dCarbonX

SECURITY OF SUPPLY CONSULTATION

SUBMISSION TO THE DEPARTMENT OF THE ENVIRONMENT, CLIMATE & COMMUNICATIONS

OCTOBER 28, 2022

Executive Summary

It is essential to transform Ireland's energy system to achieve its goal of a climate-neutral economy by 2050 whilst also ensuring that the energy system is secure and reliable. Of particular importance is the need to ensure that there is sufficient indigenous long-term infrastructure that can support Ireland's current energy supply requirements, whilst also ensuring that this infrastructure can evolve to cater for the increased penetration of renewables, particularly green hydrogen.

In addressing this topic, dCarbonX firmly believes that a key consideration is to ensure security of supply, as compared to a complementary diversity of supply. Specifically, on the basis that Ireland does not want to outsource its security of supply, dCarbonX believes that the development of local large-scale underground energy storage capacity (via underground gas storage or UGS) is essential for Ireland's energy security requirements given the current energy crisis (driven by the war in Ukraine), the lack of indigenous gas production or storage in Ireland and the need to start preparing essential large-scale underground storage for the increased role of green hydrogen in Ireland's decarbonisation plans, which underpins the significant investment being undertaken and planned to be taken in offshore wind development.

Critically, the use of large-scale underground gas storage is not a new technology, having been established and utilised through-out most EU countries for the past 50 years to provide essential security of supply. Importantly, it is also not new to Ireland as the SW Kinsale natural gas storage facility (2.3 TWh) operated successfully from 2001 to 2016 under the Gas (Interim) (Regulation) Act, 2002 and Associated Regulations, (The Act of 2002)[1].

In addition to SW Kinsale and adjacent reservoirs in the Celtic Sea (the "Kinsale Head Area"), Ireland has further specific offshore potential for UGS. dCarbonX has carried out extensive proprietary evaluations of the geology offshore Ireland which confirms the presence of suitable underground formations (be they saline aquifers or salt structures) which could host future UGS developments. These areas include offshore Dublin in the Kish Basin, offshore Cork in the Celtic Sea Basin (Kinsale Head Area), and off the west coast in the Slyne Basin. All of these areas are adjacent to existing onshore infrastructure.

Following the recent revision of the EU Gas Security of Supply, underground gas storage is now designated as "**critical infrastructure**". This is defined as "*an asset, system or part thereof located on EU territory, which is essential for the maintenance of vital societal functions, health, safety, security, economic or well-being of people, and the disruption or destruction of which would have a significant impact on at least two Member States, as result of the failure to maintain those functions*". Given this recent categorisation of underground gas storage, the role of underground storage facilities, suitable for repurposing for future hydrogen storage, need to be considered in Ireland's security of supply policy.

In making this submission, dCarbonX wishes to draw the attention of DECC to dCarbonX and its key strategic partners:

- dCarbonX is an asset focused GeoEnergy company established to develop underground assets for molecular clean energy storage and for the sequestration of CO2. Based in London & Dublin, dCarbonX has as its leading corporate shareholder, Snam S.p.A. (Snam), one of the world's leading

[1] *Gas (Interim) (Regulation) Act, 2002 (irishstatutebook.ie)*

energy infrastructure operators. Snam is Europe's largest natural gas storage and distribution company.

In preparing this submission, dCarbonX has been provided with evidential material from Snam on general security of supply matters with specific examples on how Snam have managed this, particularly in the context of the Italian market. Drawing from this experience, Snam have prepared a report "*Our suggestion of how the Irish system should evolve for future energy supply of NG and Hydrogen*" (attached in Appendix A), which forms part of dCarbonX's submission to DECC.

By way of further background, among its European peers, Snam is acknowledged as best in class operator in Europe, having the largest natural gas transportation network (over 41,000 km including international assets), an unmatched gas storage capacity (approx. 20 Bcm including international assets) and has major re-gasification operations as Italy's leading LNG operator. Importantly, in the context of Ireland's decarbonisation pathway, Snam is also a leading player in the hydrogen industry bringing significant experience in this area.

- In addition to its corporate relationship with Snam, dCarbonX formed a Joint Venture with ESB Wind Development Ltd, a wholly owned subsidiary of ESB, which provides for the evaluation and development of underground energy storage capacity offshore Ireland. In addition to being Ireland's largest generator of electricity, ESB is also the largest consumer of gas in Ireland.

In preparing this submission, dCarbonX proposes that DECC immediately consider:

1. Facilitating the development of large scale underground storage as a key element of Ireland's security of supply policy.

2. Implementing specific legislative and planning measures to facilitate the development of large-scale green hydrogen storage solutions, which will promote the development of a green hydrogen sector. The regulation of natural gas storage is already catered for by the Gas (Interim) (Regulation) Act, 2002 and Associated Regulations, (The Act of 2002). Specifically, dCarbonX (Snam) and ESB are proposing the rehabilitation of the Kinsale Head Area for gas storage and its future repurposing for green hydrogen storage.

3. Extending the brief of the Commission for the Regulation of Utilities (CRU) as the regulatory body for natural gas storage and transportation to include the responsibility for hydrogen & hydrogen carrier storage / transportation.

4. Utilising, in accordance with IEA/EU Guidelines, a state agency (such as NORA) to hold strategic gas reserves (natural gas now and green hydrogen in the future) as it does for liquid petroleum products.

On the following pages, dCarbonX and Snam have provided some answers and/or commentary to various questions posed by DECC as listed in the *"Review of the Security of Energy Supply of Ireland's Electricity and Natural Gas Systems - Consultation, 19 September 2022."*

1. RISKS - Are there any other security of supply risks that you can identify in addition to those set out in section 6?

dCarbonX concurs with the Department's assessment of major risks, namely:

- Gas - Imports from the UK
- Gas - Geopolitical risks
- Electricity - Capacity deficits
- Electricity - Low availability of wind generation

However, dCarbonX submits Planning & Consenting and Policy & Legislation should also be included and that the assessments of the above risks need to be expanded as below:

Gas – Imports from the UK

The DECC is correct to highlight the potential of a disruption at the Moffat injection point – this is the key arterial route for imported gas supply to Ireland from the north of Great Britain, especially with the decline of production from Corrib. Moffat, located in Scotland, is the export point for gas supply from the UK utilising 2 interconnectors (ICE 1 & 2) via a single compressor station.

As the recent damage to the Nordstream pipelines has highlighted, a further risk assessment should be carried out on the potential for physical damage being done to either the Moffat compressor station or the ICE 1 & 2 subsea pipelines, thereby halting inward gas supply. Additionally, the threat and impact of cyber-attacks should be provided for in Ireland's security of supply policy. Following the recent experience of the ransom-ware attack on the Colonial Pipeline in the US, the impact of gas interconnectors being shut down must be given consideration in any security of supply policy.[2]

In addition, it should be noted that the UK is no longer an EU-member state, a net gas exporter and is itself facing significant economic and energy headwinds. Furthermore, consideration should also be given to the potential of Scotland declaring independence from the United Kingdom and the impact that this may have on international treaties or agreements for gas supply via the Moffat injection point.

Gas - Geopolitical Risks

The DECC consultation report highlights many of the direct and indirect impacts (electricity generation interconnectivity) of gas supply disruptions. It is submitted that a further geopolitical risk assessment should consider that existing agreements or treaties that govern the international trading of gas may be affected as countries prioritise their own energy and security of supply concerns. Notwithstanding the current complexities of the intergovernmental nature of agreements with the UK on gas interconnection, the vulnerabilities associated with curtailment in the UK gas market should also be modelled and mitigated in greater detail.

Electricity – Low availability of wind generation

The DECC report does consider low availability of wind, but it is submitted that further consideration should be given noting the reliance that is being place on renewables going forward. Specifically, in using scenario 5 as an example, the 30-day gas interruption assumes average winter conditions, but it fails to layer additional risks to analyse a confluence of concurrent events. For example, with respect to weather, in Q3 2021, there was a period of up to 6 weeks of no wind in Ireland, the UK nor in NW Europe.

[2] *Colonial hack: How did cyber-attackers shut off pipeline? - BBC News*

CEPA's assessment acknowledges it has been carried out under the assumption that the Government's renewable energy targets have been met and the electrification of demand and the delivery of renewable generation capacity by 2030 are broadly achieved. EirGrid's 2030 projections predict there will be significant new additional load from the heat and transport sectors as they are electrified, in line with government targets set out in the Climate Action Plan 2021. (Ireland Capacity Outlook 2022-2031, October 2022). However, it must be acknowledged that in the eventuality of rising electricity demand, if Ireland has not managed to meet its electrification targets, then Ireland will be even more reliant on gas than it is currently forecasting.

Planning & Consenting

The systemic risks associated with Ireland's planning regime, and the delays in the consenting and permitting timelines for the delivery of infrastructure (particularly offshore wind), should also not be ignored and should be highlighted as a potential risk when addressing Ireland's security of supply. The European Commission in its annual 2022 Country Report – Ireland[3] identified planning as a key issue:

> "*Removing bottlenecks to the above investments will be necessary for reducing Ireland's dependence on fossil fuels. Challenges remain with the planning and permitting system, particularly the long timeframe in granting planning permission, which is also linked to the appeal procedures for planning applications. Advancing reforms in these areas would foster greater roll-out of renewables, thus helping diversify the energy mix.*"

There have been examples of large-scale projects being extensively delayed in Ireland through protracted planning and legal processes. Unlike Italy, which has established coastal port infrastructure in place (as shown in Snam's report), there have been a number of notable high profile planning and legal delays in Ireland for the development of coastal energy related terminals over the past 25 years.

Here, by way of example, we reference the Corrib Bellanaboy Terminal (operational some 20 years after the initial Corrib gas discovery), the Indaver waste-to-power plant in Cork (which is still waiting for consent some 20+ years on from its original proposal) and Covanta's facility in Dublin (which took 17 years to build from its original proposal).

These examples highlight the major difficulty in developing new infrastructure in coastal settings, especially if these are not in existing brownfield areas. The benefit of developing large-scale offshore UGS facilities is that they are not immediately adjacent to coastal communities, thereby minimising societal and environmental impacts.

Policy & Legislation

In addition to planning and consenting, consideration needs to be given to the impact of any future changes to Policy & Legislation, either in Ireland or in the EU (Section 5, Policy Context) on security of supply. Of particular note is the Private Members Bill, (Planning and Development (Liquefied Natural Gas - LNG) (Amendment) Bill 2022)[4] introduced in March 2022 by a member of the Green party (one of the 3 coalition parties in government) who stated purpose is:

> "*to provide for the amendment of the Planning and Development Act 2000 in order to restrict developments in Liquefied Natural Gas (LNG) infrastructure and to remove LNG infrastructure from listing as strategic development infrastructure projects*."

[3] [3]2022-european-semester-country-report-ireland_en.pdf (europa.eu)

[4] https://data.oireachtas.ie/ie/oireachtas/bill/2022/25/eng/initiated/b2522d.pdf

This Private Members Bill, which is currently at Second Stage in Dail Eireann, could, if adopted by the Dail, remove the LNG/FSRU as a potential mitigation option for Ireland.

2. <u>RISKS</u> - If there are other risks that you have identified, could you outline some mitigation options to address the risk(s)?

As DECC has done in its analysis, dCarbonX also looks to other EU countries to see how they address or mitigate risks for energy security. The DECC report highlights (in section 5.5, Table 2), a comparison of 5 countries and assesses their gas supply mitigation options, in the context of:

- Indigenous natural gas supply;
- Subsea interconnection;
- Land based interconnection;
- Underground gas storage;
- LNG imports.

To this list, dCarbonX would add Italy which, as shown later in the attached report by by Snam (dCarbonX's corporate shareholder), has in place all 5 gas supply mitigation options listed above.

With the addition of Italy, of the 6 countries, the one consistent theme is that all the other countries (excluding Ireland) have commercial UGS in operation as a central part of their gas supply mitigation options. Indeed, across the whole European Union, the only countries without underground gas storage are Ireland, Malta and Slovenia.

<u>The Rationale for Underground Gas Storage</u>

As noted in the Executive Summary, underground gas storage is now designated as "**<u>critical infrastructure</u>**". The main opportunity for the storage of energy in gaseous molecular form (including future hydrogen developments) in UGS is linked to the distinctive features and advantages compared to batteries and other forms of electron storage, as shown in this Frontier Economics report: "*<u>The Value of Gas Infrastructure in a Climate-Neutral Europe"</u>*[5]

To cope with peak periods, UGS facilities can be appropriately scaled, to address seasonal/annual storage needs required by the energy systems to address demand swings between e.g. summer/winter or across different years. This has the added benefit of protecting consumers from significant variations in gas prices.

<u>Underground Storage facilitates Hydrogen</u>

Looking further ahead and embracing Ireland's plans for the development of wind as part of its decarbonisation plans, UGS also provides the necessary infrastructure to support the development of green hydrogen storage.

This was acknowledged in the EU with Gas Infrastructure Europe's commissioned report "*<u>Picturing the value of underground gas storage to the European hydrogen system</u>*"[6] which highlighted the vital need for underground gas storage in Europe. This report, published in June 2021, and so predating the Russian invasion of Ukraine, further highlights the need for energy security in terms of strategic storage for both natural gas today, as well as the evolution to hydrogen storage in the future.

[5] https://www.frontier-economics.com/media/3120/value-of-gas-infrastructure-report.pdf

[6] Picturing the value of gas storage to the European hydrogen system_FINAL_140621.pdf

Key points (below) from the Executive Summary have direct read across implications on the essential need for underground gas storage, as well as the future development of hydrogen storage in Ireland:

- *"Large-scale, underground hydrogen storage is indispensable to the development of the European hydrogen market and will become an important part of the future decarbonised energy system*."
- "*As in today's energy system, supply and demand balancing will be required on all timescales (hourly, daily, weekly, and seasonal)*."
- *"The overall energy system (electricity, gases) designed to meet the ultimate objective of the energy transition—net zero emissions by 2050 at the lowest cost to society—will also have to be optimised and secure."*
- *"Underground gas storage will be a key enabler for all these objectives, as it already provides these benefits to the energy system."*
- "*Compared to its current use, the role of underground gas storage will be even more pronounced to ensure the resilience of the energy system as a whole.*
    - *On the supply side, this is mostly due to higher (green) hydrogen supply variability driven by intermittent renewable electricity production from the sun and wind.*
    - *On the demand side, this is because of the sheer volumes (especially for industrial use) and demand variability from increasing electrification and the related need to meet higher electricity demand peaks created by residual load*."
- "*If hydrogen is to be deployed at scale, a substantial deployment of storage will be needed as well, requiring a better understanding of the specific storage needs. These hydrogen storage needs will be determined by an overall sector coupling equation. Developments in hydrogen supply and demand as well as interrelations with other sectors (power, transport, heating, cooling) and the sectors' ability to use other flexibility tools (batteries, heat and cold storage, pumped hydropower, etc.) will determine the specific hydrogen storage requirements*."
- "*When hydrogen production is expected to follow intermittent renewable sources, highly flexible storage is required in addition to the large-scale seasonal volumes. Similarly, if hydrogen is used for power system balancing (short term and seasonal) and heating (directly or indirectly), substantial storage capacities with high flexibility will be required. A whole system adequacy exercise should be performed for electrical and gas systems to allow for the efficient use of energy networks, including storage. Both storage capacities and operating profiles need to be investigated."*
- "*In the early stages of hydrogen market development (up to 2030), demand will likely be concentrated around cluster areas (hydrogen valleys) that will initially mostly manage their supply locally. Underground hydrogen storage will be an integral part of these valleys, helping to significantly improve the economics of the emerging hydrogen infrastructure. In some places, underground storage sites for hydrogen might be repurposed or new ones developed even before the arrival of the European Hydrogen Backbone (EHB)*."
- "*Alternatively, hydrogen blending in storage assets is an option. This option comes with the need to either de-blend the two gases upon withdrawal or to accept a different gas purity standard. By 2030, the EHB could start to interconnect the first valleys into hydrogen regions, both intra-country and cross-border. These developments can also support the large-scale integration of renewables in these*

regions, particularly offshore wind, with hydrogen storage as a critical component. As the transition continues and hydrogen supply and demand grow, the hydrogen valleys will evolve into an interconnected hydrogen network, as shown by the EHB initiative (after 2030)."

- *"More natural gas storage will be repurposed for hydrogen, and the interconnectivity of the network will enable storage further away from hydrogen supply and demand to be used. Hydrogen might also begin to be used in heating (directly or indirectly) and to help meet peaks in electricity demand, beyond the mostly industrial (and transport) uses in the early transition. These uses would alter the demand profile for hydrogen. Peaking would require flexible storage to balance the variation in renewable electricity production, and heating would emphasise the larger need for seasonal storage. The overall hydrogen infrastructure, including storage, will enable a better hydrogen price convergence between the interconnected regions and the already established hydrogen valleys."*

- *"Our first-order estimation of hydrogen storage capacity requirements for the 21 countries covered by the EHB shows the need for around 70 TWh of hydrogen storage in 2030, growing to around 450 TWh of hydrogen storage in 2050."*

- *"All underground storage types will need to be utilised, both for capacity and geographical reasons. Repurposing and developing new storage sites will be required going forward. The decision for repurposed versus new development will be driven by a variety of factors including the development of hydrogen and natural gas storage needs over time, the availability of the storage, and the individual suitability of the storage site."*

- *"From a physical point of view, hydrogen, due to its lower energy density compared to natural gas, needs about four times higher storage volumes to store an equivalent energy amount."*

- *"Hydrogen storage in salt caverns is a low-hanging fruit and current research shows that porous structures (depleted gas fields, aquifers) are showing fair potential to cover further storage needs for pure and blended hydrogen. Given the geographical availability and expected capacities required, we will need all types of underground storage for hydrogen."*

- *"Salt caverns are suitable for large-scale pure hydrogen storage but are limited by their geographical availability across Europe. Depleted gas fields and aquifers are likely to be usable for hydrogen and are present more widely across Europe, so these will need to be utilised as well. Salt caverns (for natural gas storage) are operational in six EU member states and the UK with an estimated working gas capacity of 50 TWh of hydrogen after repurposing. Depleted gas fields and aquifers are used as gas storage in 16 EU member states and the UK with an estimated working gas capacity of 215 TWh of hydrogen after repurposing."*

- *"To be ready for substantial hydrogen demand and regional pipeline networks by 2030, we need to start on the storage now. Repurposing can take anywhere between 1 and 7 years and developing new storage assets takes between 3 and 10 years from pre-feasibility to operation. Each existing site must be investigated for its suitability to store pure and blended hydrogen. Storage system operators have a key role—their experience will be needed. Many of these operators have started to investigate the feasibility of repurposing their assets."*

- *"Certain repurposing actions could be standardised to streamline the procedure. Some storage operators have also taken commercial role in the planning of new hydrogen projects. A clear business case and an enabling regulatory environment need to be present to enable decisions to repurpose or* *develop large-scale, underground hydrogen storage. Collaboration between supply, demand, infrastructure operators, and regulators will be key. Integrated infrastructure planning including hydrogen storage is necessary for a cost-efficient and timely energy transition in Europe."*

3. RISKS - Are the five shock scenarios that were considered, and the additional scenarios related to the Russian invasion of Ukraine, sufficiently broad?

As discussed in reply to Q.1, physical, cyber and/or geopolitical disruptions could have a material impact on gas supply to Ireland and the lack of in-situ large-scale underground gas storage further exacerbates this situation.

The DECC has identified 5 appropriate scenarios and as discussed in the answer to Q. 1, dCarbonX believes that these scenarios are appropriate, but suggest that the timelines for each of these scenarios should be increased further by a factor of 3 times and that Planning & Consenting and Legislation & Policy sensitivities be considered in the time mix of additional scenarios.

4. MITIGATION OPTIONS - Do you have any additional mitigation options that you think should be considered?

As discussed in Snam's analysis of the Italian market, there is no "one size that fits all" in terms of addressing security of supply measures and many complementary mitigations should be deployed.

Benefits of Underground Gas Storage
dCarbonX's central position is that Ireland critically requires indigenous large-scale underground gas storage capacity to ensure that its strategic energy reserves are in country. In general, underground gas storage (UGS) is fundamental for an energy system as it performs the following functions:

- Provides an additional supply source to ensure continuity in case of supply interruptions due to infrastructure unavailability or commodity shortages (strategic storage);
- Balances the seasonal summer/winter differences in demand and supply;
- Balances day-to-day and within-day variability in demand and supply;
- Contributes to reduce price spikes and volatility in both the gas and electricity markets;
- Supports the additional request of flexibility deriving from the penetration of RES generation as the most efficient and economic energy storage, enhancing the cross-sectoral gas and electricity optimization.

UGS is not a new concept for Ireland and there is governing legislation in place in the form of the Gas (Interim) (Regulation) Act, 2002 and Associated Regulations, (The Act of 2002). The SW Kinsale gas storage facility (2.3 TWh) successfully operated offshore Cork from 2001 to 2016, when it was decommissioned as part of the larger decommissioning of the Kinsale Head Area producing gas fields. This storage facility provided natural gas storage, that amounted to c. 10% of the then Irish electricity market, providing Ireland with a safe, reliable in-country storage facility that ensured that peak shaving and network supportive gas resources were in place to avoid supply disruptions and importantly, provided risk mitigation from significant price fluctuations.

Underground Storage facilitates Hydrogen

As discussed, the development of UGS also provides the basic infrastructure that would support the expansion of hydrogen, which in turn, supports the significant investments being made in renewables (wind & solar). Domestic green hydrogen supply can solve Ireland's energy security by providing locally produced feedstock for dispatchable green power generation which can complement the intermittency of wind & solar, whilst also serving the 'hard to abate' decarbonisation goals in areas such as heavy goods transportation, heat intensive heavy industry & renewable heating obligations.

Diversification of Supply

The critical role of UGS was further strengthened by the recent EU policy in terms of mandatory annual temporal capacity targets. To reach these targets, it is possible to also consider the development of interim LNG facilities (i.e. leased FSRU etc.) which would give Ireland added diversification of natural gas supply. However, as LNG technology is itself energy intensive and not a substitute for large-scale gas storage (LNG provides up to 21 day's storage capacity) and is not hydrogen compatible, it should therefore be seen as an interim measure to support natural gas supply diversification.

Storage Reduces Pricing Exposure

Furthermore, LNG, whilst beneficial as an additional energy importation vector is always open to the vagaries of a fiercely competitive global LNG market especially at a time of an energy supply shock.

In this context, it is instructive to review some pricing statistics from the LNG market prior to the Ukrainian crisis. As per the attached report from the IEA[7] in October 2021 shows, in the summer 2021 (and before Russia's invasion of Ukraine) a number of factors (including slack wind and competition for the world's gas supply (LNG)) caused prices to rise dramatically.

Whilst current gas prices have recently fallen to lower levels, what is instructive about this analysis is that the multitude of factors that can influence global LNG flows and pricing at any given time, including:

- Global and local macro-economic factors;
- Supply chain rigidities;
- Storage capacity;
- Weather events (both direct & indirect);
- Maintenance/outages;
- Alternate usage/ switching from other fuel sources.

To simply rely on LNG, without the ability to store secured gas in country, would expose Ireland to both LNG supply and spot pricing volatility whereas UGS at scale would help to manage such fluctuations. And importantly, the report notes that the Europe's contestable demand is set to grow amidst declining domestic production and the gradual expiry of long-term contracts – and this was before the Russian invasion of Ukraine.

Comparing Various Mitigation Options

The table below provides an analysis of some of the largest mitigations that could be considered for Ireland. Here, the analysis focuses on comparing UGS, FSRU and LNG Terminal solutions, with the source commercial data provided by Snam (who operate all 3 asset classes in Italy).

In addition to the ability to provide the largest amount of storage of energy, thereby underpinning Ireland's Security of Supply, the levelized cost of storage (LCOS) metrics (€M/TWh basis) demonstrates

[7] *IEA - When_gas_gets_the_Economist_cover_1634854323*

the robust economics of UGS relative to FSRU or an LNG Terminal. UGS also delivers a lower carbon footprint, provides a practical pathway for hydrogen and has lesser visual and societal impacts. The indicated timeframes are not sensitized for the Planning & Consenting or the Policy & Legislation risks as detailed in the answer to Question 1.

	UGS	FSRU	LNG Terminal
Size of Storage (typical)	7 – 15 TWh	1 TWh	1 – 3 TWh
Diversity of Supply	Flexible to NG Sources incl. Biomethane	Fracked & Non-Fracked LNG	
Days of Storage	Up to 90 days (storage technology)	Up to 7 days (transportation/importation technology)	Up to 21 days (importation technology)
CO_2 footprint	Low	High (energy intensive & boil off)	
LCOS (€M/TWh)	5 – 15 1 cycle / year (5 €M/TWh is cushion gas)	40 – 70 2 cycles / year	35 – 70 2 cycles / year
Hydrogen Ready / Green Offramp	Yes – hydrogen ready facilities, geology tbc	No – would need substantial re-engineering	
Capex (€M/TWh)	≈ 50 - 150	≈ 450 - 550	≈ 400 - 500
Years of operation	ca. 40	ca. 20 - 25	ca. 30
Visual Impact	Unseen (underground offshore)	High visibility (natural harbour)	High visibility (coastal land)
Tried & Tested	Kinsale Field (Irish experience)	Overseas examples	
Critical seasonal storage factors	None	LNG storage in tanks is subject to boil-off gas (70% lost / year), fractionation and variation in composition due to evaporation of the more volatile phase (with potential loss of specs for grid injection)	
Years to First Gas	4 – 5 (+ offshore permitting)	4 – 5 (+ nearshore / coastal permitting)	
Security of Supply	**Yes**	**No**	

Source material: Courtesy of Snam

5. MITIGATION OPTIONS – Which gas supply mitigation options, if any, should be considered for implementation?

With reference to Section 7.2 of the DECC Consultation Report, dCarbonX submits that the Irish government should consider implementation of Underground Gas Storage (UGS) as the number one Gas Supply Mitigation Option, especially as this also helps to address the other elements referenced in the Gas Mitigation Package.

Development of Large-Scale Underground Storage

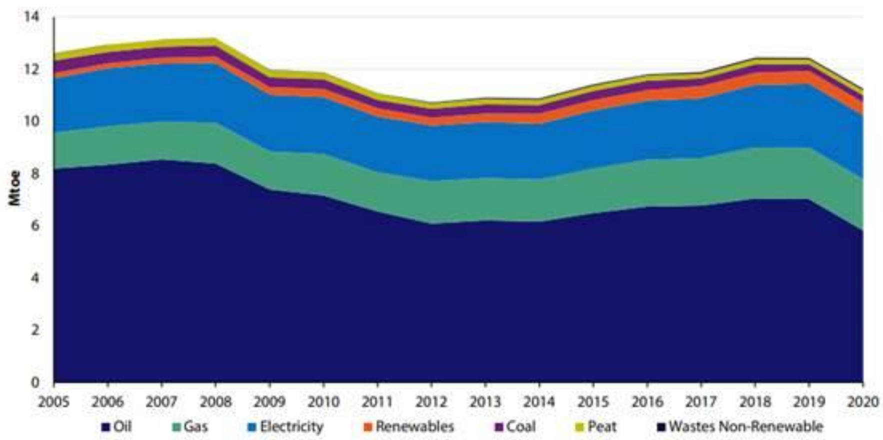
Following on from the recent revision of the EU Gas Security of Supply, UGS is designated as "critical infrastructure". This is defined as:

> *"an asset, system or part thereof located on EU territory, which is essential for the maintenance of vital societal functions, health, safety, security, economic or well-being of people, and the disruption or destruction of which would have a significant impact on at least two Member States, as result of the failure to maintain those functions"*.

Given this recent categorisation of underground gas storage, the role of underground storage facilities, suitable for repurposing for future hydrogen storage, should be considered in Ireland's security of supply policy.

SEAI's "*Energy in Ireland 2021*" report[8] provided a summary of Ireland's Total Primary Energy Requirement (TPER). As detailed in this report (and shown below), the predominant sources of energy consumption in Ireland were carbon-based. Whilst the expansion of renewable electrification has made great strides over the past 2 decades, it must be noted electricity (generated from both carbon-based and renewable sources) still only represents c. 27% of TPER in 2020.

Figure 3: Total final consumption by fuel



Source: SEAI

Promoting the Development of Green Hydrogen

Future plans to increase renewable energy penetration (primarily by floating offshore wind) will create the need for further baseload energy to support the electricity system. This is acknowledged by the government as it looks to expand the fleet of gas fired power stations, thereby removing more carbon intensive power stations.

The future production of green hydrogen can also underpin dispatchable zero carbon power generation. Surplus green hydrogen can also be re-profiled and utilised for decarbonising the 'hard-to-abate' sectors, supplying green energy to those areas not directly served through the electricity market, as well as underpinning security of energy supply and supporting future export opportunities.

Wind Energy Ireland point out in their report "*Seizing our Green Hydrogen Opportunity*[9] that green hydrogen can be central to creating a clean, decarbonised Irish economy by providing long-term energy storage for the decarbonising electricity market for when 'the wind isn't blowing, and the sun isn't shining'.

Energy storage in the form of green hydrogen can also provide the assurance that Ireland can guarantee a secure energy supply for its citizens and importantly, with even more ambitious wind energy resource targets being set, green hydrogen production and its storage can provide further market support against curtailment, thereby assisting in the economics of wind deployment. The successful acceleration of decarbonising the Irish electricity sector, will create a requirement to ensure that there is suitable "renewable" or "decarbonised" energy storage.

Hydrogen storage can play a critical role in providing future security of supply as natural gas storage currently does for much of Europe in the face of the Ukrainian crisis. Whilst interconnection provides for a diversification of supply, it is only in-country storage that can provide for a security of supply. Without

[8] https://www.seai.ie/publications/Energy-in-Ireland-2021_Final.pdf
[9] 20220127-greenhydrogenactionreport-002.pdf (windenergyireland.com)

the wind > green hydrogen > storage > power cycle, Ireland's considerable offshore wind resources cannot be developed due to both the intermittency and regionality of weather systems. Given Ireland's lack of indigenous gas resources, it is only by developing its offshore wind resource that Ireland can ultimately gain both security of supply and energy independence and therefore, large-scale molecular energy storage is critical.

Establish Minimum Storage Thresholds

Under the EU's Oil Stocks Directive (2009/119/EC)[10], EU countries must maintain emergency stocks of crude oil and/or petroleum products equal to at least 90 days of net imports or 61 days of consumption, whichever is higher. Stocks must be readily available so that in the event of a crisis, they can be allocated quickly to where they are most needed. Ireland adheres to this EU Directive and so if follows that for any principal consumed energy, a similar 90 days of gas storage should apply.

Today, Ireland has no operating underground gas storage facilities. Ireland's only underground gas storage facility (SW Kinsale) was closed in 2017 and most of its physical infrastructure is currently in the final stages of decommissioning and removal.

Historically, Ireland has relied largely on "carbon-based" energy storage, including the storage of coal at Moneypoint (90 days), peat at ESB power stations (1 year), natural gas at SW Kinsale (90 days) and NORA's strategic oil reserves (90 days). In 2020, it is noteworthy that whilst 86% of TPER was fossil based (oil/gas/coal/peat), 96% of primary energy storage was "carbon-based".

Post-Brexit, Ireland also has its only gas inter-connection to a non-EU state (UK) which itself currently has only 5 days natural gas storage. In response to this storage crisis, the UK has recently sanctioned the reinstatement of the offshore North Sea Rough Gas Storage Facility, with the UK government intervening to assist in the purchase of the cushion gas required to make it commercially operational. However, Rough will add just 9 additional days to UK storage capacity.

To ensure that the future Irish energy system is secure, reliable & resilient, Ireland needs to put in place a significant amount of large-scale underground energy storage capacity for natural gas today and green hydrogen in the future. There are a range of potential TPER scenarios for 2030, net zero electricity, net zero energy - all which generate substantial storage requirements.

Wind Energy Ireland's 0 by 50 report[11], identifies ~120 TWh primary energy in 2050. 90 days primary energy storage (best practice in EU) is equivalent to ~30 TWh storage (this is equivalent to the storage capacity of >15,000 Turlough Hill pumped storage units).

Whilst other renewable and short-term storage initiatives (such as short cycle batteries, flywheels, micro hydropower etc.) can and will play an assisting role, Ireland's energy system will require much larger scale storage solutions to address the intermittency of renewable power, as well as the plans for significant green hydrogen that will be produced as a result of material increases in offshore wind power over the coming decades. Such large-scale energy storage can only take the form of underground natural gas storage, which has the flexibility to migrate via blending to green hydrogen storage as green hydrogen production increases.

[10] https://energy.ec.europa.eu/topics/energy-security/eu-oil-stocks_en

[11] https://windenergyireland.com/images/files/our-climate-neutral-future-0by50-final-report.pdf

It is common (and best) practice in mainland Europe to have c. 90 days (heating season) of annual gas consumption stored in underground geological formations, and in a June 29, 2022, EU directive[12] to address security of supply arising from the Ukrainian crisis, further measures for EU states to fill their gas storage facilities were implemented. These new rules require the EU Member States to fill storage facilities to 80% of capacity by November 2022 and to 90% in the years thereafter. REPowerEU recommends that members states carry at least 90 days of storage.

As stated above, Ireland already does this for oil reserves but to adhere to EU guidelines, 90 days of molecular storage (natural gas and green hydrogen) should be implemented and managed by a state agency such as NORA. **Based on forecast TEPR, this would represent upwards of 30 TWh of energy storage in the short term.**

6. MITIGATION OPTIONS - Which electricity supply mitigation options, if any, should be considered for implementation?

Whilst dCarbonX is not involved in the supply of electricity, its role as a developer of underground energy storage is relevant. As has been evidenced in the past year, natural gas is a proxy for electricity in Ireland given the central role of gas fired power generation. This role is set to grow given the recent CRU capacity auctions to enlarge the Irish national CCGT fleet by 2 GW and GNI predictions of up to 40% increase in gas usage in Ireland over the next five years.

The storage of gas can therefore be considered as a potential bunker for power generation once it is located proximate, or has direct access, to the power stations. For instance, given the geography of the current two injection points at Moffat & Bellanaboy, power stations in the south of the country, such as Aghada and Whitegate, that have a combined capacity of c. 1 GW, would be hugely exposed to any future gas supply shock.

In addition, these stations also power the nearby Whitegate oil refinery, which produces 30-40% of Ireland's finished fuel products. Therefore, any disruption to these power stations could have major knock-on implications for both power generation as well as transportation.

Development of underground gas storage in the Kinsale Head Area, which is co-located with the Aghada (ESB) and Whitegate (BGE) gas fired power stations, could secure both 1 GW of power generation in the Cork region together with the finished transportation fuels produced at Irving Oil's Whitegate oil refinery.

7. MITIGATION OPTIONS - What measures should be considered on the demand side to support security of supply of electricity and gas?

Given Ireland's current reliance on natural gas for power generation & residential/industrial heating sectors, Ireland should secure its energy system through the development of large-scale underground gas storage. In addition, further supply diversification is considered positive, but very much subordinated to large-scale storage. Importantly, these measures will need to support both the existing

[12] https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ:L:2022:173:TOC&uri=uriserv:OJ.L_.2022.173.01.0017.01.ENG

fossil-based energy system but will also need to be future proofed so as not to result in the development of 'carbon-locked' assets which will ultimately be stranded by the Energy Transition.

As such, energy storage projects, such as UGS, need to be designed with a future role for hydrogen/hydrogen carrier storage and power generation capacity auctions need to include a hydrogen-ready turbine requirement.

LNG, which is a gas transportation versus a gas storage technology, can only be considered as an interim measure, given the lack of hydrogen-ready LNG FSRU technology.

8. MITIGATION OPTIONS - Do you have any views on how the mitigation options should be implemented?

dCarbonX believes that the development of large-scale offshore underground gas storage is critical to underpin the current fossil-based Irish energy system whilst it transitions to green hydrogen in the years ahead. Whilst legislation already exists for natural gas storage, it is imperative that enabling legislation and regulations that promote the development of underground hydrogen storage are put in place immediately.

Generally, energy storage should be located proximate to the end user to minimise costs. However, as discussed above, Ireland's future energy system will require large-scale green hydrogen storage, and due to geological, societal and planning considerations, the most appropriate location for such large-scale storage is offshore and underground. This provides societal, safety and consenting benefits as the storage infrastructure is unseen.

dCarbonX's extensive evaluation of the geology offshore Ireland has highlighted suitable formations for large-scale underground energy storage offshore Dublin (salt caverns), offshore Shannon (salt caverns) and offshore Cork (the decommissioned Kinsale Head Area, which previously hosted a 2.3 TWh natural gas storage facility and which can readily be repurposed/re-activated for clean molecular gas storage). dCarbonX's technical evaluation confirms that these three identified areas, importantly adjacent to existing onshore energy infrastructure, can provide suitable storage capacity to meet a 30 TWh requirement.

The development of new energy infrastructure requires societal consent. The benefit of developing large-scale offshore underground storage facilities is that they are not immediately adjacent to communities, thereby minimising societal and environmental impacts. Obviously, to access these storage facilities, pipeline infrastructure will be required to integrate with onshore facilities for the processing and forward utilisation/transportation. It is worth noting that the successful SW Kinsale 2.3 TWh natural gas storage facility operated safely and reliably for c. 15 years offshore Cork with no public resistance from local communities.

In addition to large-scale, offshore underground storage, as is common practice in the natural gas industry worldwide, there are opportunities to deploy small scale "step-down" storage facilities (either underground silos or surface dewars) for smaller quantities of natural gas and in the future, green hydrogen (10s-100s tonnes). These "step-down" storage facilities can be located adjacent to hydrogen producing or consuming locations, which may be off grid.

9. POLICY MEASURES - Do you support the policy measures proposed in section 8 of the consultation paper?

dCarbonX concurs with the DECC's proposed policy measures:

- Joint planning;
- Regular energy reviews;
- International arrangements.

dCarbonX submits that the CRU and NORA should also be involved in the Joint Planning and Regular Energy Reviews and that DECC's budget should be increased to ensure that it has appropriate human resources to coordinate overall energy policy.

CRU

The CRU has already put in place appropriate licensing, safety and environmental frameworks for the handling, transportation and storage of molecular energy (natural gas) in Ireland. As the CRU[13] is Ireland's independent energy and water regulator, it has a wide range of economic, customer protection and safety responsibilities in energy and water.

Specifically, under the *Gas Safety Framework*, the CRU has the statutory function to:

- Regulate the activities of gas undertakings with respect to safety. This includes gas network operators and gas suppliers;
- Regulate gas installers with respect to safety; and,
- Promote the safety of gas customers and the general public with regards to the shipping, supply, storage, transmission, distribution and use of natural gas.

NORA

In accordance with EU Guidelines for strategic storage, the Irish government should utilise a state agency (such as NORA) to hold strategic gas reserves (natural gas now and green hydrogen in the future) as it does for liquid petroleum products.

10. POLICY MEASURES - What further tools and measures do you think would contribute the most to Ireland's energy security of supply?

Combining Strategic and Commercial Storage

A key consideration of the consultation process is the suggested limitation that certain of these gas supply mitigation measures be of a non-commercial nature. dCarbonX submits that this proposal is the least economically beneficial to the Irish state and its energy consumers given the significant capital and operating costs associated with such developments.

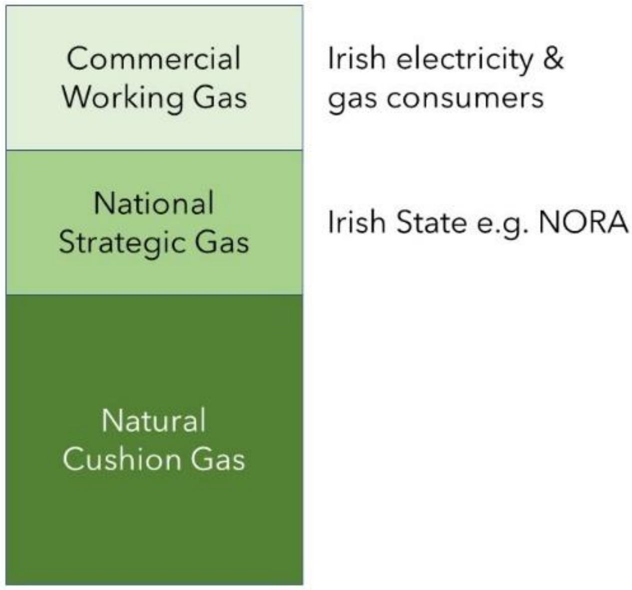
Whilst it is essential that energy security controls need to be in place to ensure that the State has strategic gas storage when needed, it is important to examine this security of supply element through the lenses of the energy trilemma, such as the cost to consumers. A non-commercial UGS facility that only operates at times of crisis would be suboptimal from an economic perspective, with the cost ultimately being borne by consumers.

[13] *CRU Gas Safety Framework for Professionals in the Energy Sector*

In addition, such UGS developments are complex in terms of their design, planning, consent, procurement, safety & operations and it would be best directed to commercial industry leaders who can optimise design/cost as well as fund from the international capital markets. Commercial access to such developments would also allow natural gas power generators to optimise prices for Irish consumers with EU third party storage access rules already in place (CRU).

The Italian model of gas storage is instrumental in this regard – the gas storage market is a regulated asset business (RAB), thereby providing the state with control of the assets, whilst also opening it up for third party access. The Italian gas storage projects always contain a volume of 'strategic gas' which is always first available to the state to be drawn down in an emergency. Again, there are plenty of established models that demonstrate how a state's strategic requirement is not prejudiced by a developer's ability to also allow third party access for storage. This also provides for a better outcome for consumers given that the commercial capacity off takers will reduce the costs to the state for storing 'strategic gas', as well as providing lower priced 'summer gas' for power generation feedstock.

Schematic representation of Italian gas storage model in an Irish context



And as noted throughout this submission, another key element of UGS is that it provides a pragmatic pathway for hydrogen – and given the scale of hydrogen storage that will be needed in the years ahead, it is questionable whether a UGS operated on a state-only crisis basis could be an effective bridge to commercial hydrogen storage.

As publicly stated, offshore Ireland, dCarbonX is working with ESB in the development of offshore storage facilities proximate to the Moneypoint, Aghada & Poolbeg ESB-operated power stations. These sites have been identified by ESB and dCarbonX for future potential green hydrogen production and the group have already commenced work to assess the storage potential in the nearby South Slyne Basin (salt cavern), Kinsale Head Area gas fields (depleted reservoirs) & Kish Basin (salt cavern), respectively.

Establishing Hydrogen Standards

Similar to the natural gas industry, dCarbonX would expect the Irish government to adopt internationally recognised standards in safety and certification for hydrogen. Specifically, dCarbonX wishes to see Ireland align with those standards accepted by the EU given the vast and unrivalled energy export potential that Ireland possesses for green hydrogen to EU markets, such as Germany. dCarbonX submits that it would make sense for the CRU to be the safety regulator and the National Standards Authority of Ireland (NSAI) to develop the standards/certification for green hydrogen.

Standards and taxonomies classify activities that are sustainable and aligned with climate targets, and those which are not, providing clear direction for energy investment and the basis for incentives, standards, and regulations. Taxonomies, such as the EU taxonomy, can help to ensure capital flows into clean energy projects and technologies, and away from unabated or emissions intense fossil fuels. Such taxonomies and standards, and certification that hydrogen projects and products comply with them, can significantly de-risk investment.

Certification of hydrogen in Ireland could play a major role directing capital to low-carbon projects and giving both producers and consumers the confidence —and data — that a switch to hydrogen will support their decarbonization efforts. An effective carbon price — or clarity on when such a price will be implemented — would also incentivize clean energy and disincentivize unabated fossil fuels. By properly pricing the damage caused by emissions, but also pricing at a level that makes low-carbon technologies commercially viable, hydrogen investment would be significantly de-risked.

Appendix A

Snam's report:

"Our suggestion of how the Irish system should evolve for future energy supply *of NG and Hydrogen"*

Appendix B

International Energy Agency's Report:

"When gas gets the Economist cover: recent market trends and medium-term outlook – October 19, 2021"

Appendix C – Summary List of Footnotes

- *Gas (Interim) (Regulation) Act, 2002 (irishstatutebook.ie)*
- *2022-european-semester-country-report-ireland_en.pdf (europa.eu)*
- *https://data.oireachtas.ie/ie/oireachtas/bill/2022/25/eng/initiated/b2522d.pdf*
- *https://www.frontier-economics.com/media/3120/value-of-gas-infrastructure-report.pdf*
- *Picturing the value of gas storage to the European hydrogen system_FINAL_140621.pdf*
- *IEA - When_gas_gets_the_Economist_cover_1634854323*
- *https://www.seai.ie/publications/Energy-in-Ireland-2021_Final.pdf*
- *20220127-greenhydrogenactionreport-002.pdf (windenergyireland.com)*
- *https://energy.ec.europa.eu/topics/energy-security/eu-oil-stocks_en*
- *https://windenergyireland.com/images/files/our-climate-neutral-future-0by50-final-report.pdf*
- *https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ:L:2022:173:TOC&uri=uriserv:OJ.L_.2022.173.01.0017.01.ENG*
- *CRU Gas Safety Framework for Professionals in the Energy Sector*

Reply on public consultation

Review of the Security of Energy Supply of Ireland's Electricity and Natural Gas Systems

Consultation

19 September 2022

Our suggestion of how the Irish energy system should evolve for future energy supply of NG and Hydrogen

October 28th, 2022

Contents

List of Figures

List of Tables

Executive Summary

- The global gas market is going through unprecedented times in terms of pricing and supply due to a multitude of factors including geopolitical impacts (i.e., Russia/Ukraine), weather, decarbonization plans and increased LNG demand;
- In planning a resilient energy system that addresses security of supply, history shows that it is important to expect the unexpected;
- Underground Storage (UGS) has become a key strategic asset for most countries and indeed following on from the recent revision of the EU Gas Security of Supply, underground gas storage is now designated as "critical infrastructure".
- With the SW Kinsale gas storage facility being decommissioned, Ireland currently has no gas storage in place and so it relies on the depleting Corrib gas field and imports. Imported gas accounts for c. 65% of its supply through an interconnector to the UK (Scotland). As a result, Ireland is exposed to significant security of supply events at a time when gas demand is increasing at c. 15% per annum;
- Ireland is mostly dependent from UK which is in turn dependent from Europe and leverage on European Storage facilities. Due this UK has currently defined a new strategy based on building new storage NG capacity and revamp Rough (the UGS facility recently closed, for which Centrica is in charge of reopen)
- There is a need to ensure that Ireland's energy system can cater for today's urgent requirements for gas whilst also ensuring that there is a clear pathway for the development (and storage) of green hydrogen in order to meet Ireland's ambitious decarbonization plans. UGS provides a direct pathway for future hydrogen storage;
- Snam's experience in managing the gas infrastructure in Italy clearly demonstrates that a resilient energy system needs multiple solutions for diversification of supply (increased interconnectivity/LNG regassification) - all of which must be underpinned by large scale UGS;
- Energy storage (through UGS) represents the fundamental part of security of supply as it allows a company to limit the dependence on imports and last-minute shocks in terms of both supply and demand;
- All the experts and analysts in the energy market agree that underground molecular storage will continue to play a fundamental role to balance the energy system, as it represents the most efficient and economical way to store very large volumes of energy on a multi-day basis;
- The EU has on average 25% of its yearly demand (c. 3 months of gas consumption) in UGS;
- UGS is the best and most efficient solution for Ireland's energy security for the following reasons:
  - **Capacity**: single projects can easily allow for >1 Bcm (≈11 TWh) storage capacity;
  - **Costs**: lower levelized cost of storage (LCOS) vs any other solution assuming 2 cycles per year;
  - **Transition to H2**: the conversion of natural gas storage infrastructure is currently under development, with very positive results provided by the first pilot tests. The surface infrastructure can be built already hydrogen ready and the underground field can be tested for injecting a blending on Natural gas and Hydrogen or pure Hydrogen.
  - **Provides an additional supply source** to ensure continuity in case of supply interruptions due to infrastructure unavailability or commodity shortages (Strategic storage);
  - **Balances**:
    - the seasonal summer/winter differences in demand and supply;
    - day-to-day and within-day variability in demand and supply;
- Noting EU best practice, Ireland should add c. 1.5-2.0 Bcm (≈16-22 TWh) of UGS capacity (or 25%-30% of total demand) and have c.0.5 Bcm (≈5.5 TWh) of strategic storage reserves.

Today’s context for Natural Gas

2021 natural gas demand has grown 9% in Europe and 15% in China and rest of Asia. Progressive coal phase out, especially in Asia (including accelerated households’ switch from coal to gas in China), will support gas demand growth until 2040. By 2030, Chinese demand is expected around 500 Bcm (≈5500TWh), ten times 2005 levels, five times 2010, and nearly twice 2018.

Competition with Asia for the few available LNG tankers has been boosted due to:

i) demand growth,
ii) drop of domestic production in the North Sea,
iii) severe unexpected weather conditions,
iv) scheduled LNG plants maintenance,

This context leads to a hike in gas and electricity prices in Europe even before the beginning of the crisis between Russia and Ukraine. The extra cost for gas and power in Europe at the end of 2021 was estimated at c. €400 Bn on an annual basis, with LNG being the marginal source at which gas hub prices clear in Europe, thus influencing pipeline (take-or-pay) contracts and indirectly electricity prices.

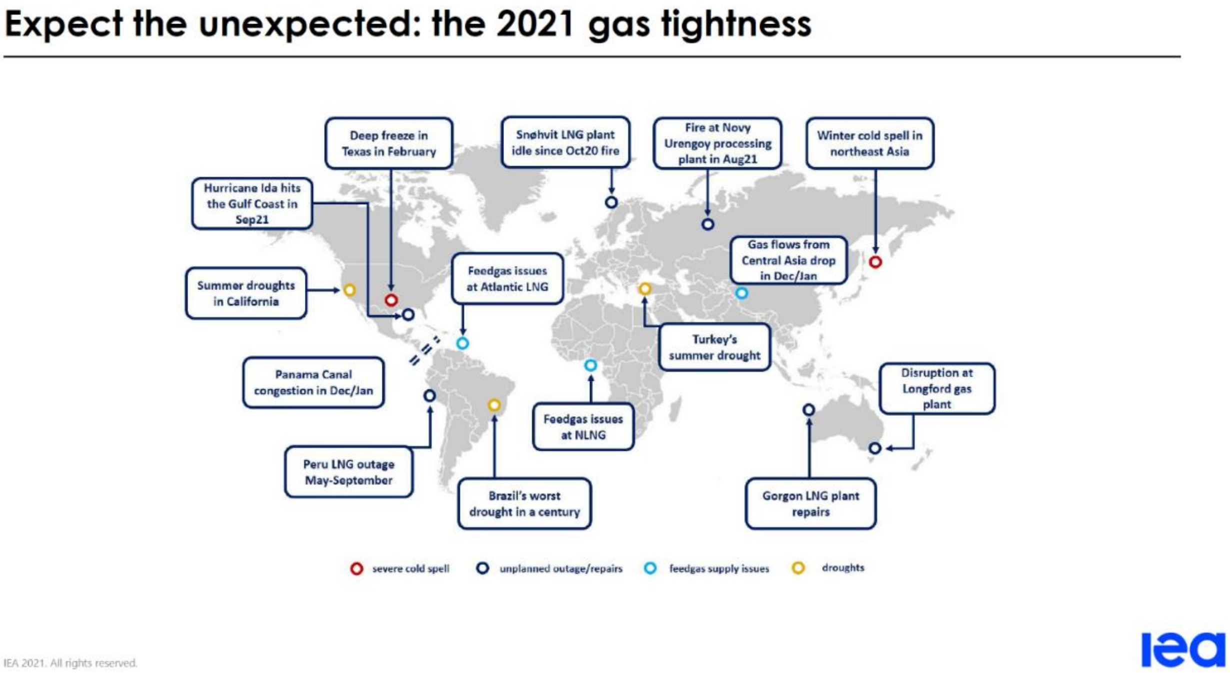


Figure 1 Gas tightness Globally

The onset of the crisis between Russia and Ukraine in February 2022, and the subsequent escalation of events which brought a severe cut of the supply of natural gas from Russia, underlined the fragility of the European Energy System from both an infrastructural and a commercial point of view due to the strong dependence on one single source of gas (Russia). As such, diversification of sources and security of supply has become of paramount importance at both European and individual country level.

Security of supply

Underground gas storage has quickly become a key strategic asset, as it provides countries such as Germany and Italy (c. 24 Bcm (≈263 TWh) and 18 Bcm (≈197 TWh) of working gas capacity respectively), which have c. 80-90 days of storage, additional resiliency and flexibility in the management of their energy system, by significantly reducing the dependency from imports when the gas market is particularly tight.

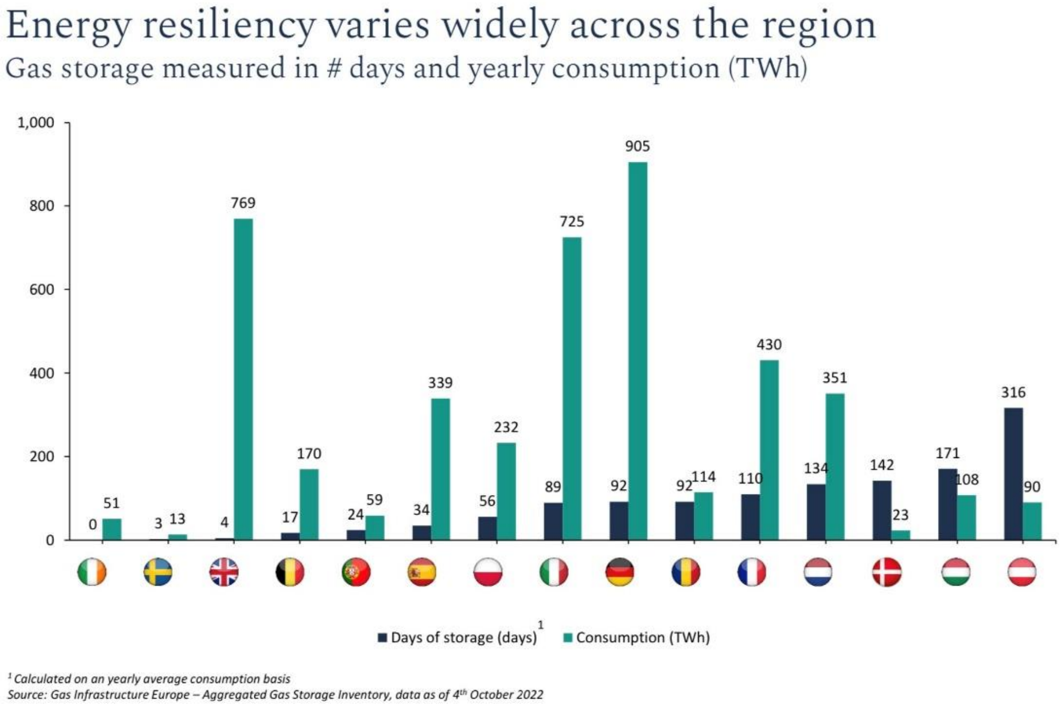


Figure 2 #of days of storage per country and Total Energy gas demand (on year base)

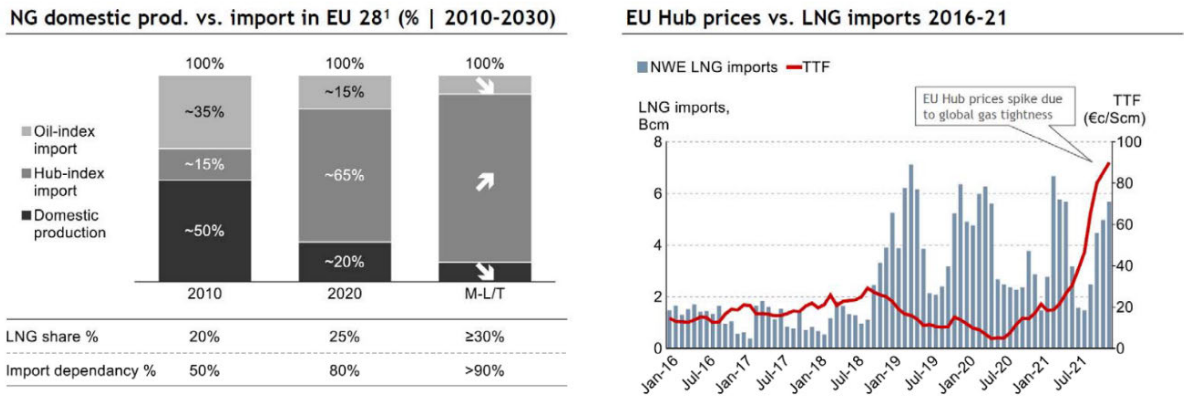


Figure 3 Natural Gas demand import vs domestic production (EU28) and TTF price trend

While the surge in the price of gas has significantly impacted all EU countries, it is evident that gas storage represents the most efficient and effective way to contain energy price volatility and ensure security of supply. As a matter of fact, countries less impacted by the natural gas crisis have all in common a diversified source of gas, redundancy in their infrastructure, including gas storage, and they have made huge investments in this essential infrastructure over the past years.

Diversification of sources

With declining production in the North Sea, and with limited natural gas availability from other sources via pipeline (i.e., North Africa and Azerbaijan), LNG has quickly become a key source of natural gas supply for most EU countries with sea access competing for the few available existing FSRU vessels (e.g., Italy has completed the acquisition of 2 vessels for a total c. 10Bcm (≈110 TWh) import capacity[12]);

[1] https://www.snam.it/en/Media/Press-releases/2022/Snam_purchases_new_floating_unit.html
https://www.snam.it/en/Media/Press-releases/2022/Snam_purchases_floating_LNG_regasification_from_Golar_LNG.HTML

[2] https://www.reuters.com/business/energy/germany-says-fifth-floating-lng-terminal-be-built-by-end-2022-2022-07-19/

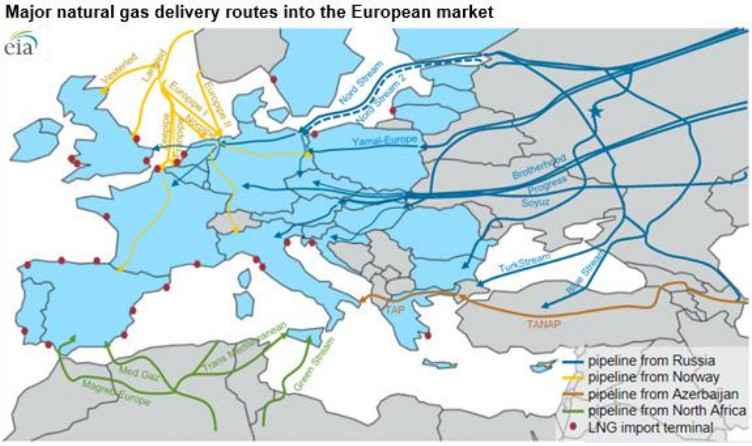


Figure 4 Natural gas flow scheme

The expected evolution of the EU energy system

The ongoing evolution trends, as well as the strict decarbonization and net zero targets set by the EU Commission (e.g., Fit for 55[3]), are pushing for a revolution of the European energy system characterized by growing interconnection[4] and interdependence between electrons and molecules (i.e., so-called sector coupling).

In this context, we are witnessing a continuous growth of intermittent renewables capacity, mainly solar and wind, driven by both the required switch from fossil fuel generation and significant electrification of final uses which require, and will continue to require, a boost in investment. However, as clearly highlighted by recent events, the increase of variability in the energy system will require adequate energy storage infrastructure, for each single country, to be able to efficiently balance the energy system throughout the different time spans, from seconds to seasons.

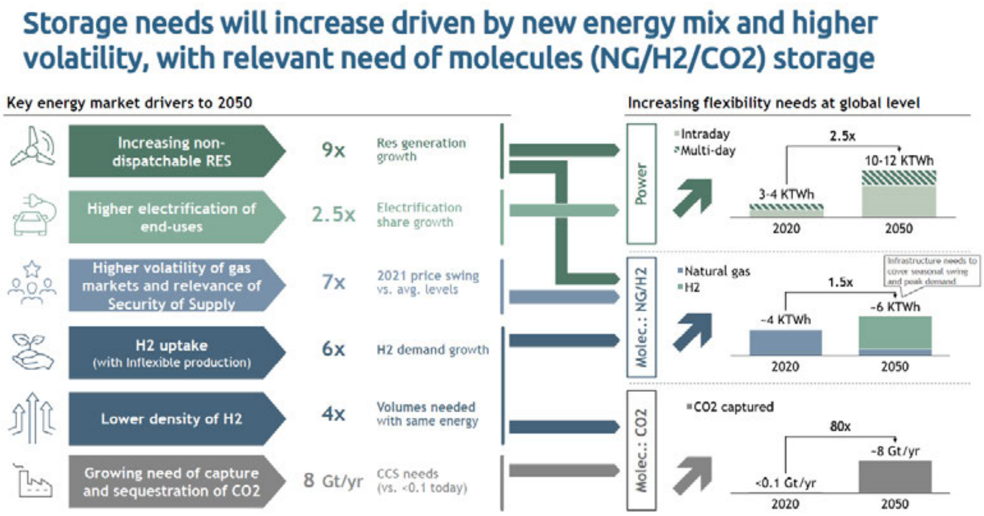


Figure 5 Storage need, flexibility increase at global level[5]

Within this frame of reference, and regardless of the scenario considered, all the experts and analysts in the energy market agree that underground molecular storage will continue to play a fundamental role to balance the energy system, as it represents the most efficient way to store very large volumes of energy on a multi-day basis.

---

[3] https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541
[4] State of the Energy Union 2022 – 18-10-22 COM (2022) 547 final
[5] Source: internal evaluation

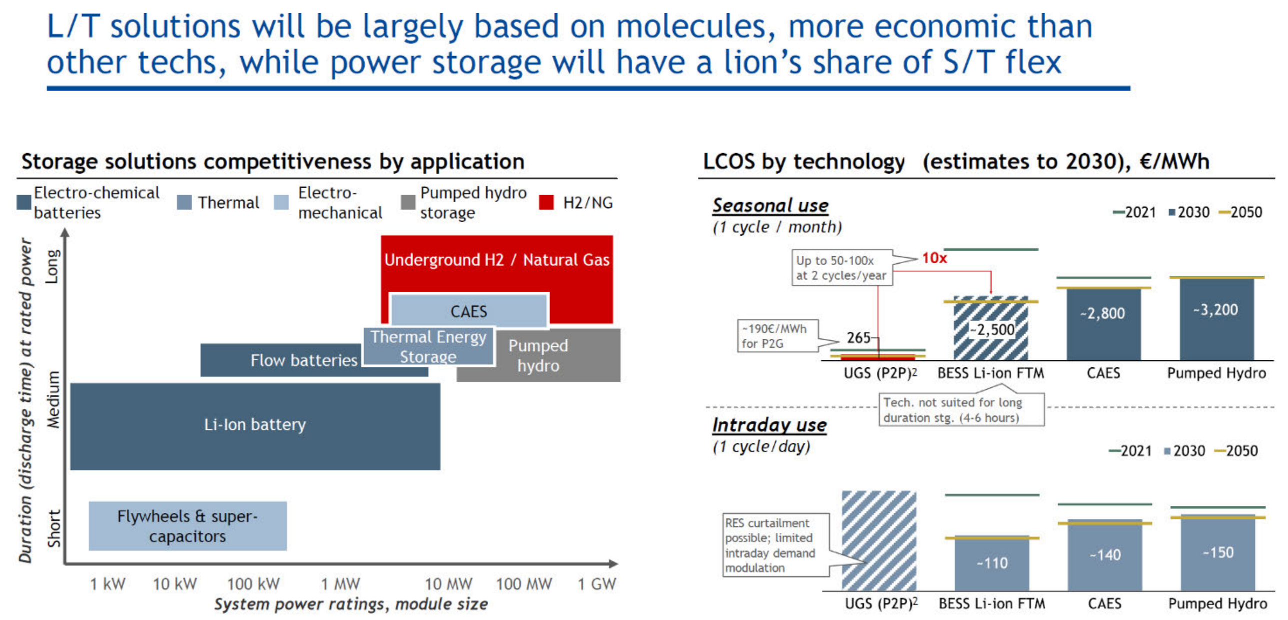


Figure 6 Storage cost estimate of electricity over production[6]

In this context, Italy is particularly well positioned, compared to other EU countries, thanks to its diversified gas supply infrastructure and gas storage system and should be considered as a role model in the existing energy paradigm.

Italian Gas infrastructure

The Italian energy mix is highly dependent on natural gas, which represents c. 40% of the total energy mix, with a total annual consumption of approximately 75 Bcm (≈818 TWh). As such, over the past 80 years, Italy has invested significantly in gas infrastructure, across the value chain, and today the country can rely on a vast and capillary energy system encompassing:

- 8 entry points;
- c. 33.000 km of natural gas transportation network;
- 8+1 underground storage sites for a total capacity of c. 18 Bcm (≈196 TWh) of working gas; and
- 3 regassification terminals + additional 2 FSRUs that are waiting to be anchored off the coast and connected to the gas grid.

Italian natural gas infrastructure evolution across the years

Italian natural gas infrastructure started from domestic gas production, particularly in the Po valley region in the industrialized northern part of the country. The country also has developed offshore gas fields.
During the economic development of the 1960's, more pipelines were needed. In the mid 1960's, the first underground gas storage facility and regassification terminal were developed (among the first in Europe).

As gas demand increased, a lot of effort was concentrated on the building of reliable import pipelines, considering that the indigenous gas production supply wasn't enough to meet demand. Currently, Italy imports more than 90% of their annual consumption (about 75 Bcm (≈818TWh)).

The Italian gas infrastructure that is owned and operated by SNAM resulted from the liberalization and unbundling of gas infrastructure assets from the international oil & gas company, Eni. In 2001, Snam was created as a separate company and listed on the market exchange. Snam became an infrastructure company, without ownership, neither title to produce, buy or sell the natural gas.

[6] Source: internal evaluation

Snam the Italian Natural gas infrastructure Owner

Today, Snam S.p.A. is one of the world's leading energy infrastructure operators and one of the largest Italian listed companies in terms of market capitalization. Snam S.p.A., organized under the laws of Italy, is a joint stock company listed on the Milan Stock Exchange with c. €14 billion market capitalization and an enterprise value of c.a. €28 billion as of September 2022. Cassa Depositi e Prestiti S.p.A. – the Italian development bank with over €425 billion group assets and consolidated equity of €36.7 billion – declared to exercise control over Snam S.p.A. through its subsidiary CDP Reti S.p.A., which holds 31.038% of the share capital of Snam S.p.A.

As of 31st December 2021, Snam Group reported consolidated revenues of €3.3 billion, an adjusted EBITDA of €2.3 billion and an adjusted Net Income of €1.2 billion. Snam is a holding company of a group whose core business is the full life management of natural gas infrastructures, with 33,000 km of transmission network, approx. 18 Bcm (≈196 TWh) of storage capacity and 16 Bcm/y (≈175TWh/y) of regasification capacity.
Snam is a leader in Europe in the development, operation and management of natural gas infrastructure: Snam transports, dispatches and stores natural gas and unloads, stores and regasifies liquefied natural gas (LNG).

As an integrated infrastructure operator, Snam plays a leading role in Italy's natural gas system owning, directly or indirectly, among others:

- 100% of Snam Rete Gas S.p.A., responsible for the management and development of the natural gas transportation system;
- 100% of Infrastrutture Trasporto Gas S.p.A., being the third Italian operator in the transport of natural gas, that manages the pipeline that connects the Adriatic LNG regasification terminal (Cavarzere, near Venice) to the national transport network near Minerbio (Bologna);
- 100% of GNL Italia S.p.A., operating in the regasification field;
- 100% of Stogit S.p.A., providing natural gas storage services;
- 55% of Enura S.p.A., a company in charge of the implementation of the gas transport infrastructure in the Italian region of Sardinia;
- 49.07% of OLT Offshore LNG Toscana S.p.A., the second largest liquefied natural gas (LNG) terminal in Italy. Snam has joint control of OLT alongside First State Investments International Ltd.

As of today, Snam holds interests, directly or indirectly, in the following companies that are active in the European gas infrastructure sector:

1. 20% stake in Trans Adriatic Pipeline AG, a joint venture with BP, Socar, Fluxys, Enagas and Axpo, based in Baar (Switzerland).
2. 40.5% stake in Terega S.A., a company certified under the ownership unbundling regime and jointly controlled by Snam and GIC of Singapore, based in Pau (France) and operating in the gas transmission and storage segment in South-West of France;
3. 84.47% stake in Trans Austria Gasleitung GmbH, a company certified under the ITO model and jointly controlled by Snam and Gas Connect Austria GmbH, based in Vienna which owns and operates the Austrian section of the pipeline system that connects Russia to Italy;
4. 19.6% stake in Gas Connect Austria GmbH, the independent transmission system operator certified under the ITO model and based in Vienna and controlled by the OMV Group, which owns and operates an 886 km natural gas pipeline grid in Austria;
5. 23.68% in the share capital of Interconnector UK Ltd, owner and operator of the bi-directional subsea pipeline between the UK (Bacton) and Belgium (Zeebrugge). IUK is certified by the UK and Belgian regulatory authorities under the ownership unbundling regime; and

6. 35.64% of Hellenic Gas Transmission System Operator S.A., Greece's national operator in the natural gas infrastructure sector, through a joint investment with other European gas transmission operators
7. Minority stake in ADNOC Gas Pipeline Assets LLC (49% participation in consortium with other members)
8. 25% of East Mediterranean Gas Company, owner of the Arish-Ashkelon gas pipeline, an undersea infrastructure 90 km long, is one of the main energy supply sources for Egypt
9. Snam currently holds 28.89% of dCarbonX, a U.K. and Ireland based company focused on subsurface storage of clean molecular energy and the geological sequestration of CO_2.

SNAM Infrastructure

Italian Natural gas supply is provided by (2020 data):

- **5 Entry points via pipeline (built starting from '60 with Tarvisio, Passo Gries and completed with TAP in 2020)**
    - Tarvisio – Mainly importing Russian gas from Austria and Germany;
    - Passo Gries – Mainly importing gas from the Netherlands and North Sea through Germany and Switzerland;
    - Mazara del Vallo – Mainly importing gas from Algeria;
    - Gela – Mainly importing gas from Algeria, through Tunisia;
    - Melendugno (TAP) – Importing gas from Azerbaijan through Turkey, Greece and Albania.

- **Underground gas storage facilities (Operation Date)** for about 19 Bcm (≈208TWh) of storage capacity (about 25% of the total demand), of which about 4.5 Bcm (≈49 TWh) of strategic storage for emergencies
    - Corte Maggiore (1964)
    - Sergnano (1965)
    - Brugherio (1966)
    - RIpalta (1967)
    - Minerbio (1975)
    - Fiume Treste (1982)
    - Sabbioncello (1985)
    - Settala (1986)
    - Bordolano (2015)

- **LNG through 3 regasification terminals**:
    - Panigaglia: in operation since late '70 onshore regassification terminal with a nominal capacity of 3.4 Bcm/year (≈38 TWh/y) and a storage capacity of c. 100,000 Scm of LNG, equal to c. 60 MScm (≈0,7 TWh) of regassified natural gas;
    - OLT (in operation since 2002): Floating Storage Regassification Unit (FSRU) with a nominal capacity of 3.75 Bcm/year (≈41TWh/y)and a storage capacity of 137,100 Scm of LNG, equal to c. 80 MScm (≈0,9 TWh) of regassified natural gas;
    - Adriatic LNG (in operation since 2009): Floating Storage Regassification Unit (FSRU) with a nominal capacity of c. 9.0 Bcm/year (≈98TWh/y) and a storage capacity of 250,000 Scm of LNG, equal to c. 150 MScm (≈1,6 TWh)of regassified natural gas;

SNAM Italian Transport System

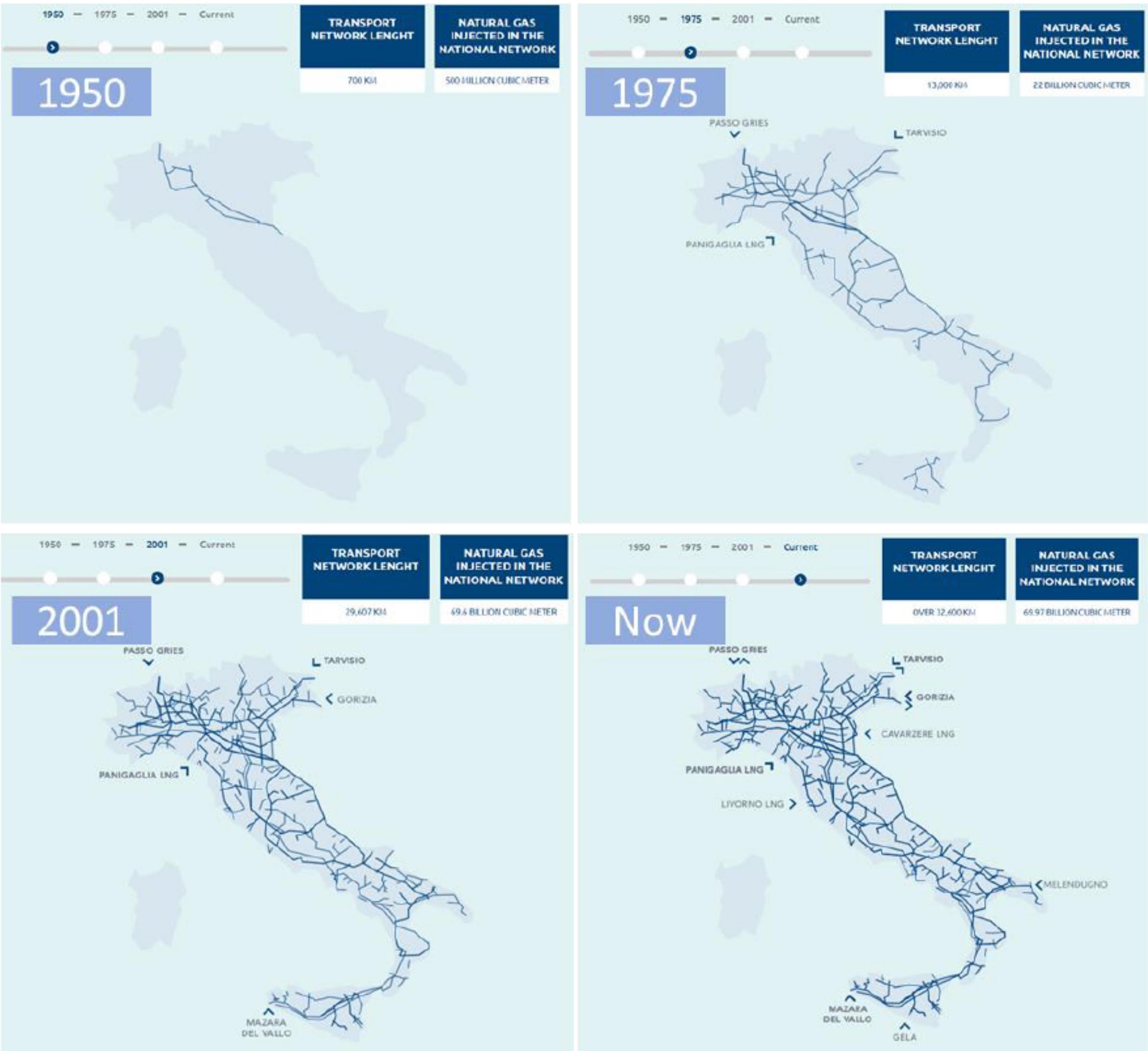


Figure 7 SNAM Italian transport system

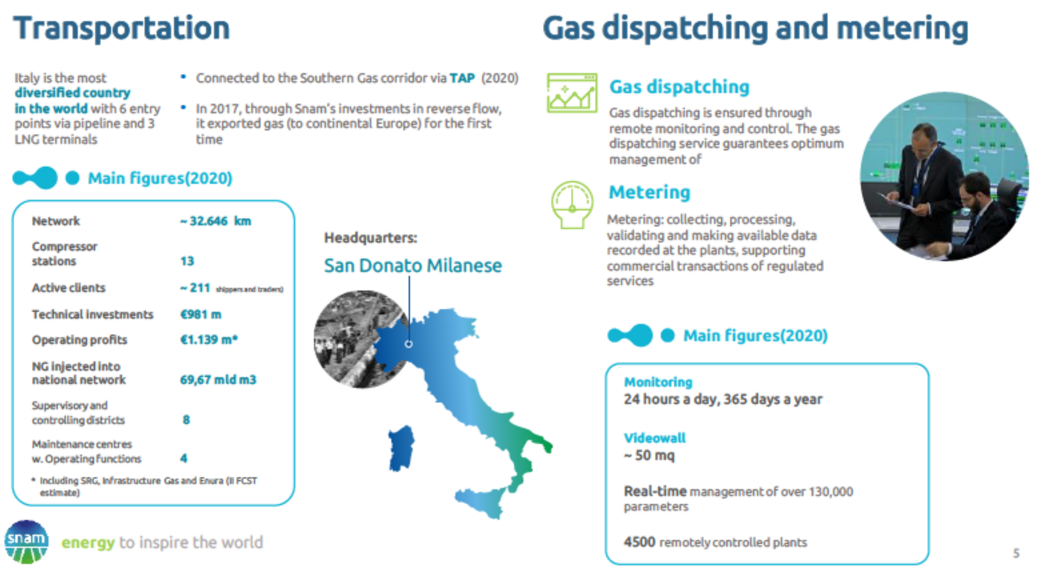


Figure 8 Extract from Official SNAM public presentation

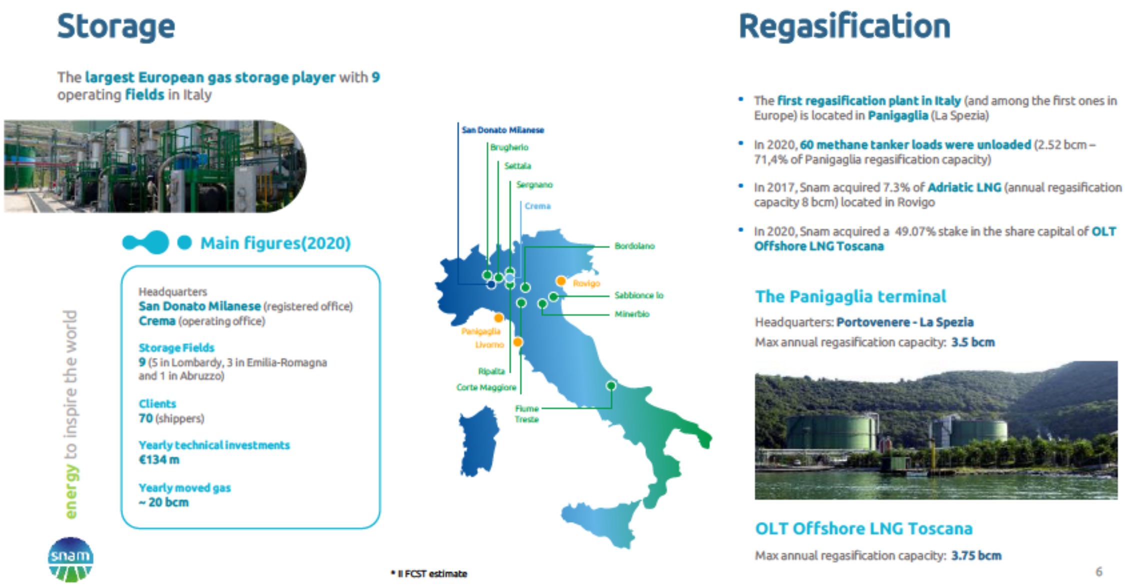


Figure 9 Few Details Italian Infrastructure

Italian natural gas demand is satisfied by several sources and the infrastructures system is perfectly compliant with N-1 rule defined accordingly to the EU regulation on security of supply. Considering the physical flows in 2021, Italy is 96% dependent on imports.

Italian strategy and main measures for guaranteeing diversification and security of supply

Despite an already diversified supply of gas, Italy has recently activated a huge investment plan for reducing the dependence from Russian gas, which today still represents c. 38% of total gas demand or c. 29 Bcm/year (≈318TWh/y) and guarantee the security of supply by enhancing the underground gas storage capacity.

Main measures are:

- Increase the flux of NG from TAP in Melendugno entry point with plans to double the import capacity of the pipeline;
- Acquisition of 2 Floating Regassification and Storage Units (FRSUs), for an additional capacity of c. 10 Bcm/year (≈109 TWh/y);
- Ensuring, through the regulatory framework, the constant filling of the 8 national storage sites to reach >90% (starting from 2022);
- Reverse flow plan from Italy to Europe (at the three northernmost national entry points) as part of the European general strategy.

The Italian strategy over the past few years and planned for the next decade is mainly focused on:

- enhancing the security of supply;
- diversifying the source of supply.

These two aspects need two different technological solution:

- The most effective way for security of supply is through enhancing the indigenous production of gas and the further development of underground gas storage;
- LNG regassification systems, costal deposit, and new pipelines provide a good answer for the diversification of sources, but do not guarantee the security of supply.

Ireland - Comparison to Italy and potential lessons learned

Ireland's situation is even more complicated compared to other European countries, since the country is not directly connected to Europe, the country has no gas storage, and the only source of supply is the depleting Corrib gas field and the existing gas interconnector with the UK, which in turn has lack of gas storage in place and limited LNG availability. Taking into consideration the Italian gas infrastructure as a reference, we believe that there are potential areas of intervention for Ireland that will deliver the objective of increasing security of supply and diversification.

Security of Supply

Energy storage represents the fundamental part of security of supply as it allows the country to limit the dependence of imports and last-minute shocks in terms of both supply and demand. There are different potential solutions answering to different specific needs, in particular, there needs to be solutions that address:

- Large and long-term energy storage (e.g., UGS) to provide seasonal services and security of supply;
- Very fast and flexible storage (e.g. Li-ion batteries, salt caverns, LNG) to provide balancing and peak shaving services for a very short period of time;

The European gas storage network, provides for 100 Bcm (≈1094 TWh) of total storage capacity, compared to a total natural gas consumption in 2021 of c. 412 Bcm (≈4507 TWh), which means that, on average, the EU has a storage capacity totaling c. 25% of its yearly demand or c. 3 months of gas consumption.

In Italy, 13 Underground Gas Storage (UGS) facilities account for about 20 Bcm (≈219TWh) or c. 30% of the total yearly gas demand, (usually partly used for covering peak demand in winter, but also available to mitigate international crisis. A dedicated strategic storage is sized to *ensure for 30 consecutive days, during the winter period, supply from the most relevant import source (Defined by Ministerial Decree)*.

Looking at the EU best practice, Ireland should add c. 1,5 – 2,0 Bcm (≈16-22 TWh) of storage capacity (i.e., 25%-30% of total demand) and have c. 05bcm (≈5,5 TWh) of Strategic storage reserves.

We consider underground storage as the best and most efficient solution to be developed for the following reasons:

- **Capacity**: single projects can easily allow for >1 Bcm storage capacity;
- **Costs**: lower LCOS [See table 2] vs any other solution assuming 2 cycles per year as both unitary capex and opex are lower vs LNG or any other solutions. In addition, UGS does not require significant energy to keep the stored gas in a liquefied status and does not present boil-off issues which is typical of LNG terminals;
- **Transition to H2**: the conversion of natural gas storage infrastructure is currently under development, with very positive results provided by the first pilot tests. The surface infrastructure can be built already hydrogen ready and the underground field can be tested for injecting a blending on Natural gas and Hydrogen or pure Hydrogen. LNG facilities instead are much more difficult / costly to repurpose given the very different technical characteristics of the two molecules. Italy for example is heavily investing in upgrading both its infrastructure and storage sites to hydrogen compatibility, as part of the wider European hydrogen backbone project[7].
- **Provides an additional supply source** to ensure continuity in case of supply interruptions due to infrastructure unavailability or commodity shortages (Strategic storage);
- **Balances**:
  - the seasonal summer/winter differences in demand and supply;
  - day-to-day and within-day variability in demand and supply;

[7] https://ehb.eu/

Diversification of Supply

LNG, in particular through the acquisition of FSRUs, represents a flexible and available solution to diversify the supply of natural gas for the country. On average, European countries derive approx. 20% of their supply from LNG sources (either as FSRUs or costal depots with regasification facilities). Italy has currently c. 16 Bcm (≈175 TWh) of LNG capacity (c.23%) split on the existing 3 regassification infrastructures. However, the current geopolitical situation has pushed the Italian government to pursue the acquisition of an additional 2 FSRU vessels which will add an additional c. 10 Bcm (≈109 TWh) capacity in the next 2 years, increasing the potential proportion of LNG to meet total gas demand to c. 37%.

Other EU countries, such as Germany, Belgium and the Netherlands are pursuing similar strategies to reduce their dependence from Russian gas.

Looking at EU best practice, Ireland should add c. 1.2-1.5 Bcm (≈13-16TWh) additional yearly import capacity though LNG terminals or FRSU (i.e. 20%-25% of total demand).

However, one should keep in mind that the LNG/FSRU market is currently tight:

- on the vessel side, as the current global situation has pushed many countries to look for FSRUs in the market;
- on the supply side, as LNG investments have been postponed in the last few years due to the very variable demand for LNG supply in EU over the last few years.

The current energy crisis has boosted investments throughout the value chain with ongoing expansion / new liquefaction plants, as well as new regassification vessels, being built which will add capacity on both ends providing more stability to the global LNG market, but the delivery of this at scale is some several years away.

Conclusions

In general terms, UGS sites and FSRUs can co-exist to deliver a resilient and safe gas market, where one considers the FSRU as an alternative import source and the UGS as the flexibility and resilience tool that also provides security of supply in country.

Today, Ireland has only two sources of gas supply, the depleting Corrib gas field and the interconnection pipe linking Ireland to UK (Scotland). In order to seek diversification, the government may decide to introduce in the energy supply mix around:

- 1.5-2 Bcm (≈16-22 TWh) of Storage capacity through underground gas storage;
- 1.2-1.5 Bcm (≈13-16TWh) of additional yearly import capacity though LNG terminals or FRSU.

Almost all the countries which have access to the sea have LNG/FSRU terminals, and almost all European countries have underground gas storage. In pursuing such a strategy, one should take into consideration that LNG/FSRU's do bring attentive issues that might conflict with the Irish government's stance on decarbonization as the international LNG market is highly competitive and therefore subject to market price escalation (depending on supply and demand) where the sourcing of LNG may be from countries that are not pursuing a similar decarbonization plan (i.e. fracked gas). Additionally, the operation of an LNG and or FSRU facility require substantial energy to be used to keep the LNG in a liquified state before regassification.

The essential role of UGS has been further endorsed by the recent EU policy in terms of mandatory targets for filling levels and capacity. To reach these targets, it is possible to consider also the LNG physically stored and available in LNG facilities, even if LNG storage is commonly considered as very short-term storage (e.g., weekly), while UGS can provide seasonal storage.

Potential, concrete Irish case for UGS development at Kinsale

Based on number of technical and operational factors, we believe that reservoirs in the Kinsale Head area could represent a good location for UGS in Ireland in the immediate future, especially as this area was successfully used for underground gas storage until 2016. The Kinsale Head field was originally operated by Marathon Oil (since the late 1970's) and subsequently by Petronas (since 2010). In addition to being Ireland's major source of natural gas production for nearly 40 years, the Kinsale Head area also hosted the SW Kinsale gas storage facility which operated from 2001 through 2016.

This SW Kinsale UGS facility provided natural gas storage for Ireland, that amounted to c. 10% of the then Irish electricity market, providing Ireland with a safe, reliable in-country storage facility that ensured that peak shaving and network supportive gas resources were in place to avoid supply disruptions and importantly, provided risk mitigation from significant price fluctuations.

With the decline of production from the main Kinsale gas producing fields, by 2016, the Petronas (Operator) took a decision to move to a cessation of all gas production and gas storage activities. The Kinsale Head area is currently being decommissioned.

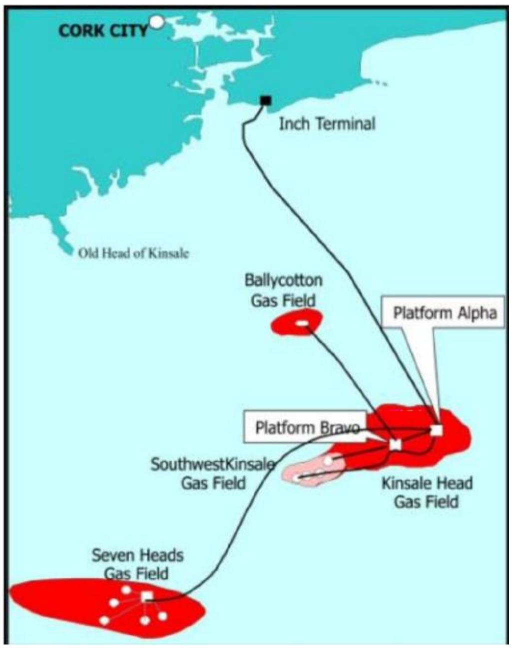


Figure 10 Location of Ballycotton and Kinsale
Graphic courtesy of Kinsale Energy Limited

Based on Italian fields and high-level expertise on the public production data, preliminary estimation about the potential storage capacities of the Kinsale Head area, and referencing the historical data on storage activities between 2001 and 2016, as well as extensive proprietary technical work carried out by Snam and its affiliate dCarbonX on the sub-surface and associated infrastructure, we are satisfied that the redevelopment of the Kinsale Head area for UGS could deliver a **total working gas capacity of 1.55 Bcm** (≈17 TWh) which would address the immediate storage needs summarized in the previous sections.

Providing the realization of appropriate studies and based on the experience gained during the ongoing hydrogen Italian development program, we also consider that the Kinsale Head area is a good candidate for later conversion to green hydrogen storage. The redevelopment for gas storage could be done to ensure that the newly installed facilities are hydrogen ready from the beginning.

Snam would welcome the opportunity to further share its analysis and recommendations with the relevant authorities on the redevelopment of UGS at Kinsale Head.

Summary Facts about UGS and FRSU

Below, we provide a generic analysis of the major considerations regarding UGS and FSRU for Ireland. In preparing this analysis, it should be noted that we have not provided factored in any potential additional timing implications for planning and consenting in Ireland, nor have we considered the impact of any existing or proposed legislative amendments in Ireland.

UGS

- From now, online @2026;
- Proven model successfully deployed in Ireland - Ireland had a successful offshore storage at Kinsale from 2001 through 2016;
- Medium and long-range storage assets additionally act as a larger buffer in case of supply disruptions and/or exceptional demand events;
- Certainty of gas availability;
- Annual cost defined ex ante (insurance policy-like);
- Potentially used also to create hydrogen strategic storage for the future green energy environment;
- Less environmental impact as offshore and sub-sea;
- Total investment for storage development, on average, 0.5€/m3 of working natural gas (for depleted field) or 1€/m3 of working natural gas (for salt caverns)

FSRU

- From now, online @2025, but currently there is a shortage in FSRU availability and costs are rising due to increased demand;
- Never deployed in Ireland;
- Certainty of gas availability just for the LNG tank capacity;
- To cover a longer period of shock, need to attract more LNG cargoes but:
    - Market conditions can be penalizing;
    - Geopolitics can impact supply;
    - Weather conditions don't guarantee the timely gas availability;
- Cost of security not defined *ex ante;*
- Using FSRU only for security reasons imply high operating costs, mainly due to the boil-off and cooling costs (and with a substantially higher carbon footprint);
- FSRU (floating storage regassification unit) are flexible assets capable either to transport and re-gasify LNG, likewise onshore terminals. Regassification capacity can vary in accordance with the engineering set up. As of today, most of the 49 FSRUs currently built have a storage capacity between 138,000 and 175,000 cm of LNG equivalent to approx. 80 to 105 Mscm (0,87-1,14 TWh) of natural gas;
- As of today, FSRU market is particularly tight and only a few vessels are potentially available in 2025-2026 time horizon;
- Because of current global turmoil, several players have actively procured FSRUs to increase regassification capacity. Prices have significantly increased ranging on the chartering market from $110-$150k/d (CAPEX part) and to purchase from $350M - $450M[8;] FSRUs are suitable to store LNG for a short /mid-term time horizon because of cost of storing and natural boil-off process, implying a loss of 0.15%- 0.2%/day of the total storage capacity.

[8] https://www.snam.it/en/Media/Press-releases/2022/Snam_purchases_new_floating_unit.html

Comparison – UGS, FSRU AND LNG Terminal

Table 1 Comparison - UGS, FRSU and LNG terminal

	UGS	FSRU	LNG Terminal
Security of Supply	Yes	No	No
Diversity of Supply	Flexible to NG Sources incl. Biomethane	Fracked & Non-Fracked LNG	
Days of Storage	30-90 days (storage technology)	Up to 7 days for conventional use (import technology)	Up to few weeks for conventional use (import technology)
CO_2 footprint	Low	High (energy intensive & boil off)	
LCOS (levelized cost of storage) (Mln€/TWh)[9]	**≈5-15[10] One cycles of loading and unloading per year**	**≈ 40-70 Two cycles of loading and unloading per year**	**≈ 35-70 Two cycles of loading and unloading per year**
Hydrogen Ready	Surface facilities can be built Hydrogen ready, the subsurface facility can be tested	No, need a substantial revamping	
Adjusted Capex (€ MLN/TWh)[11]	≈50-150	≈450-550[12]	≈400-500[13]
Years of operation [14]	c.a. 40	c.a. 20-25	c.a. 30
Visual Impact	Unseen (subsurface offshore)	High visibility (natural harbor)	High visibility (coastal land, few sqkm)
Tried & Tested	Kinsale Field (Irish experience)	Overseas examples	
Key critical aspects for seasonal storage application		LNG storage in tanks is subject to boil-off gas, fractionation and variation in composition due to evaporation of the more volatile phase (with potential loss of specs for grid injection)	

[9] Source Internal Estimation based on conventional LCOS methodology with avg interest rate 7%
[10] Depending mainly on the presence of cushion gas
[11] Of Storage Capacity
[12] Capex based on recent market deals, calculated oversizing the LNG storage capacity for guaranteeing the same availability (during the operation a portion of the LNG storage is lost due to BOG, reducing the amount of storage capacity available)
[13] Capex based on IHS database, calculated oversizing the LNG storage capacity for guaranteeing the same availability (during the operation a portion of the LNG storage is lost due to BOG, reducing the amount of storage capacity available)
[14]Before substantial revamping

List of acronyms

- EU: European Union
- FSRU: Floating storage and regasification unit
- LCOS: Levelized cost of storage
- LNG: Liquefied natural gas
- NG: Natural Gas
- TAP: Trans Adriatic Pipeline
- UGS: Underground gas storage

Conversion

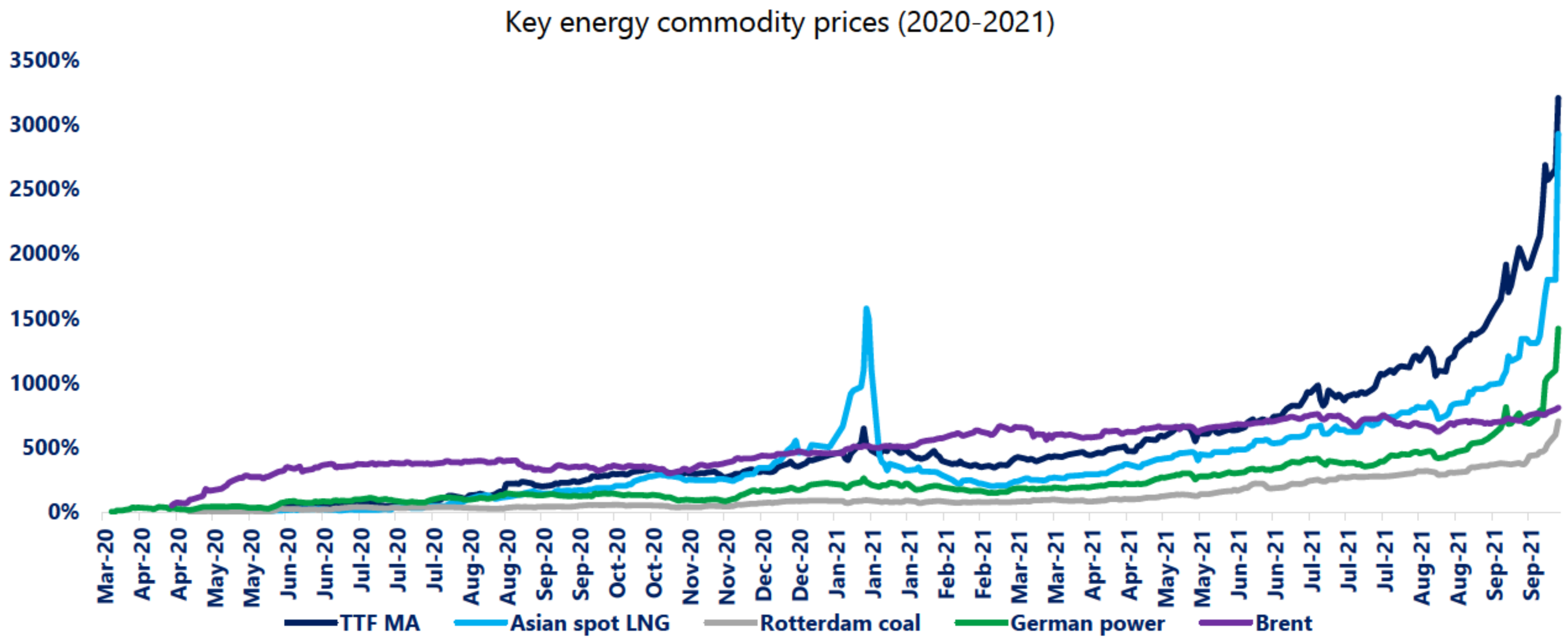
- 1bcm=10,94 TWh[15]

[15] SNAM Website https://www.snam.it/en/storage/tools/converter.html PCS 39,4MJ/Smc

When gas gets the Economist cover: recent market trends and medium-term outlook

51st International Gas Conference, Siófok 19 October 2021

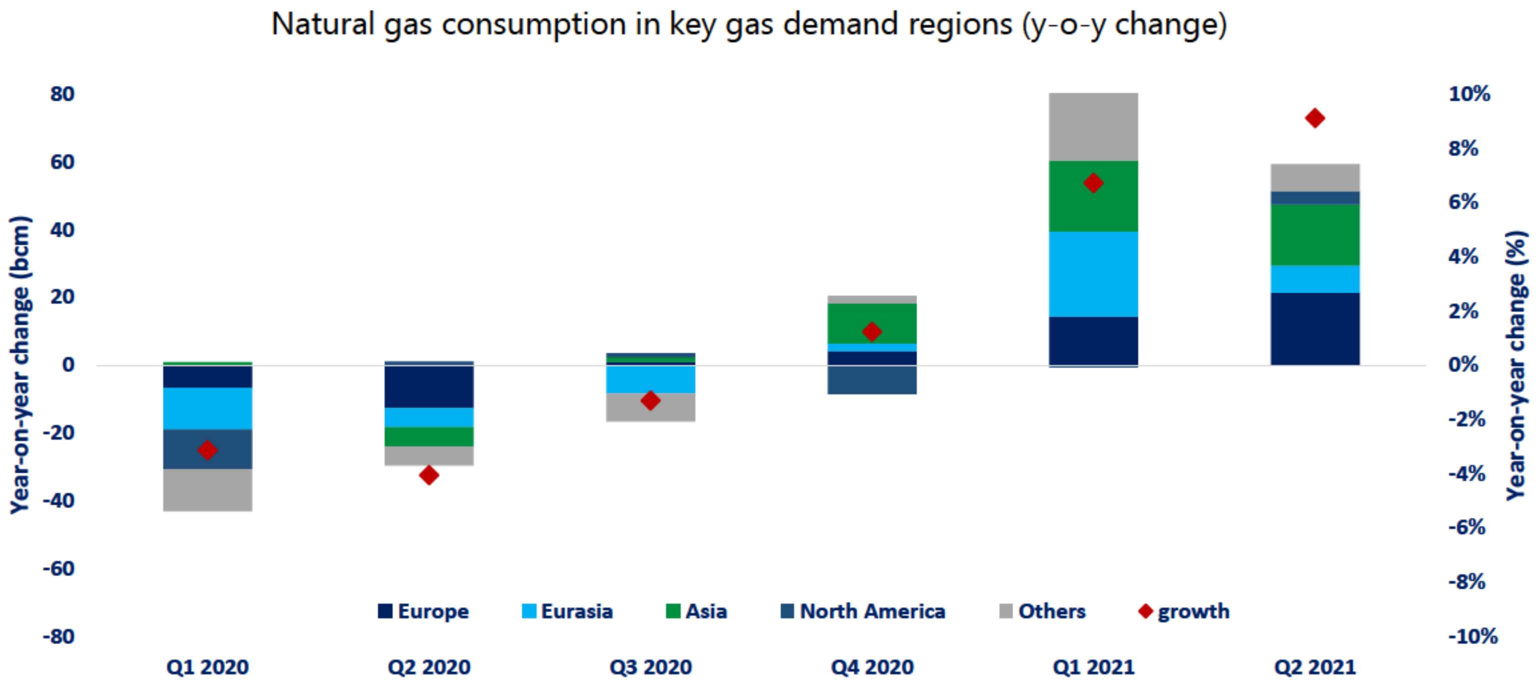
Gas prices surged from record lows in 2020 to all-time highs in 2021



Strong demand recovery together with supply chain rigidities led to sharp increase in all energy commodities, with natural gas taking the centre stage.

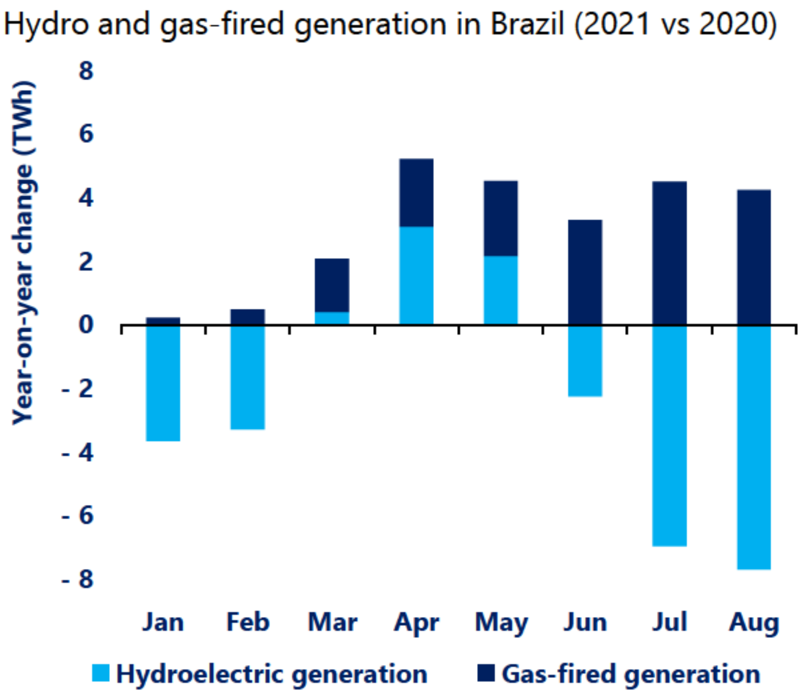
Expect the unexpected: the 2021 gas tightness

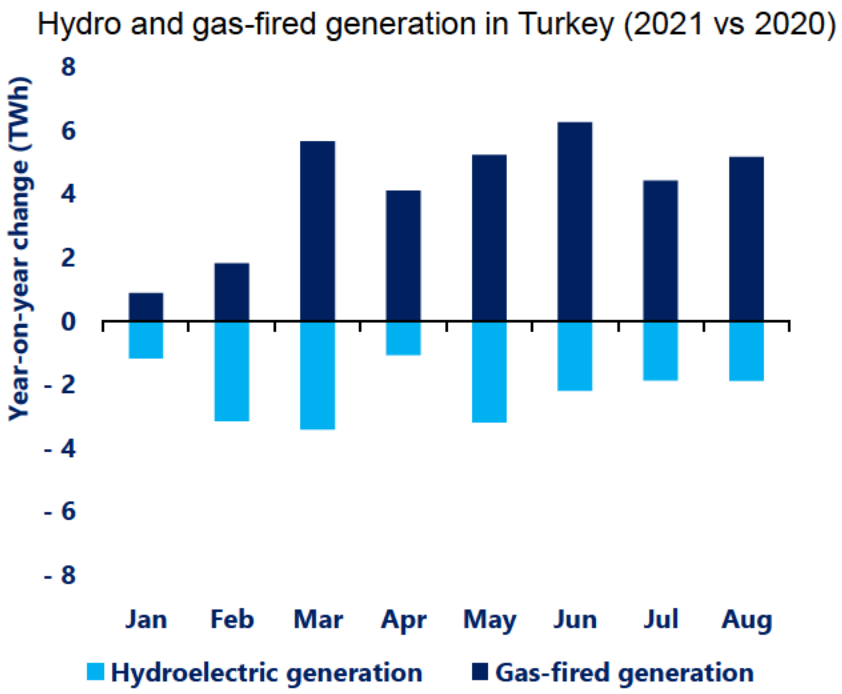
Gas demand: a strong rebound in H1 2021



Natural gas demand grew more strongly than expected. Besides recovery in economic activity, weather-related events boosted gas consumption across key gas regions.

Gas played a key role in ensuring electricity supply security

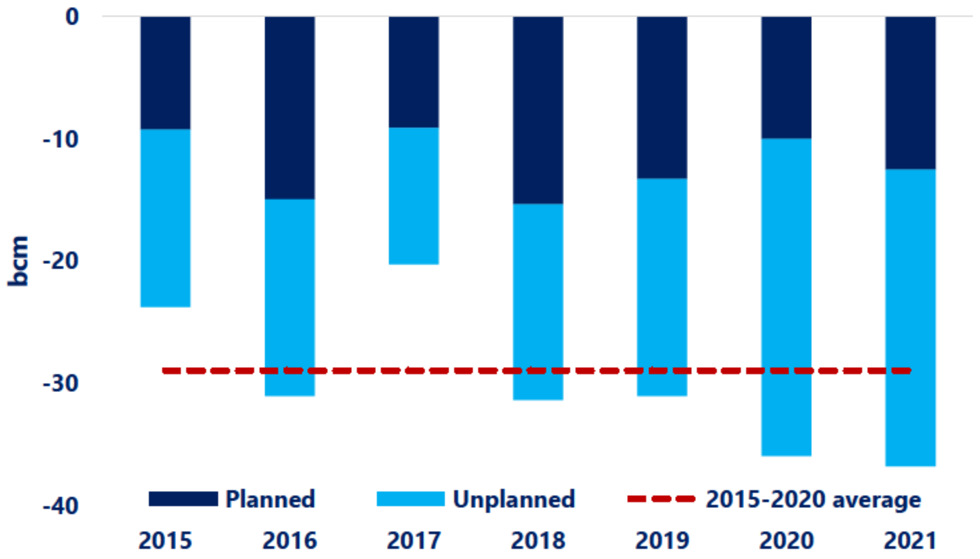




Flexible gas-fired power generation played a key role in providing back-up in hydro-rich power markets facing severe droughts through 2021.

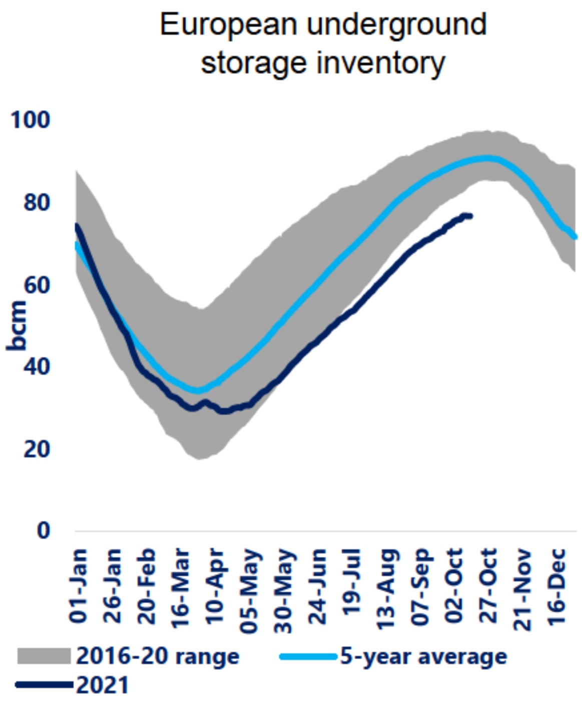
Gas supply: maintenance and outages limited output and flex

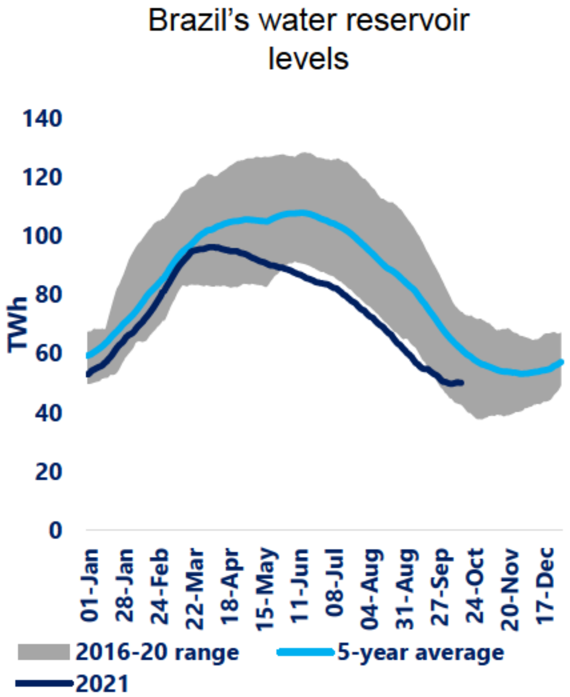
Estimated capacity impact of planned maintenance and unplanned outages (9M 2015-2021)

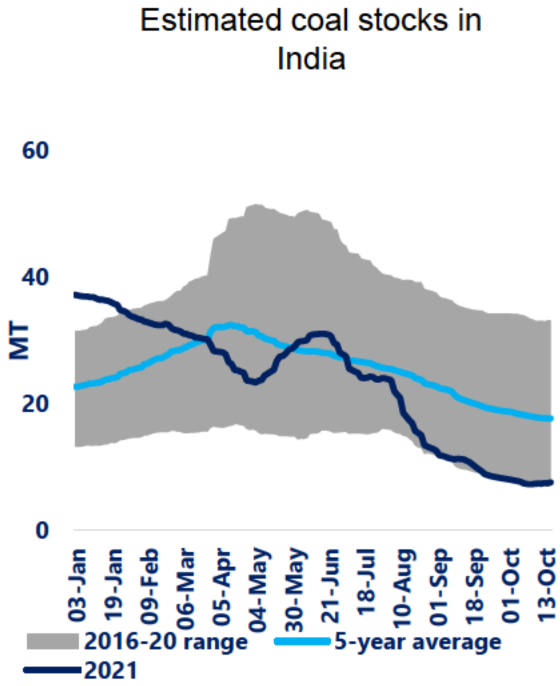


Delayed maintenance from 2020, together with unplanned outages resulted in higher supply unavailability than previously expected.

Winter is coming…



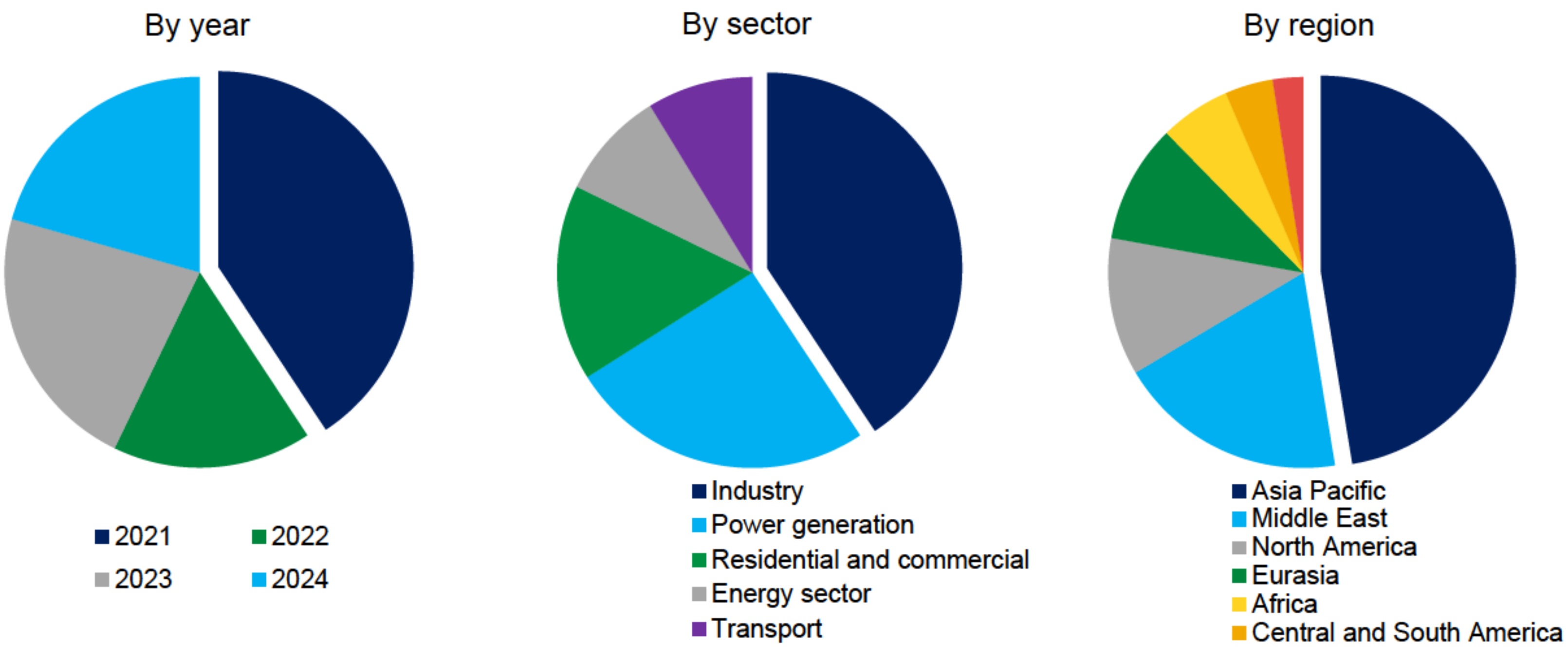




Lower storage levels could increase primary gas supply requirements during the 2021/22 heating season and fuel potential spot price volatility.

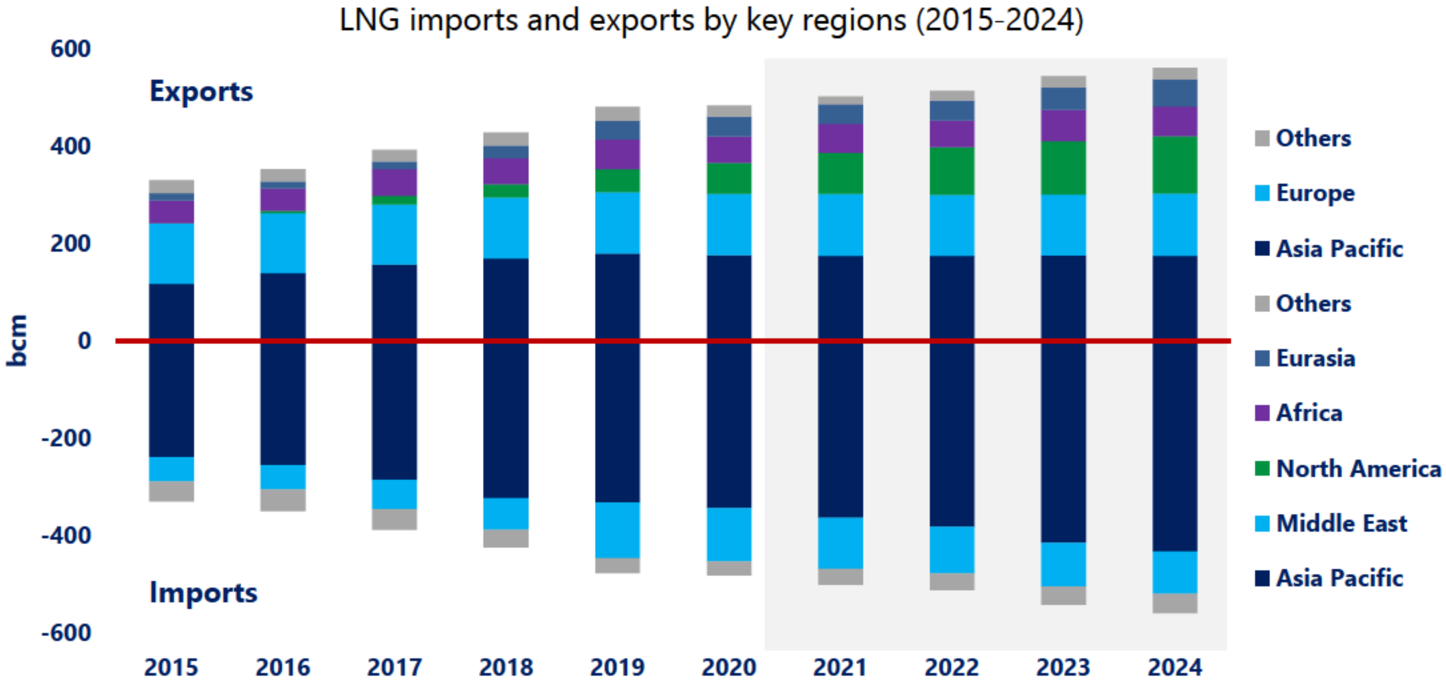
Global gas demand growth slows down after 2021

Breakdown of forecast growth in global natural gas demand, 2020-2024



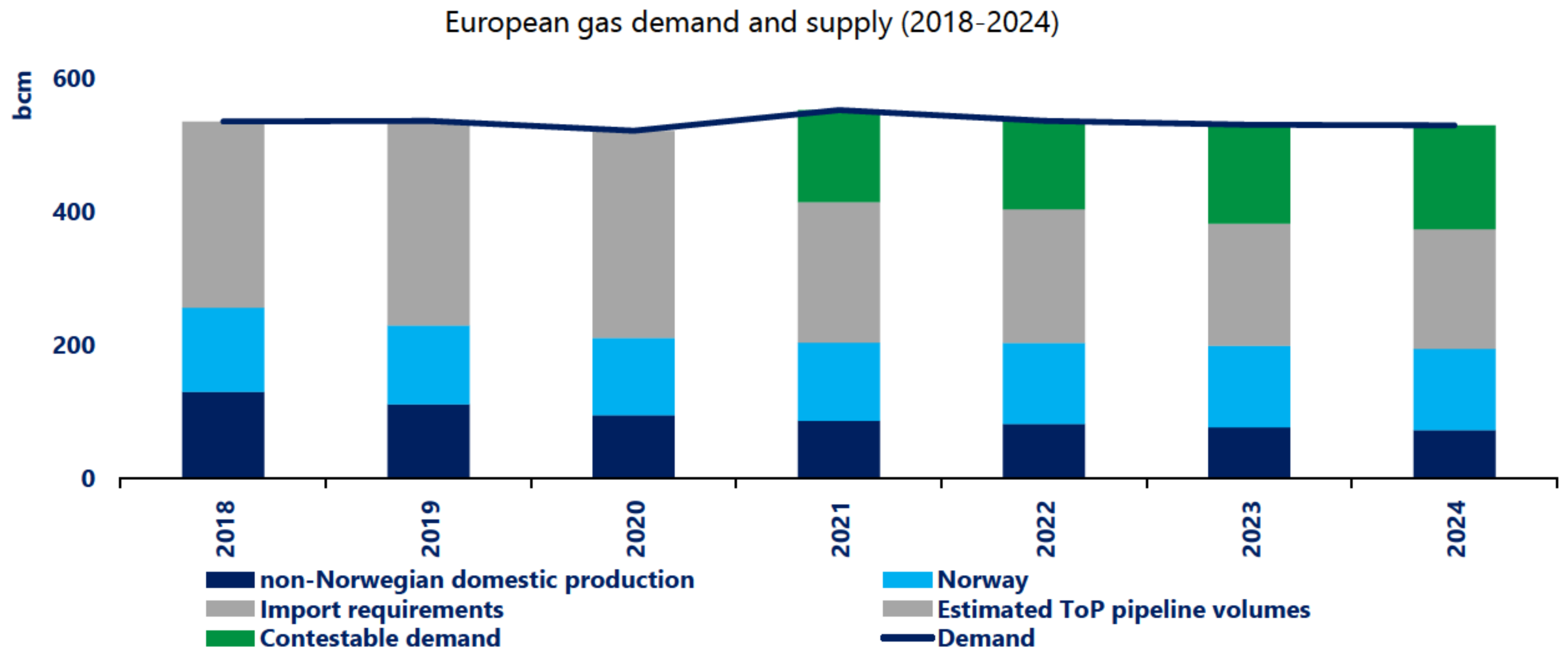
Recovery in 2021, the industrial sector and Asia region lead gas demand growth in 2020-24.

LNG is set to remain a key driver of global gas trade



Global LNG trade is expected to expand by 16% between 2020 and 2024, driven by continued demand growth in Asia and capacity expansion

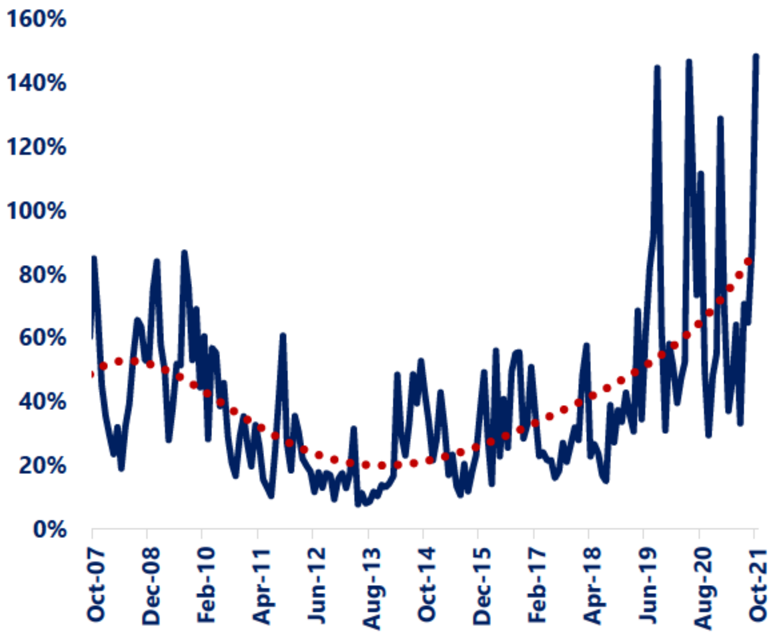
Europe's contestable market space is set to grow



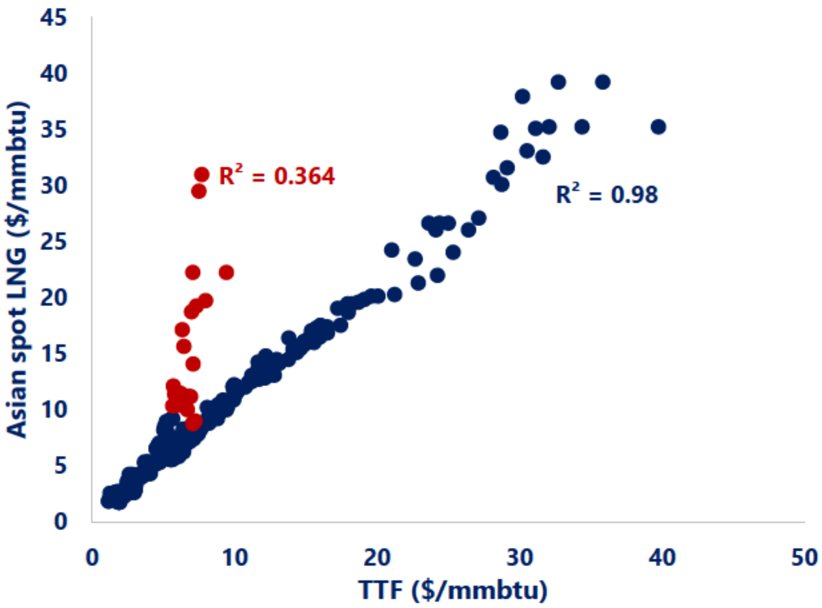
Declining domestic production, together with the gradual expiry of long-term contracts will increase Europe's contestable market space despite the region's slowly declining gas demand.

Gas prices: towards greater volatility in a globalised market?

TTF monthly volatility (2008-2021)



TTF vs Asian spot LNG (2020-21)



The volatility and variability of gas prices has been rising in recent years, while the inter-influence between Asian and European spot prices continued to grow.

Conclusions

- **Natural gas demand** grew strongly in the H1 2021, supported by economic recovery and weather factors.

- **Gas supply was tighter than expected** due to a combination of a heavier than usual maintenance and unplanned outages.

- **Prices in Asia and Europe soared to record levels** by the beginning of the heating season, while energy storages are well-below their 5-year average.

- **Gas demand growth is expected to slow-down in 2022-24**, with half of demand growth is expected to be driven by switching from more polluting fuels.

- **Europe's contestable demand is set to grow** amidst declining domestic production and the gradual expiry of long-term contracts.

- **Gas price volatility** has been rising in recent years, in an increasingly globalized gas market.