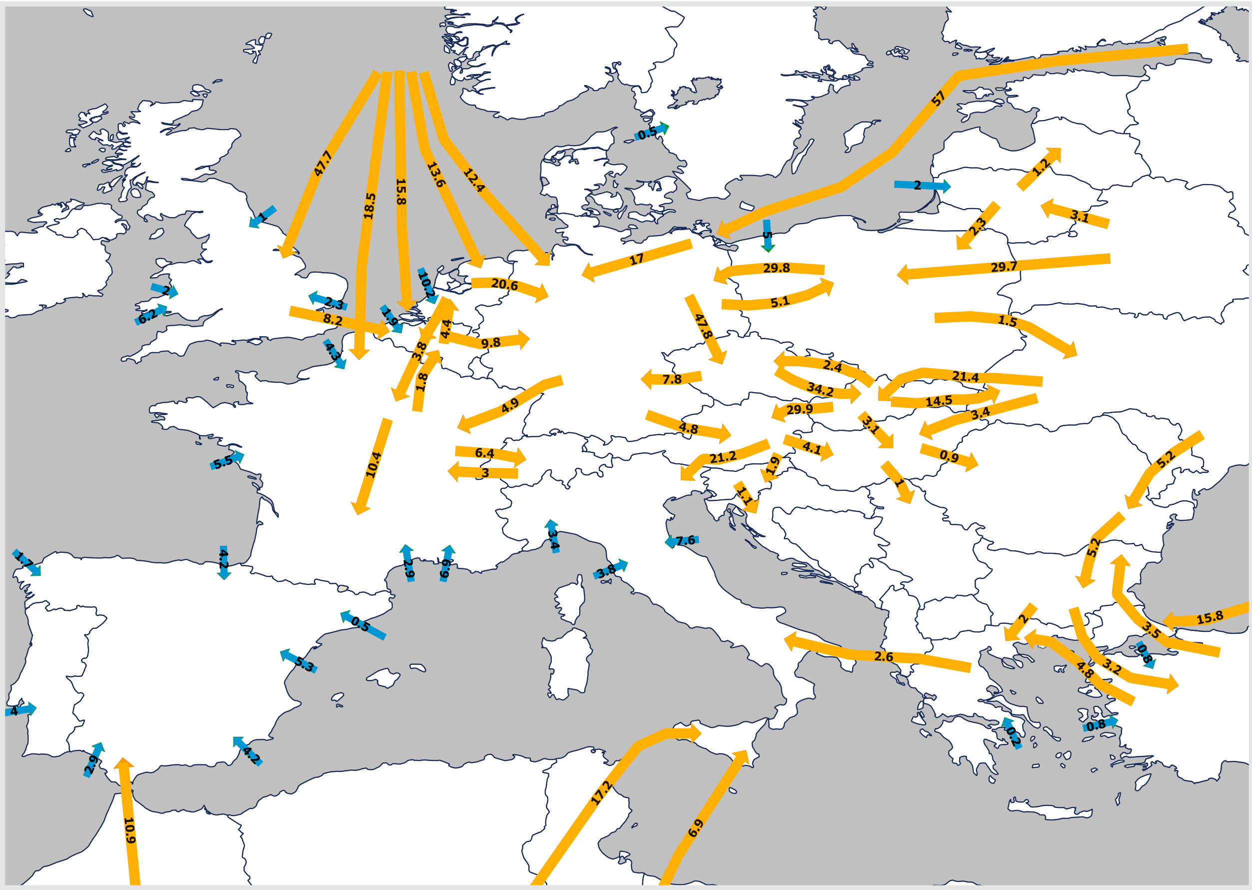


FIGURE 7: MODELLED PIPELINE AND LNG FLOWS IN 2020 IN SCENARIO A2 (LOW GLOBAL LNG DEMAND, WITHOUT NORD STREAM 2) (Source: ewi ER&S – TIGER model)

1 Debottlenecking would allow additional gas from North Western Europe into South Eastern Europe which might result in additional welfare gains of Nord Stream 2 especially for South East Europe.

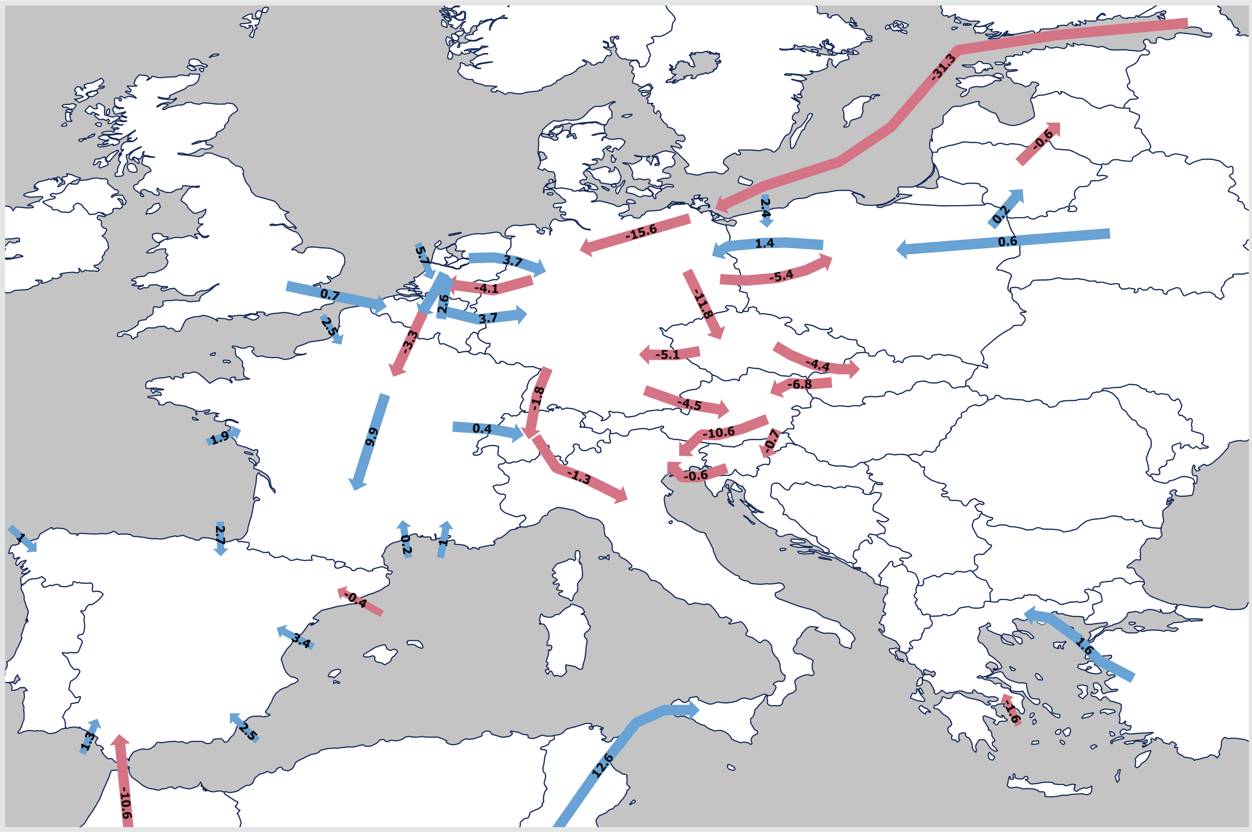


FIGURE 8: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO A1 AND A2
(Source: ewi ER&S – TIGER model)

In addition to flows, the modelling also analyzes gas prices. Figure 9 shows the level of gas prices in 2020 in scenario A1 (Nord Stream 2 available) and A2 (Nord Stream 2 not available) in the EU-28 countries compared to the 2015 actual prices (the latest data available based on the ACER Market Monitoring Report published in 2016). All 28 EU countries have lower gas prices with Nord Stream 2 in 2020 compared to 2015 levels, because (a) additional and (compared to 2015) cheaper LNG is imported by the EU in 2020 and (b) Nord Stream 2 is available leading to increased competition (Hecking et al., 2016). If Nord Stream 2 is not available, prices increase, but are still below the 2015 level. Furthermore, price differences among the countries are reduced in the modelled prices compared to the historical situation in 2015, because the realization of new interconnections (e. g. EASTRING, Baltic Connector) are assumed in 2020 in the model, enabling greater flows of gas between countries and hence more competition. The price differences historically already decreased from 2014 to 2015 (ACER, 2016). Differences in transportation costs and regasification costs (entry from LNG terminal into the grid) drive the differences in price levels between countries.

Figure 10 shows the relative difference of modeled prices in scenario A1 (includes Nord Stream 2) compared to scenario A2 (excludes Nord Stream 2) ((Price of Scenario A1 – Price of Scenario A2) / Price of Scenario A1). It can be seen that the usage of Nord Stream 2 has a price decreasing effect in all considered countries. The effect is in the range of up to 10 % (relative to the price level in scenario A2 without Nord Stream 2). All EU countries have lower gas prices with Nord Stream 2 than without it. Seasonal effects, temporal congestion, existing long term contracts for gas supply, the absolute levels of gas prices (cf. Figure 9) and the availability of alternative supplies influence the magnitude of the relative price differences.[1] In scenario A2 (in which LNG import prices are higher for the EU than in scenario A1 because less Russian gas is available and therefore more expensive LNG is required), Spain and Italy have an option to import slightly more North African gas which dampens the price effect of more expensive LNG.

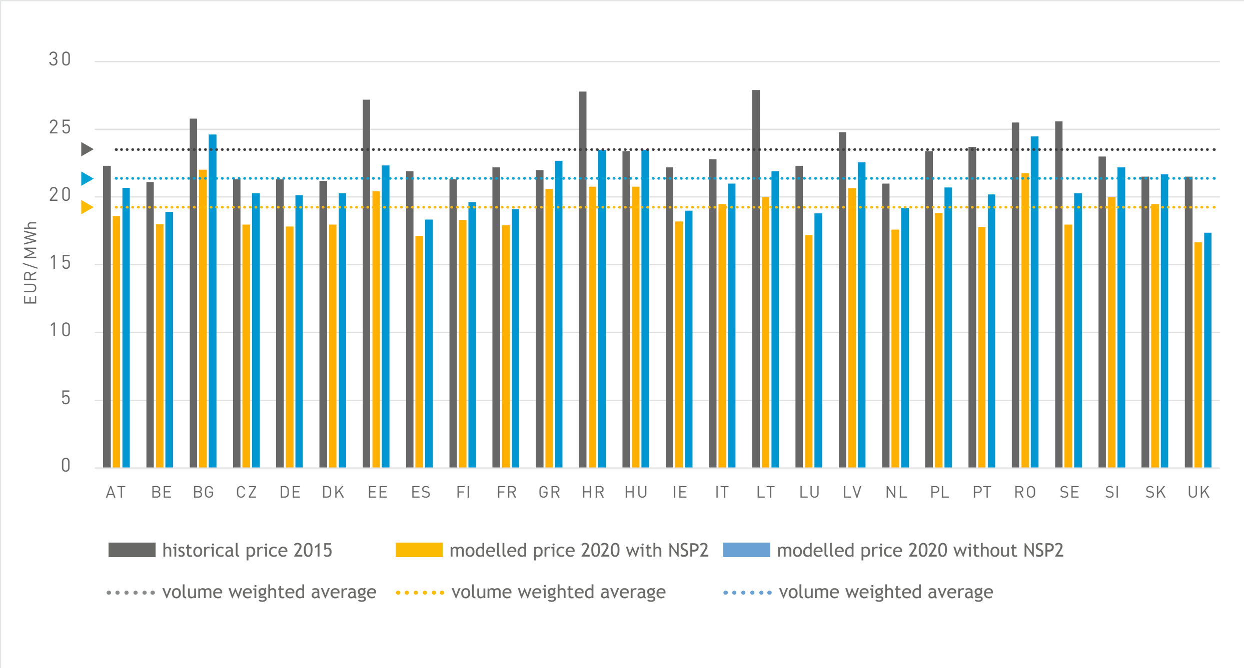


FIGURE 9: MODELLED GAS PRICES IN 2015 AND 2020 (SCENARIO A1 AND A2)
(Source: ewi ER&S – TIGER model, ACER (2016))

1 The cost for infrastructure extensions, however, are not accounted for in this analysis, i. e. tariffs are assumed to be constant among the scenarios. The infrastructure needs to be refinanced in each scenario, hence tariffs reflect average costs. If the grid of a certain TSO is extended and bookings increase proportionally to the costs of the new infrastructure, average costs and tariffs would be the same. Accordingly, over proportionally (under proportionally) increasing bookings would decrease (increase) average costs and tariffs. Since tariffs are not solely driven by realized flows, but more precisely by bookings (e. g., for security of supply reasons) as well as national or European regulation, the dynamics of tariffication are very complex and potentially impossible to forecast. For that reason and in order to not distort the welfare analysis, tariffs are kept constant among the scenarios.

The welfare effect for consumers is calculated as the product of the demand for gas within each country and the modelled gas price difference. Demand is assumed to be inelastic, i. e. no demand reduction due to an increase in prices takes place. The more positive the figure, the greater the benefit as a result of gas flowing via Nord Stream 2 compared to the scenarios where Nord Stream 2 is not available. The overall beneficial welfare effect of having Nord Stream 2 available for consumers of the EU-28 countries in scenario A1 compared to scenario A2 is 7.9 billion € in 2020.

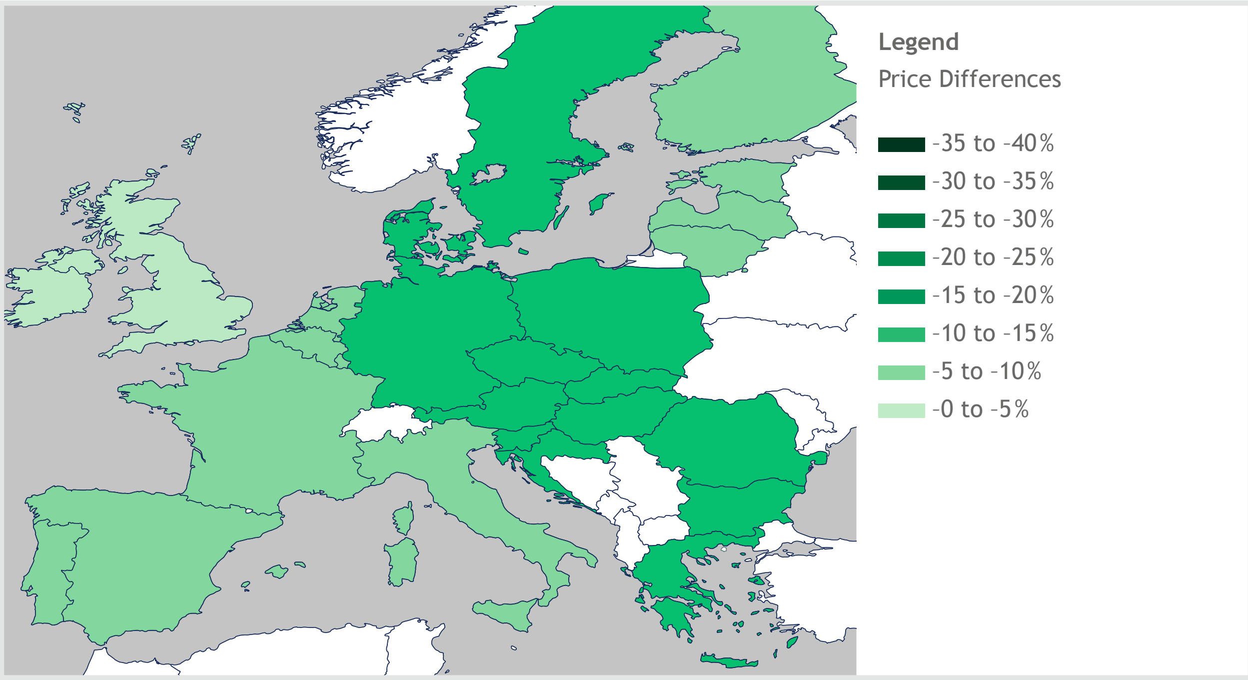


FIGURE 10: BENEFICIAL IMPACT OF NORD STREAM 2 ON PRICE LEVELS COMPARED TO SCENARIO WITHOUT NORD STREAM 2 (LOW GLOBAL LNG DEMAND) (Source: ewi ER&S – TIGER model)

4.2 High Global LNG Demand (Scenario B)

In the case of High Global LNG Demand, the EU has to pay higher LNG import prices compared to the scenario with lower global demand levels, as a result of greater demand for LNG elsewhere pushing up prices. Hence, only 48 bcm of LNG are imported in 2020 in scenario B1 (High Global LNG Demand, Nord Stream 2 available), whereas the imports are 66 bcm in the scenario A1 in 2020 (same infrastructure, but lower global LNG demand). For Nord Stream 2, this implies a higher utilization in scenario B1 compared to A1. As can be seen in Figure 11, 99 bcm/a are transitted through Nord Stream 1 and 2 in 2020 (88 bcm/a in 2020 in scenario A1). Additionally, more North African gas is imported to the EU in scenario B1 than in A1 (35 bcm instead of 32 bcm/a). Table 4 in the following section gives details of all the different flows.

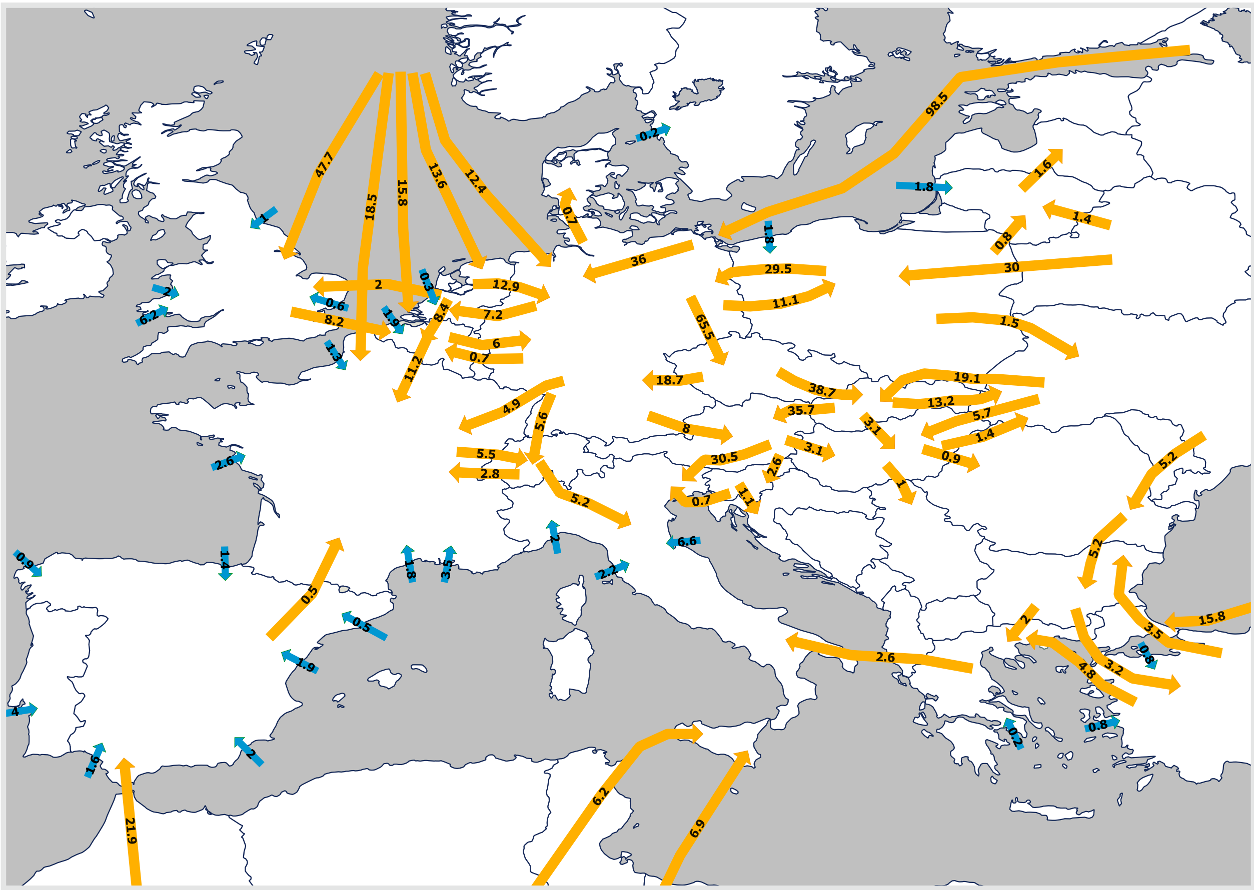


FIGURE 11: MODELLED PIPELINE AND LNG FLOWS IN 2020 IN SCENARIO B1 (HIGH GLOBAL LNG DEMAND, WITH NORD STREAM 2)
(Source: ewi ER&S – TIGER model)

Figure 12 shows the difference in flows and LNG imports between Scenario B1 (High Global LNG Demand, Nord Stream 2 available) and B2 (High Global LNG Demand, Nord Stream 2 not available). In fact, scenario B1 has a similar flow pattern as scenario A1 (same configuration as in B1, but with Low Global LNG Demand). Even if LNG is expensive, it needs to be imported in the absence of Nord Stream 2 leading to higher EU price levels.

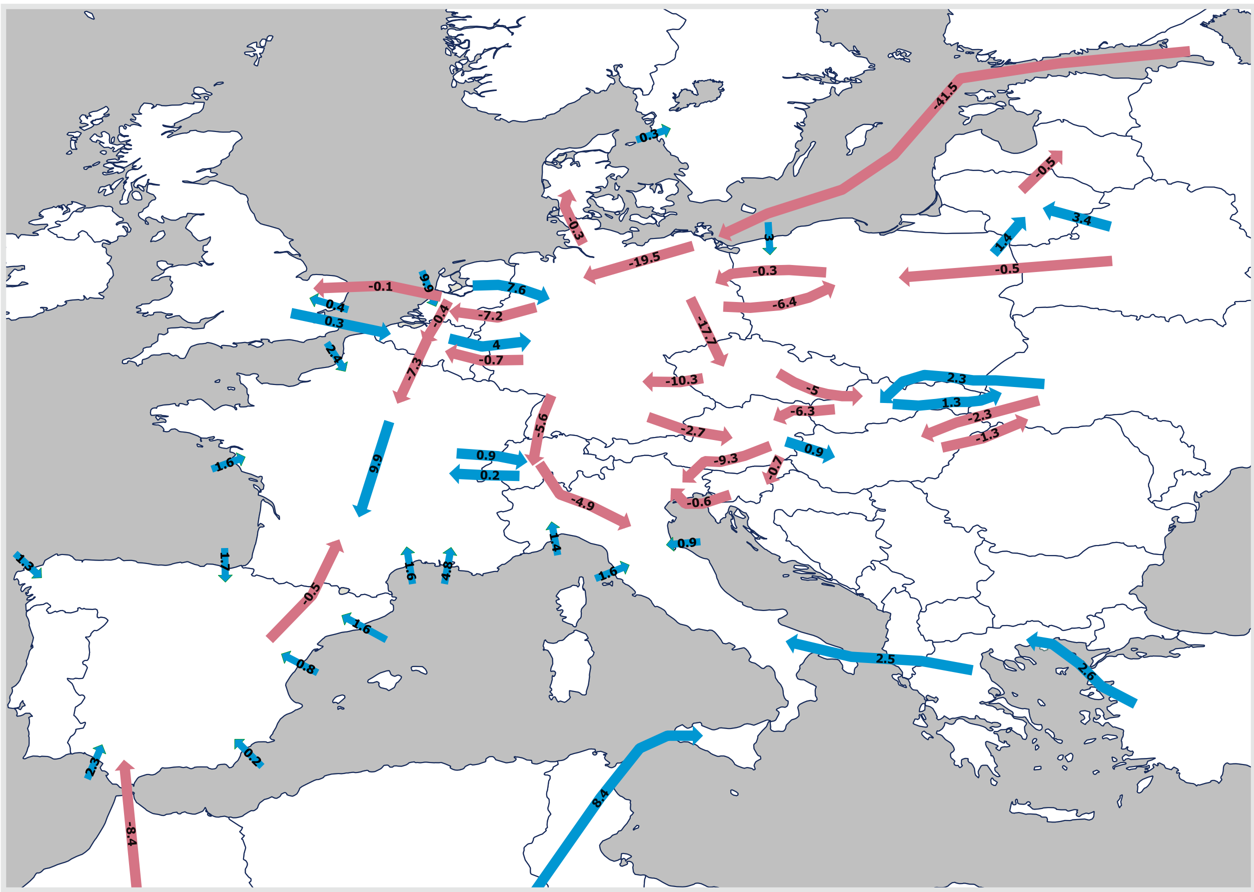


FIGURE 12: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO B1 AND B2
(Source: ewi ER&S – TIGER model)

Figure 13 shows the price differences between scenario B1 (with Nord Stream 2) and Scenario B2 (no Nord Stream 2). The reduction of gas prices as a result of Nord Stream 2 being available is larger in the case of High Global LNG demand than in the scenario with Low Global LNG Demand. In scenario B2, prices are 10% to 30% higher than in scenario B1.

The benefit to consumers of having Nord Stream 2 available is at 24.4 billion € in the EU-28 in 2020. The reason for this result is that Nord Stream 2 enables EU consumers to access more Russian gas instead of using LNG which is more expensive because of the tighter global LNG supply demand balance.

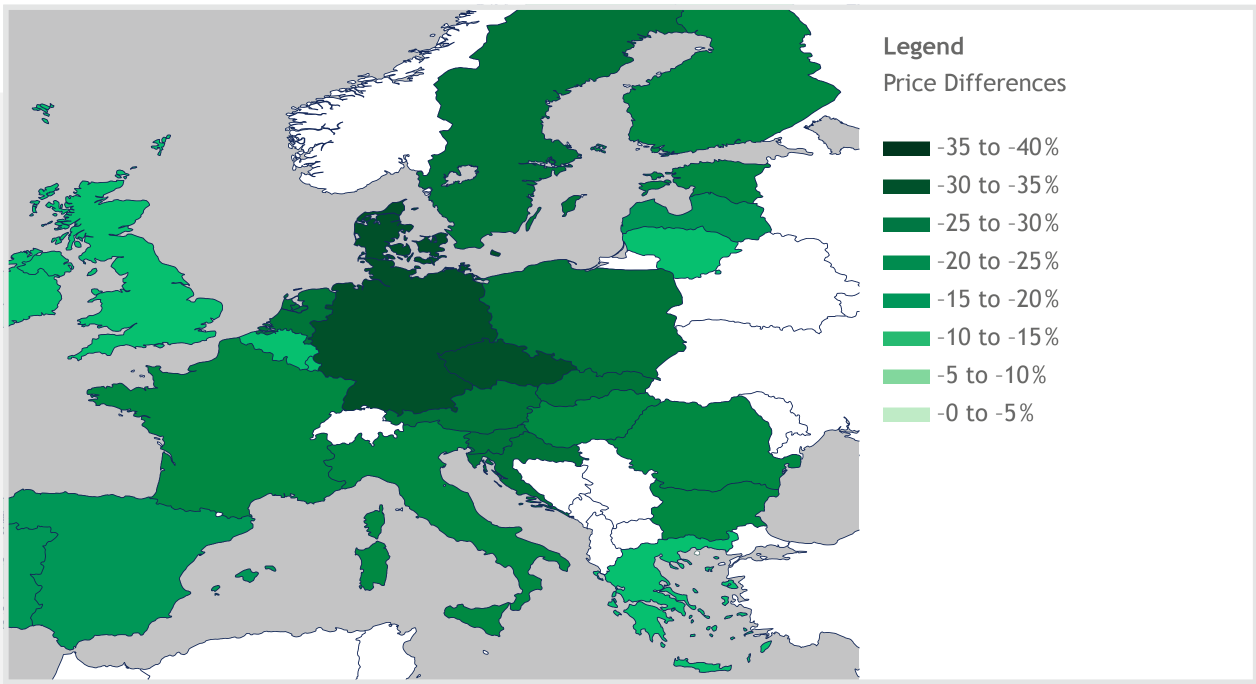


FIGURE 13: BENEFICIAL IMPACT OF NORD STREAM 2 ON PRICE LEVELS COMPARED TO SCENARIO WITHOUT NORD STREAM 2 (HIGH GLOBAL LNG DEMAND) (Source: ewi ER&S – TIGER model)

4.3 Scenario Comparison

This section provides a short overview of the main results to compare among the scenarios for the year 2020. Table 3: Overview of Scenario setting repeats Table 2 giving an overview over the scenario design.

	Low Global LNG Demand	High Global LNG Demand
Nord Stream 2 **available**	Scenario **A1**	Scenario **B1**
Nord Stream 2 **not available**	Scenario **A2**	Scenario **B2**

TABLE 3: OVERVIEW OF SCENARIO SETTING

Table 4 shows the imports from different sources to the EU-28 in the considered scenarios summing up the results discussed in Sections 4.1 and 4.2. The more restricted the use of Russian gas export routes is (as assumed in Scenarios A2, B2), the less Russian gas is marketed in the EU, mainly incentivizing more LNG and to lower extent gas from North Africa and the Southern Gas Corridor.[1]

As discussed before, these changed LNG flows imply higher EU consumer prices, leading to different welfare effects between the scenarios as illustrated in Table 5. These results underline that the availability of Nord Stream 2 has positive welfare effects for EU customers in all scenarios. The tighter the global LNG market is (as in scenarios B), the more customer welfare is generated from using Nord Stream 2.

	2020	2025	2030
A1 - A2	7.9	12.9	9.7
B1 - B2	24.4	34.8	26.9

TABLE 5: WELFARE COMPARISON AMONG SCENARIOS IN BILLION € IN EU-28

The consumer welfare effect is higher in 2025 compared to 2020, because of additional investment into liquefaction plants and higher LNG prices. In 2030, the consumer welfare effect is lower than in 2025, because the EU gas demand decreases.

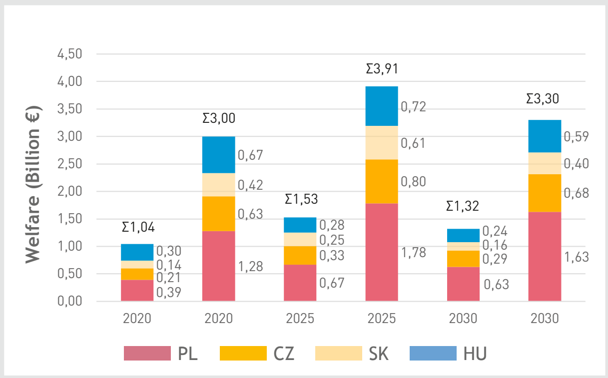
	Norway	Russia	Northern Africa	LNG	Southern Gas Corridor
Scenario A1	108	155	32	66	6
Scenario A2	108	126	35	88	8
Scenario B1	108	166	35	48	8
Scenario B2	108	130	35	82	10

TABLE 4: OVERVIEW OF IMPORT FLOWS TO THE EU-28 IN 2020 IN BCM

1 Numbers add up to slightly deviating values among the scenarios due to number rounding, differences in domestic European production and statistical effects such as storage seasonalities or gas flows from / to non-EU to / from within-EU countries.

A special focus is put on the impact of Nord Stream 2 on Central Eastern Europe (defined as Hungary, Slovakia, Poland, and Czech Republic) and South Eastern Europe (defined as Bulgaria, Croatia, Greece, Romania, Slovenia). As can be seen in Figure 14, the welfare effect in Central Eastern Europe is between 1.0 and 3.9 billion € / year, while the welfare effect for South Eastern Europe is between 0.5 and 1.7 billion € / year depending on the scenario regarding the global LNG demand.

Due to additional infrastructure connecting to Central Europe (PCI projects), additional import options (TAP / TANAP, Turk Stream) and because of lower LNG import prices, the effects of lower prices extend to Central Eastern Europe and South Eastern Europe.



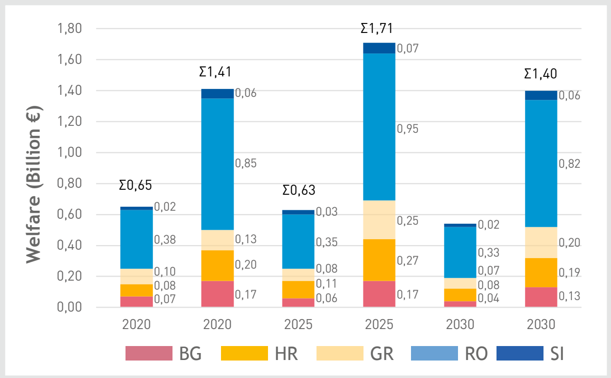


FIGURE 14: WELFARE COMPARISON IN CENTRAL EASTERN EUROPE AND SOUTH EASTERN EUROPE, SCENARIOS A1 VS. A2, AND B1 VS. B2
(Source: ewi ER&S – TIGER model)

For Poland alone, the consumer welfare effect is between 0.4 billion € in 2020 with Low Global LNG Demand, and 1.3 billion € with High Global LNG Demand (cf. Table 6: Country specific price and consumer welfare effects for Poland).

	Low Global LNG Demand	High Global LNG Demand
Nord Stream 2 **available**	**Scenario A1** Gas Price in Poland: 18.8 €/MWh	**Scenario B1** Gas Price in Poland: 22.0 €/MWh
Nord Stream 2 **not available**	**Scenario A2** Gas Price in Poland: 20.7 €/MWh Consumer Welfare Loss by not using NSP2: 393 million €	**Scenario B2** Gas Price in Poland: 28.1 €/MWh Consumer Welfare Loss by not using NSP2: 1,297 million €

TABLE 6: COUNTRY SPECIFIC PRICE AND CONSUMER WELFARE EFFECTS FOR POLAND

5. CONCLUSIONS

The study shows that Nord Stream 2 has a price decreasing and welfare enhancing effect in the EU-28 overall. In addition all EU member states benefit individually. The welfare effect for the EU customers crucially depends on the development of global LNG markets, since the price formation in European gas markets can be understood as the result of competition between LNG and Russian pipeline gas. When Nord Stream 2 is available, Russia can supply more gas to the EU decreasing the need to import more expensive LNG. Hence, the import price for the remaining LNG volumes decreases, thereby reducing the overall EU-28 price level.

Assuming continued extension of the EU infrastructure along the plans in the TYNDP, moderately low global demand levels (and hence comparably low EU LNG import prices), Nord Stream 2 leads to price decreases between 4% and 13% in the EU countries in 2020 compared to a situation in which Nord Stream is unavailable. The overall welfare effect of Nord Stream 2 is 7.9 billion € in 2020 in the case of moderately low global demand.

If LNG is scarce, the price decreasing effect of Nord Stream 2 is larger compared to a situation with abundant LNG supply, i.e. between 12% and 32% compared to a situation without Nord Stream 2. In this environment, Nord Stream 2 could increase the welfare of the EU-28 in 2020 by 24.4 billion €.

Future research could address the impact of debottlenecking congestion points, e.g. in Lanžhot, on overall welfare effects and price differentials between countries, especially in South East Europe.

Furthermore, the influence of the Ukrainian transit capacity on the results as well as the impact of delayed infrastructure extensions within the EU compared to the TYNDP could be investigated. Additionally, it would be interesting to analyze the impact of changing gas prices on a possible fuel switch in the electricity sector leading to lower CO_2 emissions.

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APPENDIX A: SUPPLEMENTARY MATERIAL

Project	Status	PCI	Commissioning Year	Capacity (bcm/a)
Interconnector BG > RS	FID	Yes	2018	1.7
Interconnector GR > BG (IGB) Phase I	FID	Yes	2018	3.0
Interconnector GR >BG (IGB) Phase II	FID	Yes	2021	2.0
Interconnector IT > AT	FID	Yes	2018	6.2
Italy Northern Export Fork	FID	Yes	2018	13.8
Liaison Nord Sud	FID	Yes	2018	32.9
Nord Stream 2	FID	No	2020	57.0
Interconnection DE >CZ	FID	No	2018	37.0
Interconnection CZ >SK	Non-FID	No	2018	16.6
Interconnection DE >PL	Non-FID	No	2018	4.3
Interconnection DE >NL	Non-FID	No	2018	8.5
TANAP	FID	Yes	2018	16.0
Reverse TENP	FID	Yes	2018	16.0
EASTRING	Non-FID	Yes	2020	20.0
TAP	FID	Yes	2020	10.0
TAP Connector	FID	Yes	2020	15.0
Turkish Stream 1	FID	No	2018	16.0
Interconnection HR >SI	FID	Yes	2019	5.3
Gas Interconnector Lithuania Poland	Non-FID	Yes	2019	2.0
Baltic Connector Finland Estonia	Non-FID	Yes	2019	2.0
Interconnector LT >LV	Non-FID	Yes	2020	1.8
Interconnector LV >ES	Non-FID	Yes	2019	1.4

TABLE 7: ASSUMED TRANSPORT CAPACITY ADDITIONS IN THE CONSIDERED SCENARIOS

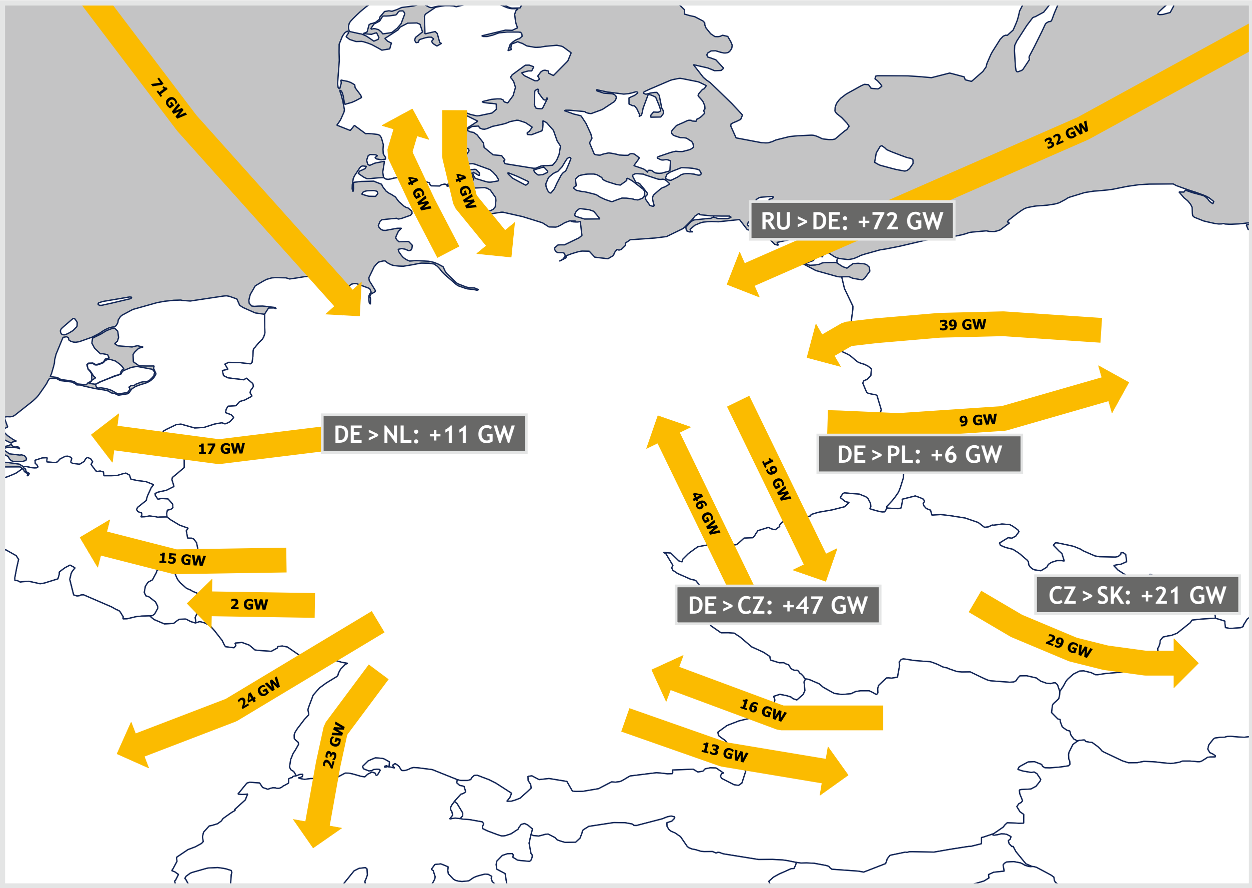

FIGURE 15: ASSUMED INFRASTRUCTURE EXTENSIONS BASED ON PRISMA AUCTION
(Source: PRISMA Website https://platform.prisma-capacity.eu/)

LNG Facility	Status	Commissioning Year	Annual Import Volume to be added (bcm/a)
Revythoussa LNG Terminal (GR)	FID	2017	2.4
Zeebrugge LNG Terminal (BE)	FID	2019	3
Musel LNG Terminal (ES)	FID	2026	7

TABLE 8: LNG TERMINAL EXTENSIONS IN THE CONSIDERED SCENARIOS

	A1	A2
AT	18.6	20.7
BE	18.0	18.9
BG	22.0	24.6
CZ	18.0	20.3
DE	17.8	20.1
DK	18.0	20.3
EE	20.4	22.3
ES	17.1	18.3
FI	18.3	19.6
FR	17.9	19.1
GR	20.6	22.7
HR	20.8	23.5
HU	20.8	23.5
IE	18.2	19.0
IT	19.5	21.0
LT	20.0	21.9
LU	17.2	18.8
LV	20.7	22.6
NL	17.6	19.2
PL	18.8	20.7
PT	17.8	20.2
RO	21.8	24.5
SE	18.0	20.3
SI	20.0	22.2
SK	19.5	21.7
UK	16.7	17.4
EU-28 (weighted average)	18.2	19.8

TABLE 9: ABSOLUTE PRICE LEVELS IN SCENARIO A1 AND A2 IN 2020 IN €/MWH

	B1	B2
AT	22.5	28.8
BE	19.7	22.1
BG	26.5	32.5
CZ	21.5	28.3
DE	21.6	28.2
DK	21.6	28.1
EE	23.8	29.4
ES	23.0	26.7
FI	23.8	29.4
FR	22.3	27.1
GR	20.3	23.0
HR	24.5	30.8
HU	24.7	30.7
IE	19.3	21.6
IT	23.6	29.2
LT	23.2	25.8
LU	21.8	27.1
LV	24.1	27.9
NL	21.5	27.1
PL	22.0	28.1
PT	22.9	26.4
RO	26.0	32.0
SE	21.8	28.1
SI	23.2	29.5
SK	22.9	29.3
UK	18.7	21.0
EU-28 (weighted average)	21.8	26.7

TABLE 10: ABSOLUTE PRICE LEVELS IN SCENARIO B1 AND B2 IN 2020 IN €/MWH

	2020				2025				2030			
	A1	A2	B1	B2	A1	A2	B1	B2	A1	A2	B1	B2
NSP1+2	88	57	99	57	93	57	108	57	99	57	112	57
Yamal	33	33	33	33	33	33	33	33	33	33	33	33
Ukraine	30	30	30	30	25	30	26	30	25	30	30	30
Oth. RU	4	6	5	10	6	7	7	11	6	10	7	10
LNG	66	88	48	82	86	113	68	111	91	123	71	122
N. Afr	33	35	35	35	26	26	26	26	17	17	17	17
Norway	108	108	108	108	101	101	101	101	94	94	94	94

TABLE 11: FLOWS INTO EU IN BCM/A IN DIFFERENT SCENARIOS

	2020	2020	2025	2025	2030	2030
	A1-A2	B1-B2	A1-A2	B1-B2	A1-A2	B1-B2
AT	-2.1	-6.3	-3.2	-7.8	-2.5	-6.3
BE	-0.9	-2.4	-2.1	-6.7	-1.6	-5.3
BG	-2.6	-6.0	-2.0	-5.9	-1.5	-4.7
CZ	-2.3	-6.8	-3.4	-8.3	-2.9	-6.9
DE	-2.3	-6.6	-3.3	-8.0	-2.7	-6.5
DK	-2.3	-6.5	-3.0	-7.3	-2.0	-4.9
EE	-1.9	-5.6	-1.2	-1.4	-0.3	-2.7
ES	-1.2	-3.7	-2.1	-6.3	-1.6	-4.8
FI	-1.3	-5.6	-1.2	-1.4	-0.3	-2.7
FR	-1.2	-4.8	-1.9	-6.0	-1.4	-4.8
GB	-0.7	-2.3	-1.9	-6.3	-1.4	-4.8
GR	-2.1	-2.7	-1.9	-5.8	-1.5	-4.7
HR	-2.7	-6.3	-3.2	-7.8	-2.6	-6.3
HU	-2.7	-6.0	-2.9	-7.5	-2.6	-6.4
IE	-0.8	-2.3	-1.9	-6.3	-1.4	-4.8
IT	-1.5	-5.6	-2.7	-7.3	-2.2	-5.9
LT	-1.9	-2.6	-1.2	-1.4	-0.3	-2.7
LU	-1.6	-5.3	-2.6	-7.2	-2.1	-5.9
LV	-1.9	-3.8	-1.2	-1.4	-0.3	-2.7
NL	-1.6	-5.6	-2.9	-7.5	-2.4	-6.1
PL	-1.9	-6.1	-2.8	-7.6	-2.4	-6.2
PT	-1.2	-3.5	-1.9	-5.9	-1.4	-4.5
RO	-2.7	-6.0	-2.8	-7.4	-2.5	-6.3
SE	-2.3	-6.3	-3.0	-7.3	-2.0	-4.8
SI	-2.2	-6.3	-3.2	-7.8	-2.5	-6.3
SK	-2.2	-6.4	-3.2	-7.8	-2.6	-6.3
EU-28 (weighted average)	-1.6	-4.9	-2.5	-7.0	-2.0	-5.6

TABLE 12: ABSOLUTE PRICE DIFFERENCE BETWEEN SCENARIOS IN €/MWH

	2020	2020	2025	2025	2030	2030
	A1-A2	B1-B2	A1-A2	B1-B2	A1-A2	B1-B2
AT	-11.3	-28.0	-14.1	-30.8	-9.4	-20.8
BE	-5.0	-12.2	-9.8	-27.1	-6.0	-17.9
BG	-11.8	-22.6	-9.1	-23.1	-5.8	-15.3
CZ	-12.8	-31.6	-15.4	-33.9	-11.1	-23.7
DE	-12.9	-30.6	-15.4	-32.5	-10.3	-22.0
DK	-12.8	-30.1	-8.9	-20.1	-3.3	-7.7
EE	-9.3	-23.5	-5.0	-5.4	-1.0	-8.8
ES	-7.0	-16.1	-9.7	-25.7	-6.1	-16.0
FI	-7.1	-23.5	-5.0	-5.4	-1.0	-8.8
FR	-6.7	-21.5	-8.9	-23.8	-5.5	-16.1
GB	-4.2	-12.3	-9.2	-26.3	-5.3	-16.4
GR	-10.2	-13.3	-9.2	-23.7	-6.0	-15.9
HR	-13.0	-25.7	-13.0	-28.6	-8.9	-19.5
HU	-13.0	-24.3	-11.9	-27.6	-9.3	-20.2
IE	-4.4	-11.9	-8.9	-25.6	-5.2	-16.0
IT	-7.7	-23.7	-11.6	-27.6	-7.9	-18.8
LT	-9.5	-11.2	-5.1	-5.4	-1.1	-9.0
LU	-9.3	-24.3	-11.6	-29.0	-7.9	-19.8
LV	-9.2	-15.8	-4.9	-5.1	-1.0	-8.8
NL	-9.1	-26.1	-13.6	-30.8	-9.2	-20.7
PL	-10.1	-27.7	-12.6	-29.8	-8.8	-20.5
PT	-6.8	-15.3	-9.0	-23.7	-5.2	-15.0
RO	-12.4	-23.1	-13.2	-30.9	-10.0	-22.1
SE	-12.8	-28.9	-8.9	-20.1	-3.3	-7.7
SI	-11.0	-27.1	-13.7	-29.9	-9.1	-20.3
SK	-11.3	-28.0	-13.9	-30.4	-9.3	-20.6

TABLE 13: RELATIVE PRICE DIFFERENCE BETWEEN SCENARIOS IN %

	2020	2020	2025	2025	2030	2030
	A1-A2	B1-B2	A1-A2	B1-B2	A1-A2	B1-B2
AT	211	626	308	760	249	619
BE	159	437	479	1,496	354	1,189
BG	72	165	56	166	42	127
CZ	214	629	326	805	287	682
DE	2,055	5,858	3,012	7,181	2,357	5,658
DK	79	223	97	235	68	168
EE	21	62	12	15	3	26
ES	405	1,217	637	1,946	446	1,348
FI	46	204	48	57	12	108
FR	536	2,208	882	2,715	597	1,998
GB	572	1,921	1,598	5,221	1,017	3,581
GR	104	131	84	252	65	199
HR	85	202	109	268	78	192
HU	296	667	276	720	240	585
IE	41	118	103	336	71	250
IT	1,187	4,356	2,103	5,618	1,681	4,497
LT	50	71	38	46	7	65
LU	22	70	38	106	31	88
LV	22	45	18	22	4	36
NL	641	2,229	1,153	2,962	900	2,293
PL	393	1,279	670	1,782	628	1,632
PT	53	156	94	287	45	150
RO	380	847	355	950	328	816
SE	58	159	76	184	50	122
SI	20	57	30	74	24	59
SK	142	421	249	615	163	402
Total EU-28	7,865	24,358	12,852	34,818	9,747	26,892

TABLE 14: CONSUMER WELFARE DIFFERENCES BETWEEN SCENARIOS PER COUNTRY IN MILLION €

2020 Scenario A (Low Global LNG Demand)

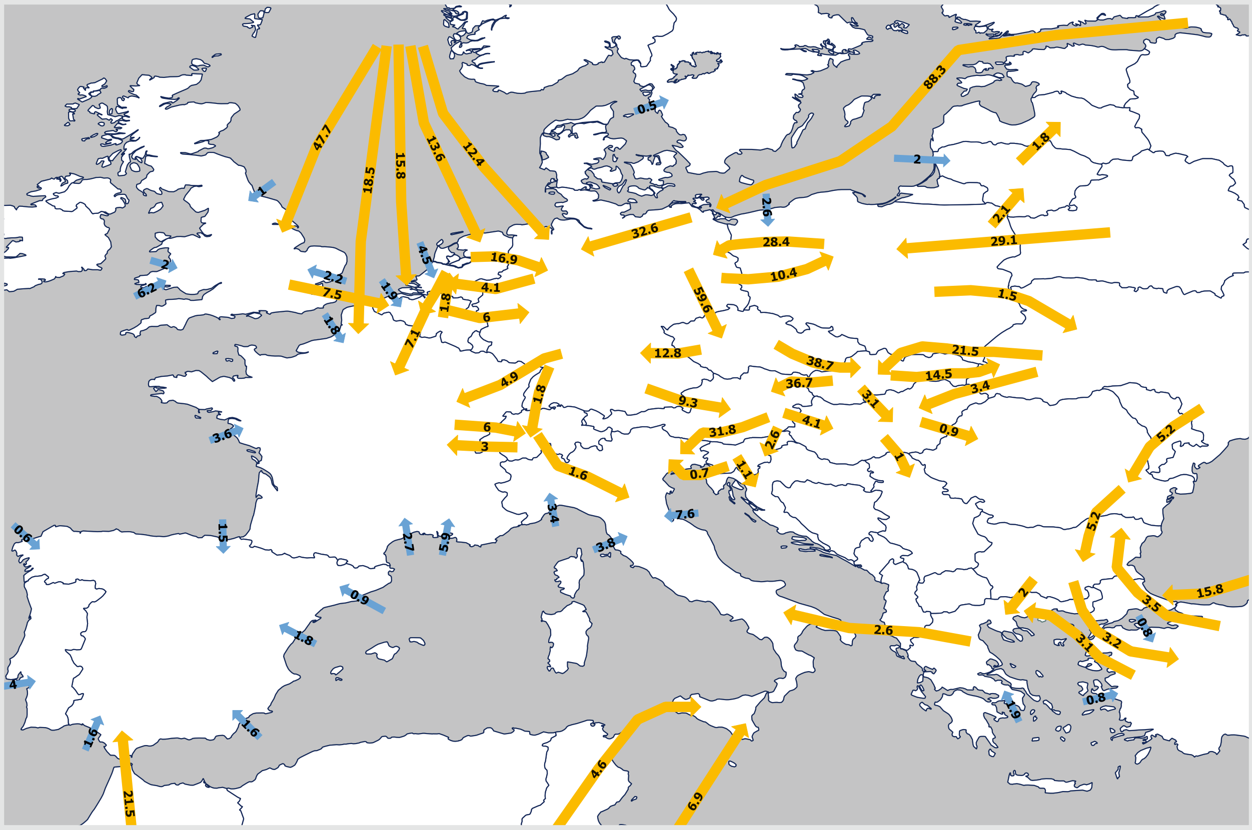

FIGURE 16: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO A1 IN 2020
(Source: ewi ER&S - TIGER model)

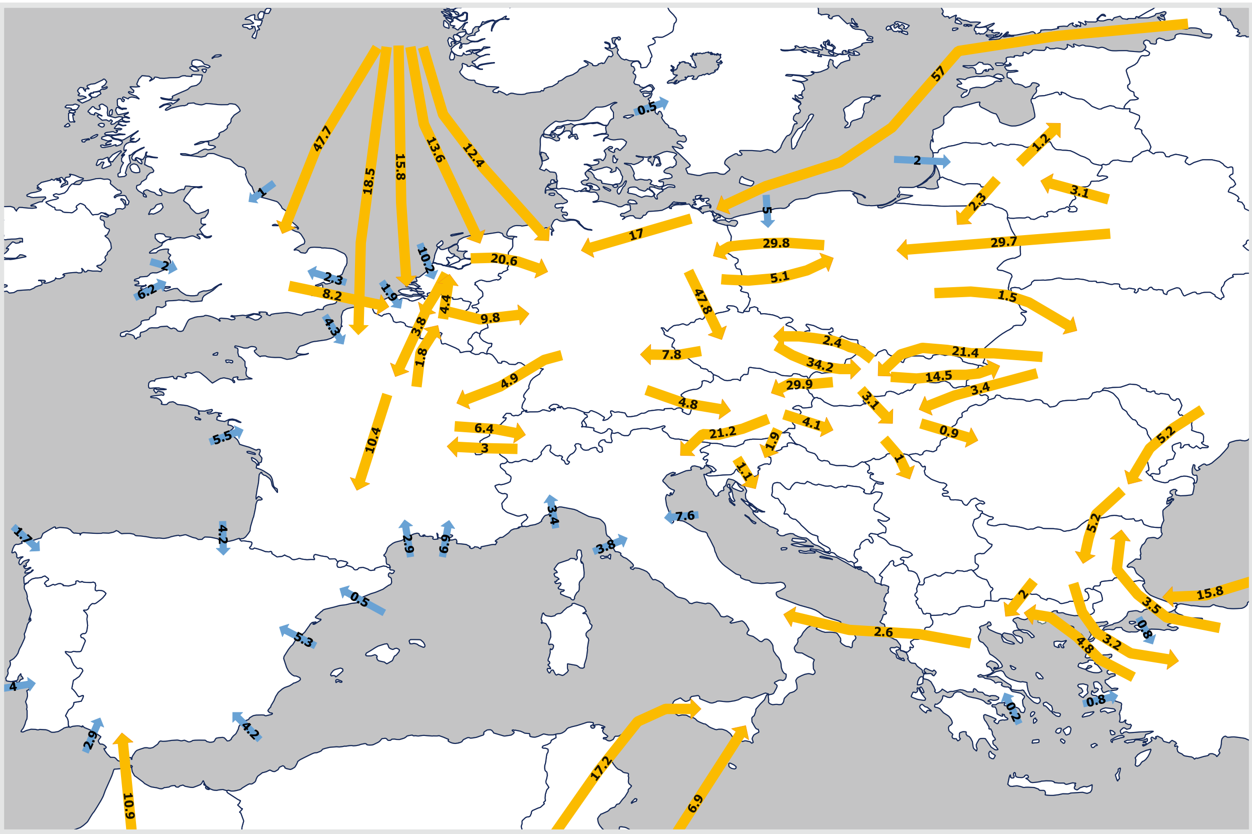

FIGURE 17: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO A2 IN 2020
(Source: ewi ER&S - TIGER model)

2020 Scenario A (Low Global LNG Demand)

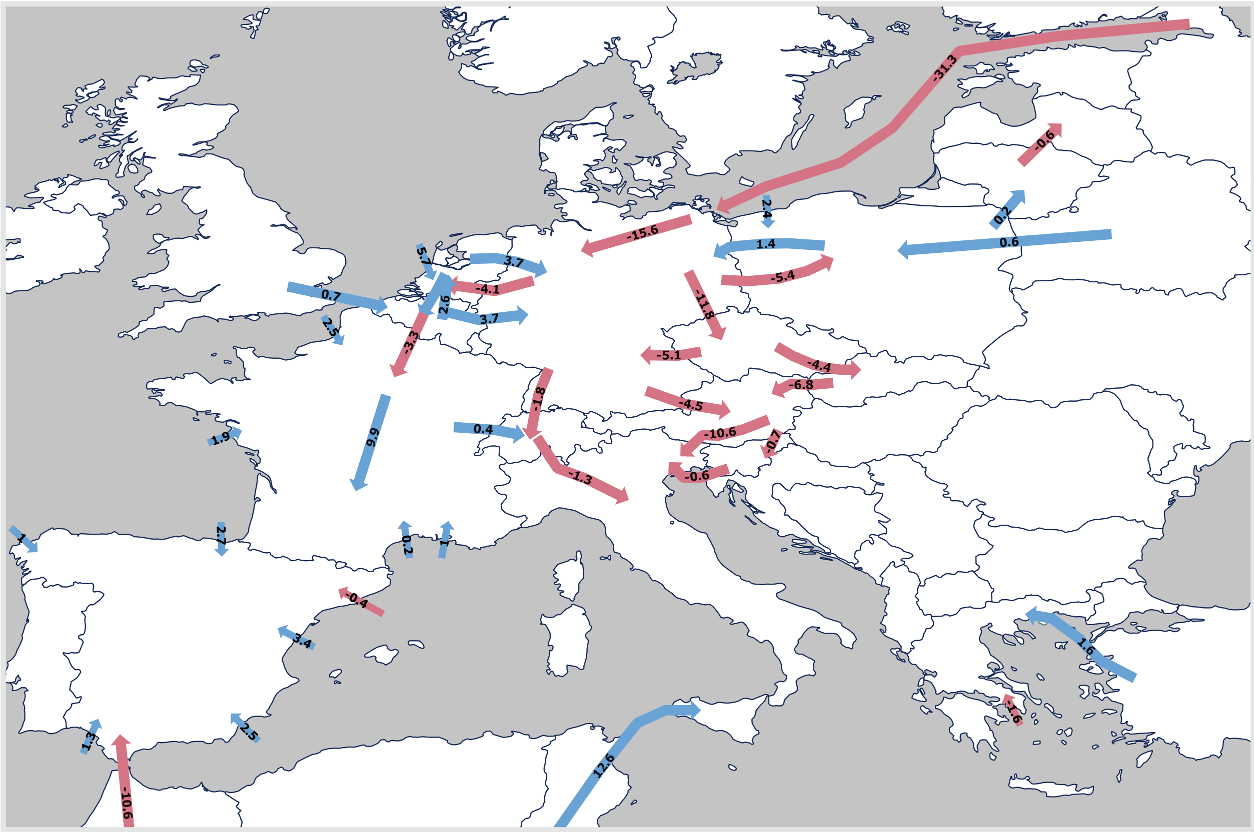

FIGURE 18: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO A1 AND A2 IN 2020
(Source: ewi ER&S - TIGER model)

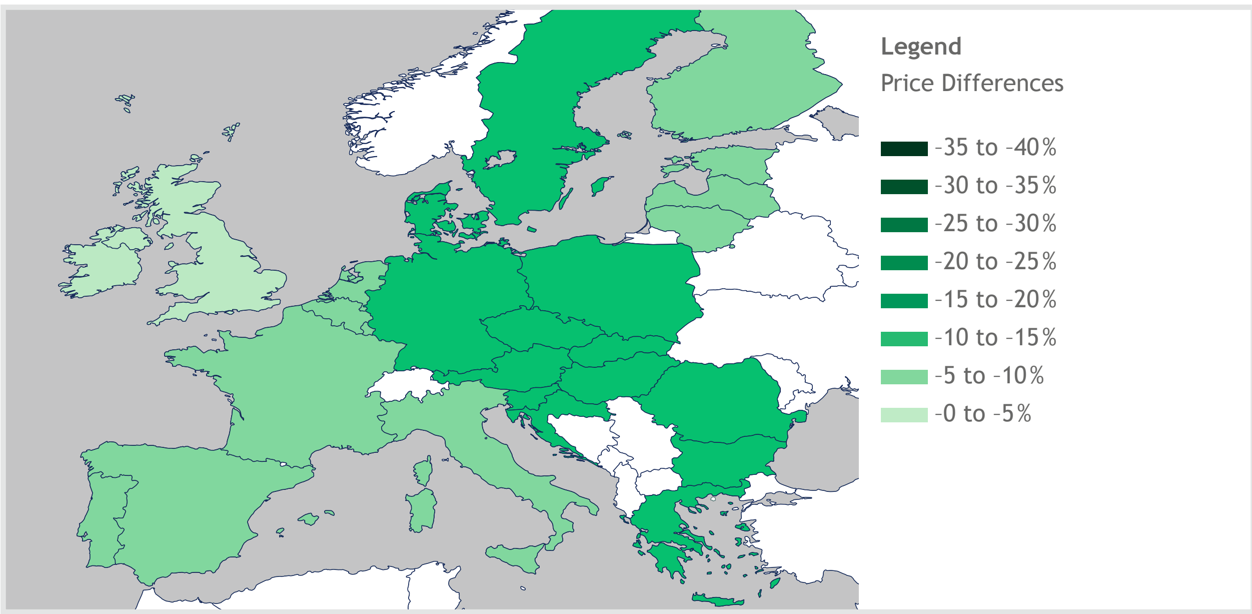

FIGURE 19: DIFFERENCES IN GAS PRICES BETWEEN SCENARIO A1 AND A2 IN 2020
(Source: ewi ER&S - TIGER model)

2020 Scenario B (High Global LNG Demand)

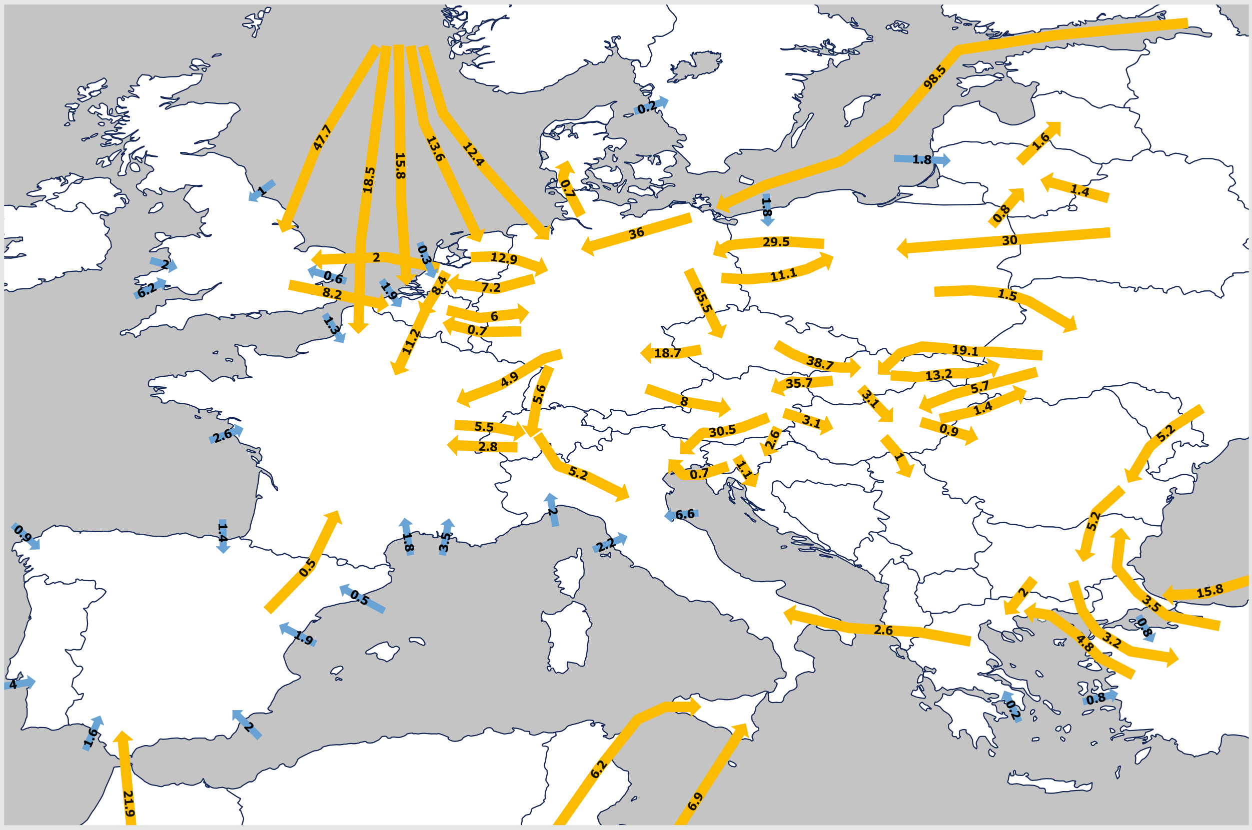

FIGURE 20: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO B1 IN 2020
(Source: ewi ER&S - TIGER model)

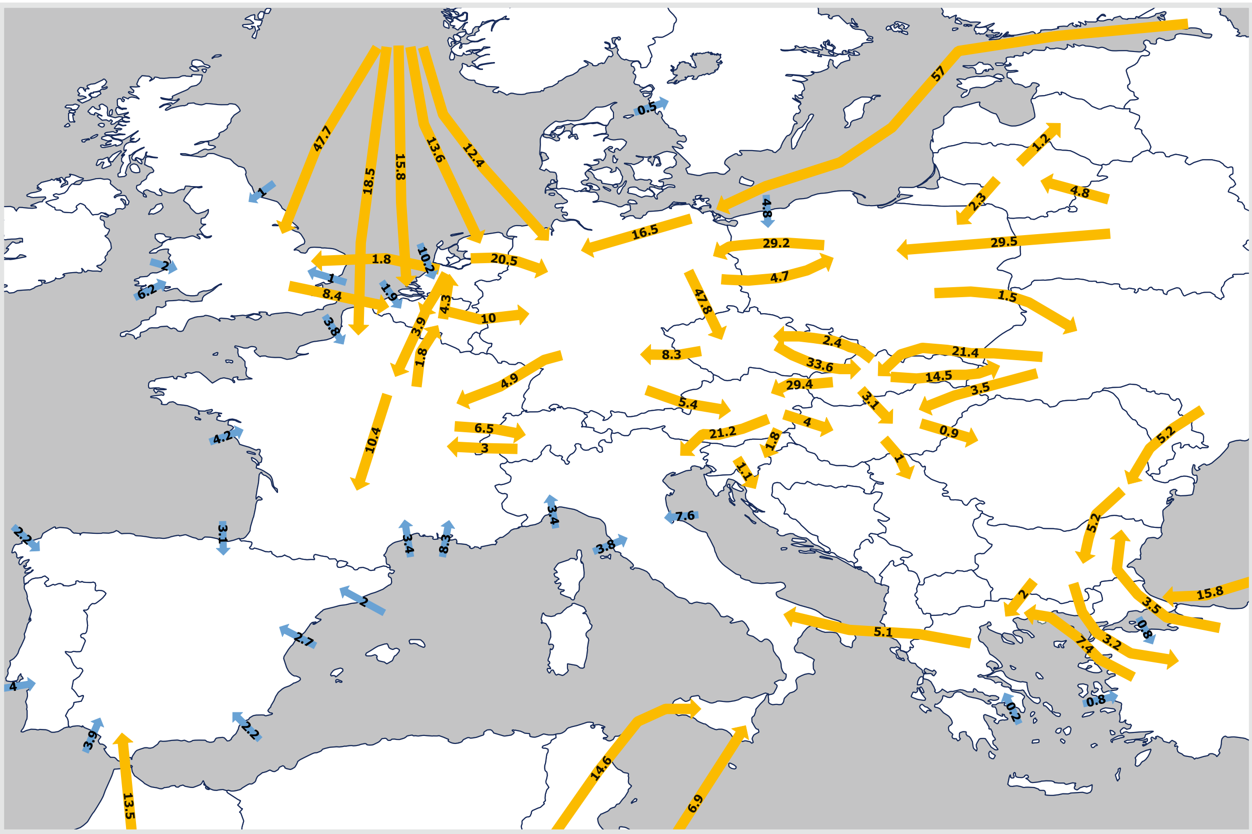

FIGURE 21: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO B2 IN 2020
(Source: ewi ER&S - TIGER model)

2020 Scenario B (High Global LNG Demand)

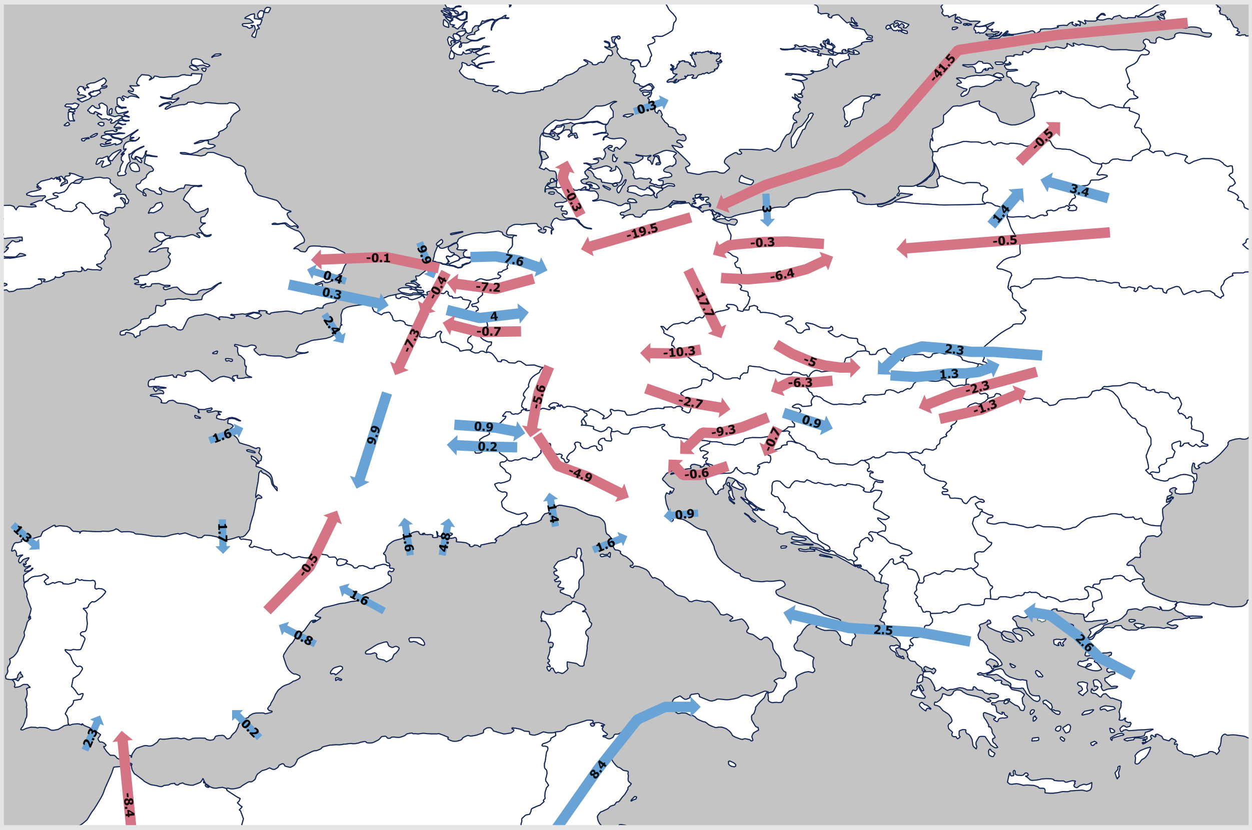

FIGURE 22: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO B1 AND B2 IN 2020
(Source: ewi ER&S - TIGER model)

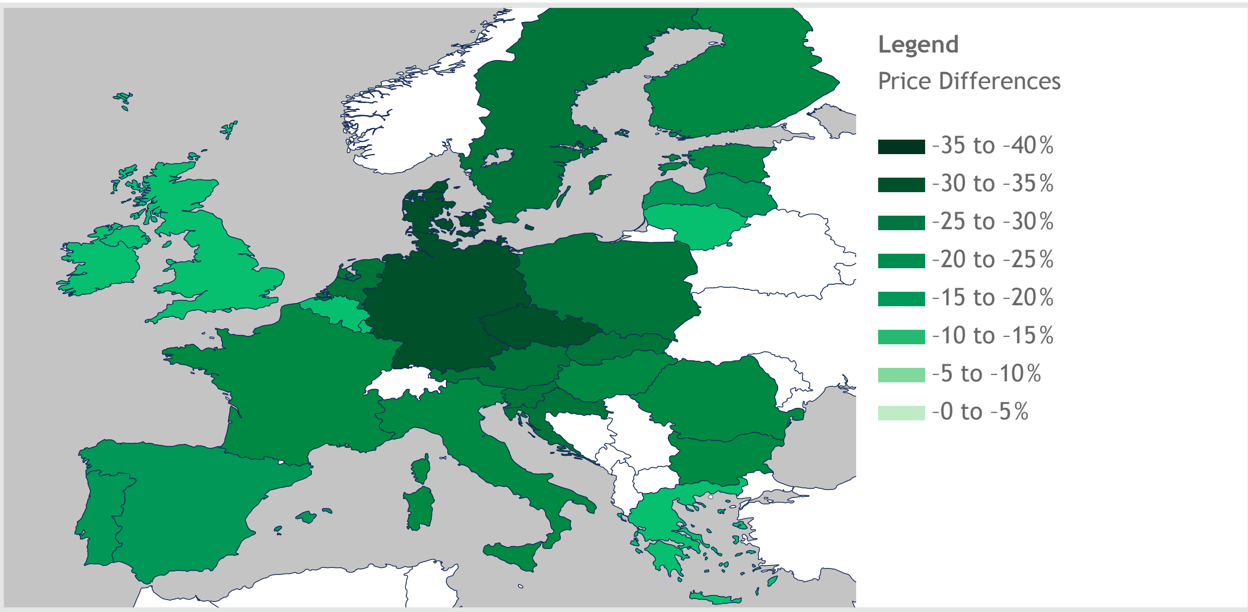

FIGURE 23: DIFFERENCES IN GAS PRICES BETWEEN SCENARIO B1 AND B2 IN 2020
(Source: ewi ER&S - TIGER model)

2025 Scenario A (Low Global LNG Demand)

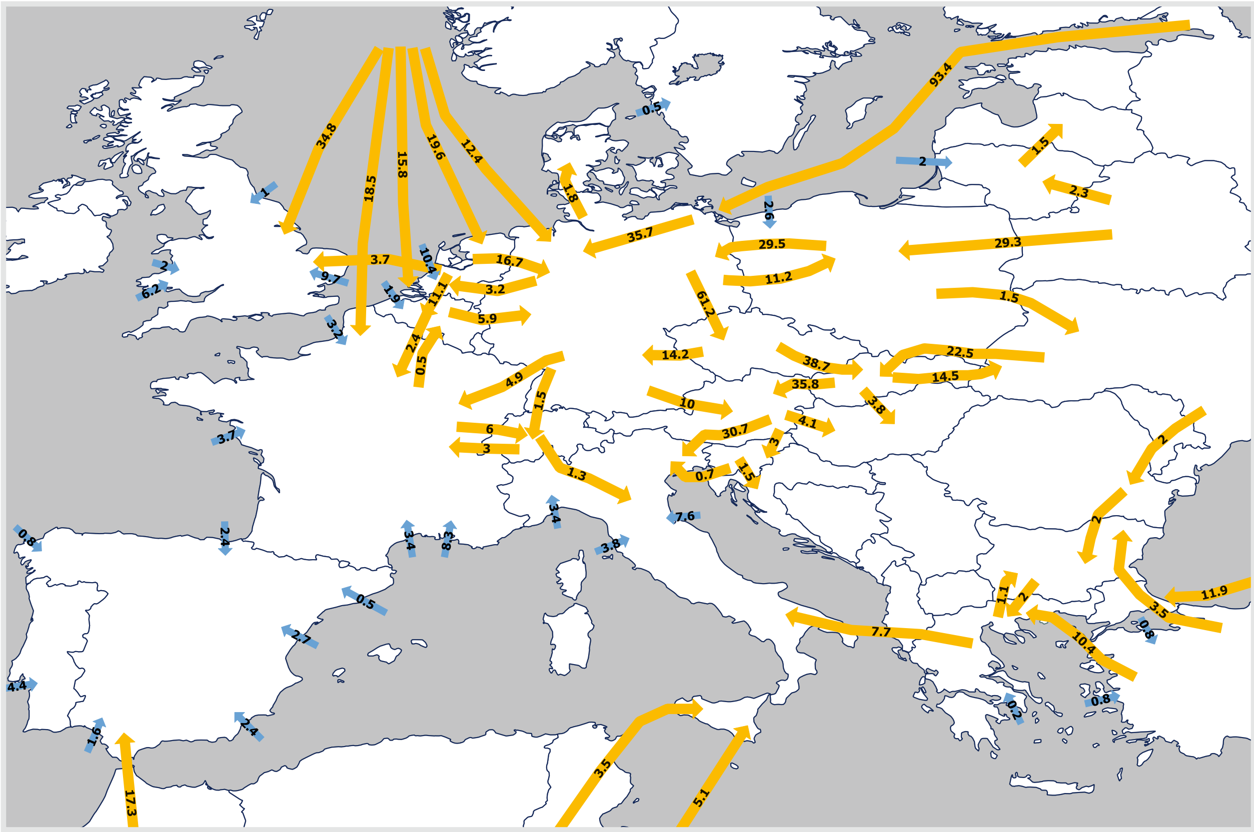

FIGURE 24: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO A1 IN 2025
(Source: ewi ER&S - TIGER model)

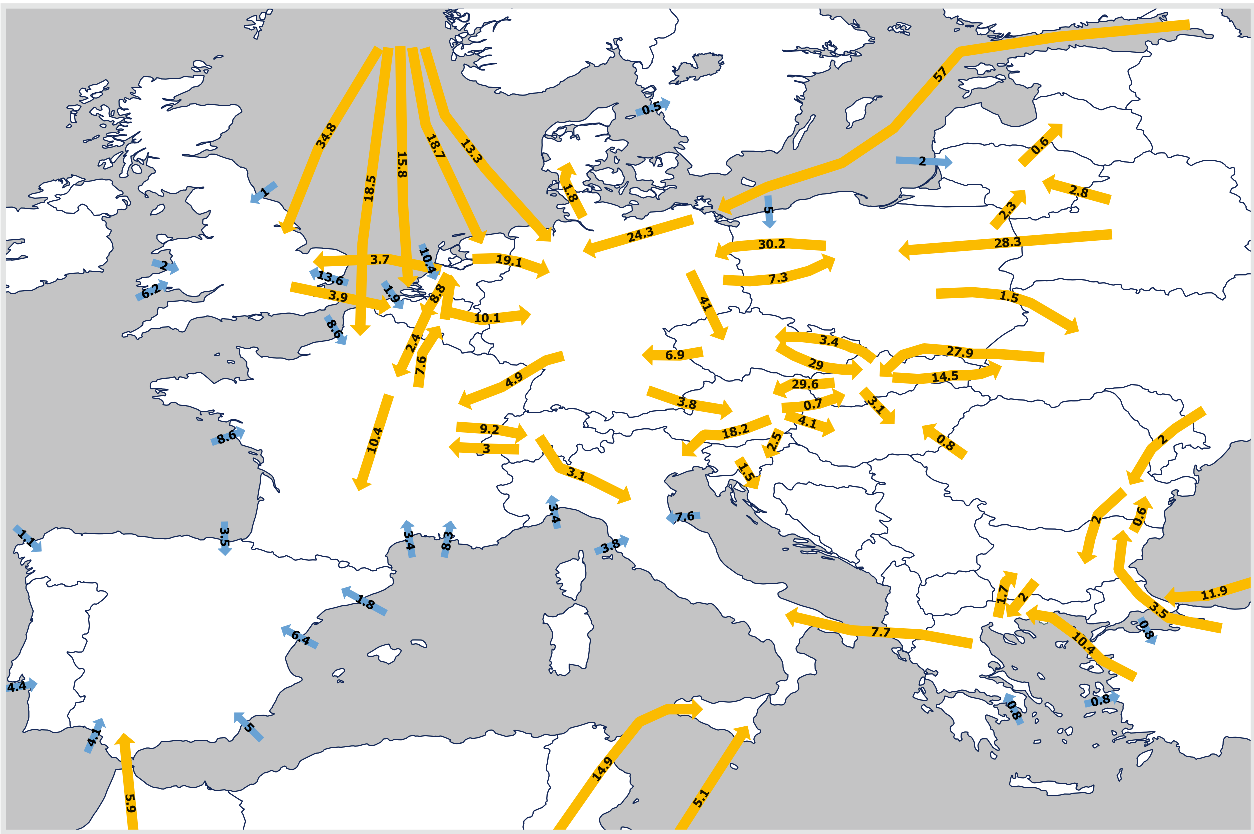

FIGURE 25: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO A2 IN 2025
(Source: ewi ER&S - TIGER model)

2025 Scenario A (Low Global LNG Demand)

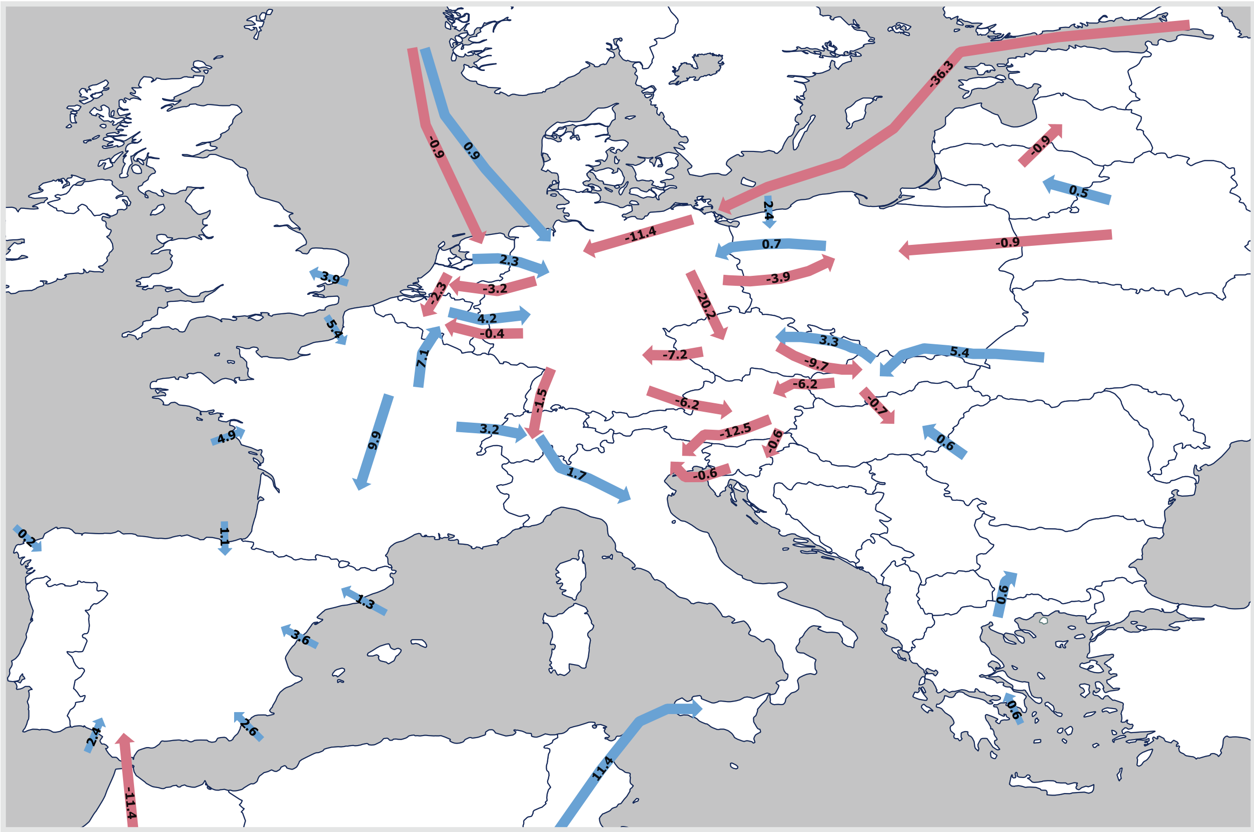

FIGURE 26: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO A1 AND A2 IN 2025
(Source: ewi ER&S - TIGER model)

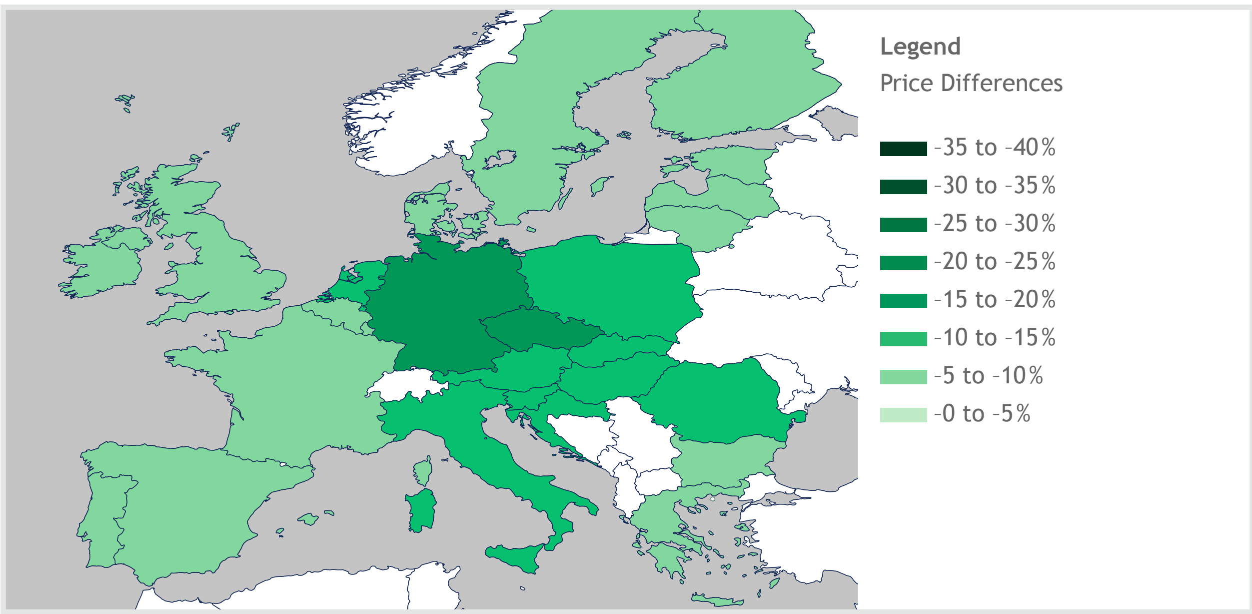

FIGURE 27: DIFFERENCES IN GAS PRICES BETWEEN SCENARIO A1 AND A2 IN 2025
(Source: ewi ER&S - TIGER model)

2025 Scenario B (High Global LNG Demand)

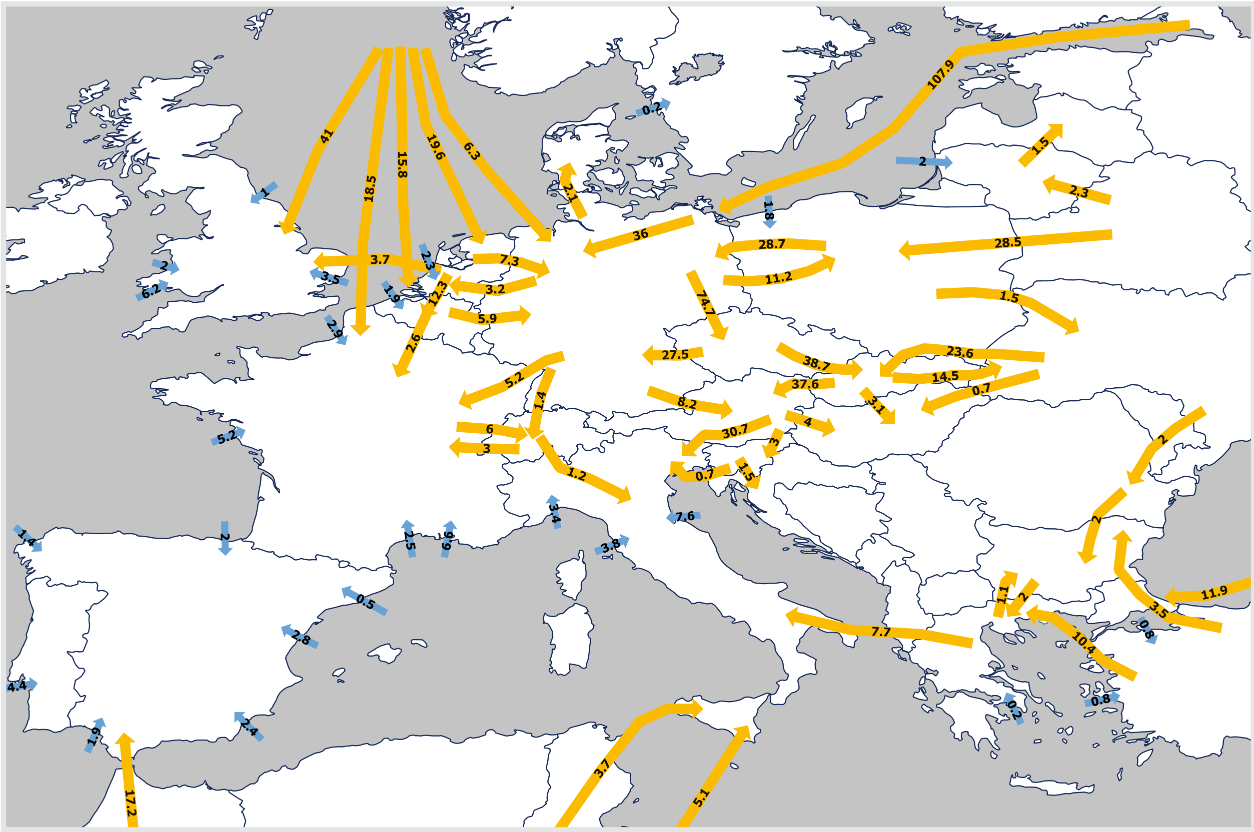

FIGURE 28: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO B1 IN 2025
(Source: ewi ER&S - TIGER model)

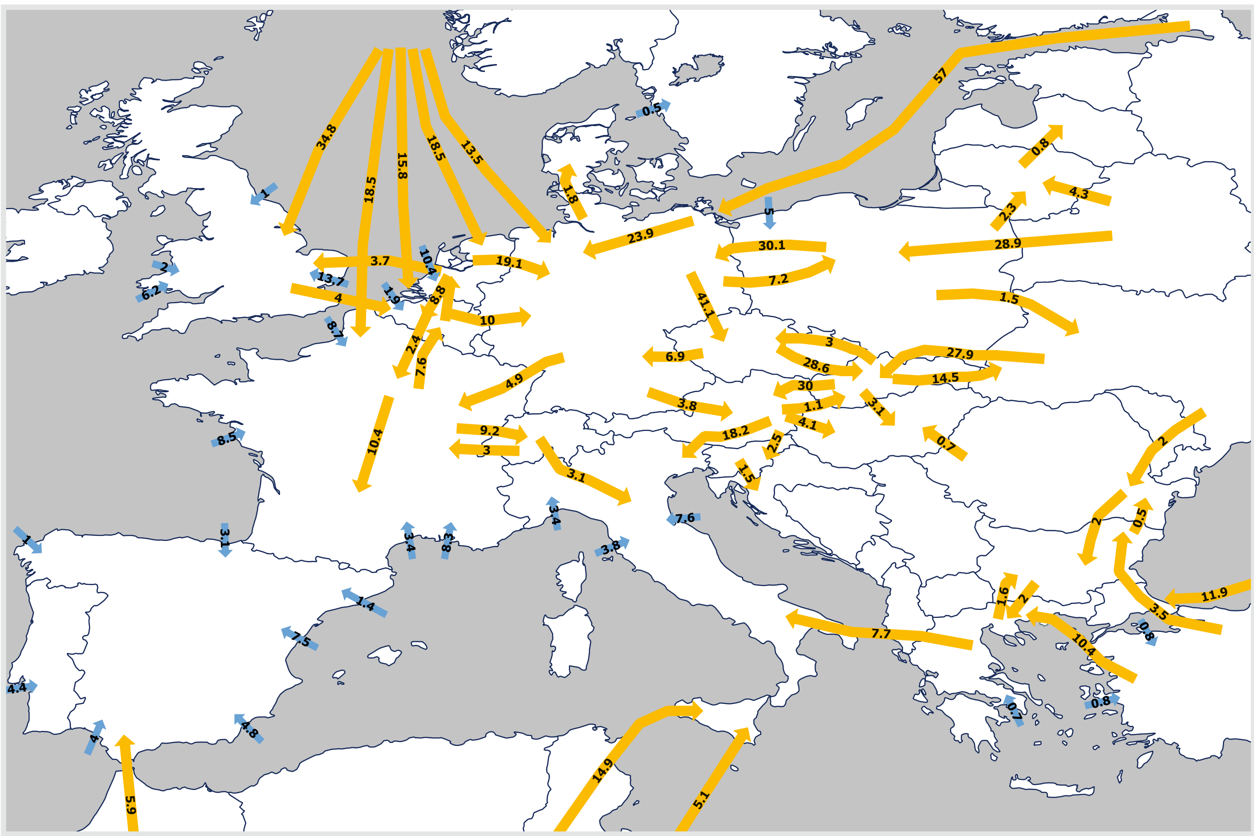

FIGURE 29: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO B2 IN 2025
(Source: ewi ER&S - TIGER model)

2025 Scenario B (High Global LNG Demand)

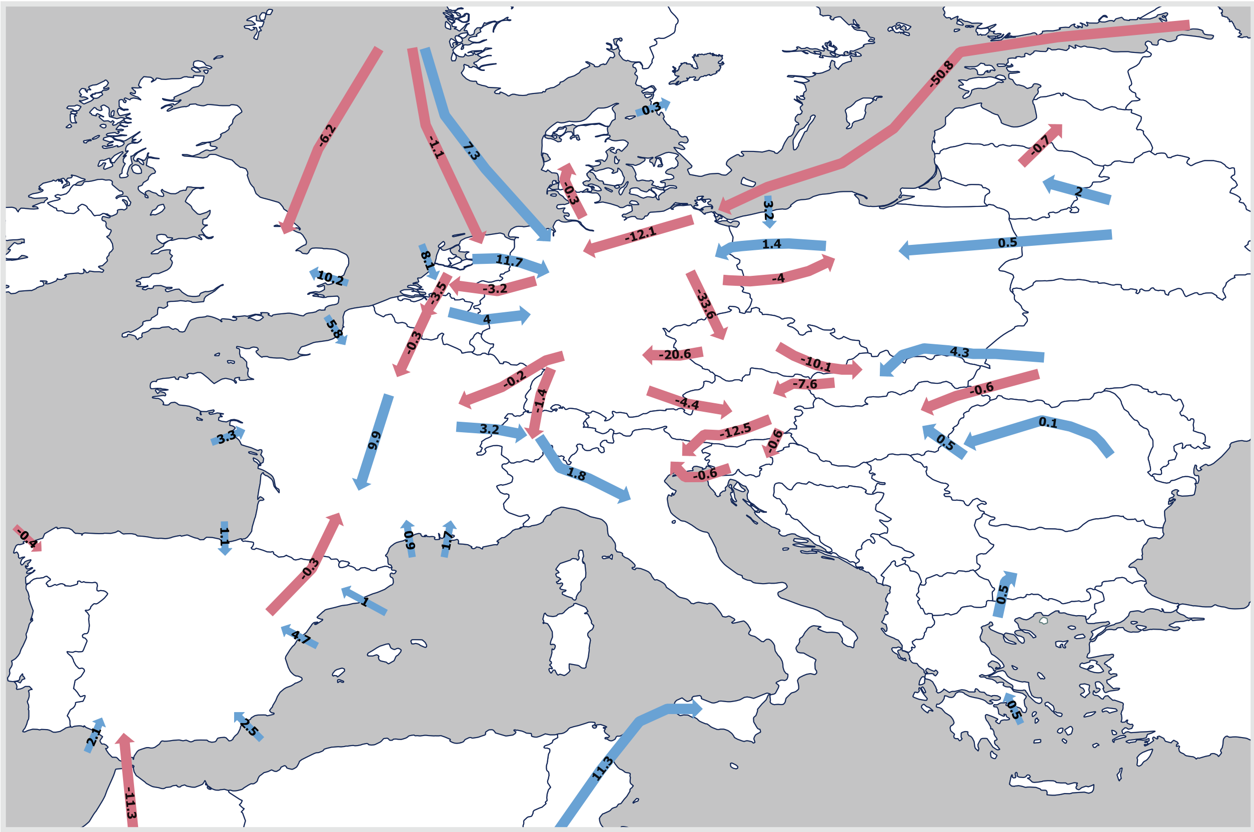

FIGURE 30: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO B1 AND B2 IN 2025
(Source: ewi ER&S - TIGER model)

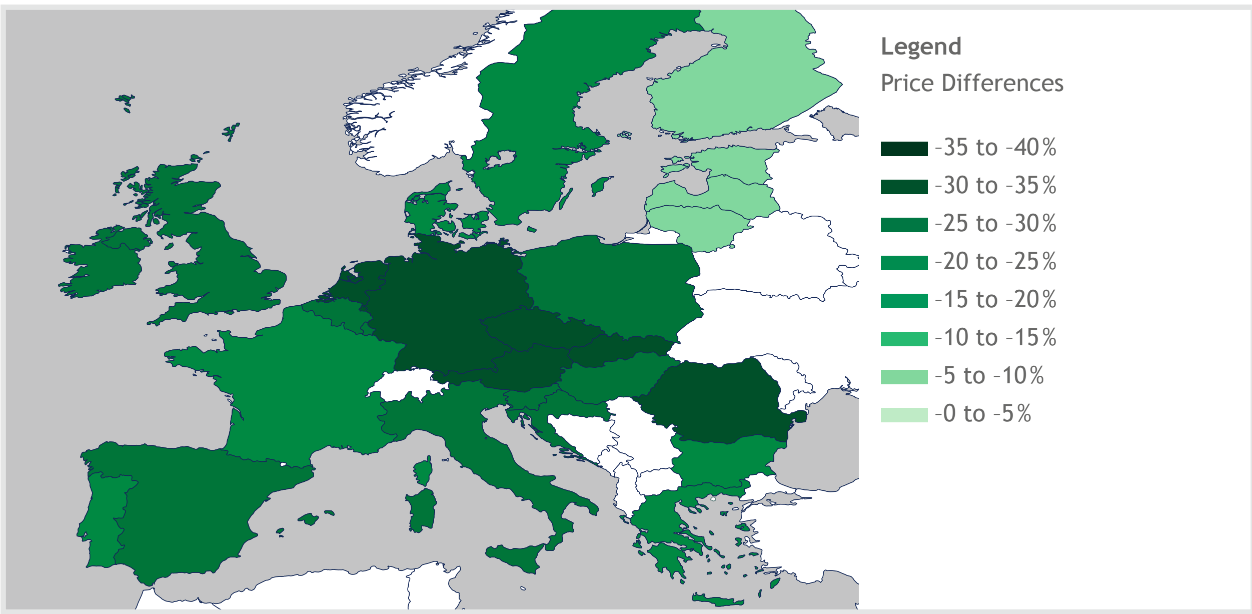

FIGURE 31: DIFFERENCES IN GAS PRICES BETWEEN SCENARIO B1 AND B2 IN 2025
(Source: ewi ER&S - TIGER model)

2030 Scenario A (Low Global LNG Demand)

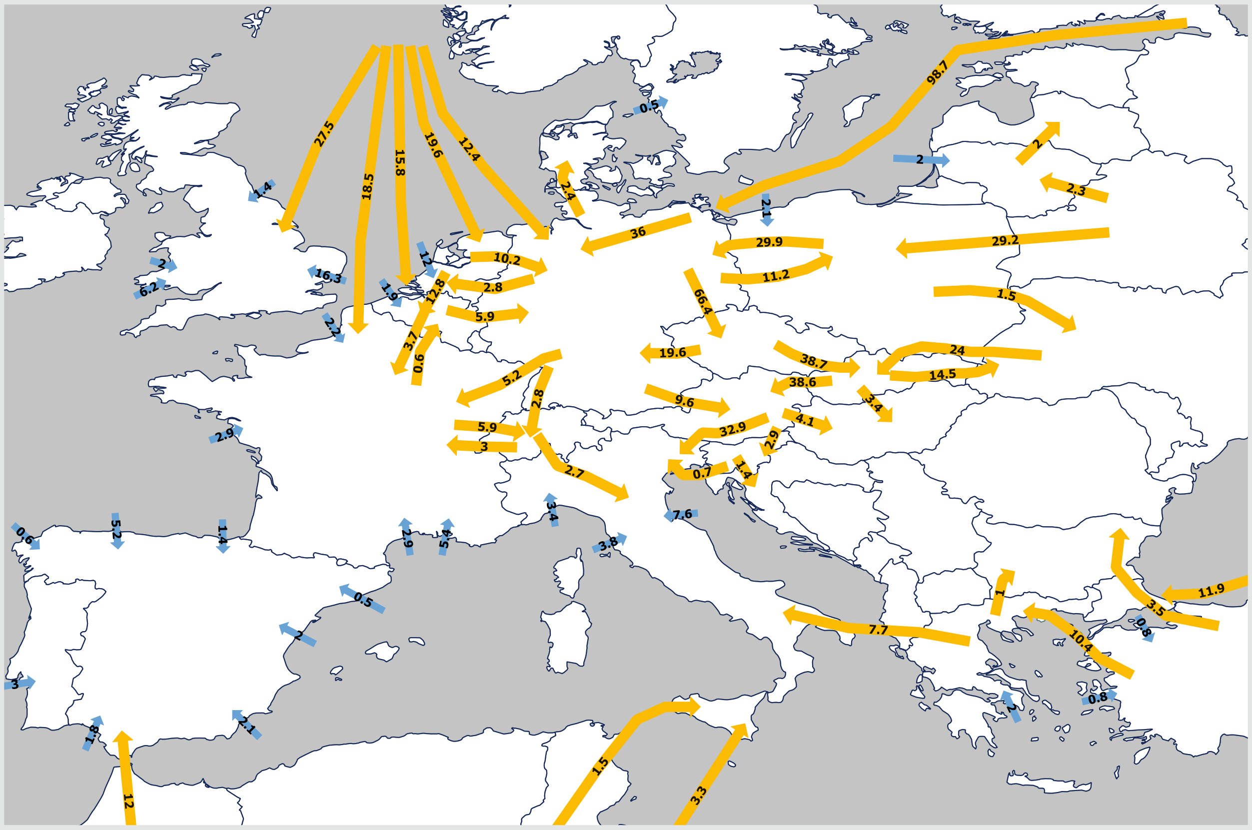

FIGURE 32: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO A1 IN 2030
(Source: ewi ER&S - TIGER model)

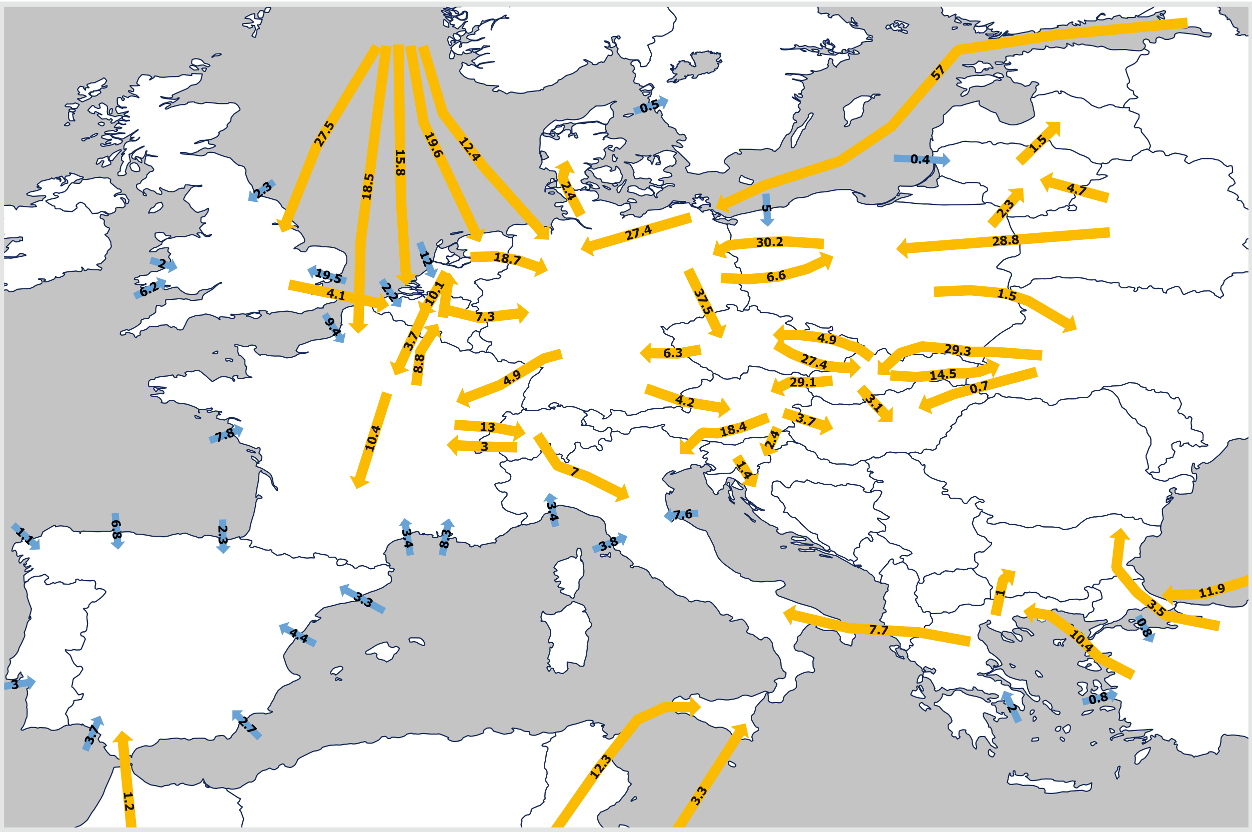

FIGURE 33: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO A2 IN 2030
(Source: ewi ER&S - TIGER model)

2030 Scenario A (Low Global LNG Demand)

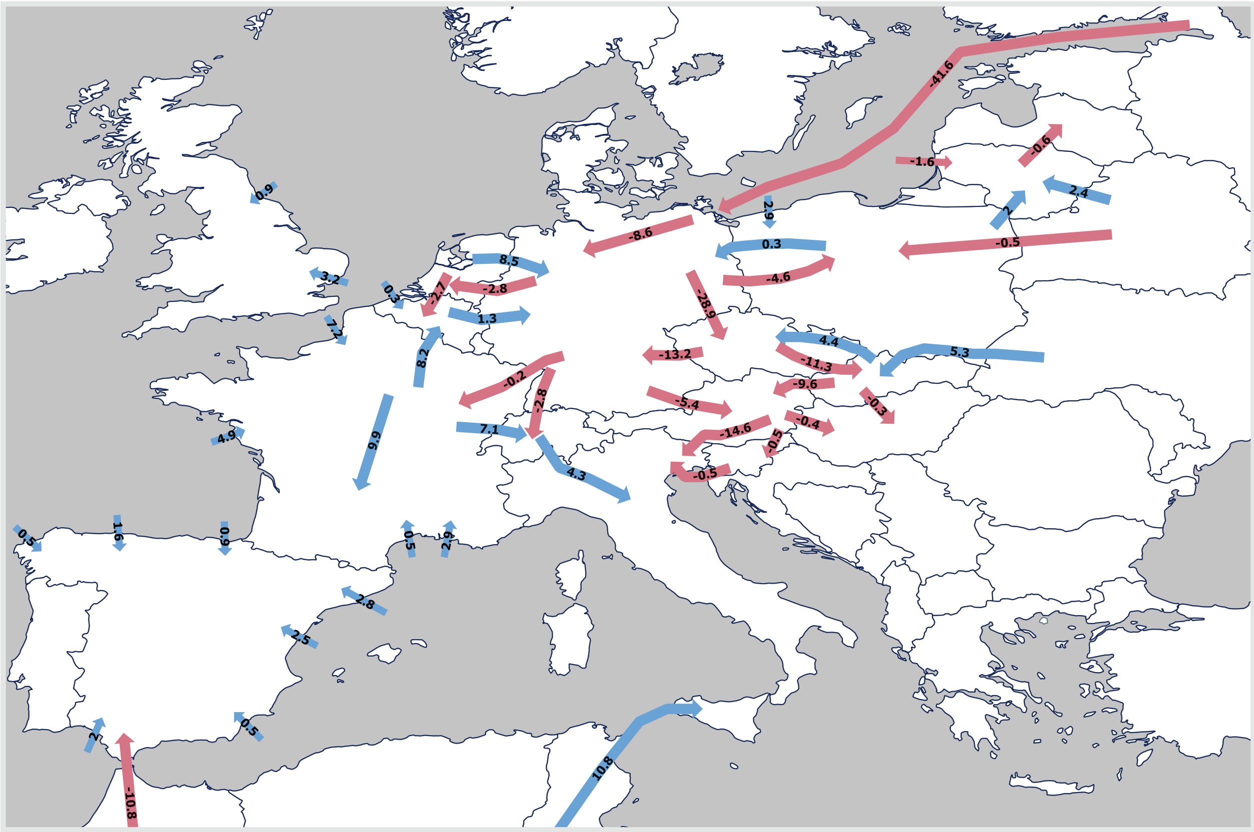

FIGURE 34: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO A1 AND A2 IN 2030
(Source: ewi ER&S - TIGER model)

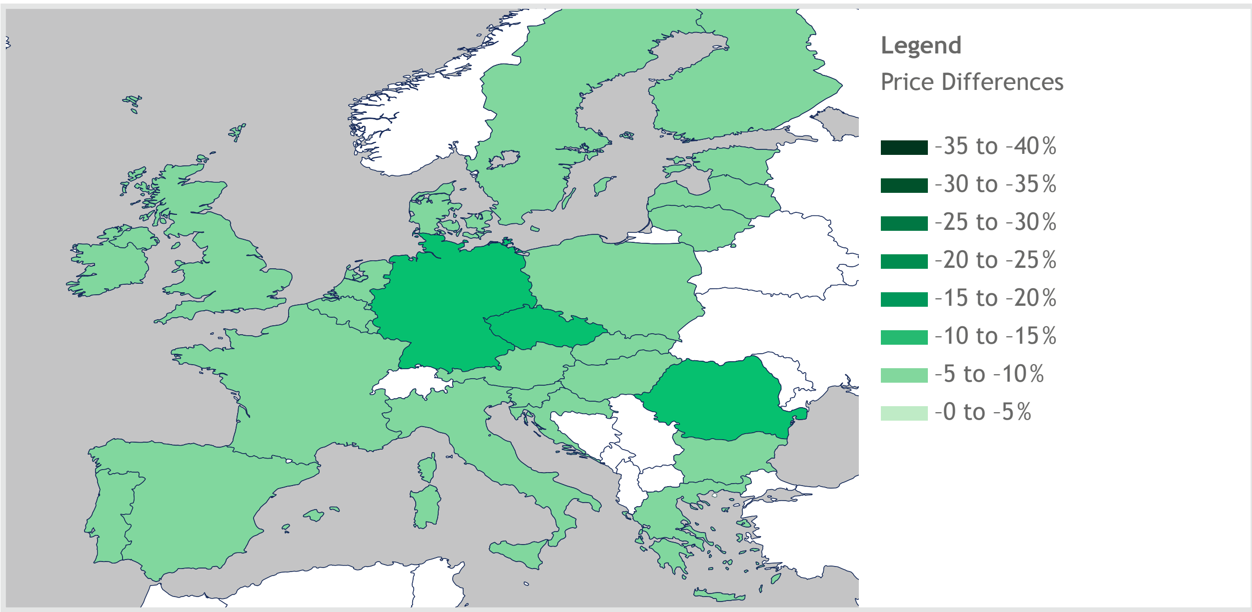

FIGURE 35: DIFFERENCES IN GAS PRICES BETWEEN SCENARIO A1 AND A2 IN 2030
(Source: ewi ER&S - TIGER model)

2030 Scenario B (High Global LNG Demand)

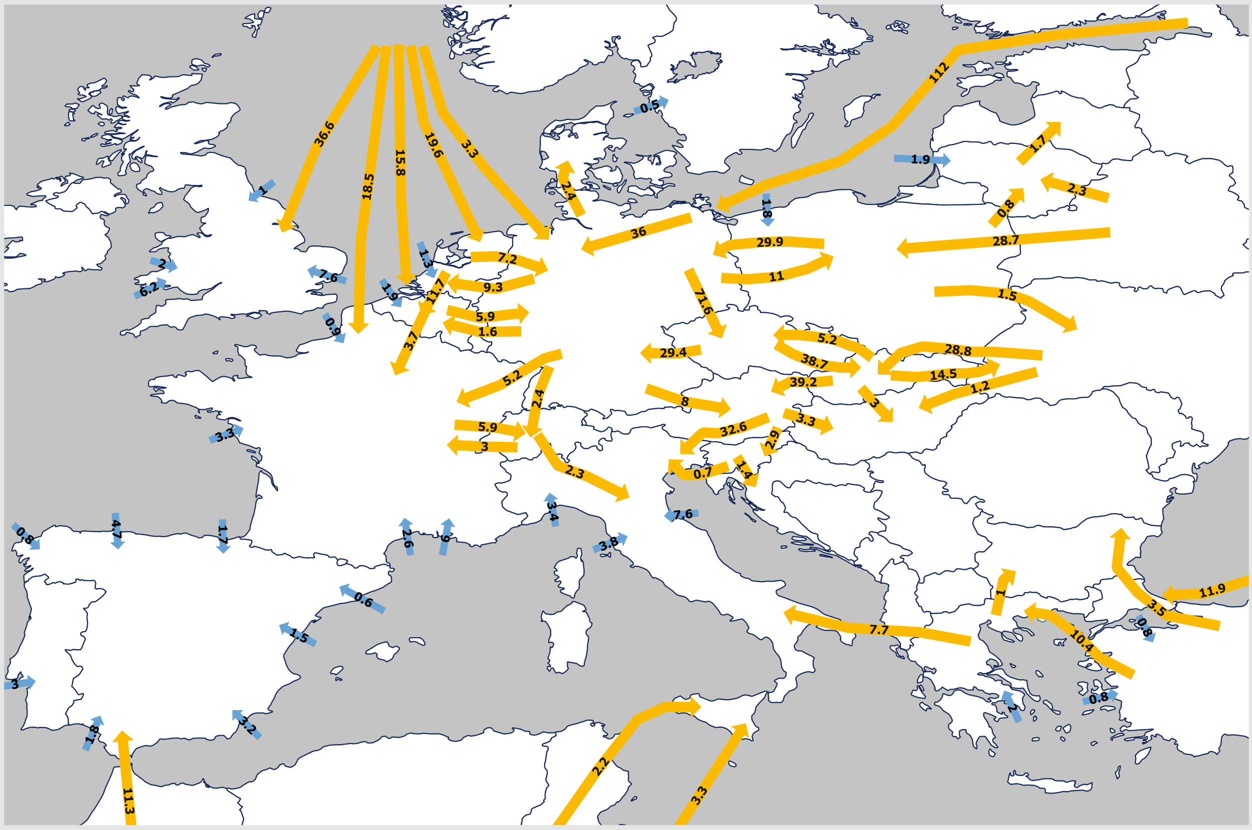

FIGURE 36: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO B1 IN 2030
(Source: ewi ER&S - TIGER model)

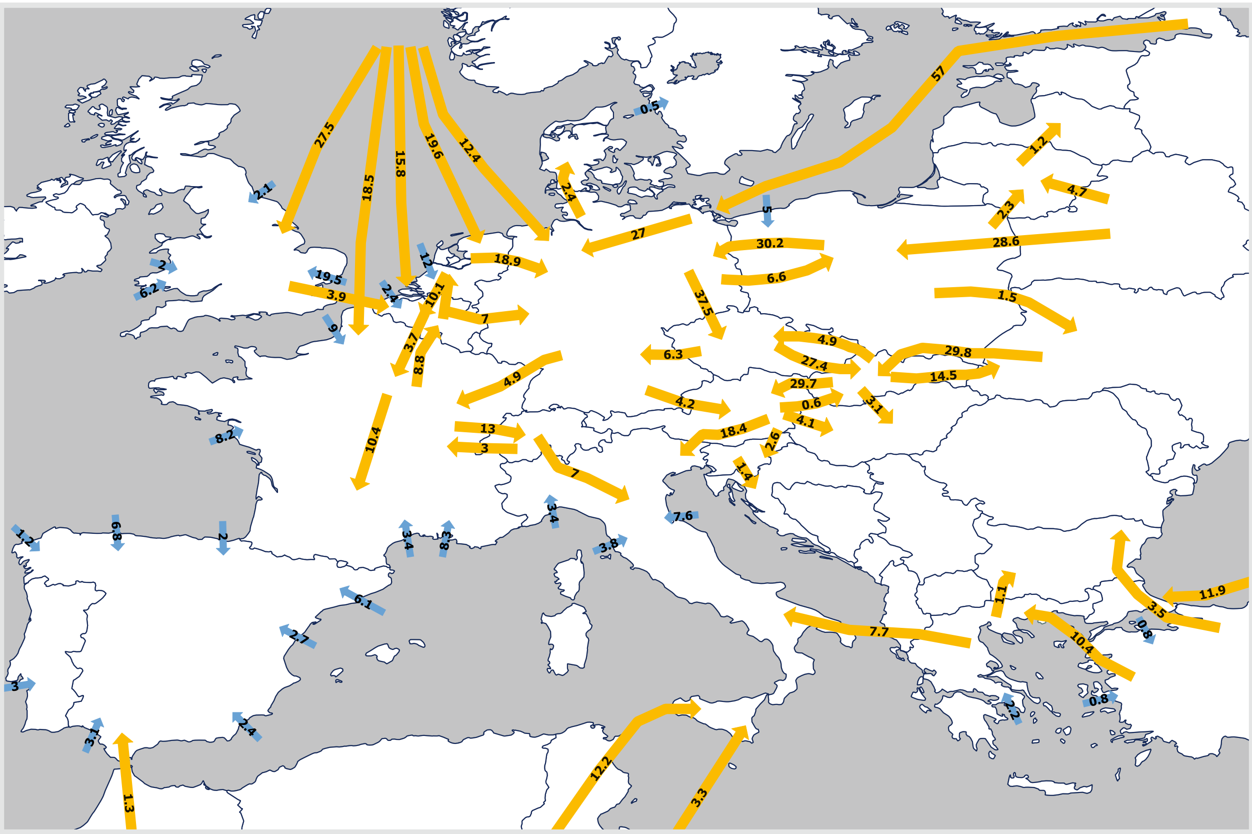

FIGURE 37: MODELLED PIPELINE AND LNG FLOWS IN SCENARIO B2 IN 2030
(Source: ewi ER&S - TIGER model)

2030 Scenario B (High Global LNG Demand)

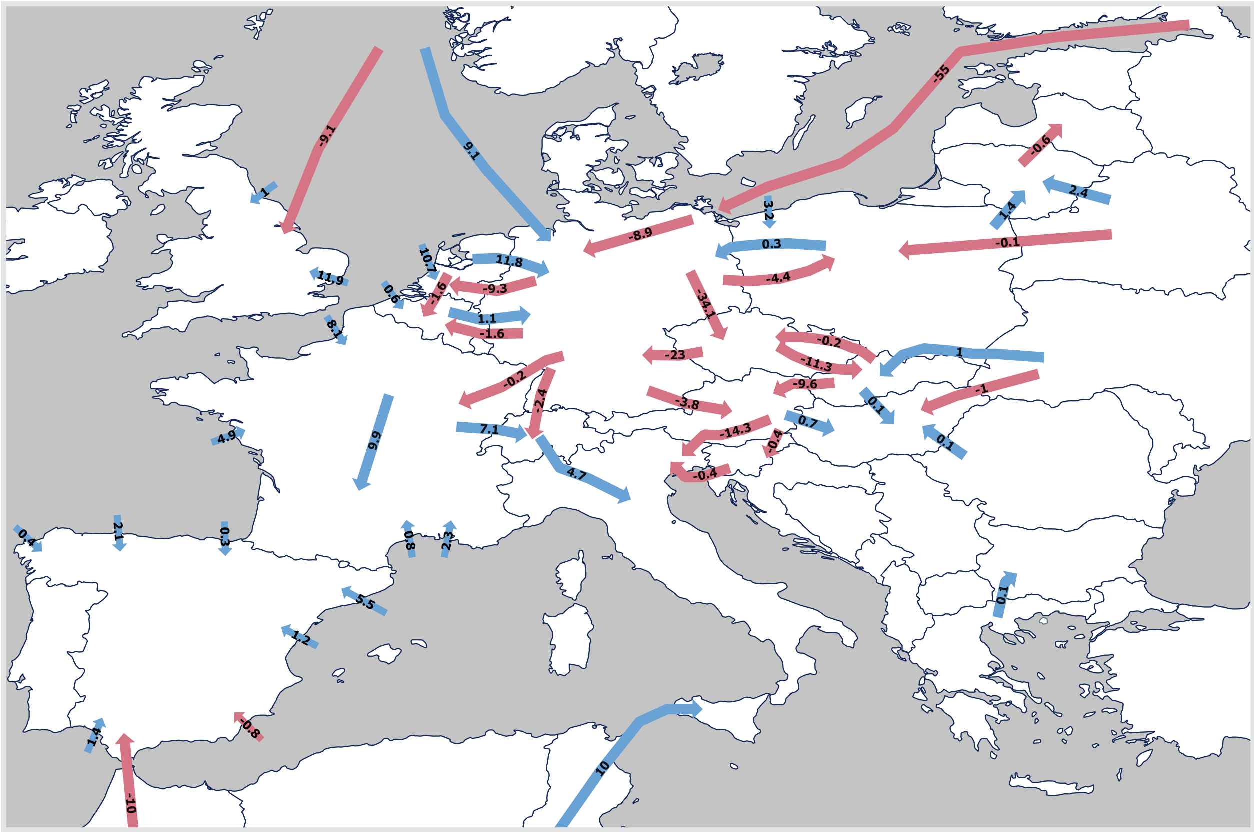

FIGURE 38: DIFFERENCES IN FLOWS AND LNG IMPORTS BETWEEN SCENARIO B1 AND B2 IN 2030
(Source: ewi ER&S - TIGER model)

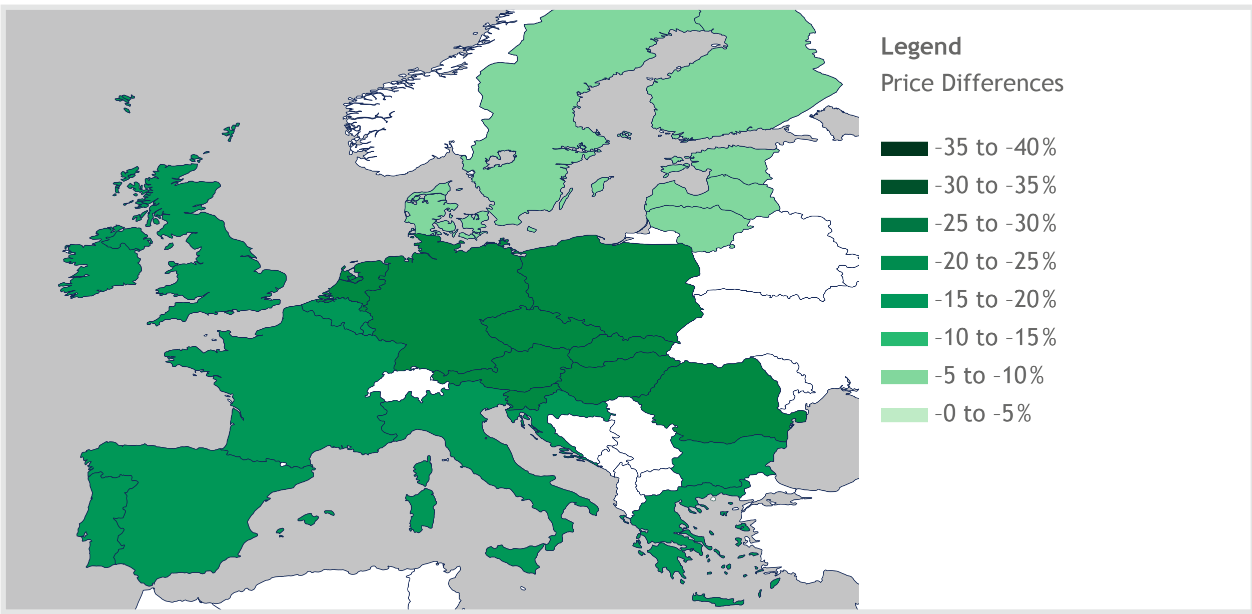

FIGURE 39: DIFFERENCES IN GAS PRICES BETWEEN SCENARIO B1 AND B2 IN 2030
(Source: ewi ER&S - TIGER model)

APPENDIX B:
EUROPEAN GAS INFRASTRUCTURE MODEL TIGER

The TIGER model is a European natural gas infrastructure and dispatch model. It simulates natural gas trade as well as physical flows and therefore the utilization of all major elements of the European gas infrastructure (high pressure transport pipelines, LNG import terminals, and underground gas storages). The model is a linear network flow model consisting of nodes and edges. Nodes represent locations in the European gas infrastructure whereas edge represent pipeline connections. A technical description of the model can be found in Lochner (2012).

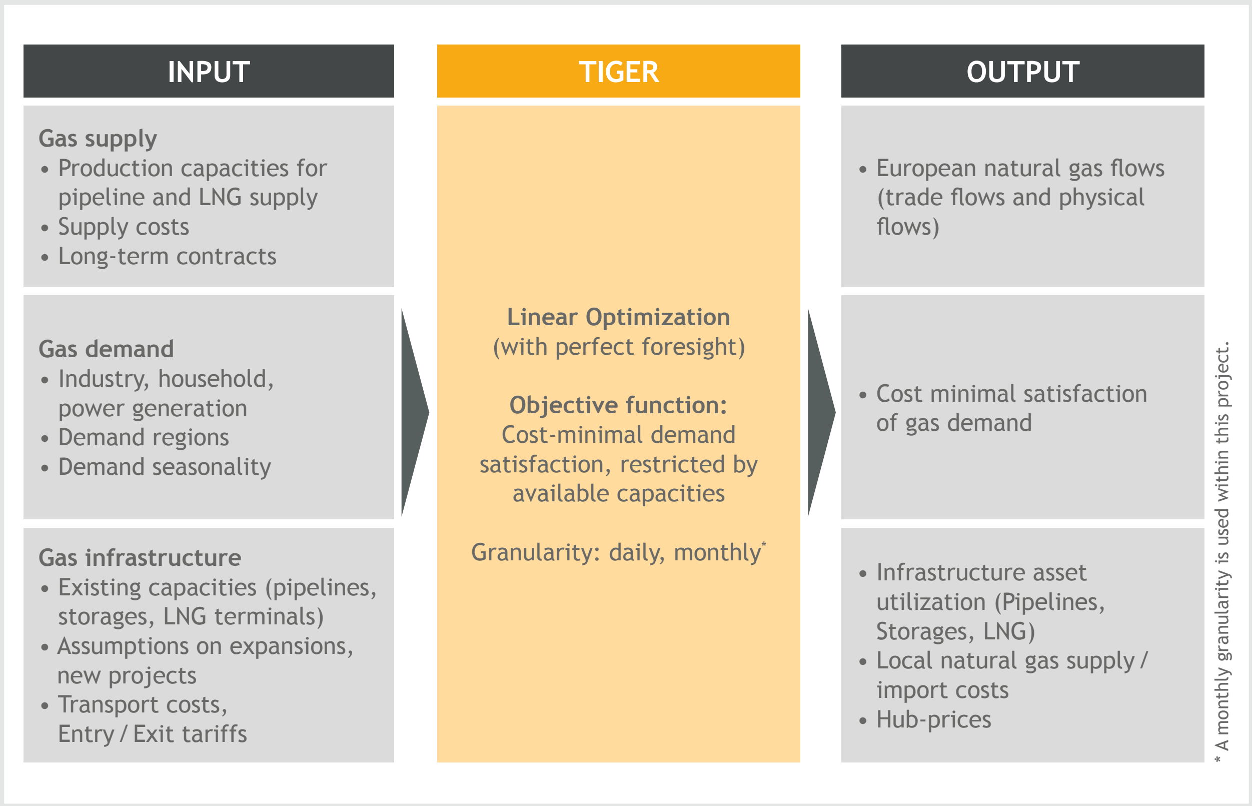

FIGURE 40: TIGER – MODEL OVERVIEW
(Source: ewi ER&S (2016))

Figure 40 gives an overview of inputs and outputs of the TIGER model. It illustrates the required input parameters, the optimization problem with its objective function as well as the output data. On the input side, the model is provided with assumptions about the natural gas demand, the natural gas supply and the natural gas infrastructure. Based on historic data, country and sector specific demand projections are broken down into monthly, regionalized demand profiles to ensure a realistic distribution of natural gas demand over area and time. In addition, assumptions about the future gas supply of the European Union can be specified (indigenous production within the EU, exporter's production capacities, exporter's LTC volumes, LTC prices and commodity prices or supply costs at the border).

Apart from the existing infrastructure, model inputs include assumptions on new projects including LNG import terminals, pipelines (e.g. Nord Stream 2) and natural gas storage facilities which become available for the optimization of flows within the market over time. Specifically, the infrastructure database connected to the TIGER model includes:

- more than 900 high-pressure natural gas transmission pipeline segments with data on location, technical capacity, directionality based on TSO information and ENTSO-G data,
- more than 200 gas storage facilities in Europe with data on location (grid connection), working gas volumes, maximum injection / withdrawal rates, storage type-specific injection and withdrawal profiles, based on Gas Storage Europe (GIE Storage Map), International Energy Agency (IEA), and storage operators' data,

- more than 30 LNG import terminals (projects and all existing ones) with data on location (grid connection), import, storage and regasification capacities based on terminal operators' data and the ENTSO-G / GIE LNG Map,
- all border points and border capacities according to ENTSO-G's Transmission Capacity Map 2016, and
- Non-European pipeline import capacities (from Russia, Algeria, Libya, Azerbaijan, Middle East) at the respective border points.

The TIGER model is formulated as a linear optimization problem. The objective function of the problem is the minimization of the total supply costs of the European natural gas supply and transport system, while meeting regionalized demand. This corresponds to the assumption of perfect competition within the European gas market. The perfect competition assumption can however be relaxed since nodal, exporter-specific mark-ups can be included in the model. Modelled costs include production, transportation (based on entry / exit tariffs) and, where applicable, regasification and storage costs. The cost optimization, with a monthly granularity, takes place subject to the restrictions of maximum available supply, demand which has to be satisfied, and the technical constraints of available transport, LNG and storage infrastructure. Decision variables for the model are the natural gas flows on each pipeline, inflows to and outflows from storages, and regasification at LNG terminals. Due to storages, an inter-temporal optimization takes place. Since TIGER does not consider uncertainty with respect to its inputs, it is a perfect foresight model. Cost optimization in combination with perfect foresight implies that the flows are efficient, i.e. all swaps and reverse flows that are possible are conducted, resulting in the lowest costs for flows of gas within the EU.

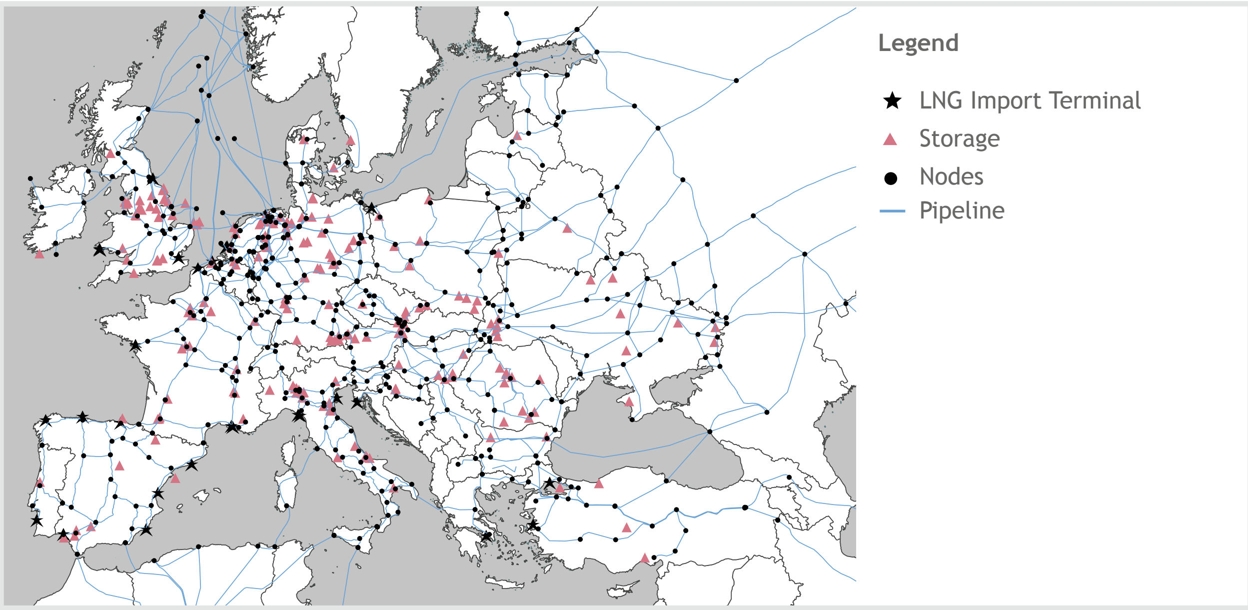

FIGURE 41: MODELLED NATURAL GAS INFRASTRUCTURE IN TIGER (SCHEMATIC)
(Source: ewi ER&S – TIGER model)

The study assumes that LNG supplies determine the price levels in all EU countries, as the marginal source of supply to the EU markets.[1] The price of Russian gas is determined by the price of LNG plus transportation costs from the closest LNG terminal compared to the cost of bringing Russian gas to this point. Such an approach implies that Russian pricing is determined by the cost of alternative supplies. This is a modification of a "perfectly competitive" strategy, which is usually assumed in linear programming gas models. The chosen approach is a reasonable way of modelling the Russian behaviour in line with past experience, hence marketing gas at the highest price possible, but not withdrawing significant volumes of gas as assumed in a Cournot oligopoly strategy.

1 The Russian marginal supply costs are usually assumed to be below the marginal supply costs of LNG (Henderson, Mitrova (2015)).

APPENDIX C: GLOBAL GAS MARKET MODEL COLUMBUS

COLUMBUS is a long-term simulation model for the global natural gas market. It is a dynamic, spatial and intertemporal model. It is based on a mixed complementary programming approach (MCP) allowing to model strategic behaviour of gas exporters, i.e. competitive behaviour and oligopolistic behaviour can be modelled. In this study, a competitive European gas market environment is assumed in the COLUMBUS model implying that the major exporters do not withhold volumes from the market in order to generate higher prices.

On the supply side, the model takes into account all major natural gas producers covering 95% of the world supply as well as specific characteristic (production costs, reserves unconventional natural gas like shale gas). Furthermore, all relevant demand countries are included (approx. 99% of global demand). Demand is specified per country and sector. Price reactions are considered in the model, i.e. demand can be reduced due to an increase in price. Hence, price elasticities of demand are an input. The global natural gas infrastructure is considered on a country specific level (storage capacity, LNG import / export capacities, transport capacities). All required data for the model is continuously updated in the ewi ER&S database.

The model endogenously invests into production capacities and infrastructure. Therefore, a model output is the future development of production and transport capacities. Additional outputs are the utilization of the existing infrastructure (transported volumes), and natural gas prices in specific countries. Figure 42 gives an overview over the COLUMBUS model.

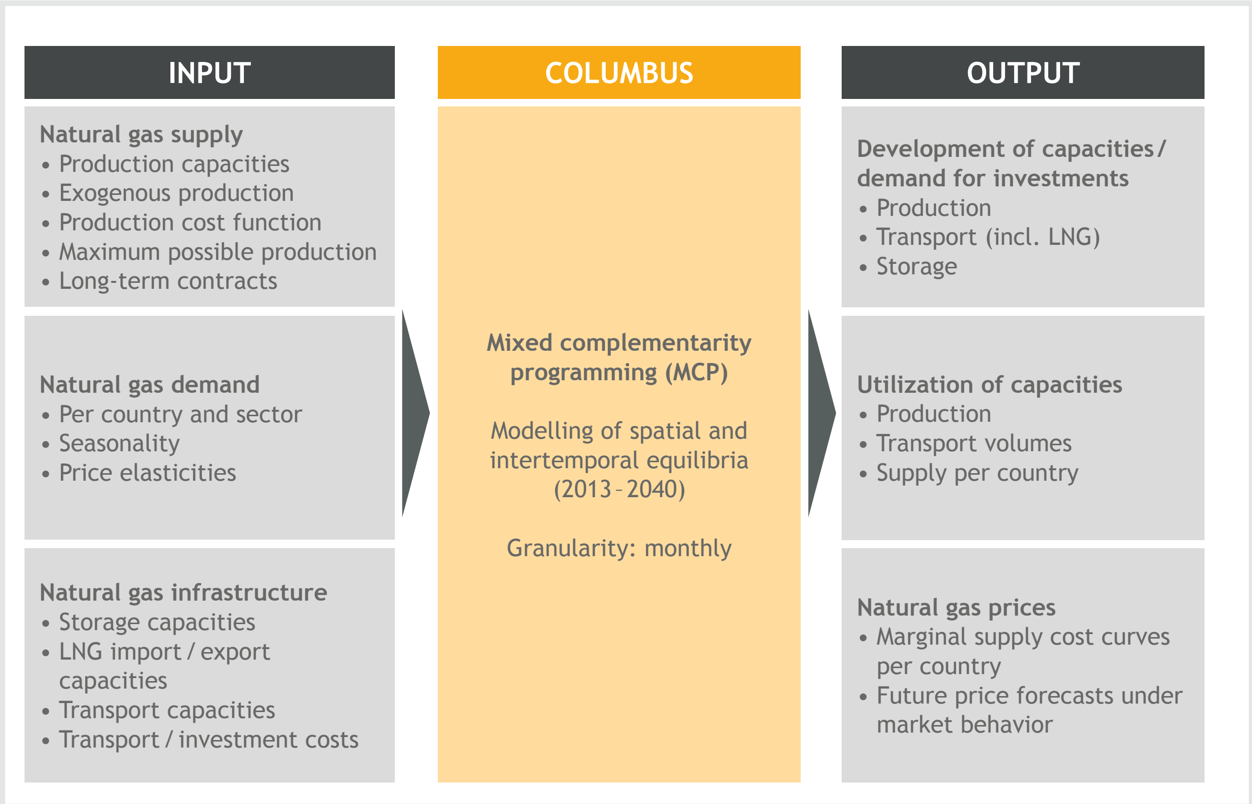

FIGURE 42: COLUMBUS – MODEL OVERVIEW
(Source: ewi ER&S (2016))

APPENDIX D: LIST OF ABBREVATIONS

AT	Austria
Bcm	Billion cubic metres
Bcm/a	Billion cubic metres per annum
BE	Belgium
BG	Bulgaria
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
EU	European Union
EUGAL	Europäische Gas-Anbindungsleitung
FI	Finland
FID	Final Investment Decision
FR	France
GB	Great Britain
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IEA	International Energy Agency
IT	Italy
LT	Latvia
LTC	Long Term Contract
LNG	Liquefied Natural Gas
LU	Luxembourg
LV	Latvia
NL	Netherlands
OPAL	Ostsee-Pipeline Anbindungsleitung
PCI	Project of Common Interest
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
TANAP	Trans Anatolian Pipeline
TAP	Trans Adriatic Pipeline
TSO	Transmission System Operator
TYNDP	Ten Year Network Development Plan
TWh	Terawatt hour
USD	US Dollar

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