An updated analysis on gas supply security in the EU energy transition

Final report

An analysis on behalf of the European Climate Foundation

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Executive summary

This report provides an independent and forward-looking assessment of the EU's gas supply security by assessing the relevance of the 32 new gas infrastructure projects on the EU's 4th Projects of Common Interest (PCI) list which are eligible for European public funds. It also analyses an additional 5 new natural gas infrastructure projects in the EU that are not part of the PCI list[1]

The 32 natural gas infrastructure PCI projects combined are calculated to come at a cost of 29 billion EUR and would add 338 GW capacity to the EU natural gas infrastructure system, which is already approaching 2000 GW of pipeline and LNG terminal capacity.

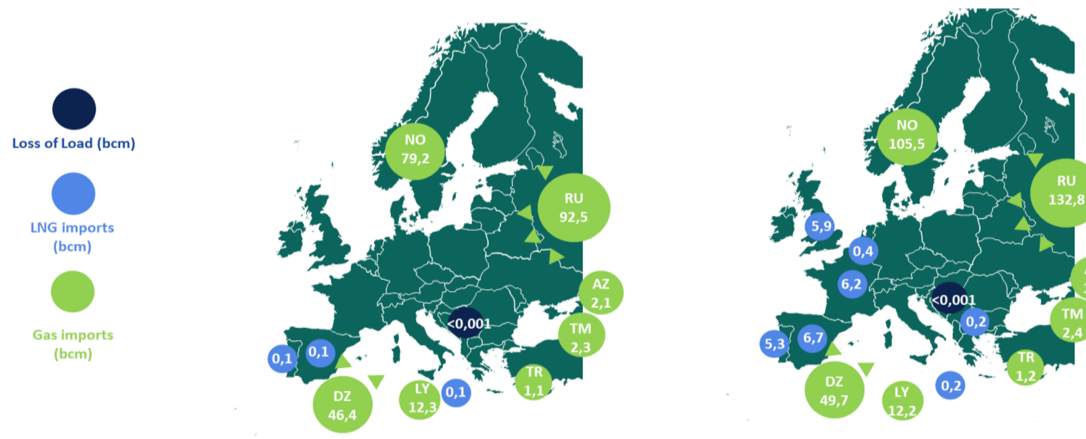
The European Commission's projections currently estimate that achieving the 2030 climate and energy targets will result in a reduction of natural gas by 29% – from 415 bcm in 2015 to 297 bcm in 2030. The report looks at the implications of that scenario on the need for new infrastructure from a gas security of supply point of view, but also considers a wider range of future natural gas demand scenarios and extreme supply disruptions cases.

The report concludes that the existing EU gas infrastructure is sufficiently capable of meeting a variety of future gas demand scenarios in the EU28, even in the event of extreme supply disruption cases.

This suggests that most of the 32 gas infrastructure projects on the 4th PCI list are unnecessary from a security of supply point of view, and represent a potential overinvestment of tens of billions of EUR, supported by European public funds.

Key findings

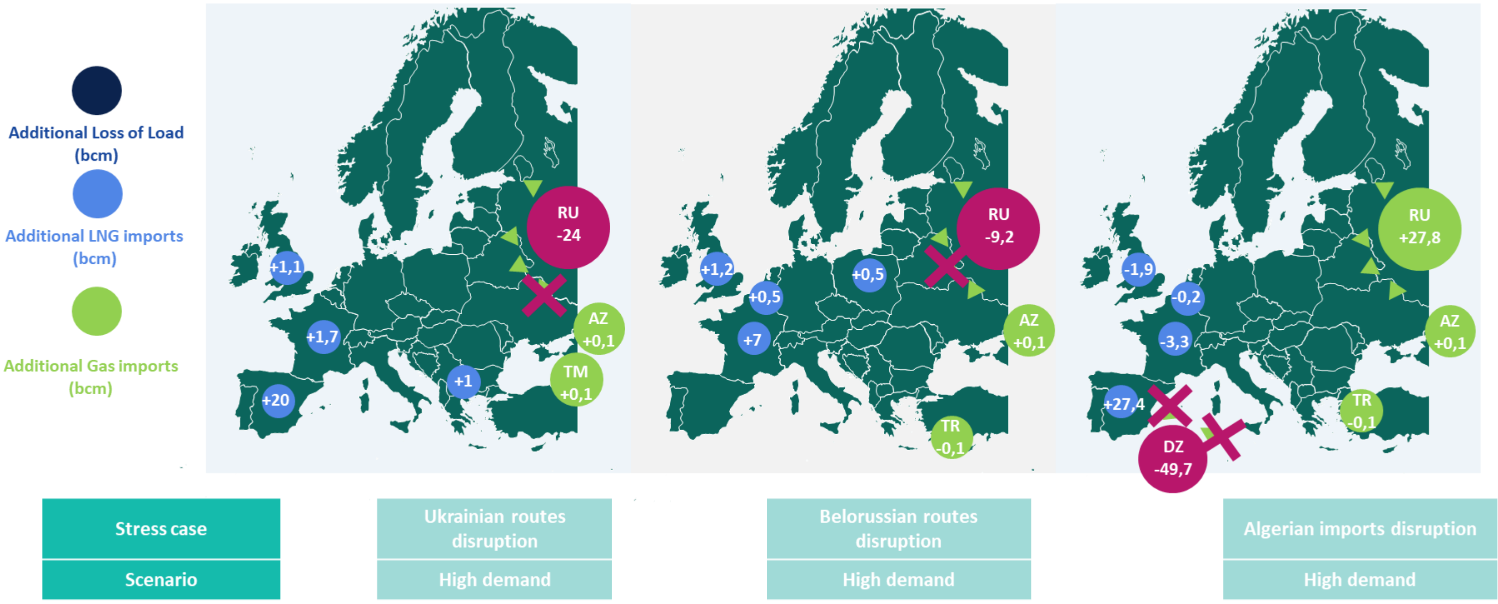
Finding 1: Under normal market conditions, existing gas infrastructure in 2030 suffices to meet gas demand in both an "On Track" and "High Demand" scenario



Scenario	EUCO3232d On track	TYNDP18 ST 2030 High demand
Total gas imports	238 bcm	330 bcm

[1] Nord Stream 2, White Stream, Turkey – Bulgaria pipeline, Wilhelmshaven and Brunsbüttel

Finding 2: Existing gas infrastructure in 2030 is resilient to a wide range of potential extreme supply disruptions, including year-long disruptions from Ukraine, Belarus and Algeria. The loss of supply from Russia or Algeria is compensated by imports from other sources, primarily via existing LNG terminals in the west of Europe.



Finding 3: Investments in projects included in the 4th PCI list are found to be unnecessary to safeguard security of supply in the EU28 and therefore risk to become stranded assets supported by European Union public funds. This remains true in scenarios with higher natural gas demand in 2030. Minor investments in some of the projects included in the 4th PCI list are found to be relevant to solve security of supply issues outside the EU28, in Bosnia-Herzegovina (the model does not select investments in any of the 5 additional projects we have considered on top of the 4th PCI list). However, most of the projects are shown to be superfluous from an economic point of view. Furthermore, from a methodological point of view, the report confirms previous findings that using an integrated gas-electricity approach to infrastructure planning is essential to avoid overinvestments.

Note: This analysis provides a follow up to an earlier assessment conducted by Artelys in 2016: *Energy Union Choices: A Perspective on Infrastructure and Energy Security in the Transition*.

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Glossary

bcm: Energy contained in one billion cubic meter of natural gas. Using a gross calorific value of 35.17 MJ/m3, 1 GW is equivalent to around 0.9 bcm / year

ENTSO-E: European Network of Transmission System Operators for Electricity

ENTSOG: European Network of Transmission System Operators for Gas

Gas infrastructure: Gas pipelines, LNG terminals and storage capacities

Gas-only approach: Approach used to assess gas infrastructure needs by only considering the gas system

Integrated gas-power approach: Approach used to assess gas infrastructure needs by considering simultaneously the gas and power systems (integrating electricity supply, storage, transmission and demand response), and their synergies/interdependencies

LNG: Liquefied Natural Gas

LNG terminals: Infrastructure to berth LNG tankers for unloading/reloading, to store LNG, to regasify LNG and send out the gas into the gas grid

Loss of load: Part of the annual energy demand that cannot be met by the considered energy system. This metric is used to assess security of supply

PCI projects: Infrastructure Projects of Common Interest of the 4th list published by the European Commission

Scenario: Description of a European energy context in a prospective approach. It includes e.g. levels of energy demand, commodity prices, power generation mix, etc.

Stress cases: a stress case represents the disruption of a supply source

1 Context and Objectives

1.1 A well-designed infrastructure is a key enabler of decarbonisation

In the final months of 2019, European institutions have announced a considerable increase of their ambition levels in the fight against climate change, in order to accelerate the pace of decarbonisation of the European economy. The European Commission has unveiled “The European Green Deal” [2], which proposes to set the 2050 climate neutrality objective into EU legislation via a “European Climate Law” by March 2020. On 12 December, the European Council has announced it endorses the 2050 climate neutrality objective.

Pathways demonstrating how different technological options and lifestyle changes may combine to achieve a climate neutral European economy have been published in the context the EU Long-term Strategy[3] that will be submitted to the UNFCCC in 2020. These pathways, as well as those published by other entities such as NGOs, TSOs, national governments, etc., recognise the key enabling role that will be played by large-scale infrastructure to allow for energy to be imported, stored and transported into the European system.

The decarbonisation of the energy system will largely rely on a massive deployment of renewables, which will enable the electrification of a large number of end-uses, either directly or indirectly (via electrolysis and subsequent conversion technologies). The very structure of energy flows is likely to change considerably compared to today’s situation. This is particularly true for the gas system, where imports of natural gas are expected to decrease massively, and European production of lower carbon alternatives will likely increase via the production of bio-methane and via the deployment of electrolysers to produce hydrogen.

A forward-looking approach to electricity and gas infrastructure planning should therefore be favoured, as synergies and interdependencies that exist between these systems are only going to increase in the coming decades as decarbonisation levels increase.

1.2 A joint approach to investment planning

In the TEN-E regulation[4], ENTSOG and ENTSO-E (collectively known as the ENTSOs) have been tasked with the development of an interlinked model, which is a crucial tool to ensure consistency between the selection of investments in the gas and electricity sectors. Currently, the ENTSOs develop joint scenarios that are the basis for project assessment (TYNDP scenarios). While the elaboration of joint scenarios is an important first step, the project assessment phase (cost-benefit analysis) and the subsequent selection of PCI projects are handled separately for gas and electricity projects. This could

[2] European Commission, COM(2019) 640 final
[3] European Commission, COM(2018) 773 final
[4] Regulation (EU) No 347/2013 of the European Parliament and of the Council

result in a sub-optimal portfolio of projects being selected as PCIs since synergies and interdependencies have not totally been considered during the projects' assessments. In order to improve the analysis of the benefits brought by infrastructure projects, the ENTSOs are currently working on developing methodologies to jointly assess relevant projects, based on recommendations developed by Artelys[5].

The Energy Union Choices study[6] published in 2016 has clearly demonstrated that not using an integrated approach (based on a joint model of gas and electricity) to project assessment can provide wrong investment signals and therefore result in overinvestments in the gas infrastructure.

The key mechanism that is responsible for the potential lower need for gas infrastructure in an integrated approach is the use of the electricity system as a source of flexibility during tight market conditions on the gas side. By displacing the conversion of gas into electricity from one country to another one using existing electricity and gas infrastructure, one can avoid having to build new gas infrastructure. A similar mechanism could also impact the identified need for electricity infrastructure, especially in contexts including a strong deployment of power-to-gas assets, where such assets could be a source of flexibility for the electricity system.

1.3 No integrated project assessment for the 4th PCI list

For the assessment of candidate projects for the 4th PCI list, on which the EU Parliament will likely vote in February 2020, the flexibility brought by the electricity sector has not been considered in the cost-benefit analysis of gas projects. Indeed, the methodology developed by ENTSOG to calculate the impacts of a project on security of supply, sustainability, market integration and competition is based on an approach that considers a fixed gas demand that must be supplied in all circumstances, without allowing for flexibility from other sectors such as the electricity sector.

1.4 Objectives of this study

The purpose of the study is to assess the need for new gas infrastructure projects included in the 4th PCI list, from the point of view of possible security of supply issues for EU28 countries at the 2030 horizon[7].

This study provides an update of the results obtained during the aforementioned 2016 study and insights that can be useful for the upcoming evaluation of the TEN-E regulation. These two objectives are described in more details in the next subsections.

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[5] ENTSOs, Investigation on the interlinkage between gas and electricity scenarios and infrastructure projects assessment

[6] https://www.energyunionchoices.eu/wp-content/uploads/2017/08/EUC_Report_Web.pdf

[7] A forward-looking assessment should also take long-term objectives into account (e.g. 2050 horizon) and consider technological options such as power-to-gas. We restrict this updated analysis to the 2030 horizon to be consistent with the previous analysis and with the time horizon used during the PCI selection process.

1.4.1 Comparison with 2016 study

The Energy Union Choices study published in 2016 has demonstrated that Europe's current gas infrastructure is resilient to a wide range of demand futures and extreme supply disruptions (Norway, Ukraine, North Africa), with a weak spot in South Eastern Europe countries under specific circumstances.

This new study aims at testing the baseline infrastructure of the 2030 European gas network in updated gas and electricity scenarios. The key differences between the gas systems investigated in the two studies are discussed below. The complete set of assumptions used in this study can be found in Section 3.

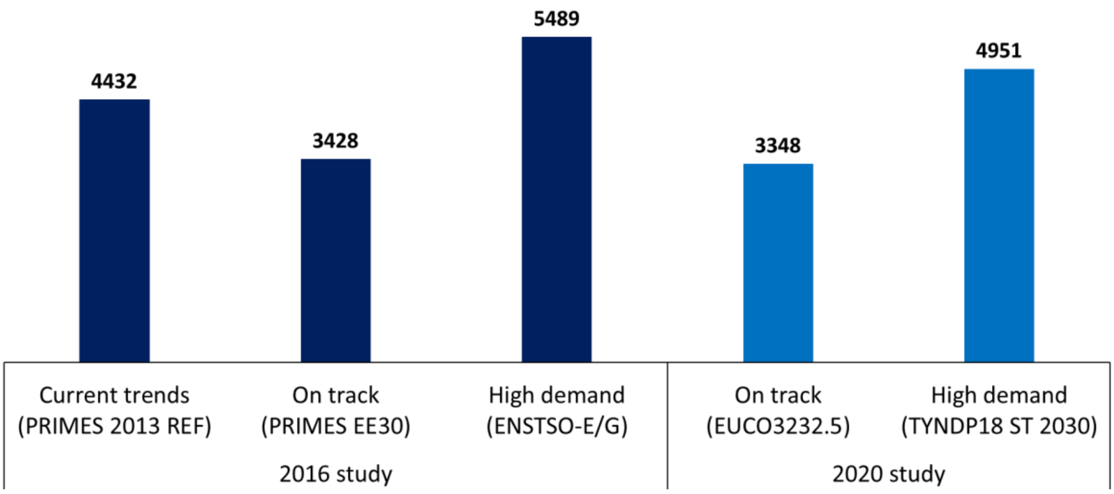

Figure 1 Gas demand in the different scenarios in the 2016 and 2020 study (EU28, excl. MT and CY) - TWh

Demand levels

Compared to the previous study, the gas demand of the EUCO3232.5 scenario (the "On Track" scenario of the 2020 study) is comparable to the "On Track" scenario of the 2016 study. However, the high demand scenario of this study (based on TYNDP 2018 – Sustainable Transition 2030) has a 10% lower demand than the "High demand" scenario used in 2016. Note that the figures may differ from the ones quoted in the original sources due to the use of different modelling frameworks, climatic years, etc.

Infrastructure levels

The 2016 study was based on the 2014 European gas infrastructure. In the 2020 study, the baseline infrastructure corresponds to the "Low" infrastructure assumption as defined by ENTSOG in the context of TYNDP 2018, corresponding to current infrastructure levels to which projects having reached final investment decision are added.

The baseline infrastructure used in the 2020 study is better interconnected than the one considered during the 2016 study (69 *vs* 53 pipelines, 975 *vs* 963 GW of pipeline capacity).

Finally, loss of load was identified as a potential issue in South Eastern European countries in the 2016 study under certain stress cases. In the 2020 study, the gas network has evolved in such a way to enable more possibilities to reduce the volume of loss of load in this region. The evolution of pipelines capacities and density towards "critical" countries between the 2016 and the 2020 study reduces the risks of loss of load.

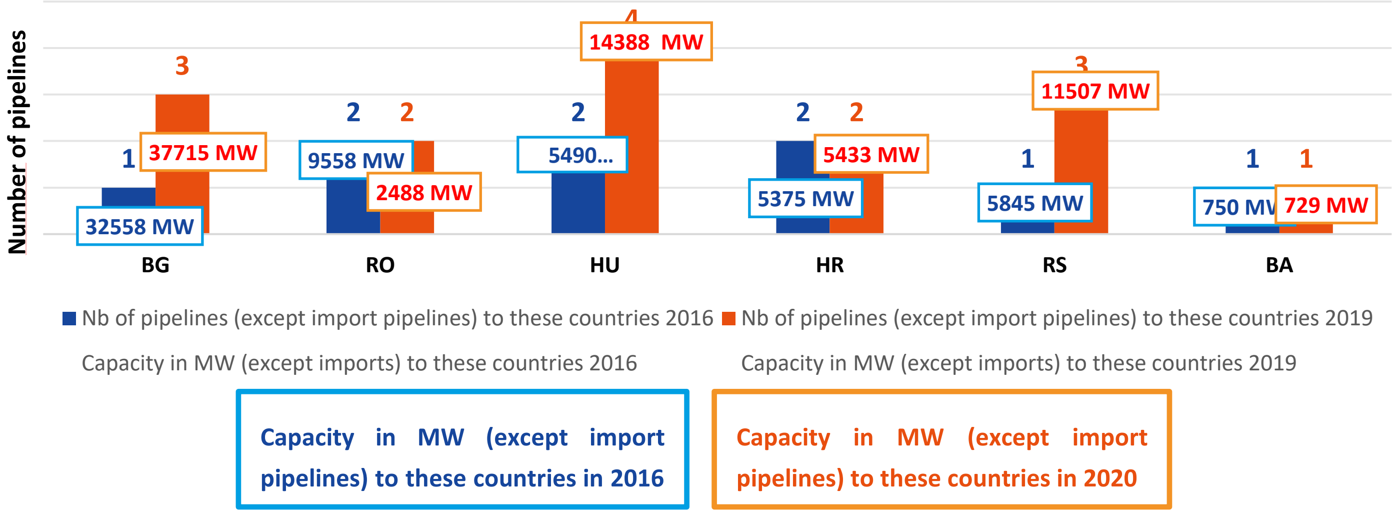

Figure 2 Evolution of the gas network between the 2016 and 2020 studies in South East Europe

1.4.2 Upcoming evaluation and review of the TEN-E regulation

The European Commission has recently launched an evaluation of the TEN-E regulation. It is expected that this regulation will be reviewed in the context of the work surrounding the European Green Deal, as indicated in the roadmap published by the European Commission[8]. We hope the results of this study, notably in terms of the benefits of using an integrated EU-wide approach compared to a conventional more fragmented approach to PCI selection, will provide useful insights for the update of the TEN-E regulation (e.g. need for interlinked assessments, role of regional groups, etc.).

1.5 Overview of the approach

The following paragraphs present an overview of the methodology that has been developed to conduct this study. The complete set of assumptions used in this study can be found in Section 3.

We perform a model-based assessment of the need for new gas infrastructure projects at the 2030 horizon for two different scenarios that reflect different gas demands and different electricity systems (generation mix, demand, commodity prices, etc.).

[8] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication-annex-roadmap_en.pdf

Key inputs

The key inputs are the gas demand, the baseline gas infrastructure (and potential disruptions), and the set of investment options (see Section 3.2.1), while the key outputs are the investments that are selected by the model to ensure an adequate level of security of supply and the utilization rate of the gas infrastructure.

The two scenarios that have been used for this study are:

- **"On track" scenario**
  This scenario is based on the EUCO3232.5 scenario[9], which has been built by the European Commission to meet the agreed-upon 2030 EU climate and energy targets (32% share of renewables in the energy consumption, and 32.5% increase in energy efficiency – allowing for an achievement of at least 40% emission reductions by 2030)
- **"High demand" scenario**
  This scenario is based on the 2030 snapshot of the Sustainable Transition scenario[10], built by ENTSO-E and ENTSOG in the context of the Ten Year Network Development Plan 2018. Since the scenario is not an energy-wide scenario, it is not possible to assess whether such a scenario would meet the EU climate and energy targets.

The following figure presents the annual gas and electricity demands in each of the scenarios[11]:

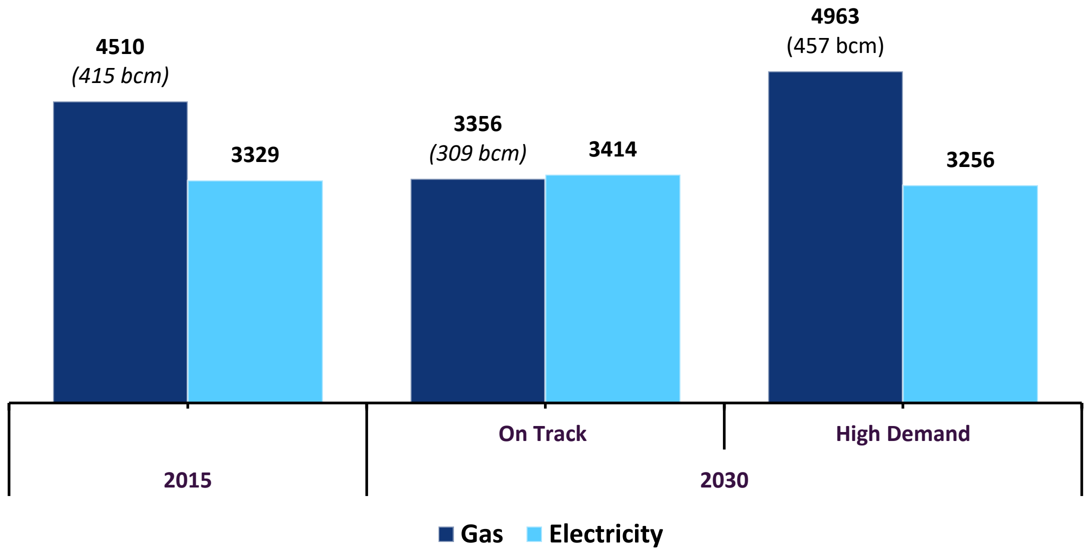

Figure 3 Gas and power demand in Europe (EU28), in TWh

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[9] https://ec.europa.eu/energy/sites/ener/files/technical_note_on_the_euco3232_final_14062019.pdf
[10] https://entsog.eu/sites/default/files/entsog-migration/publications/TYNDP/2018/entsos_tyndp_2018_Final_Scenario_Report.pdf
[11] The figures used in the modelling might slightly differ due to the required recalibration process of gas-to-power capacities (to ensure the electricity mix meets the adequacy criteria) capacities and the corresponding gas demand.

In the context of the Green European Deal, the European Commission has announced it will publish a plan to increase the EU's greenhouse gas emission reductions target for 2030 to at least 50% and towards 55% compared with 1990 levels. The two scenarios considered herein would not be reaching the revised targets, as an even steeper reduction of natural gas demand may have to be considered.

Investment options

The gas infrastructure projects from the 4th PCI list are considered as investment options. The model can invest in these projects to meet the demand at the lowest possible cost. The investment options are characterized by their costs (CAPEX and OPEX) and their capacities. In addition to the projects included in the 4th PCI list, the following pipelines and LNG terminals have been added to the list of investment options:

- Pipelines: Nord Stream 2, White Stream and the Interconnection Turkey – Bulgaria
- German LNG terminals: Wilhelmshaven and Brunsbüttel

An interlinked modelling tool

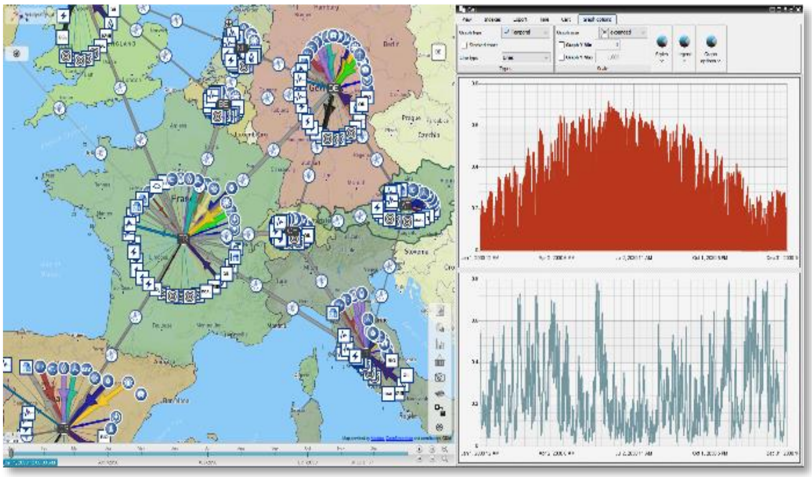


Figure 4 Artelys Crystal Super Grid

The simulations are carried out with the European multi-energy model Artelys Crystal Super Grid[12]. We use a Member State level spatial granularity and an hourly time resolution (8760 consecutive time-steps per climatic year). The model allows to jointly optimise (i) the **operational** costs of the gas and power systems over a year and (ii) the **investments** to ensure the demand can be met at the lowest

[12] https://www.artelys.com/crystal/super-grid/

possible cost. In this study, the investment options were the gas projects of the 4th PCI list and the 5 projects mentioned above.

One should note that the modelling approach used to produce the results presented in this report differs from the one used by ENTSOG in several aspects. First, we model an entire year, with all time-steps being represented, leading to different representations of climatic conditions and disruptions. Second, we use an interlinked model of the gas and electricity systems. Third, we use an investment module to select investment projects instead of performing a cost-benefit analysis of all potential projects. This allows for a better representation of the competition between infrastructure projects.

The next paragraphs describe the modelling runs to assess the resilience of the infrastructure and the assessment of infrastructure needs.

Methodology to assess the resilience of the baseline gas infrastructure

Simulations of the gas system with the baseline gas infrastructure of 2030 for an entire year are conducted to understand how the gas system behaves under normal conditions (without disruptions). Thereafter, simulations are performed over an entire year for different stress cases defined as year-long gas disruption. Three different stress cases are considered in this study: (a) disrupted transit through Ukraine routes, (b) disrupted transit through Belarus routes and (c) disrupted Algerian gas supply. These simulations aim at identifying areas with potential security of supply issues.

Methodology to assess gas infrastructure needs

The assessment of infrastructure needs is performed using two different methodologies. In both cases, the model can invest in projects from the 4th PCI list and the additional investment options listed above.

GAS ONLY APPROACH	INTEGRATED APPROACH
In the gas-only approach, the model only considers the gas system. One simulation is performed for each of the three stress cases (disruptions). The result of the simulation is the optimal investment level in each of the considered investment options.	In the integrated gas-electricity approach, the gas and electricity systems are jointly simulated when assessing gas investment needs. Furthermore, we perform a single optimization in which the three stress cases are treated simultaneously. In this approach, one benefits from synergies between the gas and electricity systems, and between regionals systems.
In order to be resilient to each stress case, we report the maximum required capacity for each investment option over the three stress cases.	By construction, the result of the integrated approach is resilient to the three stress cases.

2 Key Findings

The following sections present a detailed discussion of the key findings of the study:

- In Section 2.1, we analyse the ability of the baseline gas infrastructure to meet the demand without considering any disruption
- In Section 2.2, we assess whether disruptions may impact the ability of the gas system to meet the demand
- Finally, in Section 2.3, we assess the optimal level of investment in gas infrastructure projects enabling the system to meet the demand (including during stress episodes) at the lowest possible cost. We compare the results using two methodologies: a gas-only approach and an integrated approach that captures the interlinkages between the gas and electricity systems.

2.1 No security of supply issues in the EU under a range of future gas demand projections

The first finding of this study is that under normal conditions (i.e. without disruptions), and for 6 different climatic years, the European gas system is able to meet the gas demand levels for all EU28 countries with the baseline gas infrastructure for the two considered future gas demand scenarios (the “On Track” scenario based on the EUCO3232.5, and the “High Demand” scenario based on the 2030 snapshot of TYNDP 2018 Sustainable Transition). In the “High Demand” scenario, the European gas supply is found to increase its reliance on LNG imports.

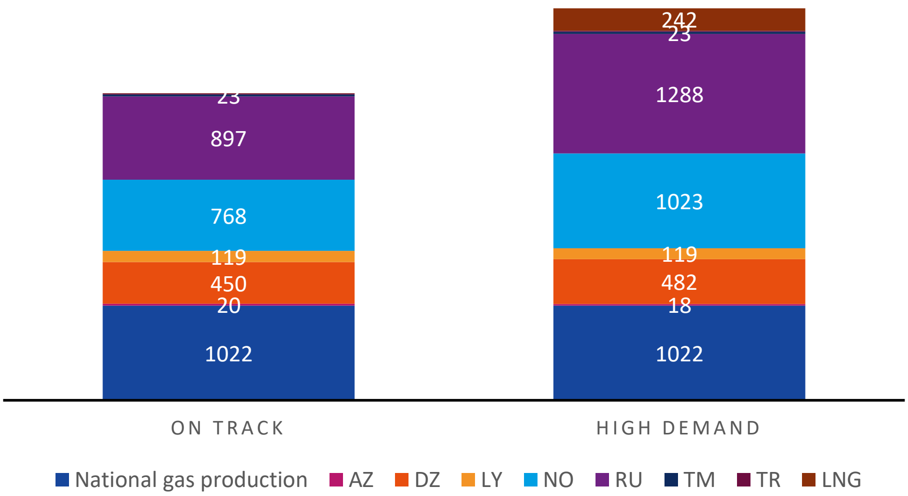
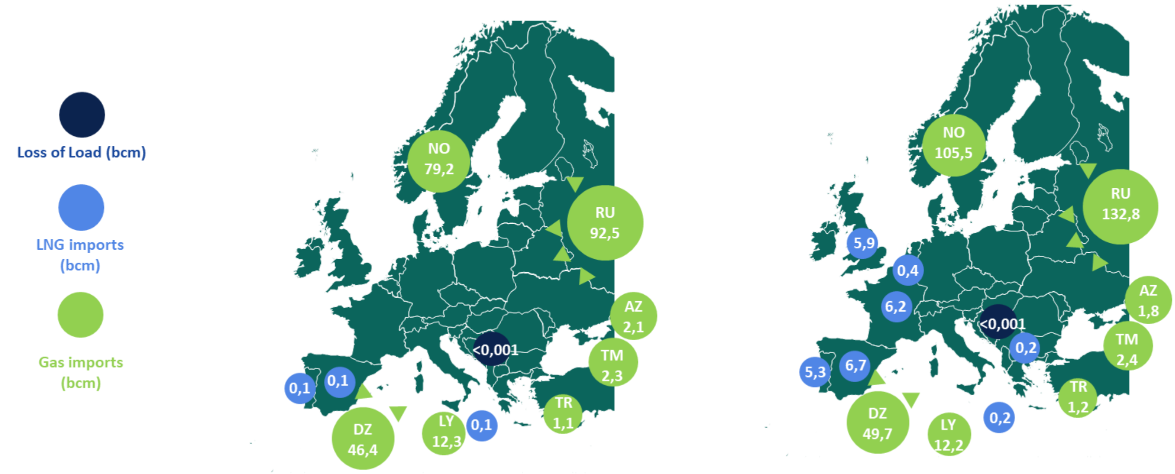


Figure 5 European gas supply in TWh under normal conditions (no disruption)

In the ”On Track” scenario, the European gas supply is mostly met by national gas production, which represents 32% share of national gas demand, against 25% in the “High Demand” scenario. Russia and Norway respectively represent 28% (and 31% for the ”High Demand” scenario) and 24% (and 25% for the ”High Demand” scenario) of the European gas supply. The imports of North African gas from Libya and Algeria are very similar in both scenarios, around 60 bcm/year. The LNG share in the total gas demand is relatively low for the ”On Track” scenario (0.3 bcm) against 25 bcm for the “High Demand” scenario.

The maps shown in Figure 6 depict the imports from the various available sources under normal conditions. These situations will be used as a reference to which the situations in the case of disruptions are compared in the following sections of this report. All subsequent maps will present the differences between the considered stress case and the situation shown below.



Scenario	EUCO3232.5 On track	TYNDP18 ST 2030 High demand
Total gas imports	238 bcm	330 bcm

Figure 6 Imports in normal conditions for the two considered scenarios

Finally, in the ”On Track” scenario, and outside the EU28, the model finds that small amounts of loss of load appear under normal conditions (i.e. without disruptions) in Bosnia-Herzegovina: this is due to congestion in the Serbia – Bosnia pipeline, limiting imports from the rest of SEE to Bosnia-Herzegovina.

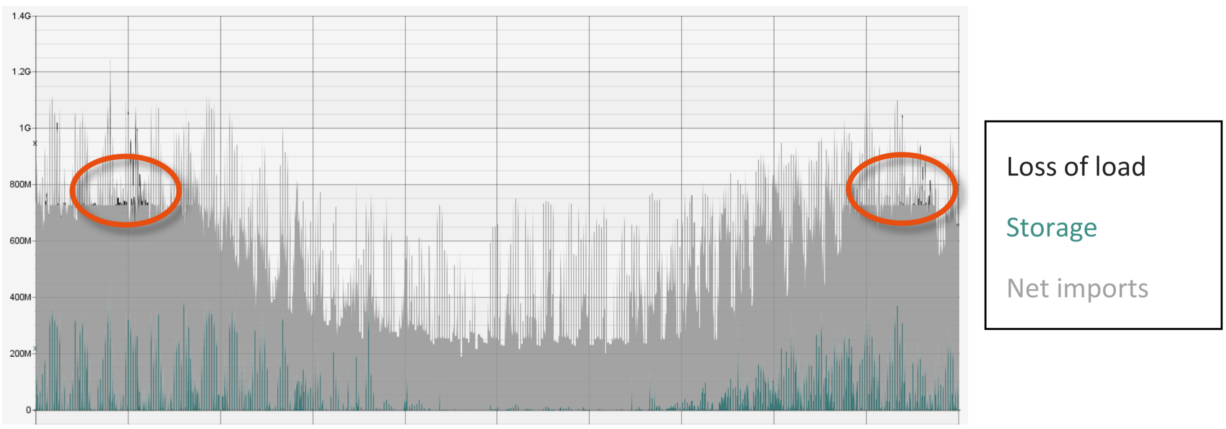


Figure 7 Gas supply sources in Bosnia Herzegovina in normal conditions for a given climatic year - *On track* scenario

2.2 Gas infrastructure in Europe is resilient to major disruptions

In Section 2.1 we have shown that there are no security of supply issues in the EU under normal conditions (without disruptions). The second step of the analysis is to test the 2030 baseline gas infrastructure by considering 3 stress cases representing 3 major gas disruptions of the European gas supply (selected on the basis of the 2016 study), namely:

- Ukrainian gas routes disruption for an entire year
- Belorussian gas routes disruption for an entire year
- Algerian gas imports disruption for an entire year

This analysis highlights the resilience of the European baseline gas infrastructure over these 3 major disruptions. In case of major disruption in Ukraine, Belarus or Algeria, the gas imports are found to be either re-routed or adapted in order to meet the demand. The utilisation rate of existing gas routes, and the possible diversification of imports through existing LNG terminals are found to be sufficient to compensate for the adverse effects caused by the disruptions. In the following sections, we present detailed results for each of the considered disruptions, with deep dives on selected areas to illustrate the findings.

2.2.1 Ukraine gas disruption

The first disruption we have considered is the unavailability of all transit routes through Ukraine. Figure 8 shows how the European gas system reacts to this disruption. The key result is that if imports from Ukraine were disrupted for an entire year, the 2030 baseline gas infrastructure would be resilient, with no additional loss of load compared to the case without disruption.

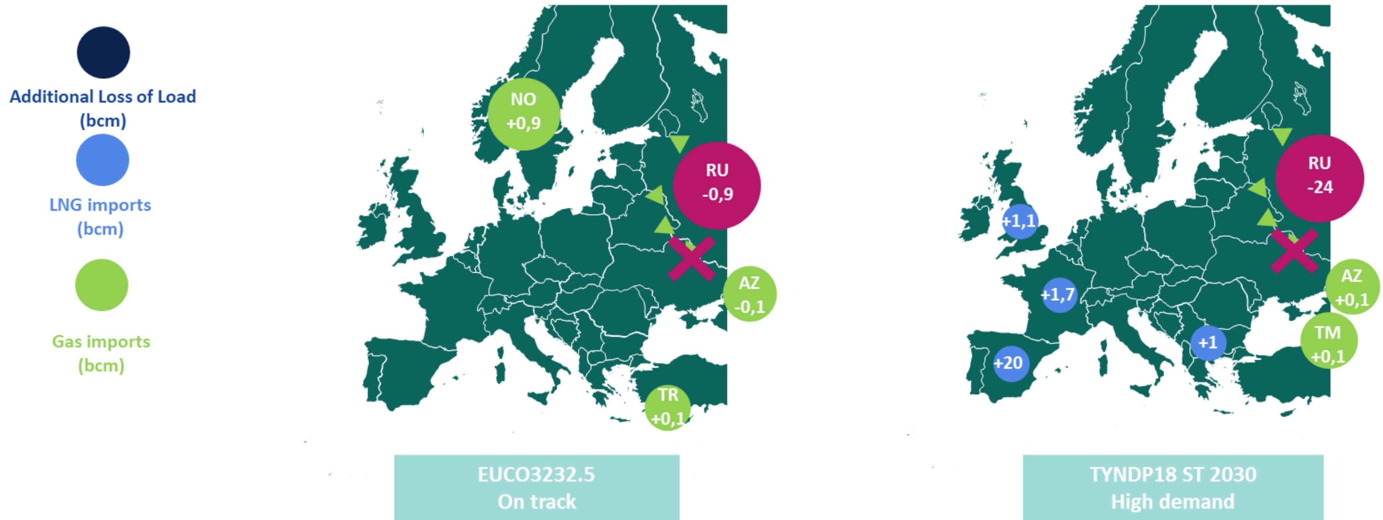


Figure 8 Change in gas imports and loss of load in the Ukraine disruption case compared to the case without disruption

In the "On Track" scenario, additional imports from Norway are used to compensate the unavailability of pipelines from Ukraine, to deliver Russian gas to the EU. Almost no additional imports, +0.9 bcm, are used, as Russian gas is mainly found to be re-routed through alternative gas routes.

As shown by Figure 9, the utilisation rates of pipelines increase in the disrupted region. Russian gas uses different routes to supply Western Europe. To compensate for the unavailability of the Ukraine – Slovakia pipeline, Poland and Czech-Republic both export more gas towards Slovakia. Exports from Germany to Central Europe is found to increase, partly thanks to the increase in Norwegian imports towards Germany.

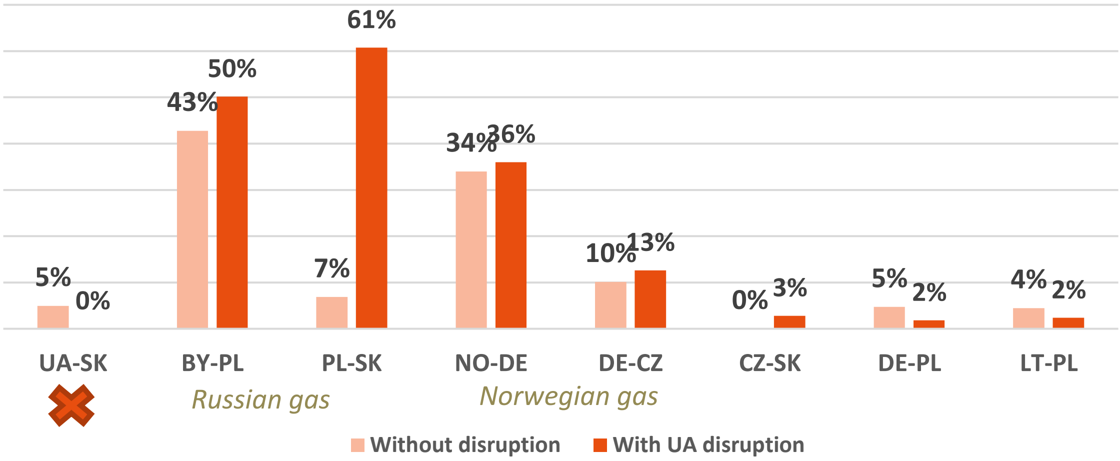


Figure 9 Utilisation rates of pipelines in case of Ukrainian disruption - *On track* scenario

In the ”High Demand” scenario, the European gas system is already under more stress since the overall gas demand is higher than in the ”On Track” scenario. As a consequence, the disrupted Ukrainian routes result in a bigger decrease of Russian imports (-24 bcm) which cannot be compensated with additional Norwegian imports, as these already reach the considered maximum capacity in the case without disruption. LNG terminals in Western Europe, which have low utilization rates in the case without disruption, are found to increase their imports in order for the system to be able to meet the demand.

Deep dive on Italy

In the “On Track” scenario, Italy is found not to be impacted by the Ukrainian route disruption as it can continue to import gas from Austria. However, in the “High Demand” scenario, Austria is found to have to reduce its export to Italy by around 200 TWh. As a consequence, Italy is found to import more gas from Algeria.

These additional imports from Algeria to Italy in turn reduce the availability of Algerian gas for Spain. This causes Spain to rely on its LNG terminals to compensate for the gas that they would have imported from Algeria in a case without disruption.

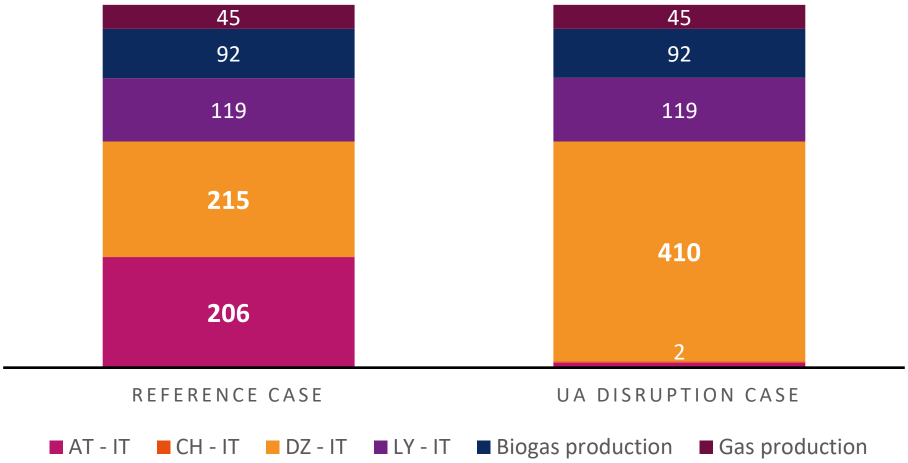


Figure 10 Italian gas supply in TWh - *High demand* scenario

2.2.2 Belarusian gas disruption

The second disruption we have considered is the unavailability of all transit routes through Belarus. Figure 11 shows how the European gas infrastructure reacts to this disruption. The key result is that if imports from Belarus were disrupted for an entire year, the 2030 baseline gas infrastructure would be resilient, with no additional loss of load compared to the case without disruption.

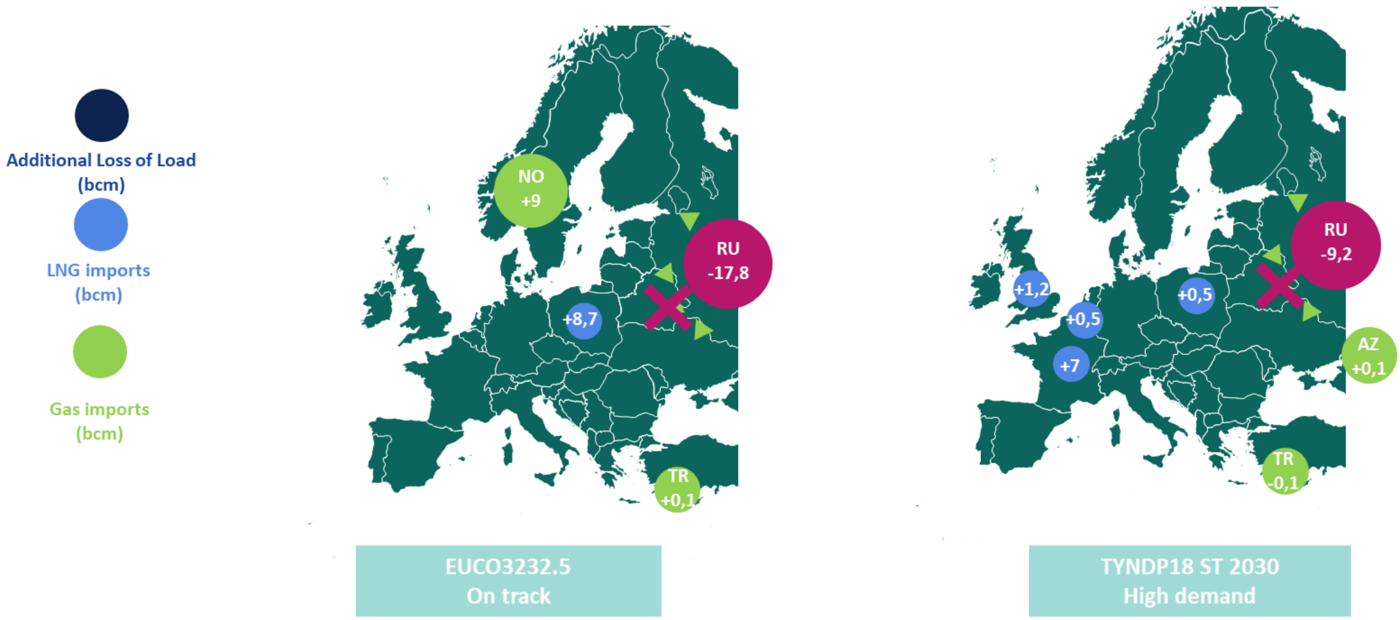


Figure 11 Additional gas imports and loss of load in the Belarusian disruption case compared to the case without disruption

In the "On Track" scenario, the Belarusian disruption causes Russian gas imports to decrease. Norway is found to react by increasing its export levels, which appear to be the optimal solution – *when available* – to overcome the disrupted routes in Belarus for Russian gas. However, re-routing Norwegian gas to enable the supply of Western Europe has to be combined with an increase of LNG in Poland in order for the system to meet the gas demand.

In the "high demand" scenario, as Norwegian imports are already reaching the considered maximal capacity in the case without disruption, it is no longer possible to use this alternative supply source. In such conditions, the model is found to be increasing LNG imports, especially in France and in the UK (+7 bcm in France, +1.2 bcm in the UK).

In both scenarios, the routes from Germany, Czech Republic and Slovakia to Poland are necessary both for Poland and Lithuanian supply who directly suffer from the Belarusian disruption, as shown by the increase in the utilisation rates of these pipelines that can be seen on Figure 12.

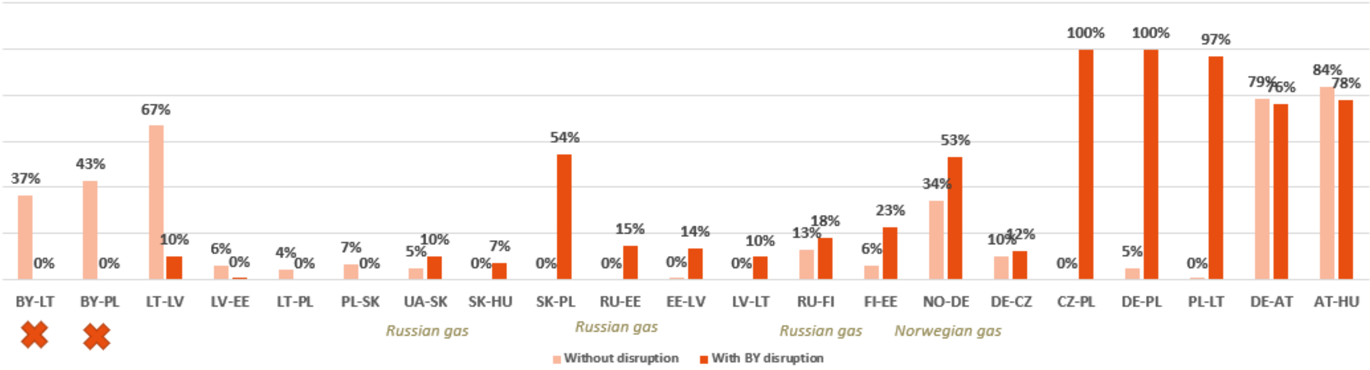


Figure 12 Utilization rates of pipelines in case of Belarusian disruption - *On track* scenario

Deep dive on Poland

In the "On Track" scenario, the gas supply in Poland is significantly impacted by the disruption of the Belarusian gas import routes. Indeed, in the case without disruption, Poland was highly dependent on Russian gas supplied through Belarusian pipelines. When this route is disrupted, the 2030 baseline gas infrastructure reroutes Russian and Norwegian gas. Germany increases its exports towards Poland by 81 TWh, Czech-Republic by 10 TWh, and Slovakia by 34 TWh compared to the case without disruption. Furthermore, LNG imports increase in Poland in order to enable export towards Lithuania which was also relying on Belarusian routes in the case without disruption.

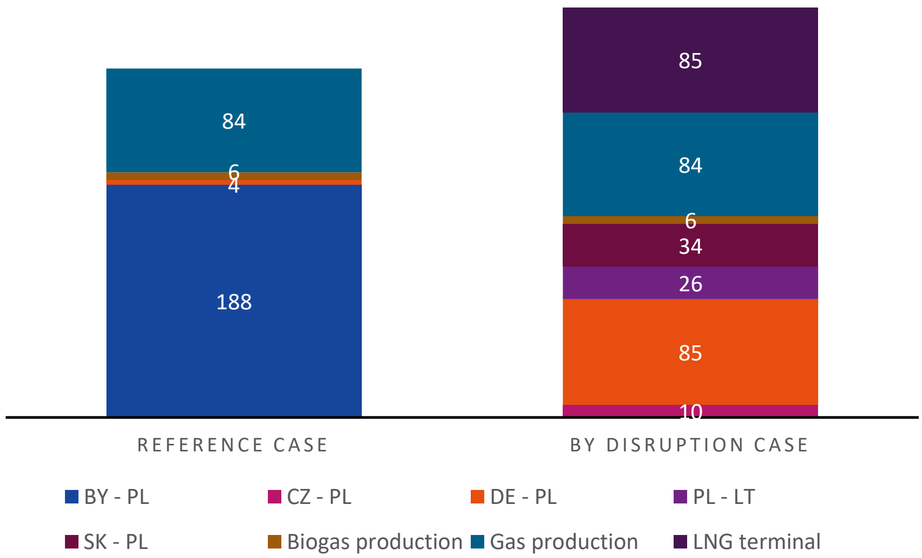


Figure 13 Poland gas supply in TWh – *On track* scenario

2.2.3 Algerian gas disruption

The third and final disruption we have considered is the unavailability of import from Algeria. Figure 14 shows how the European gas infrastructure reacts to the disruption of Algerian gas supply. The key result is that if imports from Belarus were disrupted for an entire year, the 2030 baseline gas infrastructure would be resilient, with no additional loss of load compared to the case without disruption.

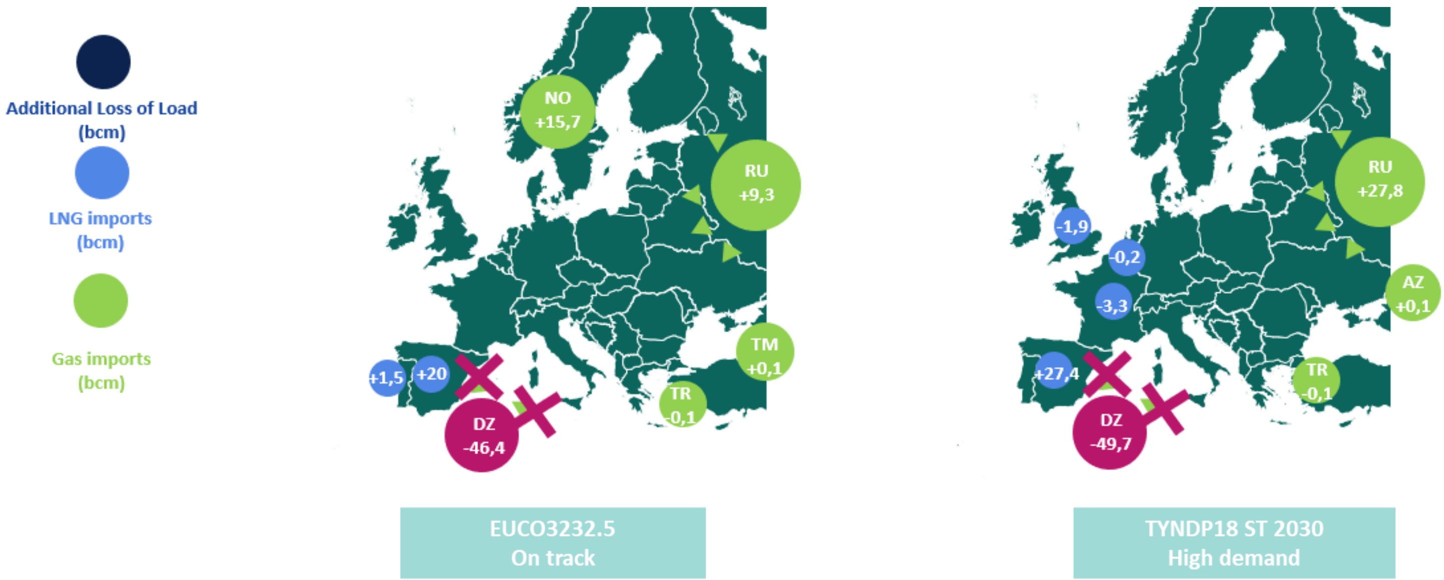


Figure 14 Additional gas imports and loss of load in the Algerian disruption case compared to the case without disruption

The most important impacts of the Algerian disruption are to be found in the supply of Western European countries, which were heavily relying on Algerian imports. Spain and Italy are found to be the most impacted due to their significant use of Algerian gas in the case without disruption. As shown on Figure 15, the diversity of existing routes and LNG imports enables the European gas system to face the Algerian imports disruption.

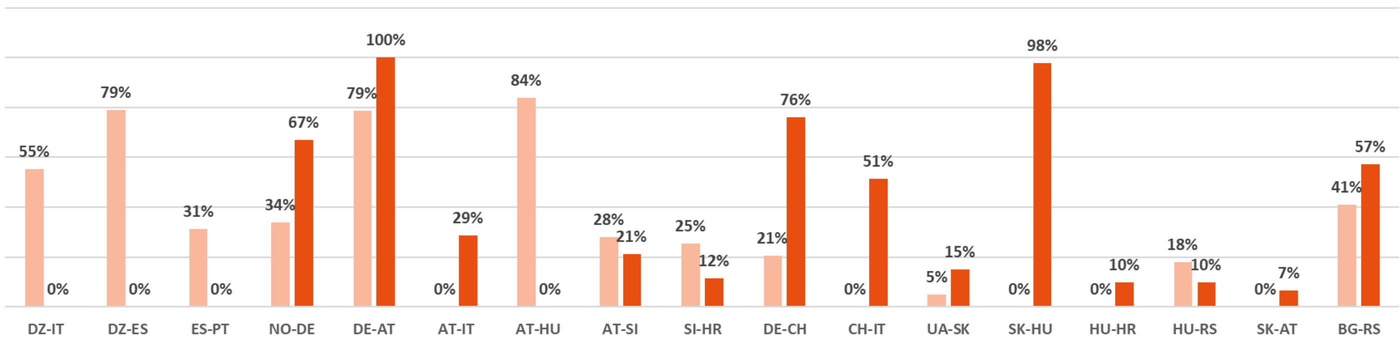


Figure 15 Utilisation rates of pipelines in case of Algerian disruption - *On track* scenario

In the “On Track” scenario, Spain and Portugal are found to replace Algerian gas imports by increasing their respective LNG imports, while Norway (+15.7 bcm) and Russia (+9.3 bcm) increase their exports towards Europe. In the “High Demand” scenario, the important increase of LNG imports in Spain impacts the LNG market, which induces countries as France and the United Kingdom to reduce their LNG imports and to rely slightly on Russian gas imports.

Deep dive on Italy

Italy, which is directly impacted by the Algerian disruption, manages to compensate the loss of Algerian gas supply by increasing its imports from Austria and Switzerland. Austria increases its exports to Italy by 120 TWh (“On Track”) and 203 TWh (“High Demand”), as shown on Figure 16. To do so, Austria increases its gas imports from Germany and Slovakia.

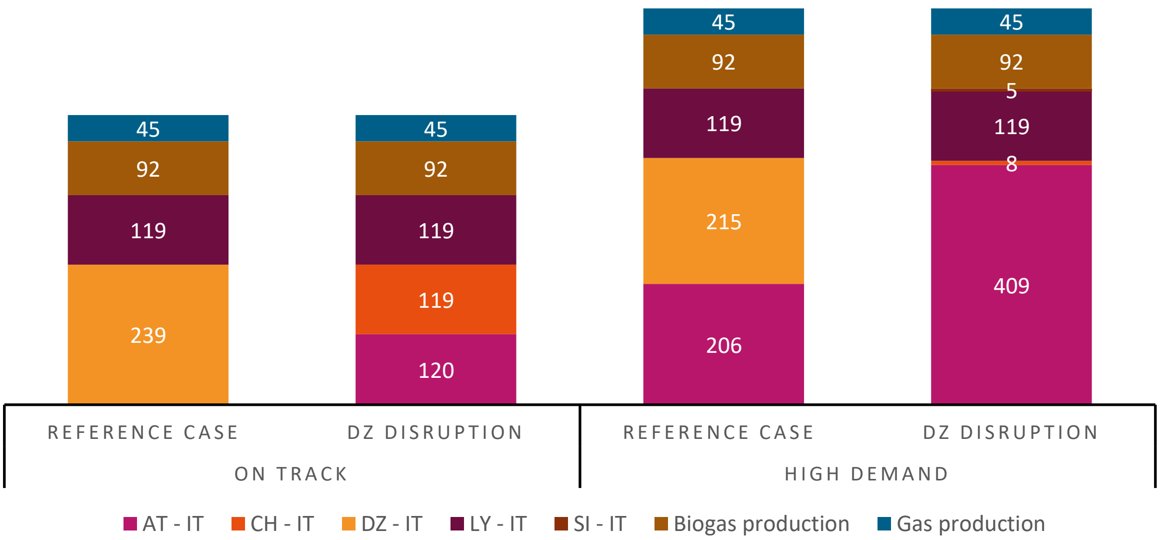


Figure 16 Italian gas supply in TWh

Deep dive on the Iberian Peninsula

In the ”On Track” scenario, Spain has to rely on its LNG terminals (+20 bcm) since France can only marginally increase its exports to Spain. In turn, Spain is found to stop its exports to France and Portugal. In the case without disruption, Portugal was relying on the ES – PT pipeline conveying Algerian gas from Spain: around 86 % of the total Portugal gas demand was supplied by Spain (Figure 17). When the Algerian imports are disrupted, Portugal is found to increase its LNG imports.

In the ”High Demand” scenario, Portugal was almost entirely relying on its LNG terminals, as the total gas demand is significantly higher in this scenario compared to the “On Track” scenario (e.g. 54 TWh vs 18 TWh in Portugal). Therefore, the disruption does not significantly impact the gas supply for Portugal, as can be read on Figure 17.

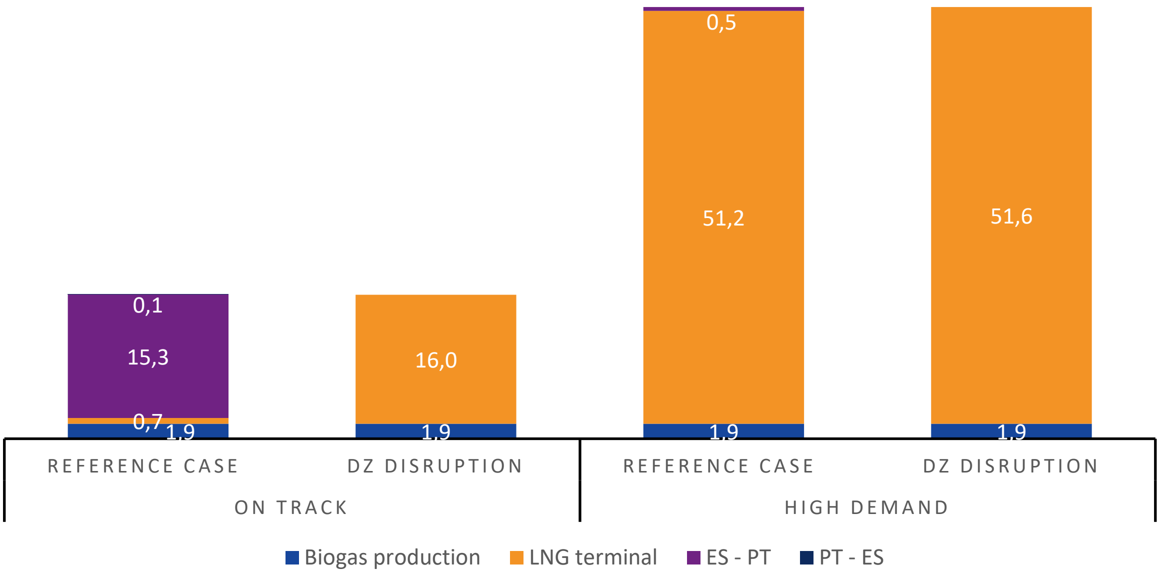


Figure 17 Portugal gas supply in TWh

As in the “On Track” scenario, Spain is found to significantly increase its LNG imports (+27.4 bcm).

2.3 Assessment of investments needs

In Section 2.2, we have found that Europe's 2030 baseline gas infrastructure is resilient to the considered disruptions both in the "On Track" and "High Demand" scenarios (no additional loss of load in the disruption cases compared to the case without disruption). In other words, potential security of supply concerns related to the disruptions considered herein do not induce the need to invest in projects of the 4th PCI list.

Therefore, additional gas projects are found to be economically relevant only if they either solve the security of supply issues that are present in Bosnia-Herzegovina in the case without disruption or if they allow to reduce the overall cost of supply by e.g. enabling imports from cheaper sources.

In the following paragraphs, we compare the investments that are found to be economically relevant using two approaches: the first one uses a gas-only approach, while the second one uses an integrated approach (see Section 1.5).

2.3.1 Gas-only approach

As described in Section 1.5, the gas-only approach considers potential investments in gas infrastructure projects without taking into account the potential role the interactions between gas and electricity could play. In other words, we are looking at gas solutions to solve gas problems, disregarding the potential contributions of other solutions.

In this case, the model finds economically relevant to invest in 4.5 GW ("On Track" scenario) and 11.1 GW ("High Demand" scenario) of additional capacity in gas infrastructure. In both cases, these investments correspond to an **overall investment cost of around 2.9 B€**. The analysis shows that even in cases of extreme supply disruptions, the investments represents only **10%** of the total 4th PCI portfolio total investment cost.

Since the model can choose not to invest in the total capacity of a project (the total capacity is the maximum the model can invest in), it may be that only a fraction of some of the projects are found to be economically relevant. When disregarding the investments that do not reach a threshold of 10% of the project capacity, only **4 PCIs** are found to be relevant out of the 32 PCIs included in the 4th list.

In the gas-only approach, the investments that are found to be economically relevant are[13]:

- Interconnector between Romania and Hungary (PCI 6.24.4) of +0.6 bcm/y ("On Track" scenario) and +4.7 bcm/y ("High Demand" scenario), mostly to remove the congestions and to enable Romania to export its national production to the rest of Europe.
- Pipeline between Serbia and Bulgaria (PCI 6.8.3) of +0.6 bcm/y ("On Track" scenario) and +0.7 bcm/y ("High Demand" scenario). This reinforcement enables Bulgaria to increase its exports to Serbia, which can export to Bosnia-Herzegovina, which was suffering from loss of load in normal conditions (see Section 2.1). The reduction of loss of load in Bosnia-Herzegovina is one of the benefits generated by the investment in infrastructure reinforcement.
- EastMed pipeline between Cyprus and Greece (PCI 7.3.1), where the reinforcement is +2.3 bcm/y. This project is selected mostly to enable potential natural gas export from Cyprus towards the rest of Europe.
- The Krk LNG terminal (PCI 6.5.1), but at a very low level compared to its maximum capacity (around 1 mcmLNG/y in the "On Track" scenario and 3.5 in the "High Demand" scenario out of a maximum of 15 mcmLNG/y).

These investments are shown on the following figure:

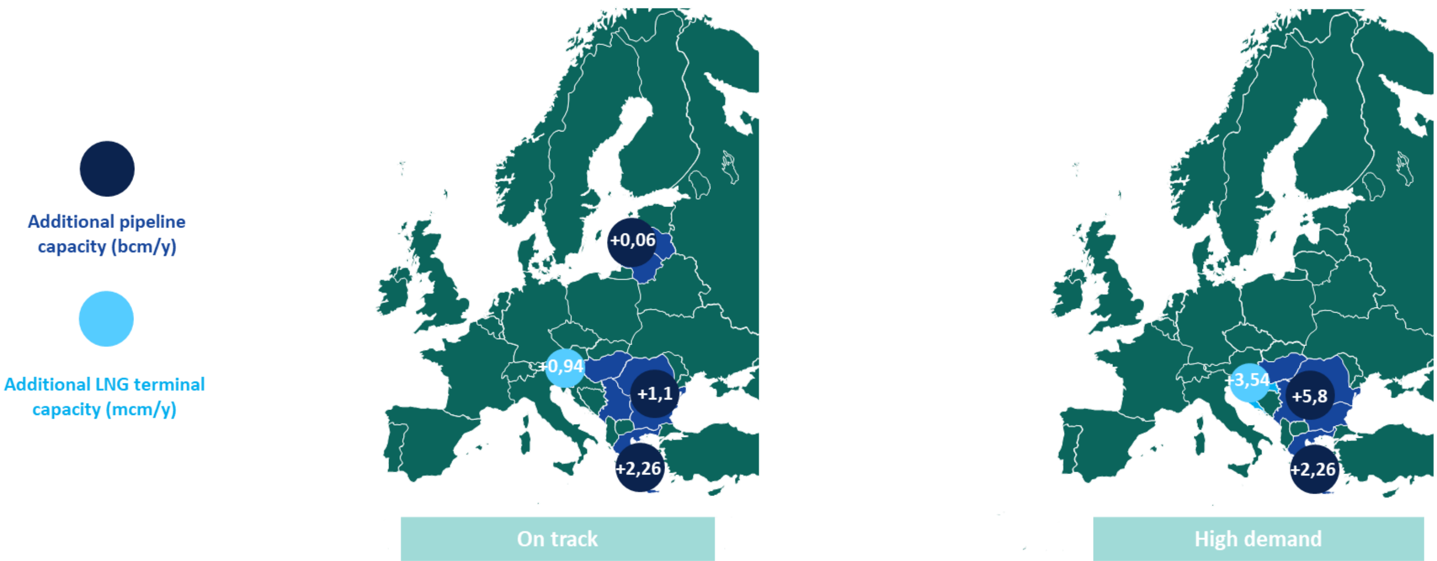


Figure 18 Gas infrastructure investments – Gas-only approach

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[13] The reinforcement of the Lithuania – Latvia pipeline is below the threshold of 10%. We therefore disregard this project.

2.3.2 Integrated approach

In an integrated approach, the model considers investments in gas infrastructure by also considering the flexibility that is brought by the electricity system. As the flexibility of the electricity sector is competing with new gas projects, the investments found in an integrated approach are structurally lower than in a gas only approach.

In this case, the model finds economically relevant to invest in 2.8 GW (“On Track” scenario) and 4 GW (“High Demand” scenario) of additional capacity in gas infrastructure. In both cases, these investments correspond to an **overall investment cost of around 2.8 B€**.

When, in a similar way as in the gas-only approach, one disregards investments not reaching a threshold of at **least 10%** of the project capacity, only **2 PCIs** are found to be relevant out of the 32 PCIs included in the 4th list.

In the integrated approach, the investments that are found to be economically relevant are much lower:

- EastMed pipeline between Cyprus and Greece (PCI 7.3.1), where the reinforcement is +2.3 bcm/y. This project is selected mostly to enable potential natural gas export from Cyprus towards the rest of Europe.
- The Krk LNG terminal (PCI 6.5.1), but at a very low level compared to its maximum capacity (around 2.5 mcmLNG/y in the “High Demand” scenario out of a maximum of 15 mcmLNG/y).

These investments are shown on the following figure:

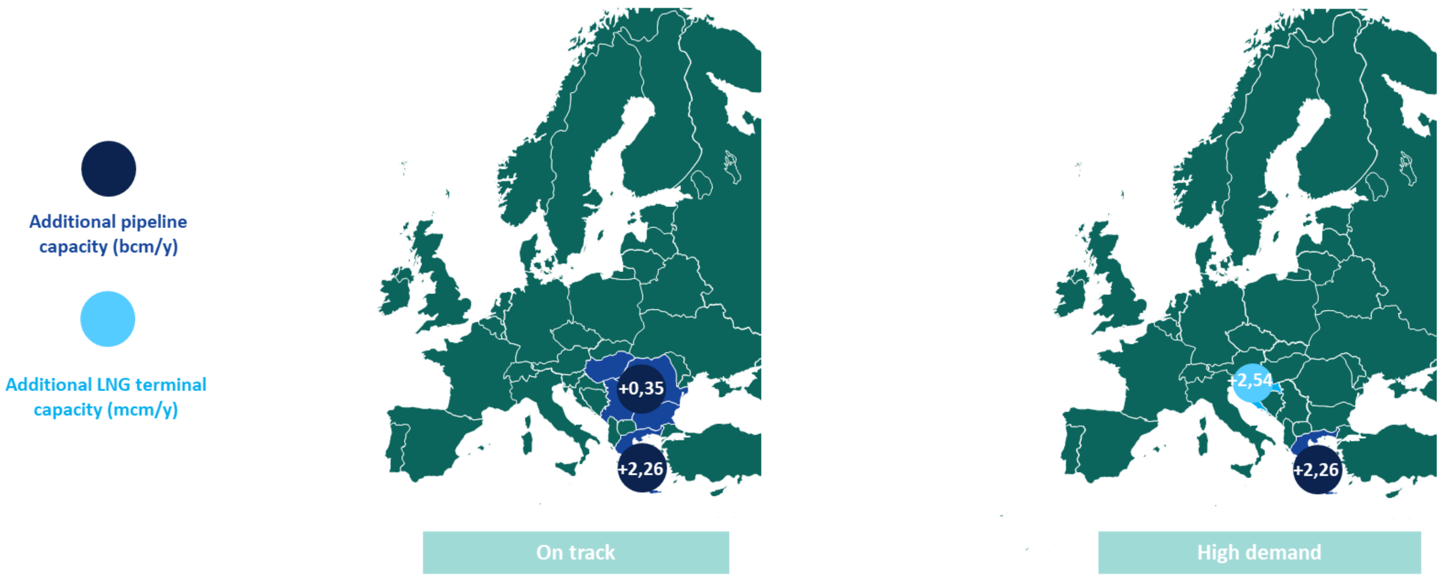

Figure 19 Gas infrastructure reinforcement – Integrated approach

Figure 21 and Figure 20 provide an overview of the investments in gas infrastructure projects, in both approaches for both scenarios.

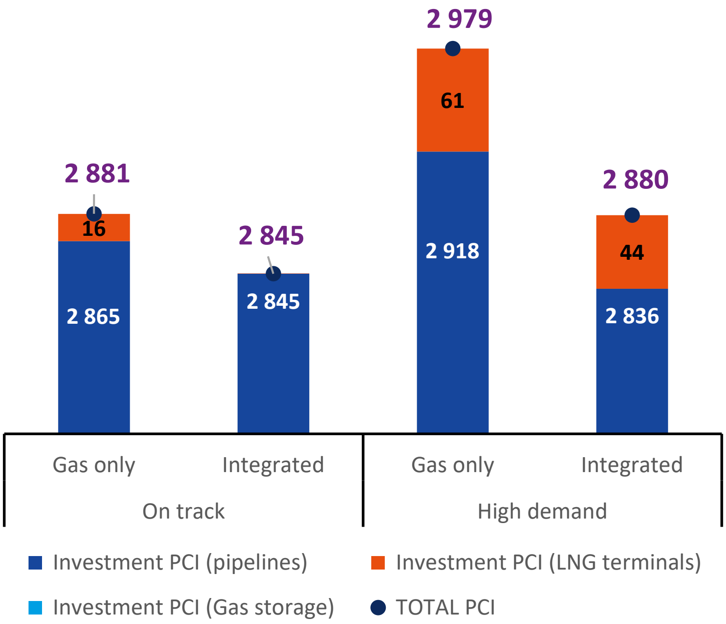

Figure 20 Overview of costs in M€ - 4th PCI list

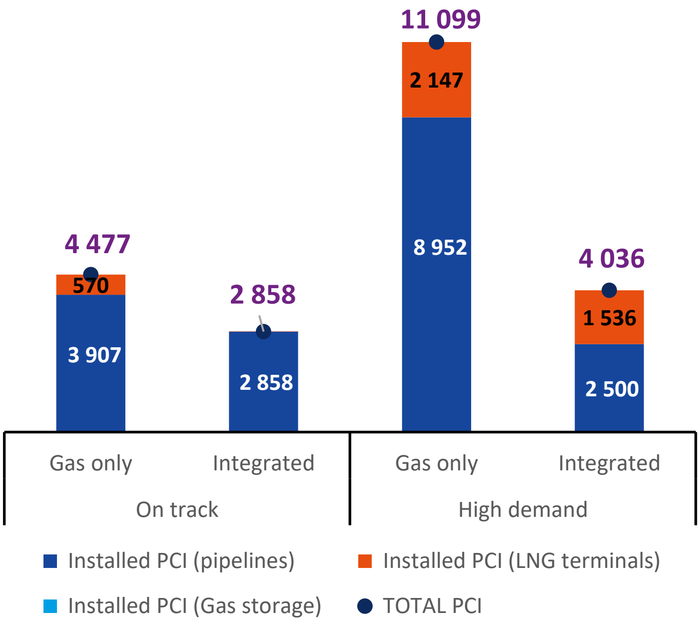

Figure 21 Overview of installed capacity in MW - 4th PCI list

In summary, the reinforcement of the gas infrastructure is not motivated by security of supply concerns arising from stress cases, but by security of supply concerns out of EU28 that were already present in normal conditions (see Section 2.1) and by cost reduction opportunities. As in the 2016 study, this analysis demonstrates the benefits of looking jointly at the gas and electricity system in an integrated approach, which reduces the need for additional infrastructure by selecting cost-effective solutions taking advantage of the interlinkages between both systems.

3 Annex – Key Assumptions

The results presented in Section 2 rely on a European multi-energy modelling framework, Artelys Crystal Super Grid, with a country-level spatial granularity and an hourly time resolution. The model allows to jointly optimize operational costs of the gas and power systems over a year, and the investments in a portfolio of investment candidates (gas infrastructure projects, see below). Each country is represented by a node with its own energy production and consumption, linked to neighbouring countries using interconnectors: pipelines (the gas system) or transmission lines (electricity system). The optimization ensures the balance between supply and demand is met at each time step for each node, without taking into account national internal market constraints. The simulation is carried out by minimizing the overall costs associated to the system, that is to say the sum of all production costs, imports, cross-border exchanges, fuel costs, CO2 emissions costs, investments in new infrastructure projects, and penalties for the volume of loss of load (in case supply for a country could not meet the demand).

As mentioned above, Artelys Crystal Super Grid is able to jointly optimise operations and investments, without simplifying the problem (i.e. keeping an hourly time resolution for the whole year). The investment decision takes into account the investment expenditures, the operational expenditures, as well as the production cost savings linked to the use of the considered investment options.

The approach designed for this study is to let the model optimize the installation of projects of the 4th PCI list and additional projects (see below), to understand whether or not it would be relevant to reinforce the European gas infrastructure in 2030 from an economic point of view.

3.1 Description of the methodology

The model includes EU28 countries, and the non-EU ENTSOG countries: Bosnia-Herzegovina, Switzerland, Macedonia and Serbia.

This model is based on Artelys Crystal Super Grid and takes into account the following assets, aggregated at the national level:

- **Gas system**: LNG terminals, gas production, pipelines, storage and demand response
- **Electricity system**: Power generation portfolio (including gas-based generation), interconnections and storage

3.1.1 Different stress cases

The simulations include 3 major disruptions (called “stress cases”) of the European system, to test how resilient the system is with and without new infrastructure. The 3 stress cases are:

- Simulation of a gas disruption from Ukraine transit: the gas can no longer be transported through Ukrainian pipelines.

- Simulation of a gas disruption from Belarusian transit: the gas can no longer be transported through Belarusian pipelines.
- Simulation of a gas disruption from Algeria: the gas imports from Algeria are interrupted for a whole year.

The model is also tested and optimized over 6 different climatic years (including a cold year based on 2012 temperatures) to ensure results are robust to temperature variations. The climatic years impact the gas and electricity demands (via a thermo-sensitivity analysis of the load, and RES production profiles).

3.1.2 Different strategies

Two investment strategies are compared in order to assess the need for additional gas infrastructure, in particular to ensure demand can be met during the disruptions mentioned above:

- The first approach is a **“gas-only” approach** where only the European gas system is considered. To face security of supply issues, the model can increase the pipeline connectivity, the gas storage capacity or the LNG terminals capacity. The gas-only analysis is conducted independently for each stress case, and the final results combine the maximum required capacity for each stress case. This ensure that the system is able to face any of the situations considered in the stress cases.
- The second approach is a coordinated **integrated approach** where both the electricity and gas systems are considered. This allows for a much better representation of the flexibility offered by the electricity system, which may result in lower amounts of gas infrastructure needs: the gas demand for electricity production (e.g. CCGTs, OCGTs, CHPs) is a source of flexibility that “competes” with investment options in gas infrastructure.

These simulations allow for an identification of the impact of considering solely the gas flexibility or the combined gas and electricity flexibilities when assessing infrastructure projects. Since a wide variety of futures were considered, the simulations also bring to light the main economic drivers for each infrastructure’s investments, and which investments are more robust to variations of the economic/energy context. For each scenario, the electric portfolio contains a different share of renewable capacities, as is shown on Figure 22.

The model includes gas-based power generation assets, which makes both electric and gas systems interdependent.

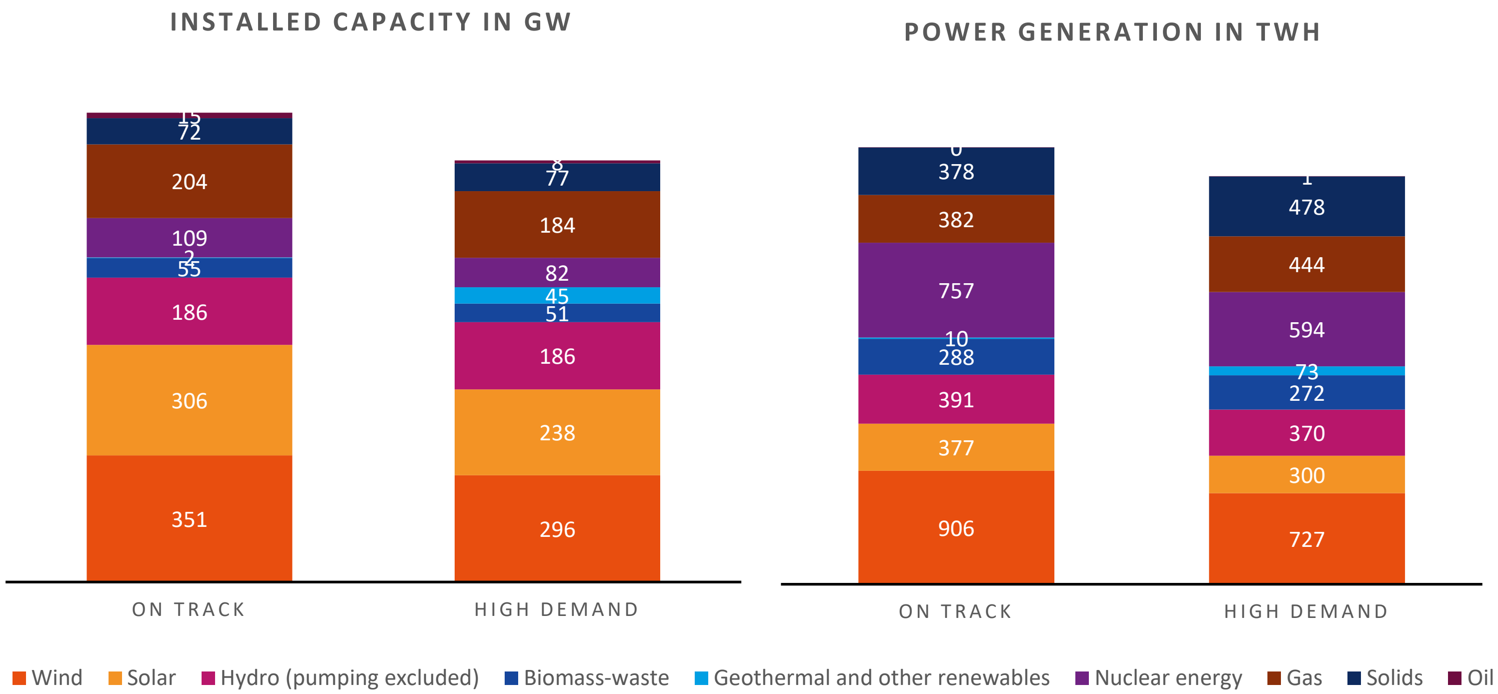

Figure 22 Electric European mix for both scenario (2030)

3.1.3 Gas supply

For this study, the European gas supply is divided between imported natural gas, imported LNG, and national production. Imported natural gas supply was ensured by 7 countries outside the EU: Russia, Norway, Azerbaijan, Algeria, Libya, Turkmenistan and Turkey. The maximum available stock is dimensioned as per the "MAX" scenario of TYNDP 2018 as shown in Figure 24.

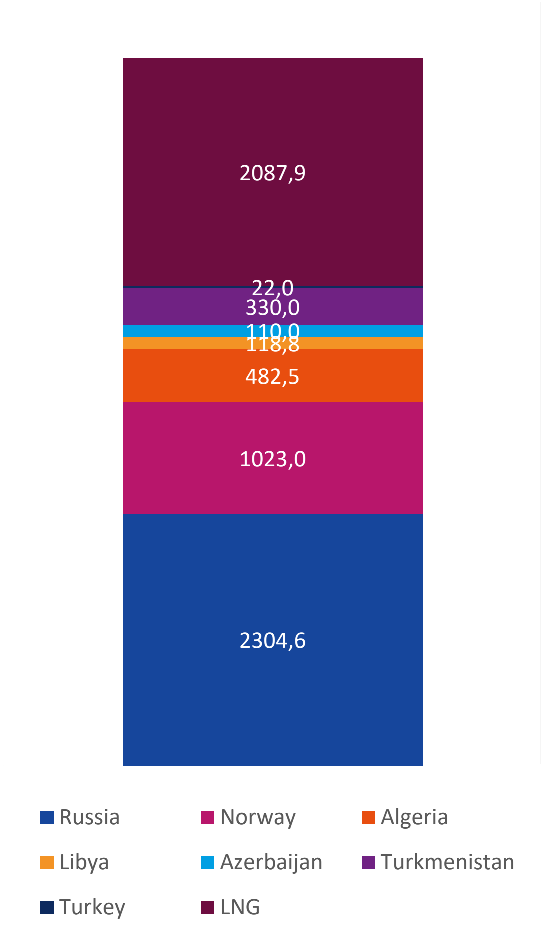

Figure 24 European gas imports in TWh

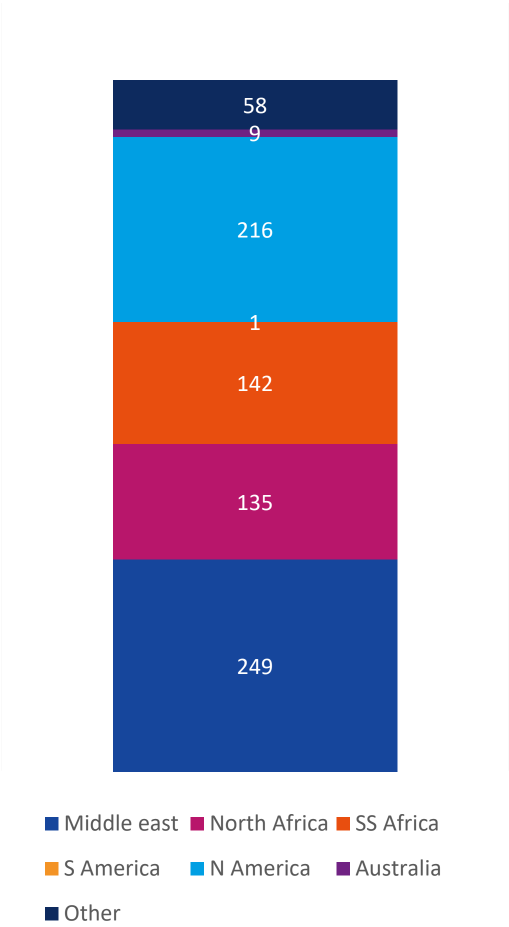

Figure 23 European LNG imports in TWh

LNG imports are supplied by 6 main regions: North and Sub-Saharan Africa, North and South America, Australia, Middle East. The maximum available stock is dimensioned as per illustrated in the "MAX" scenario of the TYNDP 2018 as shown in Figure 23. Finally, we have considered a value of lost gas load of 3000 €/MWh.

3.2 Network assumptions and description of the European gas system

The European gas infrastructures is modelled according to the topology used in the TYNDP 2018 process for the year 2030. The set of infrastructure refers to existing, and planned infrastructure for 2030, with the capacities published by ENTSOG. The level selected for this study is the “Low” level, which we have called the baseline gas infrastructure. It consists of the existing infrastructure to which projects having reached Final Investment Decision status are added. The “Low” level is the minimum level of infrastructure considered in TYNDP 2018.

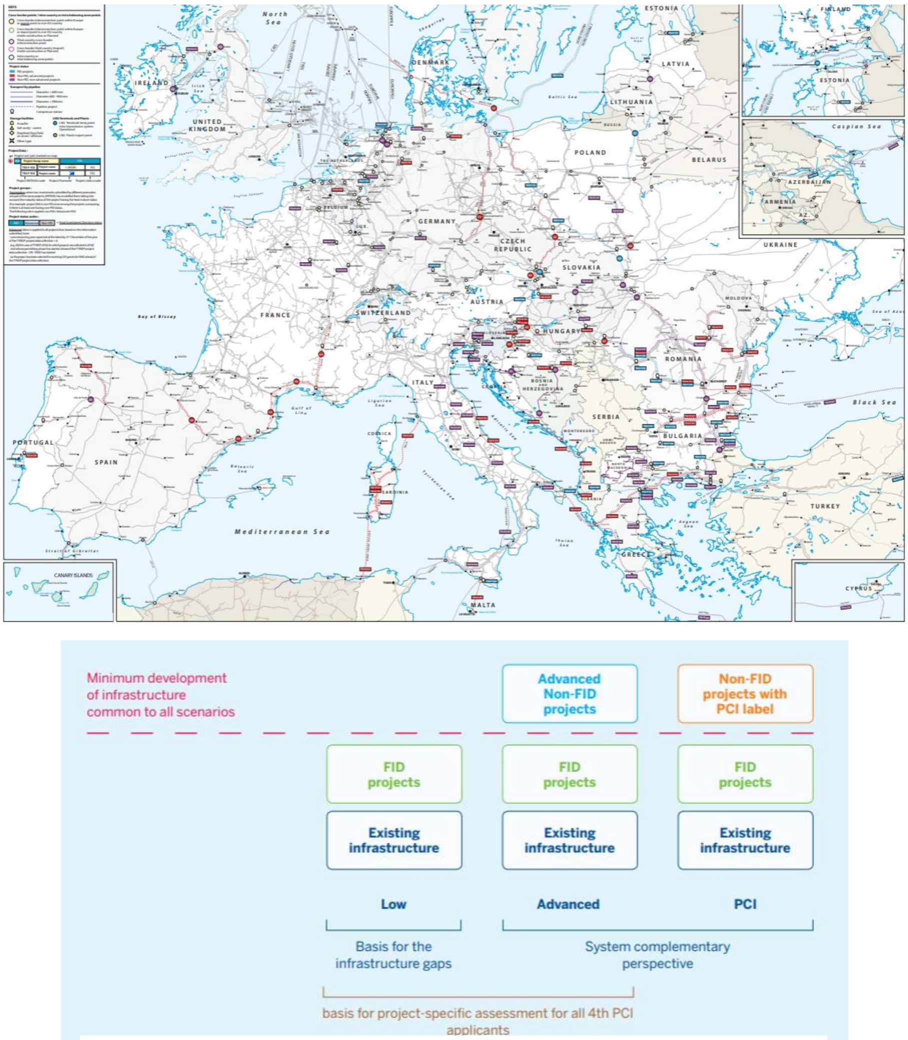

Figure 25 TYDNP 2018 infrastructure level

3.2.1 Description of the 4th PCI list

This study focuses on the gas projects of the **4th PCI list**[16] published by the European Commission in November 2019. The list contains **32 projects** amongst which **23 pipelines projects**, **4 underground storage facilities** and **5 LNG terminals** for a total investment CAPEX of **29 billion €** and around 338 GW of additional capacity. 30 out of the 32 projects were already part of the 3rd PCI gas list.

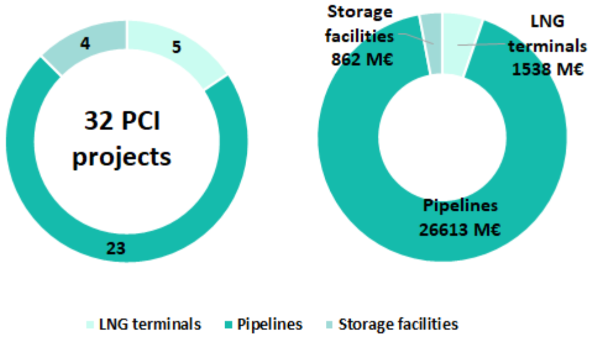

Figure 26 Description of the 4th PCI list projects

The projects from the 4th PCI list are investment options. The model is allowed to invest in these projects, provided that paying for the associated CAPEX and OPEX of the project is at least compensated for by the benefits brought by the project (security of supply, lower-cost sources, etc.). Additional investment options are also added to the list:

- Pipelines: Nord Stream 2, White Stream and the Interconnection Turkey – Bulgaria
- LNG terminals: Wilhelmshaven and Brunsbüttel

The figure below summarizes the overall capacity of both PCI projects and investments options, compared to the 2030 gas baseline infrastructure:

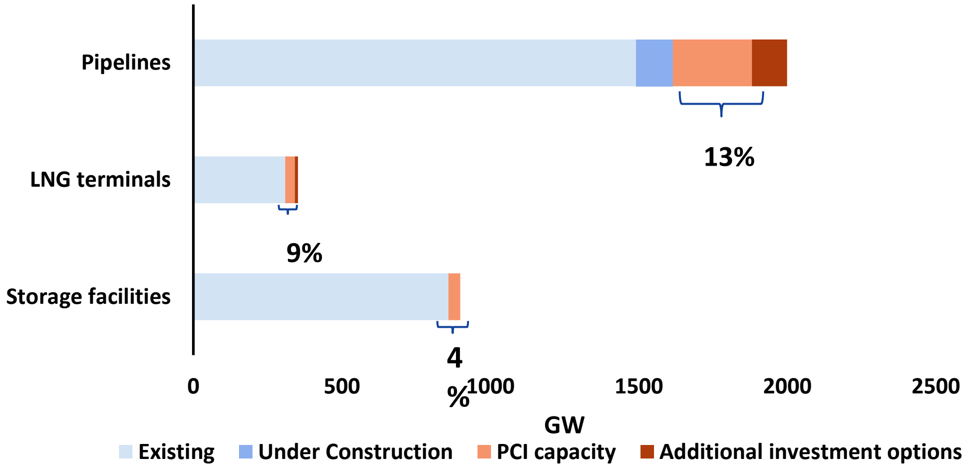

Figure 27 Overall capacity for potential investments (4th PCI list and options)

[16] European Commision. (2019). *UNION LIST OF PROJECTS OF COMMON INTEREST.*

Key characteristics of PCI investment options:

PCI PROJECT NUMBER	TYPE	COUNTRY	MAXIMAL CAPACITY IN 2030 (GWH/D)	STORAGE CAPACITY (LNG) [M3 LNG]	INJECTION RATE [MCM/D]	WITHDRAWAL RATE [MCM/D]	STORAGE CAPACITY (UGS) [MCM]	COMMON NAME
5.3	LNG terminal	IE	86	200000				Shannon
6.27	LNG terminal	PL	138	160000				FSRU Polish Baltic Sea Coast
6.5.1	LNG terminal	HR	220	160000				Krk
6.9.1	LNG terminal	GR	253	170000				Alexandroupolis
7.5	LNG terminal	CY	76	125000				Cyprus Gas2EU
6.20.2	UGS	BG			5	5	450	Chiren expansion
6.20.3	UGS	GR			5	4	360	South kavala
8.2.4	UGS	LV			38	82	2490	Incukalns
6.20.4	UGS	RO			3	3	300	Depomures
6.20.6	UGS	RO			4	3	650	Sarmasel
5.19	Pipeline	IT - MT	112					
5.21	Pipeline	BE -FR	230					
6.2.1	Pipeline	PL -SK	318,46					
6.2.13	Pipeline	HU - SK	128					
6.23	Pipeline	HU - SI	123,4					
6.24.4	Pipeline	HU - RO	406,49					ROHUAT/BRUA
6.26.1	Pipeline	AT - HR - SI	569,207					
6.5.5	Pipeline	HR - HU	13,6					
6.8.1	Pipeline	BG - GR	300					IGB
6.8.2	Pipeline	BG - TR	58,08					
6.8.3	Pipeline	BG - RS	102					IBS
7.1.1	Pipeline	BG - TM	1500					TCP + SCPFX
7.1.3	Pipeline	AL - GR - IT	2058					TAP
7.3.1	Pipeline	CY - GR	360					EastMed
7.3.3	Pipeline	GR - IT - TR	5297					Poseidon
8.2.1	Pipeline	LT - LV	120					TANAP
8.3.2	Pipeline	PL - DK	397,9					Baltic Pipe
8.5	Pipeline	LT - PL	132,2					GIPL