

## **The Trilateral Gas Talks**

**What would an interruption of Russian gas exports via Ukraine mean for EU consumers?**

Report, December 2019

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## TABLE OF CONTENTS

Executive Summary .....	1
1. Introduction .....	3
2. Methodology.....	5
2.1 Modelling Approach & Scenarios .....	5
2.2 Data & Assumptions .....	6
2.2.1 Demand and Supply .....	6
2.2.2 LNG Supply Cost Curves.....	7
2.2.3 Pipeline Infrastructure.....	8
3. Results .....	9
3.1 How is the security of supply in the EU affected?.....	9
3.2 What role would gas storage play?.....	10
3.3 What role would the LNG market play? .....	12
3.4 What would be the effect on gas prices? .....	12
3.5 How would consumers and producers be affected financially?.....	14
3.6 What would happen if the interruption lasts longer? .....	16
References.....	17
Appendix A: supplementary material .....	18
Appendix B: The TIGER Model .....	20
Appendix C: The COLUMBUS Model .....	23

## EXECUTIVE SUMMARY

Ten years after a dispute between Gazprom and Naftogaz over the latter's outstanding debts led to a 13-day halt of Russian gas flows through Ukraine, both countries, as well as the EU, are at a crossroads again: the transit contract negotiated between Gazprom and Naftogaz in the wake of the 2009 events will expire on December 31<sup>st</sup>, 2019. Trilateral talks between Russia, Ukraine and the European Commission to hammer out a new agreement began in July 2018. However, neither side is under much pressure to conclude a deal fast. The European gas market is currently exceptionally well supplied, with storage inventories still close to their maximum and prices at multi-year lows. Talks are not expected to reach a conclusion until shortly before the deadline on December 31<sup>st</sup>. This raises the possibility—on the Russian and Ukrainian sides—of brinkmanship, which could lead to a failure to conclude an agreement on time, resulting in an interruption of Russian gas transits through the Ukrainian Gas Transmission System (UGTS).

Using a combination of TIGER (EWI's high resolution dispatch model of the European gas grid) and COLUMBUS (EWI's equilibrium model of the global gas and LNG market), this study quantifies the effects of an interruption of up to three-months of the transits of Russian gas through Ukraine, from January 1<sup>st</sup>, 2020 to March 31<sup>st</sup>, 2020 and answers the following questions:

### How would an interruption of transits over the UGTS impact security of supply in the European Union?

- Russian deliveries to the EU are cut by around 6.3 bcm by an interruption in January 2020. However, the EU gas market is well-integrated and equipped with sufficient pipeline infrastructure. The interruption would not lead to gas shortfalls (unserved demand) in any of the EU's member states. Hence, the EU gas market is well prepared for an interruption in terms of security of supply.
- Beside a well-integrated pipeline infrastructure and bi-directional interconnectors, gas storages will be the backbone during an interruption of Russian gas supplies via the UGTS. Storage inventories are high enough to allow the gap to be bridged with additional withdrawals (+5.2 bcm in January) plus some additional LNG volumes (+0.9 bcm in January), even over the three-month period.
- Even in the case of a hypothetical cold spell (+10% European demand) during the interruption, no shortfalls are observed thanks to high storage inventories and flexible LNG supply.

### How would the prices be affected?

- While price increases in Northwest Europe would be moderate, the interruption would strongly impact gas prices for consumers in Southeast Europe.
- In Northwest Europe, price increases would remain within the range of 3-5%.
- Prices in Southeast Europe would rise by 45% in Greece, 24% in Bulgaria and 18% in Romania, as the missing volumes delivered through Ukraine via the Trans-Balkan Pipeline are replaced by storage withdrawals and additional LNG imports into Greece. Greek regasification capacities would be fully utilised.
- Austria, Slovenia and Italy, as the recipients of Russian gas transiting through Ukraine via Baumgarten, would also experience significant price increases by 9-10%.

- A cold spell during the interruption would result in a more substantial price increase: Greece, with its regasification capacities utilised to the full, sees the largest price increase with an increase of 56%, followed by Bulgaria (27%) and Romania (21%). Austria, Slovenia and Italy observe increases of about 13-14%, whereas Northwest Europe sees an increase within the range of 5-7%.

#### What would be the impact on revenues and consumer losses?

- Spare capacity on the alternative routes (Nord Stream and Yamal) is not high enough to compensate for the losses over Ukraine, which would leave Gazprom unable to deliver some of its contracted volumes.
- Due to the price increase, consumers in the EU have to pay an additional 1.5 billion euros for gas during the three months of interruption. This direct consumer loss due to interruption could amount to 2.1 billion euros should a cold spell occur at the same time.
- During the interruption, the direct losses of Gazprom (i.e. excluding revenues via the sales from Gazprom's storages located in Europe) resulting from the Ukrainian transit interruption, and hence reduced export volumes, could reach up to 3.4 billion euros.
- Ukraine would lose its transit revenues from the fees it collects on Russian gas transits, leading to a loss of around 0.5 billion euros over the course of the three-month interruption.

The analysis highlights the resiliency of the European gas grid, achieved also thanks to the investments made into additional (bi-directional) pipeline infrastructure, LNG import terminals and storage facilities after the 2009 gas crisis. As a result, a three-month interruption does not threaten the security of gas supply in any EU member state and the increase in gas prices is, for most countries, relatively moderate. However, the results also illustrate that no side benefits from an interruption, with all three parties involved in the trilateral gas talks incurring significant financial losses. This underscores the desirability of reaching an agreement on Ukraine transits prior to the existing set of contracts expiring at the end of December 2019. Furthermore, Russia, Ukraine, or both—depending on who would be seen as responsible for the interruption—would risk taking a substantial reputational hit from any interruption of gas flows. The costs of this reputational damage are hard to quantify, but nevertheless real and provide another reason for both parties to reach an agreement and avoid a disruptive outcome.

## 1. INTRODUCTION

Ukraine is currently the largest transit corridor for Russian natural gas exports to the European Union (EU): In 2018, roughly 50% of Gazprom's annual deliveries to the EU went through the Ukrainian Gas Transmission System (UGTS). Ten years after a dispute between Gazprom and Naftogaz over the latter's outstanding debts led to a 13-day halt of Russian gas flows through Ukraine, both countries, as well as the EU, are at a crossroads again: the transit contract negotiated between Gazprom and Naftogaz in the wake of the 2009 events will expire on December 31<sup>st</sup> (Eyl-Mazzega, 2019).

Trilateral talks between Russia, Ukraine and the European Commission to hammer out a new agreement began in July 2018. However, neither side was under much pressure to conclude a deal fast. With the elevation of Volodymyr Zelensky to the presidency and a landslide victory for his newly formed party in July's snap parliamentary elections, Ukraine is witnessing a political changing of the guard. In Brussels, the new commission will likely take office at the end of November. Gazprom in turn is waiting to see what positions the new government in Kiev and the new commission are going to adopt and how the unbundling process of Naftogaz will proceed. Real progress in the negotiations is thus unlikely to occur before December, with four weeks or less remaining until the current set of contracts expires. In addition to that, the European market is currently very well supplied with gas. Storage sites are full and LNG import prices low. This may give both Gazprom and Naftogaz an incentive to take a harder negotiating line, knowing that consumers in the EU would be unlikely to face serious supply shortages—at least in the short term. Accordingly, there is a significant risk that talks will fail to produce a result before the existing set of contracts expires, leading to a temporary shutdown of flows.<sup>1</sup>

Reassuringly, the internal market has been improved a lot since 2009. Upgrades that give grid operators the means to reverse gas flows on previously unidirectional pipelines now allow Eastern Europe to be supplied, at least partly, from the West as well as the East. Investments in infrastructure—supported by the EU through the projects of common interest (PCI)—and the implementation of the Gas Network Codes have reinforced the internal gas market on both the physical and the regulatory level. New EU LNG import facilities and import pipelines from third countries have increased the volume of gas that can be supplied to the market, the number of suppliers, and the number of routes supplies can take, thus affording additional flexibility to the system to cope with unforeseen shocks on the demand or supply side (Martinez et al., 2015, Hecking et al., 2016). A temporary interruption of transits through the UGTS is therefore unlikely to lead to outright supply shortfalls. However, it may have a significant impact on prices and thus welfare, warranting further study and quantification.

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<sup>1</sup> See Eyl-Mazzega (2019) for more background information on the trilateral talks.

How would the European gas market respond to an interruption of flows through Ukraine? At first sight, the situation looks a lot less serious than in 2009: LNG is cheap and gas storages are nearly full. Gas prices dropped to record lows in August 2019, suggesting that EU member states are well positioned to deal with a possible interruption of the flows of Russian gas through Ukraine, in particular a short one. However, an unexpected tightening in the market is still a possibility: A colder than expected winter across the northern hemisphere could increase domestic consumption and drive up LNG import prices. Moreover, it is very unlikely that the TurkStream (TS) connection and Nord Stream 2 would be put into operation by the end of the year. The Danish permission process has caused a delay in Nord Stream 2, while TurkStream's connection to the European gas network is proceeding slower than expected as well. Furthermore, due to a decision of the European Court of Justice (ECJ), capacity on the OPAL pipeline, which connects the existing Nord Stream pipeline to the Czech border, cannot be fully utilised by Gazprom as well (Montel, 2019). Lastly, an interruption could last longer than expected, closing the route for a period of months rather than weeks. It is therefore prudent to ask what such outcomes would mean for the European gas market.

## 2. METHODOLOGY

### 2.1 Modelling Approach & Scenarios

The modelling approach used in this study involves a two-step procedure: First, the global market is simulated using the COLUMBUS model to estimate the supply cost functions for LNG and Russian exports to Europe. The simulation model, with its realistic spatial structure, considers the dynamics of the global demand and supply, where important contributing factors such as Asian LNG demand trend and the development of global liquefaction capacities are taken into account.

The simulated supply functions are then used as input in the European gas dispatch model, TIGER, where the effects of an interruption of gas transits through Ukraine are estimated. TIGER is a highly detailed model of the European gas infrastructure that simulates production, consumption, transmission and storage operations in a daily resolution. TIGER, taking the European demand and production data along with the detailed infrastructure network as input, is able to provide accurate estimates of gas flows and price effects. The advantage of coupling both models is that the influence of global gas market fundamentals on European gas markets (COLUMBUS) and restrictions arising from a detailed representation of the European gas infrastructure (TIGER) are both considered.<sup>2</sup>

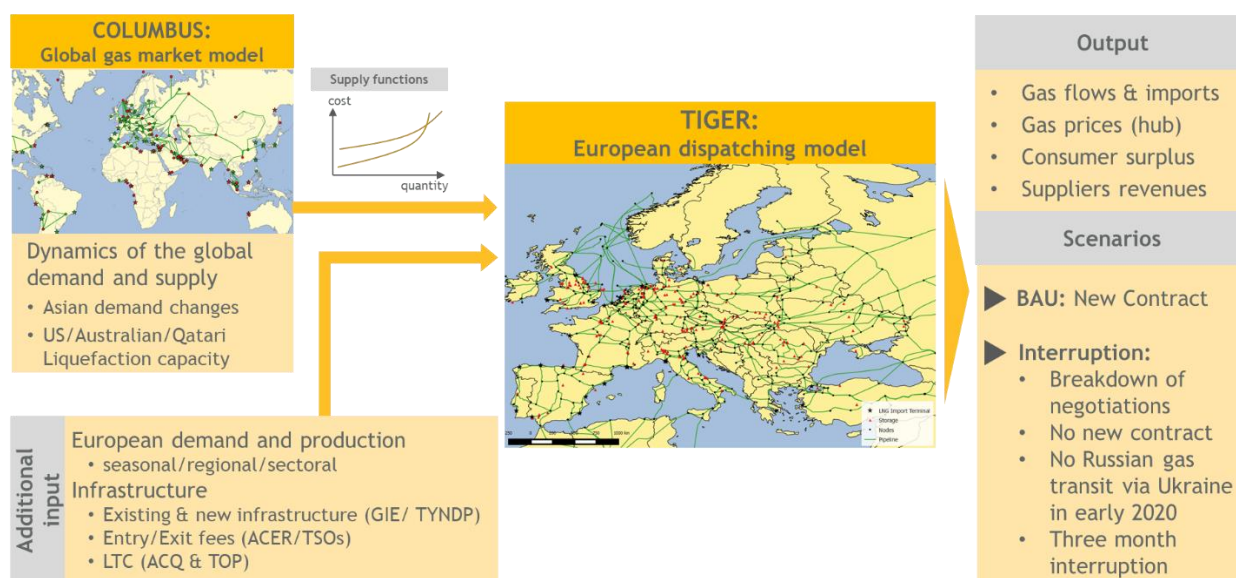


FIGURE 1: INPUT AND OUTPUT OF THE TWO-STEP PROCEDURE USED FOR SIMULATION

<sup>2</sup> A more detailed description of the models are provided in the Appendix.



The years 2019 and 2020 are modelled in daily resolution, and the effects of an interruption of Russian gas transit flows via Ukraine are quantified by comparing a business-as-usual (BAU) scenario, in which gas continues flowing, with an alternative scenario featuring an interruption of gas transits through the UGTS up to three months, starting January 1<sup>st</sup> 2020. Furthermore, a high demand sensitivity to investigate the effects of a protracted cold spell during an interruption is modelled (see Figure 2). In this sensitivity analysis, gas demand in Europe is assumed to be 10% higher throughout January, 1<sup>st</sup> 2020 to March 31<sup>st</sup>, 2020, compared to the default case.

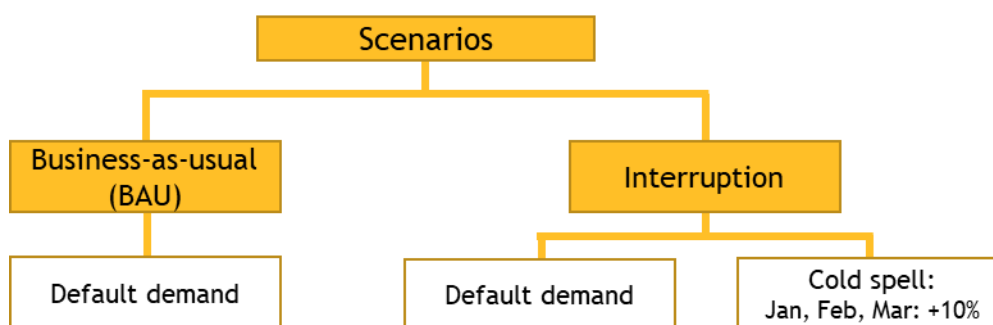


FIGURE 2: OVERVIEW OF THE CONSIDERED SCENARIOS AND SENSITIVITIES

We analyse the impact on gas flows and imports, hub prices, as well as changes in consumer surplus and supplier revenues. The core assumptions underpinning the model-based analysis are presented in the next section.

## 2.2 Data & Assumptions

### 2.2.1 Demand and Supply

For modelling purposes, we hold the demand in 2019 and 2020 flat in the BAU scenario at its 2018 level: The EU as a whole consumed 465 bcm/a of natural gas, 85 bcm/a of which were consumed in Germany, 69 bcm/a in Italy and 19 bcm/a in Poland. This is in some ways a conservative assumption, since the actual total gas consumption is likely to be higher in 2019 because of strong demand from the power sector. At the time of publication of this report, only H1 2019 consumption data was available. However, it shows that in the first half of this year, EU natural gas consumption was already two percent above the H1 2018 level (Eurostat, 2019). This uncertainty regarding higher gas demand is addressed by considering a sensitivity with higher winter demand in 2020, e.g., driven by a cold spell.

We assume natural gas production to follow the trends outlined in the Ten-Year Network Development Plan 2018. In 2019 102 bcm/a are produced in the EU, 36 bcm/a in the Netherlands and

31 bcm/a in the United Kingdom (ENTSOG, 2018). Production decreases to 95 bcm/a in 2020, falling by 2 bcm/a in the United Kingdom and 5 bcm/a in the Netherlands.<sup>3</sup> As of October 2019, gas storage sites across the EU are virtually all full, and at 65% of capacity in Ukraine.<sup>4</sup>

### 2.2.2 LNG Supply Cost Curves

The TIGER model dispatches LNG imports based on an estimated LNG supply function for the delivery to liquefaction terminals in Europe, which is derived using COLOMBUS, a long-term simulation model for the global natural gas market. In the COLOMBUS model, the current loose market conditions are projected to persist into 2020. The demand assumptions are based on figures published in the latest iteration of the International Energy Agency's medium-term gas market report (IEA, 2019). The supply cost curve estimation procedure works as follows: With Asian and other demand fixed in both scenarios, the European demand level for LNG is varied over a significant range. This results in different LNG import volumes and import prices (net of regasification costs). Based on these data points, an LNG supply cost function for Europe is derived (see Figure 3).

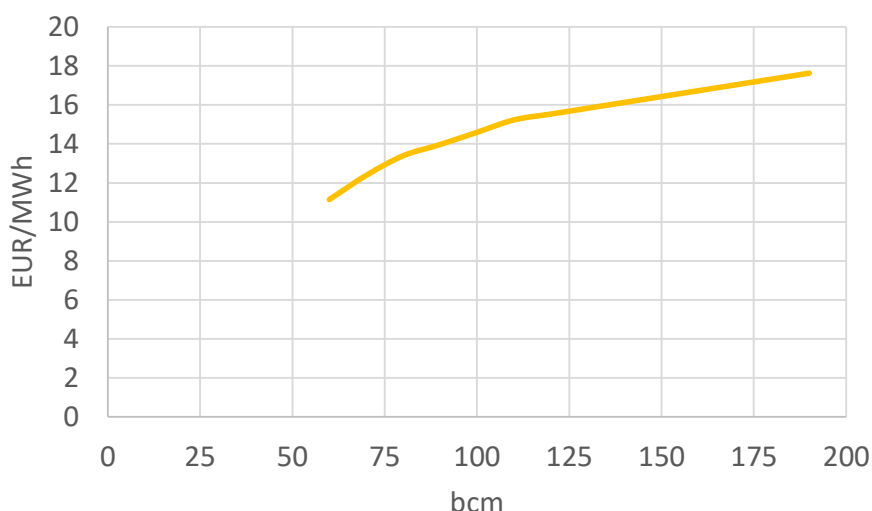


FIGURE 3: LNG SUPPLY FUNCTION FOR EUROPE, 2020

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. 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.

<sup>3</sup> The production volume for Netherlands is not taken from TYNDP, but rather is based on current developments (Source: Netherlands Ministry of Economic Affairs and Climate Policy). The value is normed using a factor of 11 kWh/m<sup>3</sup>.

<sup>4</sup> Source: AGSI+ (<https://agsi.gie.eu/>)

### 2.2.3 Pipeline Infrastructure

Currently, there are approximately 240 bcm/a of gas transmission capacity linking Russia to Europe: around 43 bcm/a (including Yamal) through Belarus and Poland, up to 120 bcm/a via Ukraine, 16 bcm/a on Blue Stream through the Black Sea/Turkey and 55 bcm/a via Nord Stream<sup>5</sup>, plus additional pipes into Finland and Baltic countries (around 6 bcm/a).

Additional pipeline capacity is currently under construction: Nord Stream 2 and TurkStream, together providing an additional 87 bcm/a of Russia-EU gas transfer capacity bypassing Ukraine, are both officially scheduled to come online at the end of 2019. However, both projects are facing delays, making their timely commissioning unlikely. The construction of Nord Stream 2 was delayed by permitting issues in the Danish sector while construction activities on the Bulgarian leg of TurkStream are starting only now, following the resolution of a legal dispute between the contractor and a rival bidder (Reuters, 2019). Therefore it is assumed that both pipelines will not be available to make up for an interruption of the flows over Ukraine during the first three months of 2020. Furthermore, in line with a European Court of Justice ruling on September 10<sup>th</sup>, 2019, the usable capacity by Gazprom on the OPAL pipeline—which connects the Nord Stream entry-point to an exit-point on the German-Czech-border—is limited to 50% at its exit-point (Montel, 2019).

The Trans-Anatolian Pipeline (TANAP), part of the EU's Southern Gas Corridor, became operational in 2018, providing up to 16 bcm/a of gas from the Shah Deniz II field in Azerbaijan to the Turkish market. However, its onward connection, the Trans-Adriatic Pipeline (TAP), running from the Turkish border through Greece and Albania to Italy, is not expected to come online any earlier than the third quarter of 2020 (EE, 2019).

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<sup>5</sup>Existing offshore pipeline between Russia and Germany which was commissioned in 2012.

### 3. RESULTS

An interruption of Russian gas transits through Ukraine from the 1<sup>st</sup> of January 2020 onwards would have a significant impact on the gas supply mix and thus wholesale gas prices in the EU. The effects on volumes and prices, and the role of gas storage and LNG are discussed below. An assessment of the effect on consumer costs, Russian export and Ukrainian transit revenues is provided as well.

#### 3.1 How is the security of supply in the EU affected?

January is usually the time with the highest gas demand of the year. Storage withdrawals play an important role in providing sufficient gas to the market at that time. Even in a business-as-usual January 2020, they would account for roughly a third of the EU gas supply mix (23 bcm/month), followed by deliveries from Russia (13 bcm/month), Norway (10 bcm/month) and LNG imports (9 bcm/month). Figure 4 compares the projected EU gas supply mix in the business-as-usual (BAU) scenario (on the left side of each chart) with the gas supply mix in the case of an interruption of gas flows through Ukraine (on the right side of each chart).

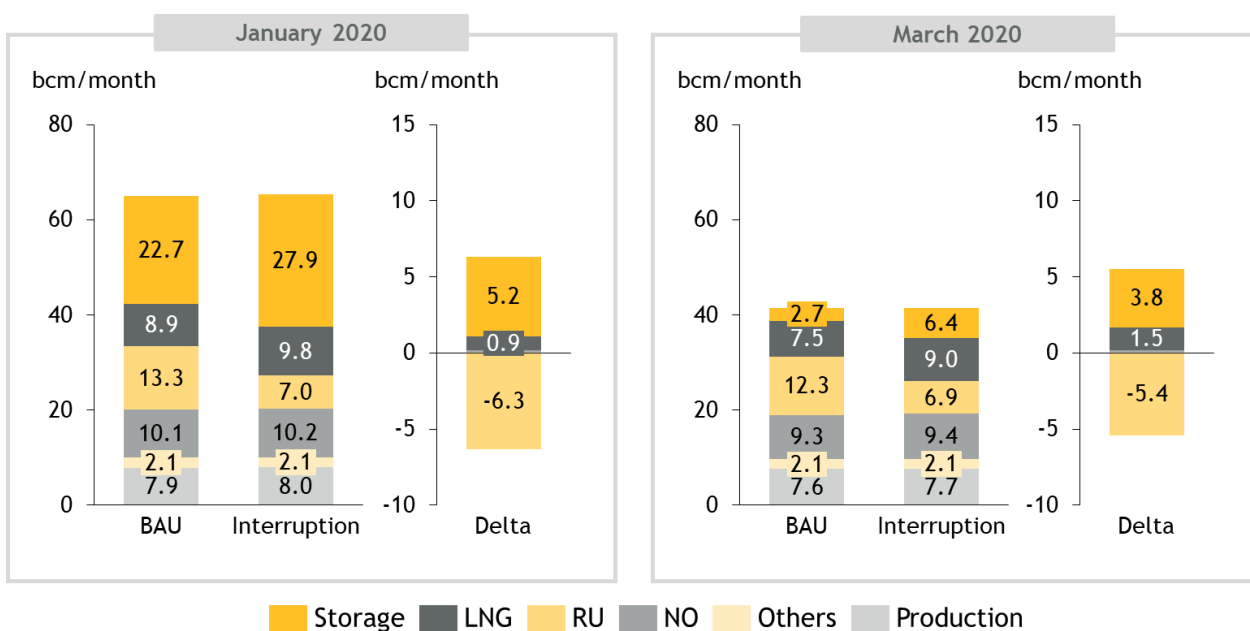


FIGURE 4: EU GAS SUPPLY BY SOURCE: JANUARY 2020 (LEFT) AND MARCH 2020 (RIGHT)

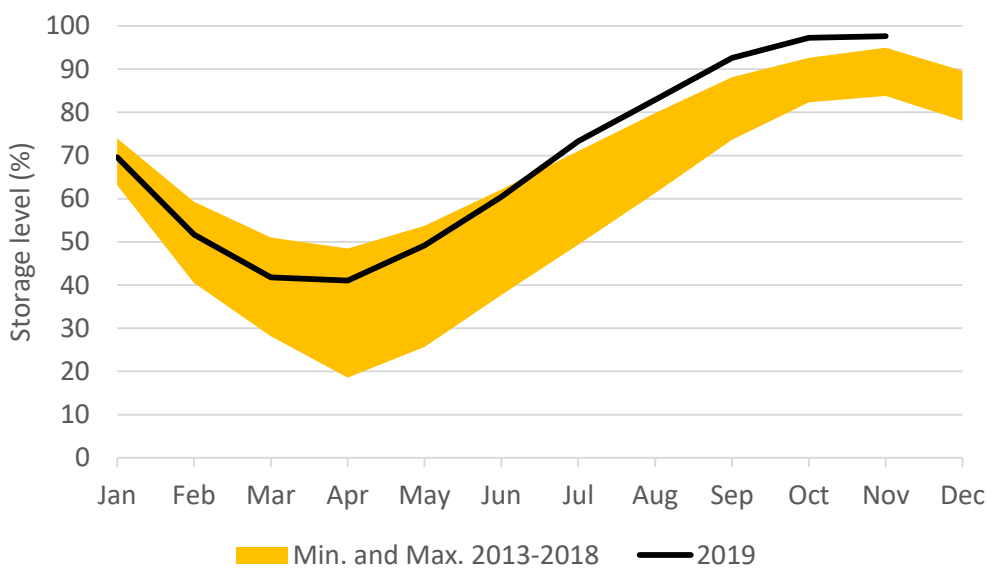
The disruption of flows would cut Russian deliveries to Europe by around 6.3 bcm in January 2020, a 47% decline compared to the BAU case. Spare capacity on the alternative routes (Nord Stream and Yamal) is not high enough to compensate for the loss of Ukraine, while the TurkStream connection to the EU and Nord Stream 2 are not yet available, which would leave Gazprom unable to

realise some of its contracted deliveries. The missing gas would be replaced by storage withdrawals (+5.2 bcm) and additional LNG (+0.9 bcm). The picture is broadly similar moving into February and March: while overall gas demand falls with the arrival of spring in most of Europe, stored gas and additional LNG cargoes continue to make up for the missing Russian deliveries. In some member states, storage levels are relatively low by March, reducing overall withdrawal rates and increasing LNG import requirements. This is discussed in more detail below.

These figures illustrate that, from a gas security-of-supply point-of-view, the EU is in a good position to deal with up to three months of reduced Russian deliveries due to an interruption of Ukraine transits, thanks to an abundance of gas in storage and a well-supplied LNG market. Actual shortfalls—in the sense of some consumers facing supply cuts—are not expected to occur in any EU member state. Hence, the EU internal market is working and pipeline capacities are sufficient to supply the market and redirect gas flows during an interruption of the UGTS. Gas flows are able to follow prices if there is a respective signal (see 3.4).

### 3.2 What role would gas storage play?

As shown above, stored gas is crucial in filling the gap left by the interruption of Ukrainian gas transits. The key reason for this rather comfortable situation is that throughout the summer of 2019, we have seen exceptionally high levels of injections all over the EU, thanks to record-low gas prices as surplus volumes from an oversupplied LNG market found their way into Europe. In early November 2019, storage inventories across the EU were still at around 95% of capacity, significantly above their 2018 levels and indeed any of the past five years (see Figure 5).



**FIGURE 5: HISTORICAL AGGREGATED EU GAS STORAGE INVENTORIES THROUGHOUT THE YEARS**

**Note:** The storage levels plotted are for the first day of the month.

The resilience provided by the storages in the EU can be further observed in Figure 6. Here, in addition to the total simulated storage level in the BAU case, the developments in the case of an interruption as well as an interruption with a cold spell are plotted. An interruption lasting from January 1<sup>st</sup> to March 31<sup>st</sup> causes the storage level to fall to a level of 30% at the end of March compared to 45% in the BAU scenario. A cold spell during the interruption further increases the withdrawal rate from the storages. However, due to historically high storage levels in October 2019 and thanks to the robust gas network system of the EU, total EU storage level does not fall below 20%.

It is worth noting, however, that during an interruption, the magnitude of storage withdrawals is dependent on how strongly a country is affected by the event. In Germany, for instance, storage inventories would dip only slightly below the levels seen in March 2019 since the country continues to be supplied through alternative routes. However, the rate of depletion is much higher in Italy, which is more reliant than Germany on the delivery of Russian gas through Ukraine. The volume of stored gas would decline to below 16% of capacity in the event of a three-month-long disruption. This means that in March 2020, the country would tap into its strategic storage reserve of 4.6 bcm to avoid a supply shortfall.<sup>6</sup>

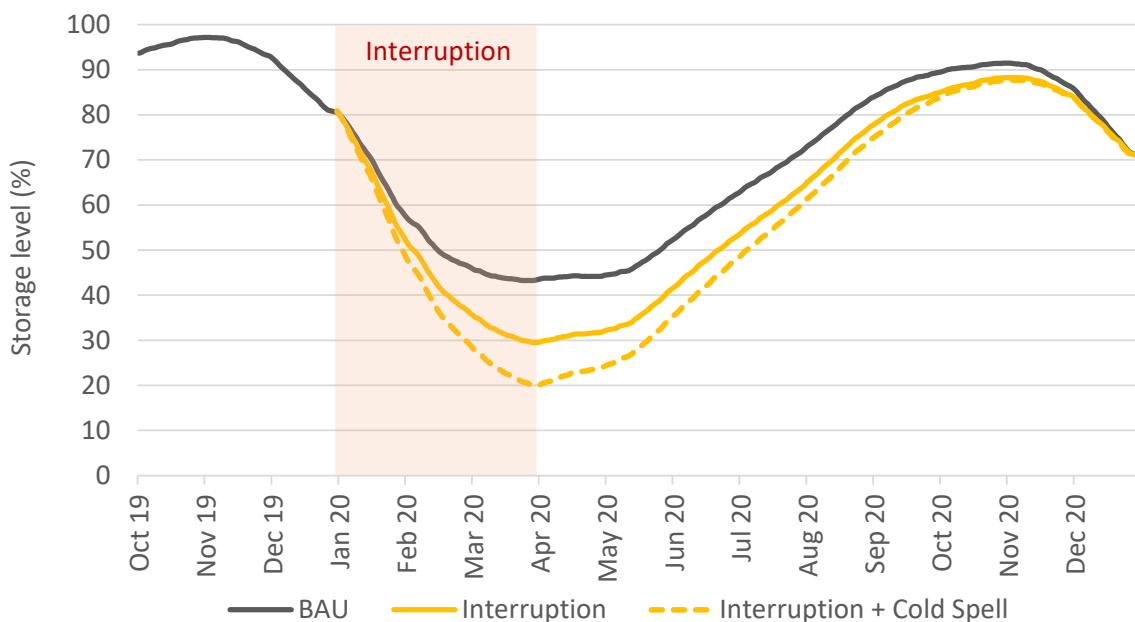


FIGURE 6: SIMULATED AGGREGATED EU GAS STORAGE INVENTORIES DURING THE CONSIDERED CASES

<sup>6</sup> See Appendix A, Figure A.1 for the simulated German and Italian storage levels.

### 3.3 What role would the LNG market play?

As shown above, January 2020 EU LNG imports would be 0.9 bcm/month and March 2020 EU LNG imports 1.5 bcm/month higher in the event of an interruption of Russian gas transits through Ukraine. There are two reasons for why the LNG market is likely to meet this additional demand without a significant effect on LNG import prices: first, the market is still awash with gas. The current supply glut is expected to persist well into the next year, which would limit the upside potential for prices despite the typical seasonal pattern. Second, the market has become more flexible, with the share of fixed destination contracts falling and the share of flexible destination and uncontracted LNG liquefaction capacity increasing (IEA, 2019b). However, it is worth keeping in mind that an unexpected tightening of the market is always a possibility. A cold spell in East Asia could significantly increase the LNG demand there, driving up prices for Europe, which serves as the residual buyer for LNG on the world market. However, while such a scenario would likely result in higher prices for European consumers, it is unlikely to lead to supply shortages that would constrain the availability of LNG shipments to Europe and constrain the ability of LNG to compensate for the supply shortfall brought about by the interruption of Ukraine.

### 3.4 What would be the effect on gas prices?

Although an interruption of UGTS for Russian gas would not be a major issue from a security of supply angle, there would be a significant impact on gas prices, in particular in Southeast Europe. By comparing prices in a BAU January 2020 with those in the event of an interruption of Ukraine transits, the price effect of the interruption can be determined. Figure shows the average wholesale gas price increase in each individual EU member state resulting from an interruption in January 2020.<sup>7</sup> It is no surprise that prices increase the most in the south-eastern member states. Although their overall gas demand is quite small when compared to countries like Germany, the United Kingdom or the Netherlands, they are reliant on Russian gas transiting through Ukraine and are further along the Trans-Balkan-Pipeline. Furthermore, their markets are less well interconnected and have more limited gas storage capacities relative to the size of their gas demand than their western neighbours.

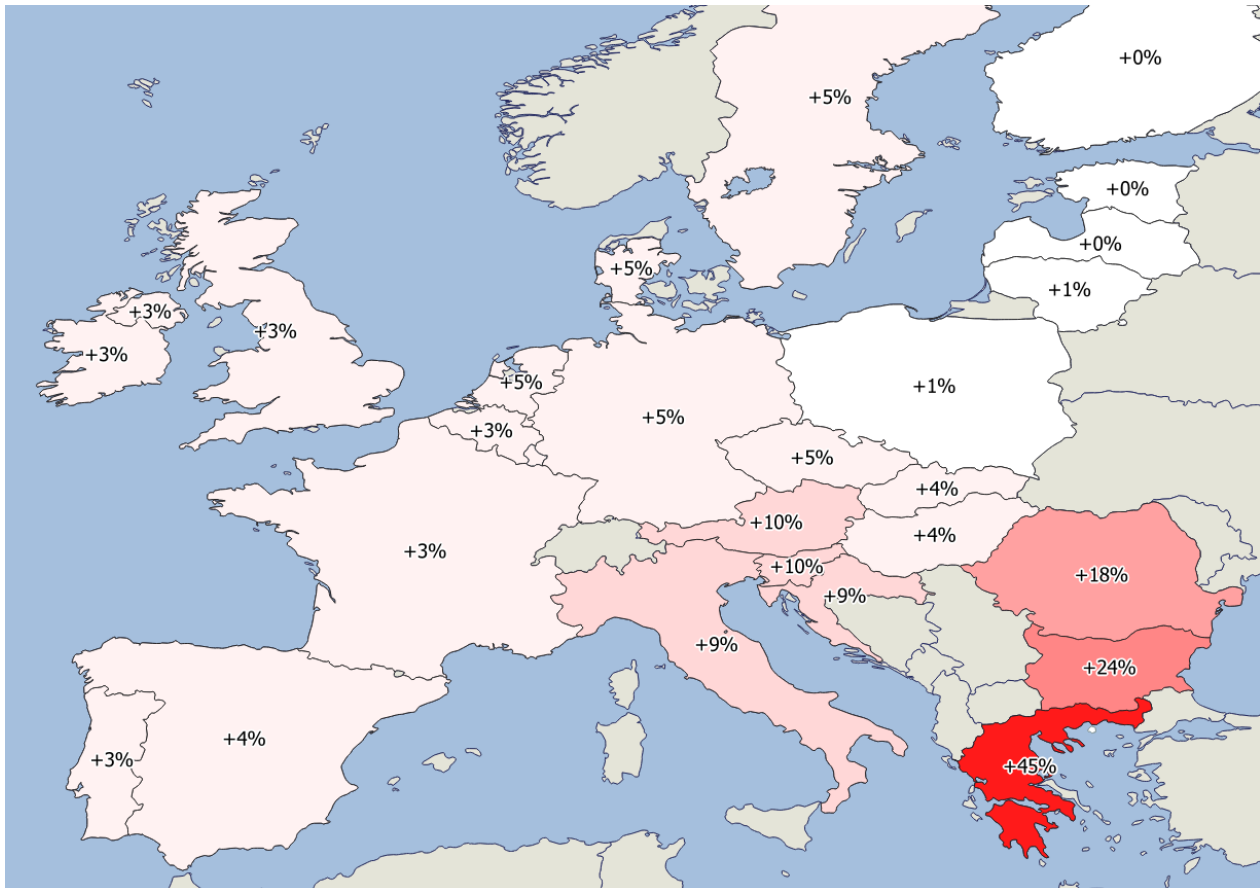
The strongest effect can be observed in Greece, resulting in a price differential of 45%. This is caused by imports from Bulgaria dropping to almost zero due to the similarly tight situation there, and at the same, by the maxing out of the regasification capacity in Greece to compensate for this loss and to cover the high winter gas demand. This price effect funnels through to Bulgaria and Romania, which see prices rise by 24% and 18%. It is very unlikely that the Interconnector Greece Bulgaria (IGB) will become operational during the considered interruption period. However, in the case that IGB becomes operational, it would help relieve the tight supply situation in

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<sup>7</sup> Note that the gas prices presented in this study are not forecasts, but are rather outcomes of the simulations of the assumed scenarios.

Greece. In that case, price increases in Greece would be less pronounced whereas Bulgaria would see slightly higher price increases.

Austria, Slovenia and Italy, all three major recipients of Russian gas transiting through Ukraine and via Baumgarten (in Austria) experience increases by 10%, 10% and 9% respectively. Across the rest of the EU, prices rise by a more modest 3% to 5% as some flows realign and market participants require additional storage withdrawals and LNG shipments in response.<sup>8</sup>

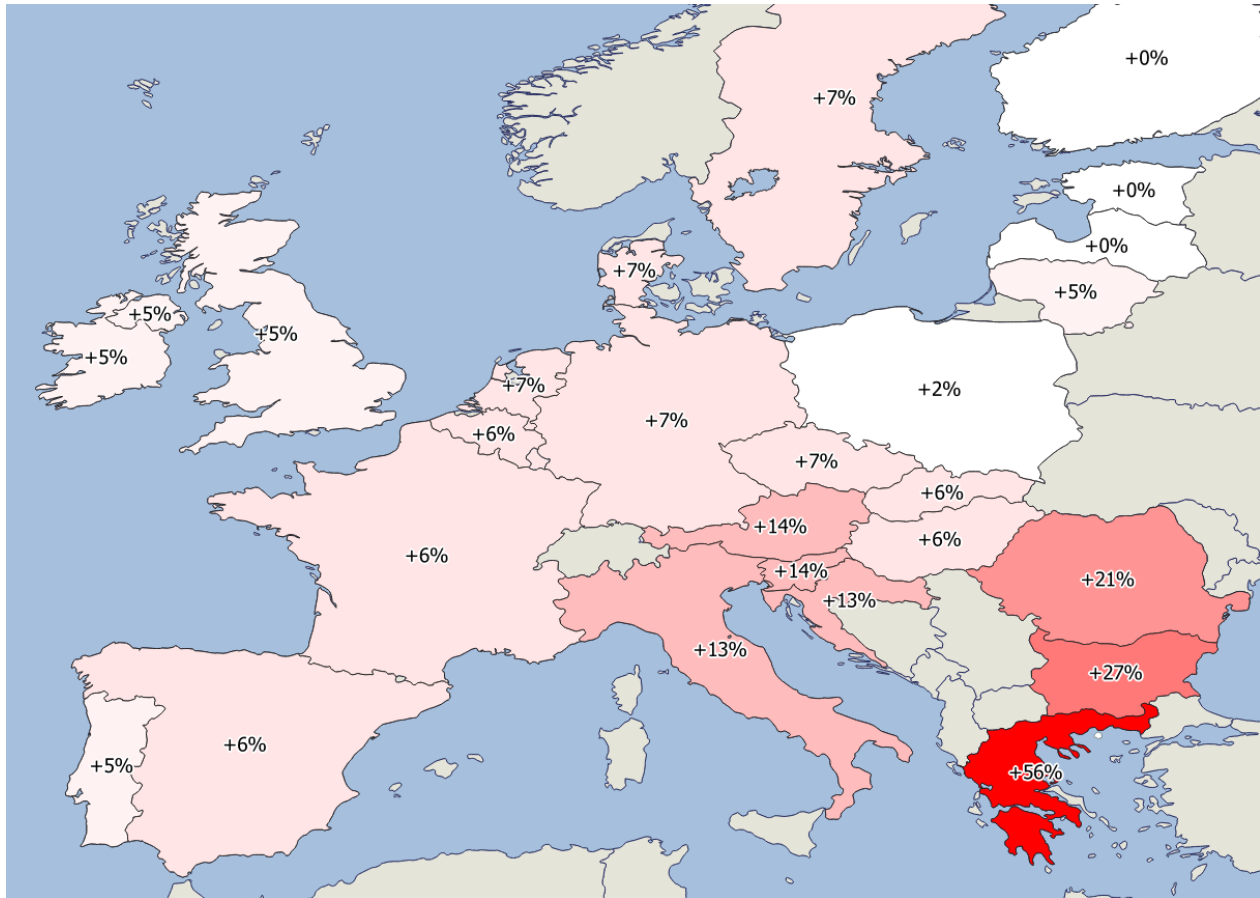


**FIGURE 7: AVERAGE PRICE DIFFERENTIALS IN JANUARY 2020 IN THE CASE OF INTERRUPTION**

Should a cold spell coincide with the interruption of transits, the rest of the EU would see a more substantial increase in prices as well (see Figure 8). This is due to higher storage withdrawals and LNG imports into Northwest Europe. Greece and Bulgaria are also in this case the countries that are affected the most, followed closely by Romania. Nevertheless, despite the tight market situation in this interruption scenario with cold spell, none of those countries experience any shortfalls—security of supply remains intact. In the case of Greece, a 56% price increase means an absolute price level of 26.8 EUR/MWh in January 2020 (see Appendix A, Table A.1). This absolute price level is high compared to BAU but lies within the observed historical range, e.g. gas prices in the winter season of 2014.

<sup>8</sup> Note that the price increases are estimated using simulations with fundamental models and are therefore based on equilibrium prices. These prices are independent of speculation which could, in reality, lead to higher price increases in the short-term.





**FIGURE 8: AVERAGE PRICE DIFFERENTIALS IN JANUARY 2020 IN THE CASE OF INTERRUPTION DURING A COLD SPELL IN EUROPE**

### 3.5 How would consumers and producers be affected financially?

The EU as a net importer of natural gas, Gazprom as a producer and exporter and Ukraine as a transit country are all affected negatively by an interruption of Russian natural gas flows through Ukraine (see Figure 9).

Due to the increase in wholesale prices outlined in the previous section, consumers in the EU have to pay an additional 1.5 billion euros for their gas during the three months of the interruption. The direct consumer loss due to the interruption would rise to approximately 2.1 billion euros should a cold spell occur at the same time. Due to the interruption, Russia's gas pipeline export monopolist Gazprom would see its sales in Europe decline. The revenue gains associated with the higher gas price are unable to compensate for the loss in revenue from selling less gas overall, leading to a loss of approximately 3.4 billion euros compared to the business-as-usual of uninterrupted transits.

Regarding the losses of Gazprom, it is important to emphasise that the results do not include possible compensatory claims connected to Gazprom’s inability to meet some of the deliveries it is obliged to make under its long-term gas supply contracts. Simulation results indicate that contractual volumes could potentially not be met in the case of exports to Italy, Romania, Greece and Bulgaria. Note that this excludes sales from Gazprom’s storages located in Europe.

Lastly, Ukraine would lose its transit revenues from the fees it collects on Russian gas transits. Depending whether the contractual tariffs suggested by Naftogaz of \$2.56/1000 m<sup>3</sup> per 100 km or \$3.21/1000 m<sup>3</sup> per 100 km is assumed, the losses are estimated to range from 0.5 to 0.6 billion euros over the course of the three-month interruption.

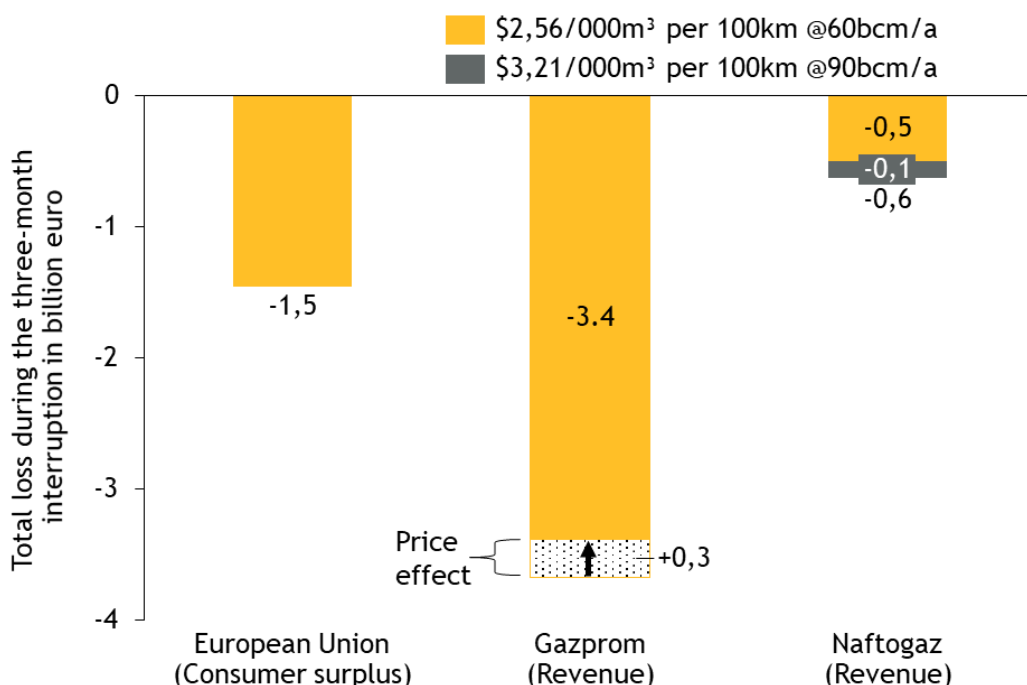


FIGURE 9: CONSUMER AND REVENUE LOSS DUE TO A 3-MONTH INTERRUPTION OF GAS TRANSITS

In addition to the direct effects of the interruption during the three months it occurs, the impact of the event would be felt over the remainder of 2020 as well since gas storage sites are more depleted than usual coming out of the event and would have to be filled prior to the next heating season. This would elevate gas prices throughout 2020 and increase the call on Russian gas which is presumed to again be able to transit freely via Ukraine. Looking at the year as a whole, this would magnify losses for European consumers and diminish them for Russia and Ukraine, as Russia is able to benefit from increased EU demand caused by the need to refill the storages and the consequential higher prices, while Ukraine would transit more gas than it usually does in the months leading up to the beginning of the new gas year when storage volumes tend to be at their highest.

Nevertheless, these figures illustrate that no side benefits from an interruption, with all three parties incurring significant losses. This again highlights the desirability of reaching an agreement on Ukraine transits prior to the existing set of contracts expiring at the end of December 2019. Furthermore, Russia, Ukraine, or both—depending on who would be seen as responsible for the interruption—would risk taking a substantial reputational hit from any interruption of gas flows. This would provide additional arguments to those seeking to nudge EU member states to further diversify their gas supplies away from Russian gas, irrespective of whether it transits through Ukraine or along one of the alternative corridors that have additional capacity coming online in the near future. The costs of this reputational damage are hard to quantify, but nevertheless real and provide another reason for both parties to reach an agreement and avoid a disruptive outcome.

### 3.6 What would happen if the interruption lasts longer?

In the case that the interruption lasts longer than the three month period considered in this study, the EU gas market would continue to have a substantial security of supply due to lower demand during the summer period and availability of flexible LNG supply to complement the missing volumes. In an extreme case, where the interruption lasts throughout the whole year of 2020 and extends to the winter of 2021, shortfalls would again be unlikely since the additional alternative import pipelines TAP, TurkStream connection to the EU and Nord Stream 2 are likely to be online by then. Therefore, it can be said that the availability of these pipelines will contribute to the security of supply situation in the EU, resulting in impacts of any future transit interruptions to be more subdued, in particular in South Eastern Europe.

However, in the medium term the UGTS will remain one of Europe's main import routes. Due to a declining indigenous production but a constant natural gas demand development the resulting import gap needs to be filled by additional imports. The Ukrainian import route would allow to import further low-cost Russian gas—in particular, during peak times—and would therefore provide additional competition with alternative supply sources such as LNG.

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## APPENDIX A: SUPPLEMENTARY MATERIAL

TABLE A.1: SIMULATED GAS PRICES OF THE EU MEMBERS, IN EURO PER MEGAWATT HOURS

	BAU		Interruption		Interruption + Cold Spell	
	Jan 2020	Mar 2020	Jan 2020	Mar 2020	Jan 2020	Mar 2020
AT	16.4	16.2	18.0	18.0	18.7	18.7
BE	16.3	16.0	16.7	16.6	17.2	17.1
BG	20.8	20.6	25.8	22.8	26.3	23.0
CZ	16.3	16.1	17.0	17.0	17.4	17.4
DE	16.3	16.1	17.1	17.0	17.5	17.5
DK	15.8	15.7	16.6	16.5	17.0	17.0
EE	17.0	16.8	17.0	16.8	17.3	17.2
ES	16.5	16.3	17.2	17.0	17.6	17.5
FI	21.4	21.2	21.4	21.2	21.6	21.6
FR	16.7	16.5	17.2	17.1	17.6	17.6
GB	17.0	16.8	17.5	17.3	17.9	17.8
GR	17.2	17.1	25.1	17.6	26.8	18.0
HR	18.2	18.0	19.8	19.8	20.5	20.5
HU	18.4	18.2	19.2	19.2	19.4	19.4
IE	18.5	18.3	19.0	18.8	19.4	19.3
IT	17.5	17.3	19.2	19.1	19.9	19.8
LT	17.5	17.3	17.3	17.2	18.3	17.8
LU	16.3	16.0	16.8	16.6	17.4	17.1
LV	17.5	17.3	17.5	17.3	17.6	17.5
NL	16.3	16.1	17.0	17.0	17.4	17.4
PL	17.5	17.3	17.3	17.3	17.8	17.8
PT	16.8	16.6	17.3	17.1	17.7	17.6
RO	19.7	19.5	23.3	20.3	23.8	20.5
SE	15.8	15.7	16.6	16.5	17.0	17.0
SI	17.1	16.9	18.7	18.7	19.4	19.4
SK	18.0	17.8	18.8	18.8	19.2	19.2

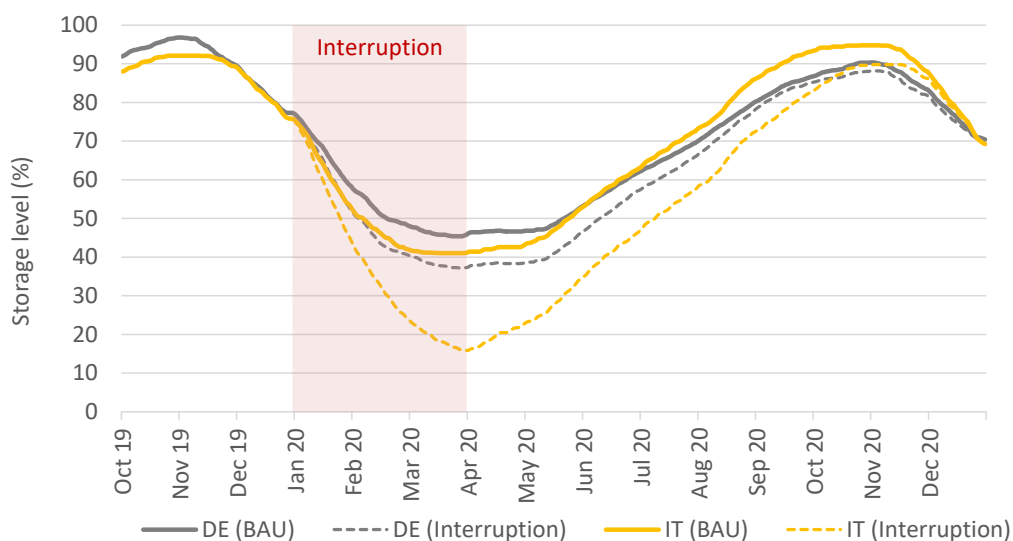


FIGURE A.1: SIMULATED STORAGE LEVELS IN GERMANY AND ITALY

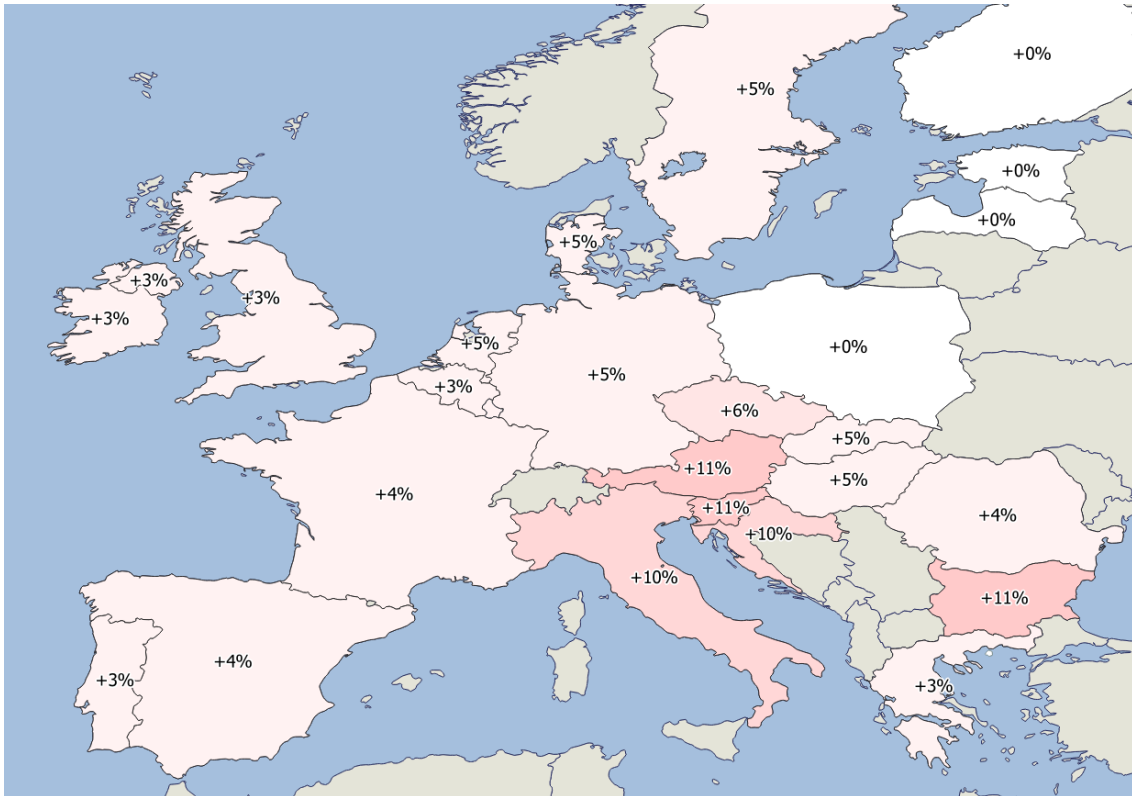


FIGURE A.2: PRICE DIFFERENTIALS IN MARCH 2020 IN THE CASE OF INTERRUPTION

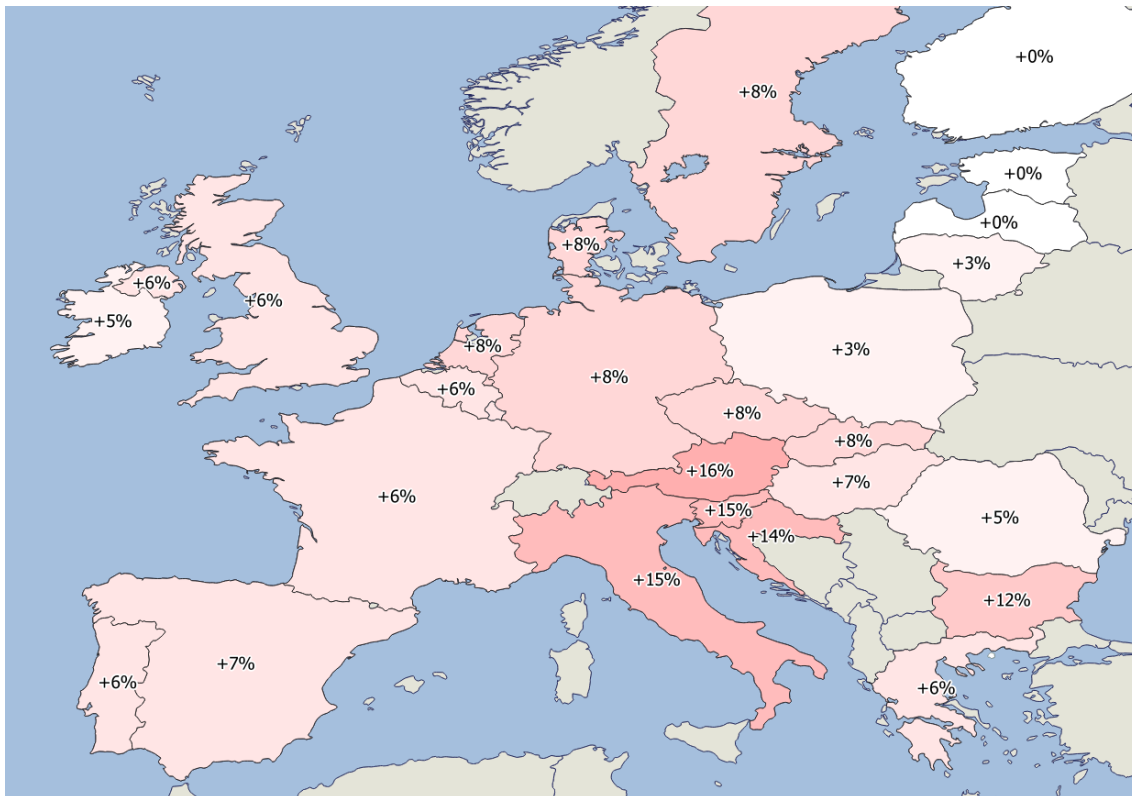


FIGURE A.3: PRICE DIFFERENTIALS IN MARCH 2020 IN THE CASE OF INTERRUPTION DURING A COLD SPELL IN EUROPE

## APPENDIX B: THE TIGER MODEL

TIGER (Transport Infrastructure for Gas with Enhanced Resolution) is a European natural gas infrastructure and dispatch model. It simulates natural gas trade as well as physical flows and therefore the utilisation of all major elements of the European gas infrastructure (high-pressure transport pipelines, LNG import terminals, and underground gas storage sites). 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.

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 historical data, country and sector specific demand projections are broken down into monthly, regionalised 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 optimisation 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 (dependent on storage level/pressure within the storage), 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 ENTSOG's Transmission Capacity Map 2016, and
- non-European pipeline import capacities (from Russia, Algeria, Libya, Azerbaijan, Middle East) at the respective border points.

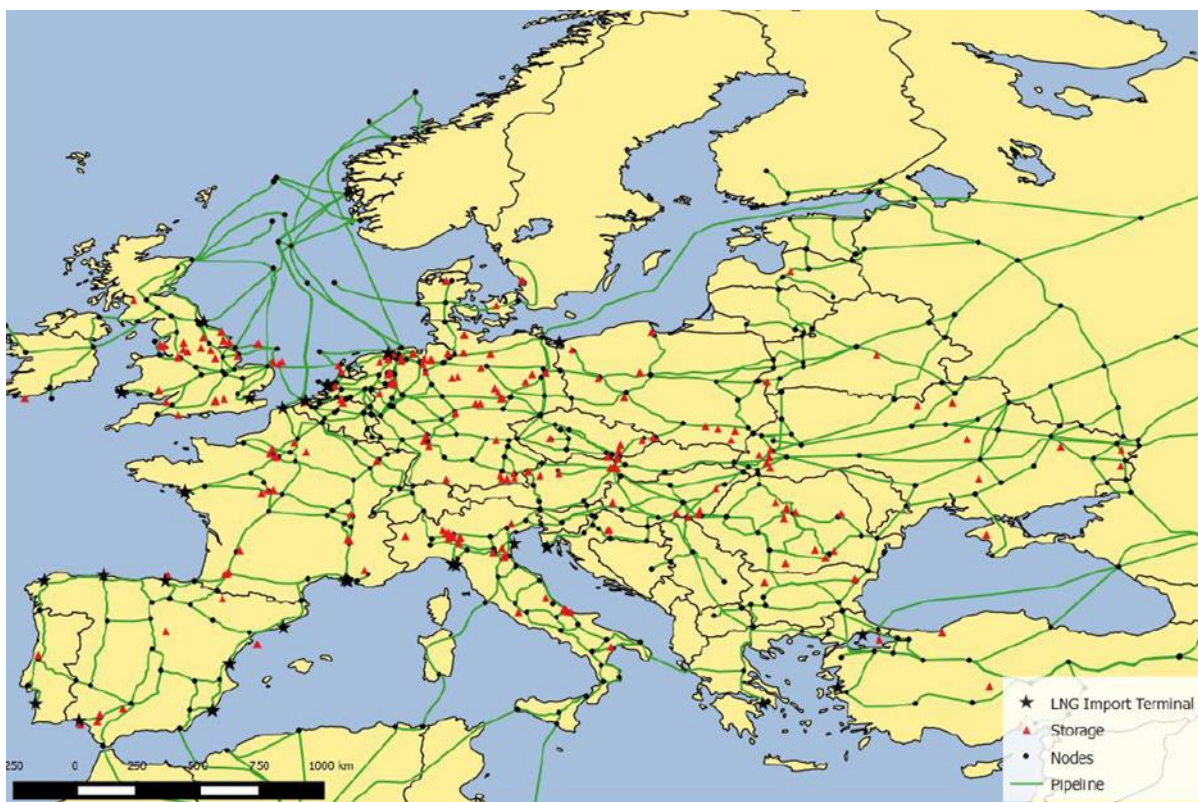
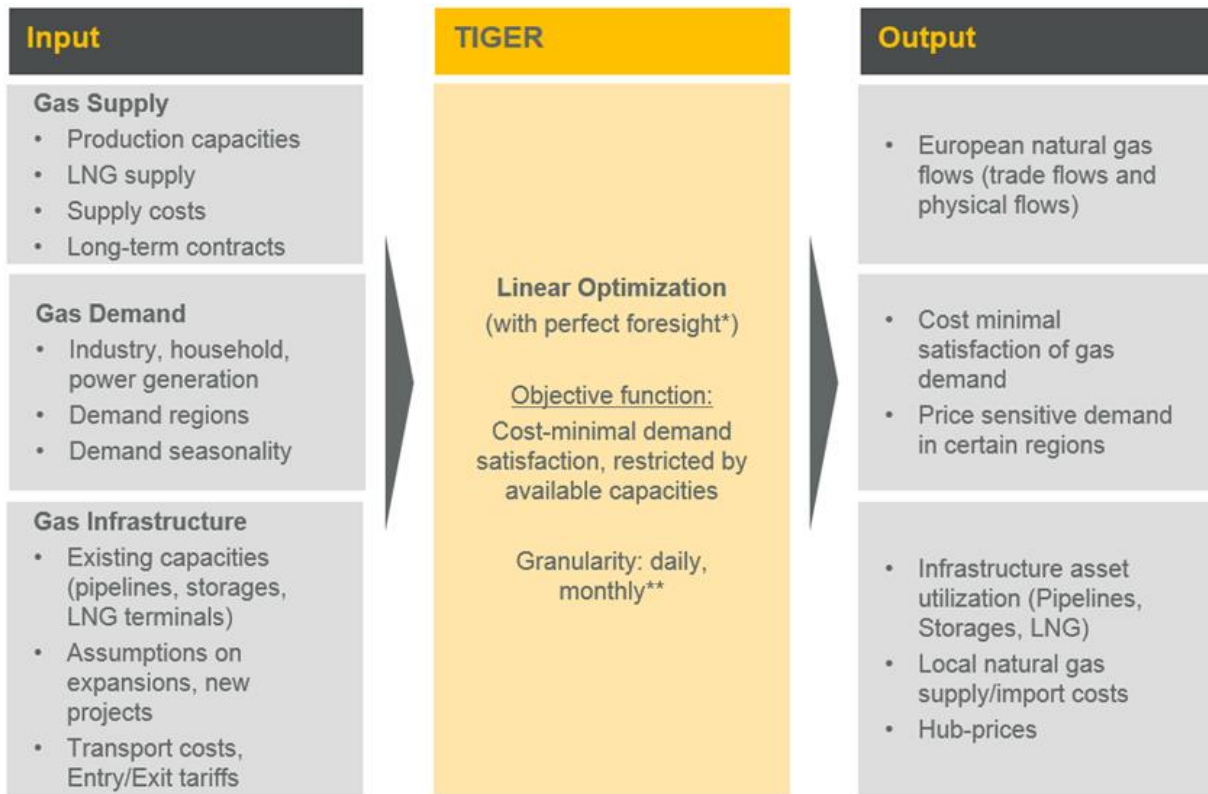


FIGURE B.1: MODELLED NATURAL GAS INFRASTRUCTURE IN TIGER (SCHEMATIC)

The TIGER model is formulated as a linear optimisation problem. The objective function of the problem is the minimisation of the total supply costs of the European natural gas supply and transport system, while meeting regionalised demand. This corresponds to an 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 optimisation, with a monthly granularity, takes place subject to the restrictions of maximum available supply, demand that 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 optimisation takes place. Since TIGER does not consider uncertainty with respect to its inputs, it is a perfect foresight model. Cost optimisation 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.





\* Storage level is equal at the beginning of each year

FIGURE B.2: AN OVERVIEW OF THE TIGER MODEL

## APPENDIX C: THE COLUMBUS MODEL

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 percent 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).

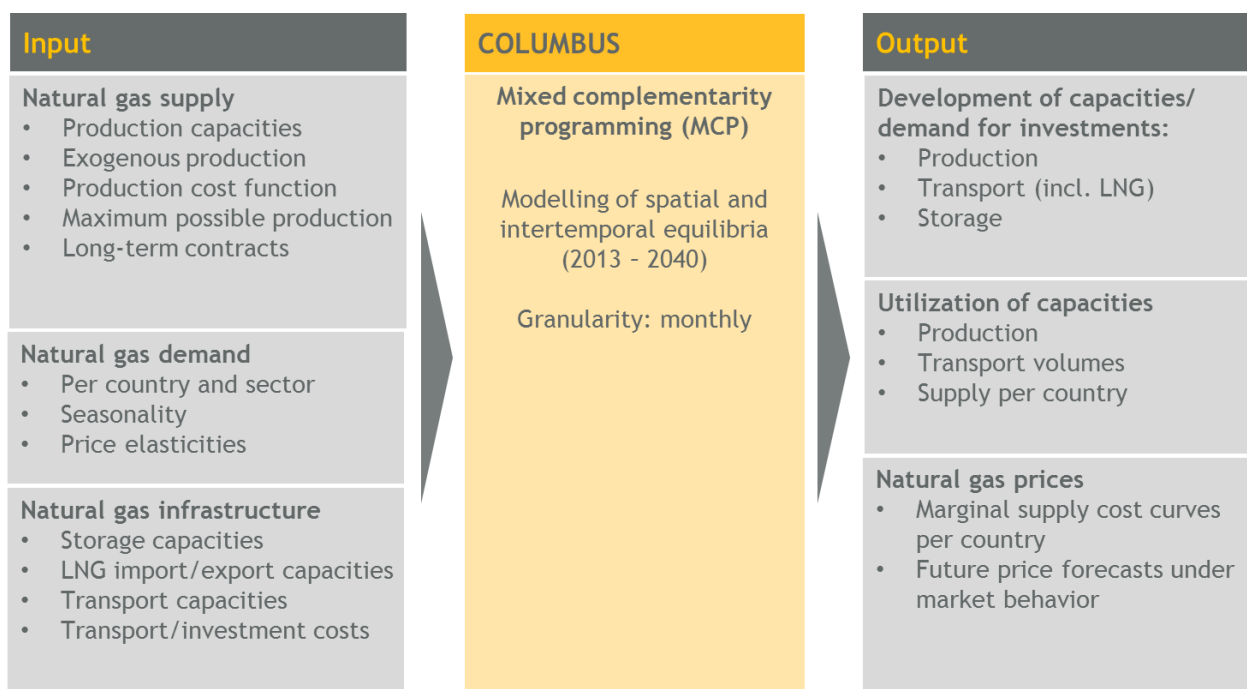


FIGURE C.1: AN OVERVIEW OF THE COLUMBUS MODEL

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.