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Regulation of Long-Term Energy Storage from a Sector-Coupling Perspective: Lessons from gas storage

CEER Analysis

Gas Infrastructure Work Stream
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Abstract

This document (C21-GIF-169-07) presents CEER's reflections on the regulation of long-term energy storage from a sector-coupling perspective and the lessons learnt from gas storage. It is intended to serve as a background paper for future work on long-term energy storage and related discussions.

Target audience

European Commission, energy suppliers, traders, electricity customers, gas consumers, electricity industry, gas industry, network operators, Member States, academics and other interested parties.

Keywords

Long-term energy storage; electricity storage; gas storage; renewable energy; natural gas; electricity infrastructure; gas infrastructure; infrastructure development; security of supply; sector coupling; dynamic regulation.

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Related documents

CEER Documents

- CEER White Paper on Long-Term Storage, 15 February 2021.

External Documents

- British Secretary of State for Business, Energy and Industrial Strategy. "UK Hydrogen Strategy", August 2021. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf
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EXECUTIVE SUMMARY

In February 2021, CEER published its White Paper on Long-Term Energy Storage[1] which gave a first overview of the needs and the state of the art in terms of storage solutions in the context of decarbonisation and sector coupling. The purpose of the present paper is to deepen the reflection on the possible regulatory aspects in the context of the experience of underground gas storage in order to help address issues regulators or policymakers may be confronted with during the decarbonisation process.

With the large-scale development of renewable energy sources (RES), the risk of misalignment between power generation and consumption might be exacerbated, but similar issues could also come with the development of new energy vectors such as hydrogen. Relying on RES generally will amplify the weather dependence of energy production. Guaranteeing energy systems' reliability and resilience will thus require filling potential gaps between production and consumption at all times, which in turn highlights the increasingly important role of energy storage in terms of security of supply (SoS) and system management.

The natural gas sector has long-standing experience with this issue. In many countries, storage plays a critical role to cover the variations of demand and is a pillar of security of supply. It was designed to complement transmission in order to optimise infrastructure developments. Over the years, the gas sector has made storage a key component of the supply chain as a buffer between a constrained supply and a partly-unpredictable consumption, while competing with other sources' flexibility and hedging options.

However, experience shows the market does not always spontaneously deliver what is needed in terms of capacity or volume of gas stored, and that the economic and technical fundamentals can justify implementing third-party access (TPA) rules to existing facilities. TPA for underground gas storage facilities is mandatory in the European Union (EU) but can take the form of negotiated or regulated access according to market characteristics. Regulatory interventions, if implemented, also relate to positive externalities (security of supply, maximisation of renewable energy production, etc.). Concepts of market and system values were developed to help understand situations where energy storage is needed collectively, but individual decisions may not provide the desired outcome.

In many Member States (MS), underground storage regulation objectively articulates market and system value, though following different orientations. The purpose is to provide services fit for users' needs and, at the same time, ensure security of supply. The national case studies presented in the annex highlight different approaches to regulation, with a relatively balanced breakdown between regulated and negotiated TPA (nTPA). Some countries have opted for specific measures aimed at guaranteeing a certain volume of gas in storage while others chose to trust the market.

In summary, regulatory intervention should be appreciated according to several dimensions including technological options (decentralised vs. centralised techniques, contestability), business models (role of storage in terms of business strategies and system management) and security of supply (investment planning and corrections of misalignments between individual decisions and collective needs). Based on the lessons from gas storage, European energy regulators draw the following conclusions:

[1] CEER White Paper on Long-Term Energy Storage, 15 February 2021, https://www.ceer.eu/documents/104400/7158746/C21-FP-48-03_CEER+White+Paper+on+long-term+storage-2.pdf/531b1a53-8bc9-7eb2-6da4-1e866fd867a0.

1. **Long-term planning:** Storage needs and means should be integrated into the network planning process, based on scenarios that incorporate assumptions on supply and demand profiles as well as the expected level of supply reliability.
2. **Existing assets as a lever for RES development:** Gas storage is a transitional lever to maximise the use of renewable energies by avoiding conversion losses. This is done by relying on existing gas facilities to maintain a high level of security of supply and gradually substitute natural gas by decarbonised solutions.
3. **Identifying the relevance of regulation:** Energy storage may be regulated in case there is a risk that individual decisions do not lead to appropriate capacities or volumes of stored energy. If the overall efficiency of the system is improved by centralised management of energy storage facilities, then TPA or storage services might be put in place.
4. **Storage support to competition**: With the development of intermittency, it may be more difficult for suppliers to meet their obligations to their customers and to the system (in particular, balancing obligations). Storage could, therefore, be of renewed importance in terms of competition. In terms of market players' competitiveness, access to storage may be needed to preserve a level playing field in supply.
5. **Measures specifically dedicated to security of supply:** If, for security of supply purposes, there is a risk of undersizing or insufficient energy storage, then strategic storage or guarantees of a minimum level of storage may be put in place. Allocating capacity at market value, via well-designed auctions for instance, could also promote high volumes of stored energy, thereby completing cost recovery from consumers who benefit from security of supply.
6. **Dynamic approach to regulation**: European regulators are aware of the uncertainty affecting future developments in the European energy system and therefore advocate for a dynamic approach to regulation. This would allow the regulatory framework to be adapted to market circumstances and industry needs.

1 Introduction

The European Green Deal's[2] objective of carbon neutrality by 2050 requires action at all levels of the energy value chains. While the development of RES is a pillar of the European energy strategy, it could lead to an increased uncertainty about production's availability due to the intermittence of generation. A lower weight of controllable generation in the electricity mix will exacerbate the risk of misalignment between generation and consumption. Decarbonisation also goes hand-in-hand with the development of new vectors supporting reduced environmental footprints of various energy uses, and hydrogen is expected to play an important role in this respect. Relying on RES will generally amplify the weather dependence of energy production. Guaranteeing energy systems' reliability and resilience will require addressing potential gaps between production and consumption at all times. Hence, energy storage will become more important as a technical solution and buffer to bridge supply and demand, releasing momentary surpluses of production when needed by consumers. That could also be the case for hydrogen. If the market for green hydrogen reaches a significant size, similar issues relating to bridging supply and demand will appear and storage could become critical in terms of security of supply and system management.

The natural gas sector has a long-standing experience with this issue since storage has been developed at a large scale to accommodate a lack of flexibility in the upstream part of the supply chain. In many countries, storage plays a critical role to cover variations in demand and was designed as a complement to transmission, in order to optimise infrastructure developments. The liquefied natural gas (LNG) chain also includes storage facilities to modulate injections into the network from "discrete" deliveries (cargos unloading). In summary, the gas sector has made storage a key component of the supply chain as a buffer between constrained supply and partly unpredictable consumption. To some extent, gas storage and the consequent development of gas turbines have also contributed to changing electricity demand. The dynamics of the electricity system tend to show that in the long run, a structural need for storage may emerge, which allows for bridging consumption and supply.

The aim of this paper is to analyse how the experience of natural gas could help in addressing the role of energy storage in the future European energy system. The paper also assesses how the potential regulation of storage can act as a complement to market-based mechanisms or to help the market develop, e.g. if similar issues were to arise for other vectors (electricity, hydrogen). The paper's purpose is not to address short-term flexibility or the regulation of storage installations that already play a role in the electricity system as part of flexibility sources and ancillary services (whose role mainly consists of contributing to short-term supply/demand balance and network stability). While recognising that participation in balancing is part of the value of storage, the present paper does not focus on this aspect, but rather addresses storage from a longer-term perspective (and a larger scale). The paper also acknowledges that storage competes with other options in terms of providing flexibility and market strategies (such as hedging over price volatility over time and, in an integrated energy system, over price differentials in different sectors). Promoting a level playing field is therefore crucial.

The main aim of this paper is to show that, when it comes to gas storage, the market does not always spontaneously deliver what is needed in terms of capacity or volume of energy stored. Moreover, the economic and technical fundamentals can justify implementing TPA rules to existing facilities. TPA to underground gas storage facilities is mandatory in the EU but can take the form of negotiated or regulated access, according to market characteristics. Regulatory interventions, if implemented, also relate to positive externalities (security of supply, maximisation of renewable energy production, etc.). Concepts of market and system values have been developed in the gas sector to help take into account situations where

[2] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

energy storage is needed collectively, but individual decisions may not provide the desired outcome. This is where regulation kicks in, to help market value be consistent with system needs and to address potential detrimental gaps.

The **CEER White Paper on Long-Term Storage** gave a first overview of the needs and the state of the art in terms of storage solutions. The purpose of the present paper is to deepen the reflection on the possible regulatory aspects in the light of the experience of underground gas storage. The aim is not to elaborate on the need for storage in the future but to develop an approach to the issues according to the conditions regulators may find during the decarbonisation process. In addition, the paper does not question the fundamentals of regulation (unbundling rules, non-discrimination, technological neutrality, role of market mechanisms to balance the system). Instead, it opens perspectives on how to address storage needs at a system level, as part of the adequacy assessment, in order to secure supplies, stimulate competition and optimise infrastructure development. The paper also addresses the potential scenario of growing constraints on energy availability.

2 Conclusions of the CEER White Paper on Long-Term Storage

In February 2021, CEER published a White Paper on Long-Term Storage whose purpose was to assess various long-term storage options and to better understand the potential role of storage with a focus on intermittence of power supply and existing gas storage facilities.

A first conclusion of the paper is that, from a technical point of view, there is no foreseeable demand for long-term storage of electricity until at least 2040 on an average European scale. The remaining controllable fossil fuel power plants would indeed provide the required generation capacities to the power sector.

In addition, the report concludes that interconnectors do not significantly reduce the demand for long-term storage and the ratio between installed PV and wind power capacities has a significant impact on the long-term storage demand. Power-to-gas (P2G) facilities, as purely market-driven long-term storage activities, might not be economically viable for a long time to come, except maybe in extreme circumstances (very high energy prices).

However, such outlook might change if guarantees of origin (GOs) along with higher CO_2 prices are considered[3], which could make alternative technologies competitive, assuming other bottlenecks do not prevent their large-scale development. In case of a 100% RES scenario, the viable pumped hydro potential in Europe could only cover a small proportion of the storage needs. Installing an excess of variable RES generation assets providing surpluses of energy as well as promoting demand-side flexibility, could be seen as solutions which, however, are only able to provide flexibility for up to a few days. This might change if price volatility grows. The increasing electrification and growing hydrogen-based energy sectors could offer new long-term flexibility potentials, though one must acknowledge that important uncertainties remain in terms of technological options.

Against this background, the only storage technology currently capable of providing the needed amounts of storage capacities is gas storage. For the future, exploring other options would be necessary. For that purpose, European energy regulators recommend achieving a level-playing field in the sector, to avoid giving priority to one technology compared to others[4]. Potential regulation should focus on services to the energy system, providing a stable, simple and cost-reflective regulatory environment.

The paper also recommends improving long-term planning by better modelling storage and sector-coupling technologies in the Ten-Year Network Development Plan (TYNDP). Currently, only pumped hydro storage facilities connected at 110kV or above are modelled. To better anticipate a sector-coupled energy system, planning tools need to extend their current system boundary.

[3] Guarantees of origin and CO_2 price increase should however deliver enough additional value to these technologies to make them competitive, such evolution should be stable enough to be included in business plans of investors.

[4] The principle is to identify the most efficient options without ex-ante prioritisation.

3 Methodological orientations for addressing storage from a regulatory perspective

Energy storage means taking a quantity of energy at a given moment for the purpose of delivering or using it at a later point in time according to needs. Such a temporal shift aims at different objectives, including ensuring security of supply (e.g. making energy available to consumers in the event of a production shortfall) or achieving greater system efficiency (e.g. optimal sizing of transmission systems in case of seasonal fluctuations of demand). Options aimed at optimisation behind the meter (e.g. electric batteries) do not directly contribute to system needs and are therefore not considered for the purpose of this paper. In the Clean Energy Package, energy storage is defined as “deferring the final use of electricity to a moment later than when it was generated”. Energy storage also includes the conversion and storage of electricity in other energy forms, with the possible subsequent reconversion to electricity. Under such a broad perspective, P2G technologies are still part of electricity storage solutions, even though they are not storage facilities as such.

3.1 The role of storage

Assessing the need for storage requires a detailed knowledge of consumers' needs, as well as of their rights. For instance, the rules on security of supply determine reliability thresholds at national or even European levels (a certain number of hours of annual non-distributed energy for electricity or an X% threshold for gas where X represents the probability of supply failure in a given winter), which allow one to determine the peak demand the system has to meet. Demand profiles/load curves also make it possible to assess the supply surpluses that will feed the storage facilities, which act as interfaces to deal with inter-temporary differences.

Storage is thus aimed at bridging the temporary gaps between supply and demand. Such gaps are further exacerbated by the development of RES, whose production depends on exogenous conditions. The amount of time to be deferred depends on market conditions and technological features of different storage solutions. These technological features lead to diverging timeframes between the gas and electricity sector, with the latter mostly focused on the short-term perspective. When the gap is seasonal in nature, we enter the domain of long-term storage.

With system integration, the whole spectrum of temporary timeframes becomes relevant for both the gas and electricity sectors: While the very short-term timeframe is covered by batteries, seasonal gaps are bridged by gas storage. However, gaps ranging from a few days to a few weeks also could emerge, e.g. in order to deal with climate hazards such as drought or prolonged low winds. Therefore, it is important to determine what kind of services and benefits storage solutions can provide, and how they position themselves among the various sources of flexibility.

In the 2021 CEER White Paper on this topic, gas storage is highlighted as the main source of long-term flexibility for the next few decades with particular regard to the possibility of storing hydrogen and biogas. However, the question is also to what extent keeping a share of natural gas in the EU energy mix might help to achieve a better integration of renewables (i.e. providing stability and security of supply). When answering this question, we also need to consider that natural gas could help by giving priority to the most efficient usages of green energy and avoid losses at certain levels of the value chains for storage or flexibility purposes.

3.2 The value of storage

While its operation occurs on a short-term basis and is influenced by the market design, storage capacity has to be designed in advance since an underground storage facility takes ten years to be developed. This bears the risk of over or under-sizing.

The value of storage is a critical aspect of the reflection on regulation. Two different kinds of values can be identified:

- **Market value**: short-term and seasonal price spreads (arbitrage purposes or participation to balancing markets). The market value is primarily influenced by the market design.
- **System value**: insurance value (security and quality of supply), system optimisation (cost savings allowed by storage use) and other positive externalities. The system value refers to technical features in terms of supply and demand.

As regards the market value, storage is part of diverse flexibility sources. In some cases it can be considered contestable by other means; in other cases not, especially when the peak in gas demand cannot be met by only relying on local production or imports. In regard to triggering storage decisions from market players, the question is whether they are in line with what is needed for security of supply. The market value is influenced by the market context (see next section). It regards market players' hedging strategies and anticipatory behaviour.

It is the value of storage from a system perspective that can make certain types of regulatory intervention necessary, in particular, where competitive alternatives are insufficient in respect to the market size and peak of demand. For instance, in many countries' natural gas markets, underground gas storage has no substitute for providing flexibility to cover seasonal variations of demand (e.g. when supply sources are insufficient to cover peaks of demand). The contribution of gas storage might thus be fundamental to ensure security of supply. Public authorities might further evaluate the imposition of security of supply standards if problems are identified. Furthermore, in the electricity sector, the development of variable energy sources increases the risk of desynchronisation between generation and consumption. Thus storing surpluses of production might become increasingly important in terms of supply continuity and system management. In networks, the role of storage could be helpful to handle congestion (i.e. by avoiding oversizing transmission assets by smoothing flows over time). This opens questions regarding storage's integration within different kinds of networks (i.e. electricity lines and pipelines). In this respect, storage solutions might provide a cost-effective alternative to network reinforcements, thus having a potential system value and bringing cost savings. Similarly, energy storage might deliver positive externalities in terms of environmental benefits if it prevents RES curtailment. The system value is a concept based on opportunity costs principles: Is it worth paying for the cost of storage (collectively) if we compare it to the cost of supply disruption? This is a classical assessment of security of supply which can include, as a benchmark, value of lost load concepts or cost of disrupted gas. One must also recall that the system value has a political dimension too.

The specific case of hydrogen

The development of low-carbon hydrogen will bring new concerns in terms of supply reliability, management of intermittent production (when RES based) or the effects of maintenance and assets' technical failures. Relying on supply by pipe means that stable pressure ranges will have to be respected. Pipes will represent a buffer between supply and demand (i.e. line pack), but beyond the very short-term flow management, implementation of redundancies and storage might be necessary. Different techniques exist in various sizes – from tanks to underground storage facilities – with different merits and costs.

Local systems may rely on small-scale assets. However, large transmission lines could justify promoting underground facilities, given that their location is subject to the availability of appropriate geological structures. Storage could become necessary not only for flow management purposes but also for the valuation of potential production surpluses. In terms of technologies, salt caverns are promising, while depleted fields and, under certain conditions, aquifers may be appropriate for larger volumes.

In terms of regulation, given the low level of development of the hydrogen sector, infrastructure planning and investment has to be the priority. Storage access and services may be further regulated in the future, but acquiring a proper understanding of the specific features of the hydrogen value chain is a prerequisite. In terms of commercial relationships, storage could play an important role to secure supply agreements between producers and consumers, which could justify developing large-scale infrastructure. Offering storage services in a centralised way could also be an option.

4 Factors influencing the type of regulatory intervention

In terms of potential regulation, two aspects have to be considered: (i) Should a TPA to storage facilities be decided in view of the potential market power of storage operators?; and (ii) in case a regulated TPA is decided upon, what kind of products and tariffs need to be designed, in particular to properly address the potential gap between market and system value? Regulation also addresses short and long-term aspects. In the short term, it concerns how to use the existing assets. In the long term, it focuses on how to ensure a proper sizing of capacities.

Regulatory intervention has several purposes, of which the main one is the correction of market failures. This includes the needs to grant access to essential facilities and to correct insufficient valuation of externalities which can lead to wrong anticipatory behaviour from market actors, thus hindering security and quality of supply. In sum, several issues would have to be addressed for determining an appropriate regime. The purpose is to develop a framework for analysing whether long-term energy storage should remain entirely within the market or be opened to third parties under a regulated or negotiated regime. The question of system operators' direct access to storage in a network management perspective could also be addressed, as well as potential internalisation of storage services within the system operation.

Energy storage provides services that may compete with other technical options. Thus, potential regulation should not distort such competition but rather focus on system management optimisation, security of supply and supporting competition among energy suppliers. In the gas sector, storage competes with production and imports, but the combination of all these modes is necessary to securing supply. The implementation of the Third Energy Package[5] improved cross-border integration, which sometimes exacerbated intermodal competition which could reduce the market's appetite for storage. From a sector coupling perspective, in a context of strong innovation, regulators do not want to close the door to any option. At the same time, regulators are aware that investment goes hand-in-hand with anticipation. This means it is necessary to provide long-term perspectives as much as possible and limit the risks of stranded costs.

The choice of the potential regulatory regime has to combine several dimensions which relate to:

- **Technological options**: There are many storage techniques and their technical and economic characteristics are diverse. Some are "contestable", others can be seen as essential facilities depending on the context. In view of the uncertainties concerning technical developments, it is necessary to focus on the general characteristics of the various storage methods, including their energy efficiency.
- **Business models and storage value**: Several designs can be envisaged for energy sector coupling in terms of infrastructure and network management that also influence the role of storage. Some options can be developed in a decentralised way, while others might benefit from a centralised approach, considering economies of scale. The different types of services need to be assessed according to their links to market design, the value for market players as well as their value for the system.
- **Long-term planning**: The need for storage facilities and their location has to be anticipated sufficiently early enough, as their development can often take years and be costly, thus requiring visibility and economic security. In this respect, joint investment planning for gas and electricity and the inclusion of storage solutions in infrastructure

[5] The Third Energy Package introduced EU energy market legislation, aiming at improving the functioning of the internal energy market and resolving certain structural problems. It entered into force in September 2009.

planning are crucial to assessing the needs in terms of storage capacity and location in networks.

4.1 Technological options

For the various time spans(short-term to seasonal), several technologies which differ in their degree of maturity can be used. In the electricity sector, most of the flexibility is provided by controllable production sources. While there are cases of electrochemical storage, they concern a relatively marginal amount of energy. Most of the electricity storage capacity is provided by hydroelectric basins. Therefore, storage is mostly used for short- to medium-term applications.

Several studies have compared the relative characteristics of storage technologies in terms of capacity, power, response time, cost and location (with the consumer, with the generator, or at the transmission or distribution grid level). A 2017 European Commission staff working document[6] on energy storage provides the following mapping of storage options:

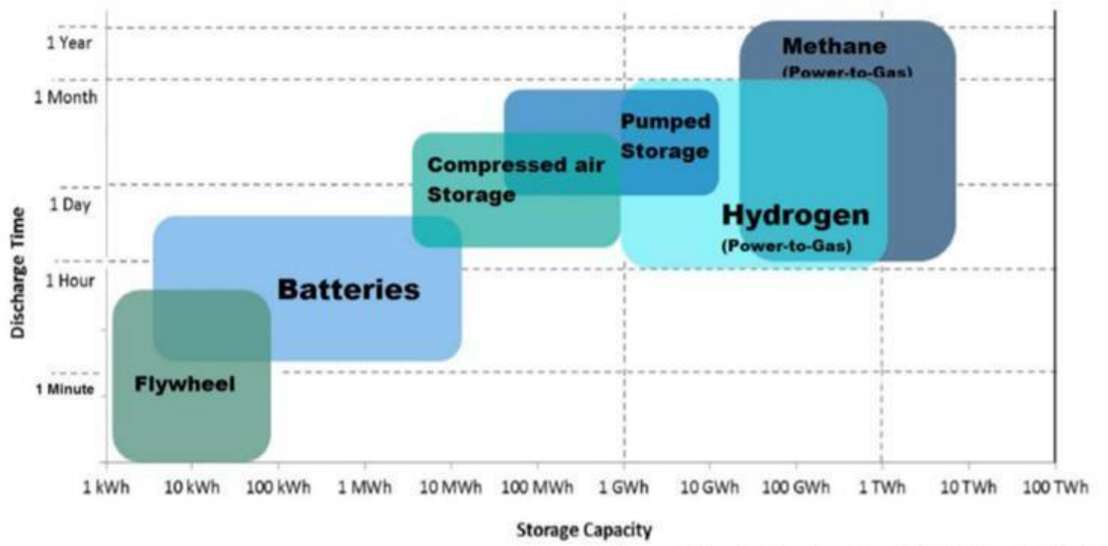

Figure 1 – Available electricity storage technologies, their capacity and discharge time (Source: European Commission staff working document, Energy storage – the role of electricity, 2017)

Long-term storage focuses on the large-scale with a long-time of withdrawal (upper-right part of the graph). The picture could be enlarged to underground gas storage which serves as back-up for intermittent power generation in association with gas turbines. From a sector-integration perspective, bio-methane storage could provide such flexibility while not being formally an electricity storage (i.e. power-to-gas-to-power). Nowadays, this role is played by natural gas storage. However, intermittence development could lead to a need for large amounts of storage capacity. Therefore, before decarbonised options are competitive and available at the right scale, gas storage could keep a role in managing long-term flexibility needs.

In the gas sector, storage is provided by depleted fields, aquifers and salt caverns, used with a medium- to long-term perspective. Relatively small volumes of storage could in principle be also provided by LNG terminals, though they are rarely used with this purpose. Gas storage

[6] https://energy.ec.europa.eu/system/files/2017-02/swd2017_61_document_travail_service_part1_v6_0.pdf

provides some flexibility to the electricity sector but cannot be seen as electricity storage *per se*, unless it builds upon surpluses of electricity, especially in the case of variable RES paired with the production of hydrogen through P2G. The efficiency of the storage chain from electricity to hydrogen and back to electricity is about 20% to 25%. This means that the storage is accompanied with a loss of most of the initial energy. Some of the existing gas storage facilities may be converted to hydrogen storage and salt caverns seem to have the appropriate characteristics in terms of sealing. However, there is still no clear view on whether, and to what extent, aquifers and depleted fields can also be converted.

The different technologies can be complementary and present synergies. There may be a benefit in combining them for providing adequate services to users. Thus, a reflection on how to jointly operate the various storage technologies and infrastructures would be useful. For example, LNG terminals provide bundled products aggregating unloading, storage and injection in the network. Such internalisation of storage by operators could provide an interesting benchmark for innovative solutions for energy networks.

4.2 Business models and storage value

Storage options may have an added value that is not fully reflected by the market, i.e. a system value. That generally would be the case if the aggregation of market participants' decisions fails in providing the appropriate level of storage or/and if particular constraints prevent market players from getting the amount of storage that they would need. In that case, if constraints upon storage represent a barrier to entry, storage can be considered as an essential facility. This would also justify an intervention to guarantee that every market player can access storage services on a non-discriminatory basis. In terms of the business model, the question is about the different roles and responsibilities of infrastructure operators and market players, with more- or less-decentralised approaches.

The assessment of storage value for market players is dependent on certain market features, including the tools they have to handle flexibility and balance their supplies and injections. Examples include the level of decentralisation of balancing responsibility, price formation on wholesale markets, relative size of storage units, market power of their operators and competing options for flexibility provision. For example, the balancing lead time influences suppliers' need for correcting their positions up or down, thus affecting the value of such services. In this respect, the reflection on a potential regulation must focus on existing assets first and then elaborate on their management, addressing potential market failures. Market players' obligations should be coherent with their capacity to effectively manage their energy production. Therefore, with the development of intermittence, it could make sense to mutualise flexibility tools such as storage to reduce constraints upon suppliers and promote system efficiency. The storage value also depends on the future role of methane as a relevant source of flexibility depending on Europe's import of low-carbon methane (or other shippable P2G).

Historically, underground storage has been a key driver of natural gas trading and gas markets in general. It provides a platform for using easily negotiable sets of standard documents which traders and the financial community are familiar with and which are in wide use in commodities and derivatives trade in general. Storage is thus a platform where secure trades can be executed at low cost and risk, giving it an advantage over trade based on physical flows over both shorter and longer periods of time. In sum, storage has provided high benefits to markets in terms of reducing risks, promoting trade, access to finance, competition, and transparent gas pricing. These advantages were mainly achieved by both traders and the financial community using these standard and secure tradable instruments.

4.3 Infrastructure planning and investment

As decarbonisation should come at least cost, infrastructure planning should contribute to identifying the most efficient solutions from a system perspective. The question of how to best integrate storage solutions within the networks is twofold. First, it is a matter of choosing between different infrastructural alternatives which are suited to address a certain need; these include both different storage solutions as well as different network options (e.g. network reinforcement). Second, it is a question of finding the optimal location of storage installations, including those aimed at the conversion between energy carriers, with a view towards the issue of network congestions. In any case, the low-carbon transition has to be addressed as a long-term process. Today, most of the flexibility needs of the energy system (electricity and gas) are met by fossil fuels (with the exception of hydroelectric generation or nuclear energy). Gas storage provides flexibility to the gas and the electricity sectors. Hence, introducing alternative options should be a gradual replacement of the original solutions in order to keep high levels of security of supply. In sum, it may not be necessary to elaborate what would be an optimised decarbonised system as this is very complex. An incremental approach with the gradual integration of new solutions and the development of biomethane and synthetic gases, replacing a growing proportion of natural gas, could be sufficient.

In this context, in case the market does not fulfil storage needs, regulatory intervention could be aimed at addressing the way in which investment decisions are taken (e.g. a more integrated planning processes and the setting up of specific investment signals). Storage needs should be assessed with a view to the co-optimisation between transmission and storage to minimise system costs, while also taking the location of demand into account. Existing gas storage facilities should be included in the analysis. However, questions remain in regard to technological improvements.

The sector organisation and potential regulation should ensure a proper balance between risk and expected profitability. In this respect, properly assessing the system value of storage is important to determine what is needed in terms of financial security for investors (how much is it worth paying for such assets from a regulatory perspective) and, in turn, to be able to reach the necessary capacity that is required for an efficient energy system.

5 Lessons from gas storage regulation in selected countries

For the purpose of this analysis, several national situations in the EU were assessed (see the national case studies in the annexes) to help understand the rationale of gas storage regulation from market and security of supply perspectives. In Europe, storage is one of the pillars of a well-functioning natural gas market (in the future, it might become a pillar of markets for low-carbon gases – hydrogen or methane), both providing short-term flexibility for balancing purposes and seasonal flexibility. Underground gas storage has been jointly developed with transmission infrastructure, according to long-term system optimisation strategies, with the aim of bypassing the bottlenecks existing along the gas value chain. Underground storage also plays a role on the upstream value chains to regulate gas fields' output, and was objectively included in the design of international corridors. This allowed minimisation of transmission costs over long distances by providing flexibility means downstream. The European system was shaped by such developments. Moreover, it should be noted that the role of storage greatly differs from one country to another, according to the location on the gas chain, the seasonality of demand, the access to alternative sources of flexibility and also the characteristics of underground geological structures (developing facilities is sometimes not possible).

5.1 Technical features

Existing storage infrastructure is capable of handling large quantities of energy. At a European level, the total storage capacity (working gas volume) amounts to 1109 TWh, which represented 22% of annual consumption (2019 figures, see table 1). Storage was first developed in an integrated way by former utilities. Gas storage management includes both profiled injections and withdrawals according to technical characteristics of facilities. It ensures that the injection campaign is consistent with the injection capacities (filling in aquifers or depleted fields can take up to 150 days). In addition, minimum storage levels are required at the beginning of the cold season in several countries. In sum, technical features and security of supply lead to a first layer of regulation.

TPA principles were introduced with the first gas Directive in 1998 and became mandatory in 2003, leaving the possibility for MS to opt for negotiated or regulated access. After two decades of liberalisation, TPA has proven relevant in many European countries. TPA is justified in particular by the fact that underground storage is a scarce resource and its development takes many years. In countries where seasonal flexibility cannot be exclusively provided from import points and production, TPA is a basic requirement for competition to develop. Choosing between negotiated or regulated access depends on the local circumstances, notably on the level of competition among storage operators. In general, countries, where there are several storage system operators (SSOs) or various technological characteristics among facilities, opt for a negotiated TPA (which does not mean that there is no regulatory oversight).

Country	Gas Storage capacity (TWh)	Gas consumption in 2019 (TWh)	Access regime
Austria	95.5	99.2	Negotiated
Belgium	9.0	196.4	Regulated
Bulgaria	6.3	31.6	Negotiated
Croatia	5.2	31.1	Regulated
Czech Republic	36.0	92.5	Negotiated

Denmark	9.1	36.1	Negotiated
France	128.5	486.4	Regulated
Germany	229.7	977.2	Negotiated
Hungary	67.7	109.4	Regulated
Italy	197.7	788.1	Regulated
Latvia	21,8	14.3	Regulated[7]
Netherlands	143.8	415.9	Negotiated
Poland	35.8	218.7	Regulated
Portugal	3.6	68.3	Regulated
Romania	33.0	118.1	Regulated
Slovakia	42.5	52.8	Negotiated
Spain	34.2	399.4	Regulated
Sweden	0.0	12.2	-
United Kingdom	9.6	868.5	Negotiated
Total	1,109.0	5016.2	

Table 1 – Gas storage capacities and access regimes in the EU (Source: GIE and NRAs)

5.2 Storage regulation trade-offs

As several MS' experience shows, a potential gas storage regulation could include methodologies aimed at determining the appropriate size of storage capacity (corresponding to the system's needs). Principles about proper filling levels by users could be included, preventing situations where the market does not ensure that those levels are achieved. Storage services are generally composed of the subscription of injection and withdrawal capacities as well as a volume of working gas capacity, either in a separated or in a bundled way. The case studies, however, show that services are mostly provided in a bundled way and via auctions. Each SSO is responsible for carrying out access procedures for its own facilities. Capacity allocations are often carried out for a group of storage facilities (services are not directly linked to a given site). This is particularly the case in France, Italy and Spain.

Due to unbundling rules, TSOs or other regulated entities are not supposed to store gas. This means the management of stocks is incumbent on storage users, namely gas suppliers. As a result, beyond the question of competition, which is the first justification of TPA, access regimes have to take into account the issue of total stored volumes and security of supply. Situations may arise where the regulatory framework has to incentivise market players to reach the necessary volumes, playing on the articulation between the market value (from the point of view of users) and the systemic value (mostly from the point of view of the security and stability of the system). Potential inappropriate individual anticipations could translate into a security of supply risk (users not storing enough gas would affect the system's resilience in case of a cold spell or supply interruption). In this respect, various options have been used,

[7] Access to existing storage is regulated, but access to new storage may be regulated or negotiated, depending on the total volume of the natural gas to be stored in the new storage facility. If the natural gas to be stored in the storage facility exceeds 25% of the average amount of gas stored in Latvia, the access regime will be regulated, if it is less than 25% - negotiated.

such as strategic stocks or storage obligations which have different outcomes in terms of market functioning.

5.3 Regulations supporting security of supply

The national case studies confirm that in several MS, storage access regimes objectively recognise a role for storage in terms of security of supply. When regulatory approaches include security-of-supply parameters, there is often a reflection on the proper combination of market and system values in terms of allocation of storage capacity and tariffs. “Hybrid” regulations including market-based capacity allocations and security-of-supply measures have been developed. Some countries have opted for a clear separation of commercial storage facilities from strategic stocks of gas, such as Italy and Spain. In these countries, commercial storage capacities are allocated via auctions and subscriptions are driven by hedging strategies of market players, while strategic stocks play a role of last-resort supply source and are set aside from market-based allocation mechanisms. Their cost is borne by consumers who benefit from the SoS measure via network tariffs.

France used to have a framework of storage obligations, associated with a negotiated access regime. In this case, suppliers were obliged to book a minimum volume of storage capacity calculated according to their portfolio of consumers. In 2018, the French government opted for an allocation at market value, supplemented by tariff compensation levied uniformly on French consumers, as a contribution to the balance of the system. The results have been, at this stage, very positive and encouraging even if, from one year to another, the results of auctions can differ widely.

On the other hand, some countries have not implemented any specific regulation in terms of security of supply. In Germany, the number of storage operators and the characteristics of the market allowed it to keep satisfactory levels of volumes of gas stored with a negotiated access regime. No security net has been necessary which may show the market value is coherent with the system value. In Austria, where the gas storage capacity is very large compared to the national consumption, each operator is responsible for marketing its capacities without any specific requirement related to security of supply. In the Czech Republic, the auction mechanism allows for balancing the summer and winter inequalities between gas supply and consumption; 100% of the storage capacity has been sold in 2020 at a relatively high price. In Great Britain (GB), the picture is slightly different: investigations have been carried out about the role of storage for security of supply but the value of storage (market and system) happens to be low. The Rough facility was even closed, highlighting that the British system has access to several flexibility sources including to the upstream part of the supply chain; a specific situation which cannot be replicated in most other countries.

5.4 Contrasting situations advocate for contrasting regulatory regimes

In summary, the value and need for storage can vary widely from one country to another. The need for regulation must be addressed according to the local characteristics of supply and demand. What is important is that the focus on resilience of gas systems and the adoption of regulations on gas security of supply have shed new light on the resilience of the European gas market. The paradigm includes an analysis of interdependency and solidarity between MS. The emergency measures and scenarios elaborated in the framework of the Regulation 2017/1938 concerning measures to safeguard the security of gas supply show that the role of storage has to be addressed at a cross-border level if problems concerning gas security of supply are detected. In this respect, in spite of different TPA regimes, the role of infrastructure operators (system operators) is to ensure a certain continuity of supply.

Enlarging the scope to energy systems, a reflection on the relevant level of centralisation could be opened according to technologies and individual obligations. The balancing regimes provide for incentives to balance supply and demand at the "perimeter" of suppliers but may not protect the system from wrong anticipatory behaviour. Thus, addressing the insurance value of storage will maintain its relevance. Technical synergies and complementarities between various storage technologies could also justify aggregating assets for providing storage services to market parties. This aspect should be analysed in the light of hedging needs and strategies for market players who develop their business in the context of the energy transition. In the gas business, gas storage has indeed been critical for the development of trading and competition.

6 Conclusions

In this paper, the ambition of European energy regulators was to elaborate on ways of addressing regulation of long-term energy storage according to possible future developments. It does not aim at promoting the regulation of activities which are not yet regulated , such as hydro pumped storage or also storage facilities in general in some MS. It rather aims at investigating what can be learnt from the natural gas sector where storage plays a structural role.

The natural gas sector provides two interesting illustrations of storage regulation and management. Underground storage regulation, in many MS, objectively articulates market and system value, though following different orientations. In terms of access, storage regulation shows how to provide services fit for users' needs and, at the same time, ensuring security of supply. LNG terminals also provide models of internalisation of storage within infrastructure management, since LNG operators deal with the gaps between energy deliveries from cargos and deliveries to the system.

Ongoing and future developments in the European energy mix will lead to a decrease in controllable energy production, not only for electricity but also for gas. This raises new challenges in terms of managing the balance between supply and demand. This will have an effect on the way contractual relationships between suppliers and their customers are organised. At a macro level, it will require changes in the way security of supply is guaranteed for European consumers. These changes must be made within the framework of a cost control strategy.

In this context, energy storage will play an increasingly important role. At the market level, it will provide the physical means to cope with uncertainties in the production operated by the different suppliers. At the system level, energy storage can guarantee security of supply, but also improve network architecture and operators' flow management. Gas storage provides strong lessons on all these aspects.

In summary, regulatory intervention emphasises various dimensions, including technological options (decentralised vs centralised techniques, contestability), business models (role of storage in terms of business strategies and system management) and security of supply (investment planning and corrections of potential misalignments between individual decisions and collective needs). Given the preceding analysis, European regulators have drawn the following conclusions:

1. **Long-term planning:** Storage needs and means should be integrated into the network planning process. Infrastructure development must be based on scenarios that incorporate assumptions on supply and demand profiles as well as the expected level of supply reliability. The security of supply criteria defined in this way should enable conceptualisation of infrastructure development trajectories.
2. **Existing assets as a lever for RES development:** European regulators strongly recommend relying on existing gas facilities to maintain a high level of security of supply and gradually substitute natural gas by decarbonised solutions. At the same time, they advise making gas storage a transitional lever to maximise the use of renewable energies. This step would avoid conversion losses and allow the most direct use possible of the energy produced (electricity or renewable gas).
3. **Identifying the relevance of regulation:** European regulators advocate for regulating energy storage only when the market fundamentals make it worthwhile, i.e. there is a risk that individual decisions will not lead to appropriate capacities or volumes of stored energy. This means that where markets are functioning, the principles of calling on players via price-based incentives should be preserved. This principle applies to all

recommendations made in this chapter. Regulation becomes relevant when the pooling of energy storage facilities is economically necessary and relevant for fair competition. If the overall efficiency of the system is improved by centralised management of energy storage facilities, then TPA or storage service might be put in place. This would require the design of regulatory oversight to ensure a high level of transparency, non-discriminatory access regimes and fair tariffs.

4. **Storage can support competition**: With the development of intermittency, it may be more difficult for suppliers to meet their obligations to their customers and to the system (in particular, balancing obligations). Storage could therefore be of renewed importance in terms of competition. Large players with the means to store energy or operating large portfolios of generation assets could have a significant competitive advantage over smaller players. This has been one of the justifications for the introduction of TPA to underground gas storage. The role of energy storage in terms of market players' competitiveness will have to be carefully analysed in order to preserve a level playing field in supply.
5. **Measures specifically dedicated to security of supply:** If, for security of supply purposes, there is a risk of undersizing or insufficient energy storage, then possible measures, such as promoting the convergence between allocation price and storage value, strategic storage or guarantees of a minimum level of storage, could be taken. European regulators suggest favouring allocations of commercial storage capacity at market value (by auction for example) and organising a recovery of security of supply costs (including strategic storage where relevant) from the categories of consumers who benefit from it.
6. **Dynamic approach to regulation**: European regulators are aware of the extent of the uncertainty affecting future developments in the European energy system and therefore advocate for a dynamic approach to regulation.[8] This would allow the regulatory framework to be adapted to market circumstances and industry needs.

[8] See also CEER's special website section on Dynamic Regulation: https://www.ceer.eu/dynamic-regulation

Annex 1 – List of abbreviations

Term	Definition
bcm	Billion cubic metres
CAM	Capacity Allocation Mechanisms
CEER	Council of European Energy Regulators
CMP	Congestion Management Procedures
EU	European Union
GO	Guarantee of origin
LNG	Liquefied natural gas
Mcm	Million cubic metres
MS	Member State(s)
NC	Network Code
NRAs	National regulatory authorities
nTPA	Negotiated third-party access
P2G	Power-to-gas
RES	Renewable energy sources
SoS	Security of supply
SSO	Storage system operator
TPA	Third-party access
TSO	Transmission system operator
TYNDP	Ten-year network development plan

Annex 2 – Austria[9]

1. Storage facilities and capacities

The Austrian gas storage facilities are located in the concession areas of two gas and oil producers: OMV Aktiengesellschaft (OMV AG) (in the north-eastern part of Austria) and Rohöl Aufsuchungs Aktiengesellschaft (RAG AG) (in the north-western part of Austria). They are depleted gas fields (pore storage facilities) that have been converted into storage facilities. The storage facilities were developed on the basis of long-term commitments, mainly before the liberalisation of the Austrian gas market in 2002.

Since 2010, storage capacity has been significantly increased through the expansion of 7Fields, Haidach, and Aigelsbrunn. Thus, the increase of the working gas volume from 2010 to 2015 was around 81% (from 50.9 TWh to 92.1 TWh). These storage facilities were developed on the bases of long-term commitments, too.

On 1 April 2017, there was a shutdown of the Thann storage facility for investment reasons. However, due to additional drilling the capacity could be increased in the Haidach and in the 7Fields storage facility, so that the working gas volume in total was 95.5 TWh at the end of 2020.

Storage capacity in Austria is offered to the market by five SSO: OMV Gas Storage GmbH (OGS), RAG Energy Storage GmbH (RES), E.ON Gas Storage GmbH (EGS), Astora GmbH & Co. KG (Astora) and GSA LLC (GSA). With approximately 26% (25.2 TWh) working gas volume, OMV Gas Storage has the largest share in storage capacity in Austria. OMV Gas Storage has also the largest market share of storage facilities in the Market Area East (approximately 40%).

Only the storage capacities of OGS, RES and EGS are directly connected to the virtual trading point (VTP) in the eastern market area. In order to use the storage capacities of Astora and GSA, transport out of the German market area NetConnect Germany (NCG) into the Austrian eastern market area must be organised and paid for.

2. National legislation

Pursuant to section 98(1) Natural Gas Act 2011, Austria has a **negotiated access** regime for natural gas storage. This implies transparent and non-discriminatory access. However, the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology may prescribe storage access on a regulated basis by ordinance. This may regard the methods for calculating storage charges, the general terms and conditions for storage access and/or the capacity allocation mechanisms and procedures.

The basis for this decision whether to introduce regulated access to natural gas storage facilities and replacing the current negotiated access regime is a **competition assessment** in the Austrian flexibility and storage market pursuant to section 98(2) Natural Gas Act 2011 (in line with Directive 2009/73/EC). The Austrian regulatory authority has to conduct this assessment at least every three years to re-evaluate the following parameters: 1) assess the level of competition on the storage market by referencing price comparisons; 2) the range of products on offer and their use 3) the market concentration (supply and demand side) with consideration of the availability of alternative sources of flexibility; and 4) the availability of storage capacity compared to demand for it. E-Control is currently working on the report for 2021, assessing the development since the last study in 2018.

There are no storage obligations in Austria.

[9] All data provided by the Austrian NRA, E-Control, unless otherwise noted.

3. Capacity allocation

Pursuant to section 103(1) of the Natural Gas Act 2011, the mechanism that best ensures non-discriminatory and transparent capacity allocation must be chosen. Whenever demand exceeds the capacity available, auctions shall be held. The regulatory authority must be notified of all planned capacity allocation procedures in a timely manner. If the regulator requests it, the procedure must be adjusted or redesigned.

Since 2013, capacity was allocated through the first-come-first-served principle on a bilateral basis. Since 2013, the Austrian SSO, except RES, have started to auction the available storage capacity, mainly as one-year contracts. OGS offers the capacity via the CEGH storage platform, Astora via PRISMA, while Uniper and GSA LLC use their own websites.

The main part of the storage capacity is still used on the basis of long-term contracts. Most of them run until 2027 or 2031 respectively. Storage contracts concluded in recent years have a much shorter duration.

4. Pricing storage capacity

Storage pricing is not regulated in Austria. E-Control has the legal possibility to check the cost basis of the pricing of the SSOs under certain circumstances.

In pricing storage capacity, a hybrid system based on different allocation procedures has evolved. On the one hand, SSOs publish storage fees for standard bundles. These apply to storage capacity that is allocated on a FCFS basis. The published prices for standard products have increased slightly since 2018 (on average 1.6%) and are now between 5 to 7 EUR/MWh working gas volume.

On the other hand, storage prices in individual storage contracts result from auctions. These auction prices are not published by the SSOs.

Transport capacity is booked once a year by the SSOs. SSOs are legally allowed to cover the transport fees in the agreed storage charges under section 170(9) of the Natural Gas Act of 2011.

Annex 3 – Czech Republic[10]

1. Number of storage operators

Generally, in the gas infrastructure of the Czech Republic, gas storage facilities have an irreplaceable role in compensating for seasonal differences in gas consumption, thus contributing to increasing security and continuity of supply.

There are three gas SSOs in the Czech Republic in 2021: RWE Gas Storage CZ, s.r.o., MND Gas Storage a.s. and Moravia Gas Storage a.s.

There is, however, a fourth operator, SPP Storage, that is located in the Czech Republic but its storage capacities are connected solely with the Slovak pipeline system. Nevertheless, these capacities should be also connected to the Czech pipeline system in the near future. In the context of flexibility, market participants might use capacity provided by this SSO to provide flexibility for either the Czech or the Slovak market.

The total consumption of gas in the Czech Republic 2020 reached 8,694.2 mcm, i.e. 92,894.4 GWh. The total utilisation of gas storage facilities in the Czech Republic before the winter season was approximately 3.3 bcm of gas, which currently represents 39% of annual gas consumption in the Czech Republic and 58% of gas consumption in the heating season in the Czech Republic.

2. TPA regime

Access to storage capacity is offered under the negotiated third-party regime. Any free storage capacity has to be offered to the market via auction mechanism. The Czech regulator ERÚ sets the general conditions for access by the Market Rules Decree. However, the conditions of each auction, including the starting price are fully within the competence of the gas SSO and are published on its website. ERÚ continuously monitors and evaluates these conditions. The results of the auction are published by remote access. The market for storage capacity is thus relatively transparent.

In 2020, SSOs announced a total of 28 auctions for storage capacity. These auctions offered various combinations of storage capacity, withdrawal capacity or injection capacity.

Storage capacity was sold for a significantly higher price than in the past. In this respect, it can be concluded that parties interested in storage capacity assessed individual products based on two main factors: the low gas prices in the summer and the bet on a high seasonal difference in gas prices (the spread)which.

3. The role of storage

Gas storage facilities thus play a significant role in balancing the summer and winter inequalities between gas supply and consumption. This is not only the case in times of supply constraints, but also for purposes of ensuring the reliable operation of the Czech gas system in general.

It can be concluded from results of auctions that the low gas prices in the summer and the bet on a high seasonal difference in gas prices (the so-called spread) were the main factors on which parties interested in storage capacity assessed individual products. Therefore, storage capacity is a significant tool or opportunity for traders to differentiate their supply portfolio and thus minimise risk and maximise profit. Gas storage facilities also allow gas suppliers to respond flexibly to unexpected increases in gas consumption, especially in the cold months of the year, thus helping the wholesale market.

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[10] All data provided by the Czech NRA, ERÚ, unless otherwise noted.

All storage tanks were filled to almost 100% on 1 October 2020[11]. The main reasons for this were 1) the favourable gas price and 2) the mild temperatures in the autumn and winter of 2019/2020. After this period, the storage tanks were filled between 35-76%. The table below presents a comparison of the volume of gas in gas storage facilities after the extraction season 2019-2020 and before the extraction season 2020-2021.

	UGS filling rate [%] on 31. 3. 2020*	UGS filling rate [%] on 30. 9. 2020[12]
RWE Gas Storage CZ, s.r.o.	35.14	99.25
Moravia Gas Storage a.s.	75.13	97.11
MND Gas Storage a.s.	75.77	98.22

Table 2 – Comparison of gas volumes in gas storage tanks after and before the extraction season in Czech Republic

4. Security of supply

The supply security standard is a mechanism that aims to ensure secure gas supply in the required quantity for so-called protected customers . Protected customers include mainly households, medical and social facilities, food businesses, etc. For these selected groups of customers, traders are obliged to provide part of the supply security standard by storing gas in storage tanks. This method should guarantee secure supplies, especially in the winter, i.e. during the heating season, and prevent supply disruptions from exogenous events in transit countries, for example.

The obligation to ensure the supply security standard was introduced directly by Regulation № 944/2010 of the European Parliament and of the Council, on measures to ensure security of gas supply. Today, the obligation is covered by Regulation (EU) 2017/1938. This Regulation was subsequently implemented into Czech legislation through the Energy Act (№ 458/2000 Coll.). The methods of securing the supply security standard, its calculation and other related requirements are specified in Decree № 344/2012 Coll., “On the state of emergency in the gas industry and on the method of ensuring the security standard of gas supply”, as amended.

The supply security standard is ensured from January to March and October to December. Most gas suppliers use confirmation of securing the supply security standard from another market participant, which means that one supplier provides the supply security standard. This includes meeting at least 30% threshold of the supply security standard in gas storage facilities in the Czech Republic and other EU countries in the evaluated period.

The supply security standard was ensured in 2020 for the months of January to March and October to December, as described above. According to the reports delivered to ERU, BSD was secured throughout the heating period, including at least 30% of the gas stored in gas storage facilities in the EU. Most gas traders used supply security standard’s confirmation provided by another gas market participant. In practice, this means that one trader provides the supply security standard, including 30% of the stored gas, to several other traders.

Gas stored as the supply security standard is intended to ensure sufficient gas supplies to customers in emergency situations. However, in this context we note that the stored gas does

[11] 1 October is considered as the annual starting date of the heating season and the date when gas extraction from storage facility usually begins.

[12] Value expressing the ratio of the amount of gas in the storage tank to its technical capacity.

not have to be intended only for customers in the Czech Republic, but the trader can also store it for the trader's customers abroad.

Regarding the supply security standard and role of state administration, all the processes in the Czech Republic are on a commercial basis. In other words, traders are in charge of procuring gas, storage and transmission capacities and have to report if the minimum requirements were met.

ERÚ monitors and evaluates compliance with the supply security standard in the Czech Republic.

Based on a detailed analysis of individual gas storage facilities, the use of storage capacities has not changed despite various indications. The storage facilities are mostly used in the traditional way (summer injection and winter withdrawal). However, injection in summer is less stable than in the past and depends on the development of gas prices on commodity exchanges.

Taking into account all the above-mentioned features of the supply security standard, ERÚ is convinced that the liberalised approach to storage capacity has provided the most transparent and appropriate way of using these capacities.

Annex 4 – France[13]

1. Underground gas storage in France

In France, three operators (Storengy, Teréga and Géométhane) manage 15 gas storage facilities, three of which are currently mothballed (11 aquifers, four salt caverns and one depleted field). The storage facilities represent a working volume of 138.5 TWh and a withdrawal capacity of 2,376 GWh/d. There are currently no plans to develop new storage capacity.

France imports all the gas it consumes. A large part is used for heating, which causes strong variations in consumption between summer and winter. Storage is therefore a central tool for adjusting supply and demand. The presence of storage solutions is essential to ensure a reliable and continuous delivery of gas throughout the year. Suppliers inject gas during periods of low consumption (summer) and withdraw it when demand is higher (winter). Withdrawal from storage facilities represents about one-third of winter consumption (about 90 TWh of the 300 TWh consumed per winter). On certain days, the storage facilities can cover more than half of the needs.

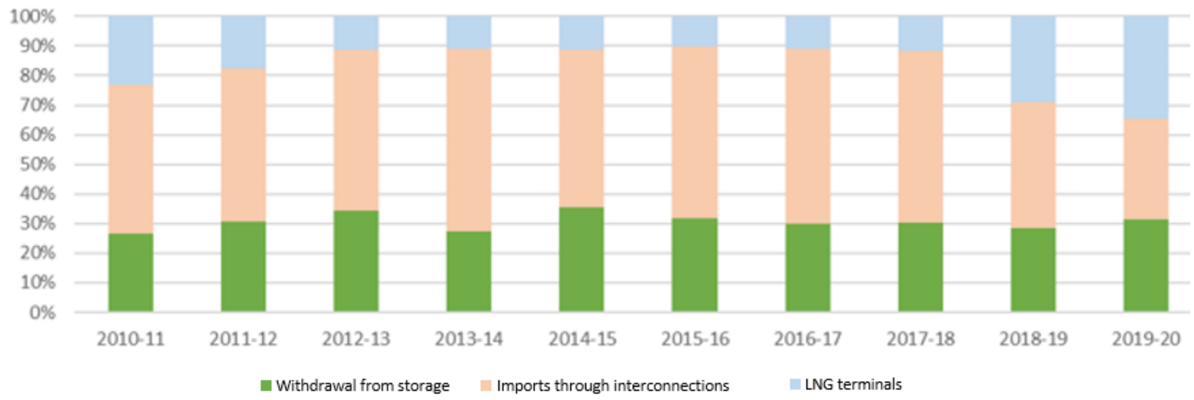

Figure 2 – Share of different sources of supply in winter, France (Source: CRE based on data from infrastructure operators)

The configuration of the network is the result of a long construction process based on the complementarity of the various infrastructures, with a view on long-term optimisation. The storage facilities make it possible to limit the use of entry points to the transmission system during periods of high consumption. Thus, the peak sizing of entry points to the French network has been reduced compared to a situation without storage facilities.

2. From negotiated to regulated access

In 2018, France introduced a regulated TPA to storage, which replaced the previously existing negotiated access regime associated with storage obligations. The storage obligations system aimed to ensure security of supply at the national level by forcing suppliers to hold a minimum volume of stock at the beginning of the winter based on their customer portfolio. These obligations have represented, since 2014, about two-thirds of the storage capacities marketed in France. French storage operators were therefore guaranteed to sell a significant portion of their capacity at the price they set. This situation carried a risk of excessive tariffs and therefore

[13] All data provided by the French NRA, CRE, unless otherwise noted.

of increasing the cost of security of supply for the end consumer. This risk was reinforced by the low level of transparency in the setting of prices by the operators.

Until 2011, the gas price differential between summer and winter was sufficient to cover the costs of seasonal storage. Prices then fell sharply, with the spread dropping to 1.5-2 EUR/MWh against a storage price of 6-7 EUR/MWh. The obligation system was then strongly contested from a legal point of view and storage was less and less subscribed, which increased the risks of tension in winter. This regime was therefore, replaced by a regulated access. Its objective was to guarantee the filling of storage facilities necessary for security of supply, while also providing transparency on storage costs and removing the complexity of the individual storage obligation system. In addition, the newly-introduced regulation of operators' revenues aims to ensure that the final consumer pays the right price for the storage necessary for security of supply.

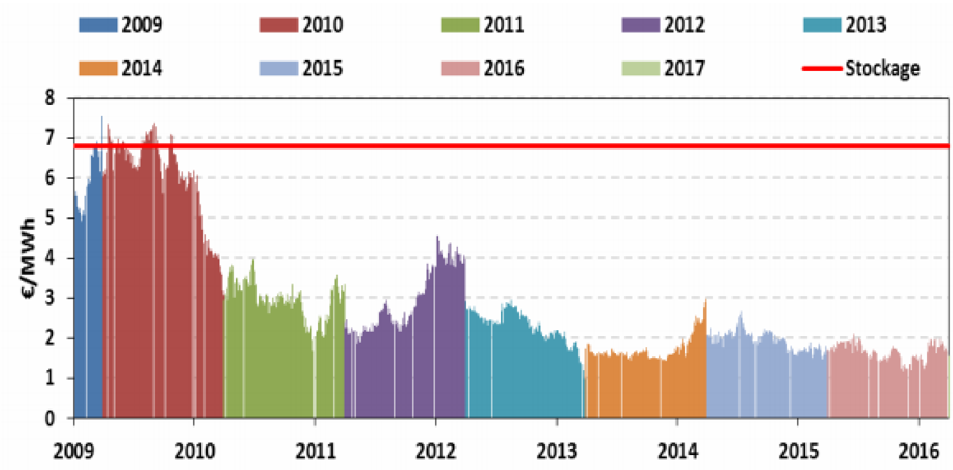

Figure 3 – Summer-Winter gas price spreads in France, 2009-2016 (Source: French Ministry of Energy)

3. The current regulatory framework in France

Law number 2017-1839 of 30 December 2017 put an end to the exploration as well as the exploitation of hydrocarbons (known as the Hydrocarbons Law) and introduced an economic regulation of storage infrastructure operators. It provides that

- the multiannual energy programming mentioned in Article L. 141-1 provides the storage capacities that guarantee the security of supply. These infrastructures are maintained by the operators.
- the income of storage operators is regulated.
- storage capacities are sold by auction according to the terms and conditions defined by the French regulator CRE.
- a dedicated tariff term within the tariff for the use of the natural gas transmission system compensates the difference, positive or negative, between the revenues mainly coming from auctions and those from storage operators’ regulated income.

The allowed revenue of storage operators is set by CRE. The tariff period is four years with annual updates. The tariff provides for incentives that are harmonised with other regulated infrastructure (incentives for cost control, quality of service, etc.). When setting the terms and conditions of commercialisation, CRE aims firstly to maximise capacity subscriptions, to ensure that the capacity is filled in accordance with security of supply requirements, and secondly to achieve the highest possible level of revenue.

Auctioning of storage capacities

Storage capacities are marketed in auctions that take place several times per year. They can be sold up to four years in advance. The diversity of sites allows for a plurality of products: salt caverns offer very fast products while aquifers are slower but have large volumes.

Auctions are single round with uniform price. Each player submits a desired quantity curve according to the price. The operators add up the requests and deduce the single auction price (pay as cleared), corresponding to the maximum price for which all the capacity on sale is purchased (demand = supply). If the total demand is lower than the capacity on sale, the auction price is equal to the reserve price.

The reserve price is zero for auctions corresponding to storage capacities for the storage year N+1. The marketing procedures also provide for the sale of capacities for the years N+2 to N+4, with a non-zero reserve price, corresponding to the difference between the average over the ten days preceding the auction of the winter/summer spread observed for the storage year in question and a normative value of the storage costs for this same year.

A "safety net" system completes the auction system. Each year, a decree sets the level of stocks that must be reached on 1 November to secure winter supplies. If, at the end of the auctions, the capacities acquired by all the suppliers prove to be insufficient, the storage operators are obliged to buy and store up to 20 TWh of gas. If this remains insufficient, suppliers may be obliged to subscribe to additional storage capacities. To date, this mechanism has never been activated.

Results after three years of implementation

The different auction campaigns have been successful. Almost all capacities have been subscribed. The factor with the most direct influence on the results is the summer/winter price difference at the time of the storage auction. The effective auction price corresponds to the seasonal spread, minus the storage costs (tariff at PITS, gas immobilisation costs) and plus a premium linked to additional arbitrage possibilities (volatility of the seasonal spread, intra-seasonal spot price differences) depending on the performance of the products marketed.

For the winter of 2021-2022, the average auction price was 1.91 EUR/MWh. This was lower than the average price of the 2020-2021 campaign, marked by a particularly high seasonal price spread, but in line with that of the 2019-2020 season (1.84 EUR/MWh).

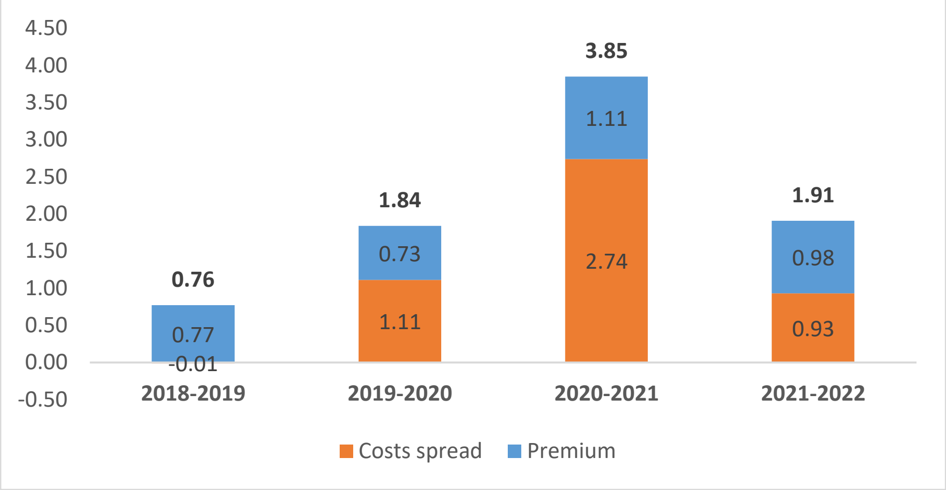

Figure 4 – Average auction price of storage capacities in France in EUR/MWh (Source: CRE)

For 2021, the revenue collected in the auctions covers 47% of the storage operators' allowed revenue, compared to 63% in 2020 and 26% in 2018 and 2019.

Storage compensation

At the end of the annual auction campaign and before 1 April each year, CRE sets the compensation for each operator to make up for the difference between the allowed revenue and the revenue forecasts resulting from the auction. This compensation is collected from shippers on GRTgaz and Teréga's transmission systems by applying a storage tariff term to them, depending on the winter modulation of their customers connected to the gas transmission and public distribution systems (the higher the winter modulation, the greater the customers' contribution to the storage requirement). In the case where the auction revenues are higher than the allowed income of the storage operators, the storage tariff term is negative and results in a repayment to the shippers. The storage tariff term is calculated as the ratio between the provisional amount of the compensation in France and the sum of the shippers' modulation needs.

Following the auction of storage capacities 2021-22, CRE has set the storage tariff term (STT) at 185.11 EUR/MWh/d/year from 1 April 2021.

4. Lessons from the French example

The reform of storage in France is the result of a concerted effort. To define the reform’s conditions of application, CRE has heavily involved stakeholders, organising workshops with gas players, a public consultation and a round table.

The implementation of a regulated regime has put an end to a negotiated regime with little transparency. The old system could not guarantee that storage facilities would be filled or that suppliers would pay fair prices, given the lack of competition on the storage segment in France.

Since its entry into force, the main objective of the reform has been achieved. All marketed capacities have been allocated, allowing storage capacities to be filled (128 TWh in 2018, 129 TWh in 2019 and 128 TWh in 2020), which guarantees security of supply in France and, more generally, in the Western European zone. The auction procedures with a large number of participants have proven their worth.

The introduction of a regulation of the operators' income finally ensures that the final consumer pays the right price for the storage necessary for security of supply. The allowed revenue of storage operators for the year 2021 is down by -6.7% compared to 2018, which was the first year of regulation. The reform has thus allowed a decrease in the unit cost of storage for the community (5.2 EUR/MWh in 2021, compared to a cost of approximately 6-7 EUR/MWh before the reform).

Annex 5 – Germany[14]

1. Storage usage among flexibility sources, with a focus on seasonal flexibility

According to the German regulator's national monitoring, the German gas market had 24 SSO as of 31 December 2019. They operate and market a total of 33 underground gas storage facilities (UGS). As of 31 December 2019, the maximum usable working gas volume in these UGS totalled 275.27 TWh, giving the German gas market the largest storage volume in Europe.

Gas storage facilities play an important role in the context of security of supply. In the liberalised German gas market, they compete with other sources of flexibility, such as import-side volume adjustments or voluntary demand-side responses. In such a market, market players decide on the efficient use of flexibility sources on the basis of price signals in order to meet their legal and contractual supply obligations. For this purpose, they use those sources that reliably and economically fulfil their supply obligations.

The filling levels of gas storage facilities are essentially influenced by the economic considerations of market players and thus follow seasonal patterns in particular.

2. Type of regulation: regulated or negotiated access, capacity allocation

Gas storage access is to be granted on the basis of a negotiated TPA. Under the Energy Industry Act, operators of storage facilities must grant other companies access to their storage facilities on reasonable and non-discriminatory technical and economic terms. The regulatory authorities exercise supervision over compliance with these regulations. In the event of a violation, abuse orders may be issued.

Therefore, storage capacities are marketed directly by the storage operators in accordance with their terms and conditions. Entry and exit capacities to and from the gas network are marketed directly by the transmission system operators, based on the rules of the Network Code (NC) on Capacity Allocation Mechanisms (CAM).

3. Specific arrangements for security of supply and their rationale

After the liberalisation of the German gas market, private investors have invested extensively in the expansion of gas storage capacities and are actively using them for supply. The liberalised German gas market thus fulfils the European standards in terms of security of supply and cost efficiency.

Legal or regulatory intervention in the form of storage obligations or strategic storage facilities was not deemed necessary. In the event of possible regional extreme scenarios, e.g. extreme cold at the end of winter with simultaneous low storage levels, the market area managers are given the option of contracting a higher volume of long-term balancing energy products to further safeguard security of supply. Here, in addition to other sources of additional gas flows, gas volumes at storage facilities can also be contracted in the market. However, these volumes were not activated in recent winters.

[14] All data provided by the German NRA, BNetzA, unless otherwise noted.

4. Storage tariffs and cost recovery

Storage tariffs and cost recovery are not subject to regulation in Germany. The storage market is competitive and regulates itself. Price setting and recovery of storage operators' costs are up to this competitive market. The German regulator is not aware of any issues arising in this context and does not recognise the necessity to change the current situation. The filling of gas storage facilities is conducted according to market price signals. This method has been proven to secure sufficient filling levels and security of supply.

Annex 6 – Italy[15]

1. Number of storage operators and types of facilities

In Italy, there are currently three storage operators: Stogit (a subsidiary of SNAM), Edison Stoccaggio and Ital Gas Storage. They operate 13 concessions overall, with an overall storage capacity of around 18 bcm and a maximum withdrawal capacity of about 300 Mcm/day. The last storage facility entered into operation in 2018 and no further storage sites are currently planned. Storage is carried out exclusively in depleted gas fields. Therefore, storage concessions have historically originated from previous production concessions. Storage is a regulated activity, operated under a legal unbundling regime.

2. The role of storage

In Italy, storage plays a very important role for the security of the system, both in terms of balancing of the transmission system and security of supply (i.e. strategic storage in case of disruption of gas supply).

Storage as a flexibility source

As far as **balancing needs** are concerned, although there are also other sources of flexibility (e.g. regasification plants, modulation of imports at interconnection points with neighbouring countries), the conformation of the gas system and the significant level of gas consumption make storage a non-substitutable option. Indeed, before introducing renomination at the entry points, storage was the only flexibility tool that could be activated on an intraday basis. Since 1 October 2016, the modulation of imports on an intraday basis has begun to contribute to the intraday balancing of the system. However, this only happens to a limited extent because of the limits, the complexity, and the lack of flexibility of interconnected systems, especially of the ones outside the EU that supply Italy with a significant part of its gas imports. It is relevant to point out that Italy has only two interconnection points with EU gas systems: Tarvisio (Austria) and Gorizia (Slovenia)[16]. The other cross-border points are with non-European countries, hence EU rules on CAM and Congestion Management Procedures (CMP) are not implemented, leaving some room for market abuse and limiting the use of these sources as liquid and transparent tools for flexibility.

The following figure depicts the contribution of various sources to intraday flexibility in 2019, showing the significant contribution of storage compared to the other sources[17].

[15] All data provided by the Italian NRA, ARERA, unless otherwise noted.

[16] Interconnection point with TAP is not taken into consideration considering the lack of historical data.

[17] The i) "variation at the end of the day - beginning of the day" identifies the average variation, for each source, between the nomination at the beginning of the gas day and that at the end of the same day, thus comparing the daily flexibility of the supply sources with the one provided by storage, with a daily horizon.
The ii) “maximum hourly variation” describes the average value, in the supply period, of the maximum hourly flexibility in the day; it therefore represents an instantaneous value of flexibility with respect to the temporal granularity with which users of the gas market can renominate.
Finally, the iii) “cumulative variation during the day” represents the average value of the sum, in absolute value, of all the hourly variations that have occurred; it therefore provides additional information with respect to the first indicator i) in which the hourly changes occurring during the gas day, even of the opposite sign, are not considered. This indicator therefore measures the real capacity of the sources to supply to follow the physical needs (peaks of hourly withdrawals) and market needs during the day.

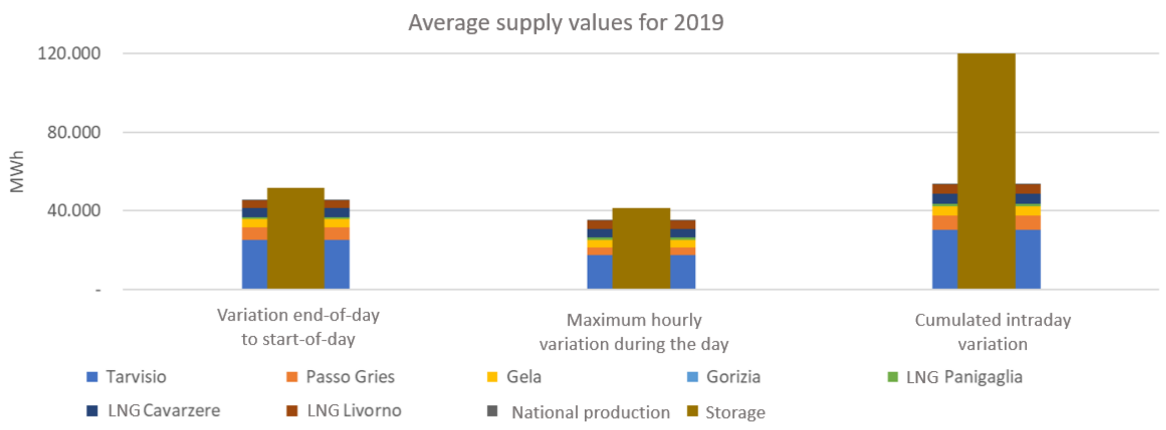

Figure 5 – Role of storage as a flexibility source in Italy

The figure shows the role of storage as a flexibility source, making it essential infrastructure for the safety and balancing of the system, since neither the gas imports from abroad nor the national gas production are sufficient.

Considering that the storage withdrawal capacity is directly linked to the level of gas stored in the site, to ensure a proper performance over the whole winter period, it is necessary to have the storage sites as full as possible at the beginning of the gas year. Moreover, it is a prerequisite to also impose certain thresholds on the daily withdrawals (storage withdrawal profiles) to avoid that the storage is emptied too soon.

3. Storage and security of supply

Storage's contribution is also particularly important to ensure **security of supply** during the winter period. This is particularly evident during incidents such as the one that occurred at the Baumgarten (Austria) compressor station on 12 December 2017, which led to a reduction of import flows from Tarvisio (when storage contributed for 122 Mcm against a daily demand of 318 Mcm, corresponding to 38% of the total requirement).

The Italian law prescribes reserving a certain volume of gas, i.e. strategic storage, which can only be used in situations of persistent reduction or lack of gas supply. The strategic storage is permanently stored and is only supplied in the event of a prolonged emergency when the market has supplied all the other storage volumes (owned by the shippers) and the gas system pressure has decreased to 45 bar. It is therefore used as a last resort measure to supply gas to vulnerable customers (e.g. households, hospitals, schools). The amount of strategic storage is established annually by the Ministry of Economic Development, after having consulted the Emergency Committee[18] following Italian law № 93/2011. The volume should at least be equal to the amount of gas needed to replace 100% of the flow related to the most used import infrastructure during the peak season or, if higher, the amount needed for modulation purposes during a cold winter based on the coldest recorded in the last 20 years.

The quota reserved for strategic storage has remained stable over the last years, and the gas currently stored was supplied only once during the emergency of the 2005/2006 winter.

[18] The Emergency Committee is composed of representatives of the Italian Ministry, NRA, gas and electricity TSOs, SSOs and LNG operators. Retrieved from: https://www.mise.gov.it/index.php/it/normativa/decreti-ministeriali/2036789-decreto-ministeriale-31-maggio-2017-composizione-del-comitato-tecnico-di-emergenza-e-monitoraggio-del-sistema-del-gas-2

Strategic storage is a regulated service. Its costs were initially charged to producers and shippers of natural gas (both from EU and non-EU countries). Today, they are charged to end-customers connected to the distribution networks as it is intended for withdrawals by these customers in emergency conditions.

4. Type of regulation: regulated access, capacity allocation

Given the role of storage for the functioning of the Italian gas market, it can be replaced only to a limited extent by alternative sources (e.g. imports, production). Therefore, storage represents an essential facility which has to be subject to regulation (including price regulation) to avoid monopolistic or oligopolistic behaviours by SSOs, such as putting in place a strategy of capacity hoarding to maximise their revenues.

As anti-competitive behaviour would be a barrier both to new entrants and to the development of a competitive gas market, since the beginning of the liberalisation of the Italian gas market in 2000, policy makers have opted for a regulated TPA. They imposed stricter storage public service obligations than those envisaged for other infrastructural activities of the gas supply chain (i.e. transmission). Since then, storage is regulated in Italy because the main aim is to maximise the benefits for end customers. Those benefits stem from an efficient and pro-competitive utilisation of the storage capacity; a goal in contrast with the SSOs' strategy of maximising the revenues proper of a negotiated TPA regime.

Hence, all storage services (the main ones being seasonal modulation, balancing for the transmission system, and strategic storage) were regulated and subject to tariff regimes, with tariffs for each service set at national level. SSOs were required to make all their capacity available to the system, and to manage the whole storage capacity in a coordinated and integrated manner to ensure better optimisation in its utilisation and the safety of the national gas system. The NRA and Ministry decide on the CAM and on the products/services SSOs could provide, thus granting operators only limited initiative in the decision-making related to commercial policies.

Due to the public service nature of storage and the public service obligation thereby imposed, notably for the protection of end customers, SSOs have been granted a partial revenue compensation mechanism. This measure covers a share of the potential difference between revenues collected from storage users and allowed revenue, which was defined by the NRA based on a consulted and transparent methodology. The compensation mechanism is managed by the *Cassa per i servizi energetici e ambientali* (a clearing and settlement agency) and currently funded by an additional commodity-based charge applied to domestic delivery points of the transmission system.

Following the progress of the liberalisation process, capacity allocation for seasonal storage changed from an initial tariff-based, pro-rata mechanism toward market-based approaches such as auctions as implemented for the first time in 2011. This reform was adopted in accordance with the indications of Regulation (EC) № 715/2009, which provides that the storage capacity allocation mechanisms should give adequate economic signals for the efficient use of capacity, ensure compatibility with market mechanisms (including spot markets), and be flexible and easily adaptable to changing market circumstances.

Following the introduction of the auctions, tariffs are no longer set for seasonal storage modulation service, and revenues for SSO collected from storage users depend on the auction results (capacity allocated and clearing price). The compensation mechanism still applies, thus also covering any potential mismatch between the auction price and the (hypothetical) tariff.

Annex 7 – Spain[19]

1. Storage facilities: general characteristics

In Spain, there are currently two storage operators and four underground storage facilities (Marismas, Serrablo, Yela and Gaviota), which Enagás GTS[20] coordinates as a single operation (a single virtual underground storage). These storage facilities have an overall working capacity of around 32,459 GWh, 127 GWh/day of injection capacity and 234 GWh/day of withdrawal capacity (injection and withdrawal capacity change daily, depending on the gas stored at each moment). They are three depleted gas fields (Marismas, Serrablo and Gaviota) and a saline aquifer (Yela). No more storage sites are currently foreseen.

In Spain, storage plays an important role in the gas system, guaranteeing security of supply (i.e. strategic storage in case of gas supply disruption) and enabling users to take advantage of gas price arbitrage (they inject in summer and withdraw in winter) and to use their storage capacity as a flexibility tool.

Storage facilities are regulated infrastructure (full r-TPA) whose access mechanisms are defined, on the one hand, by the Ministry for the Ecological Transition and the Demographic Challenge for the strategic storage (direct allocation), and on the other hand, by the Spanish regulator CNMC for the remaining capacity (market-based allocation).

2. Strategic storage (security of supply) and operative storage: direct allocation of capacity

Capacity reserved for strategic storage is based on the domestic consumption in the previous year. In the period April 2019 to March 2020, capacity reserved for strategic storage reached 20,707 GWh of the total working storage capacity. The Spanish Ministry for the Ecological Transition and the Demographic Challenge has the competences to annually define this reserve. The remaining capacity (11,651 GWh in the quoted period) is offered through a market-based mechanism (auctions) to the market. CNMC is responsible for establishing this market-based TPA regulation and monitoring its application.

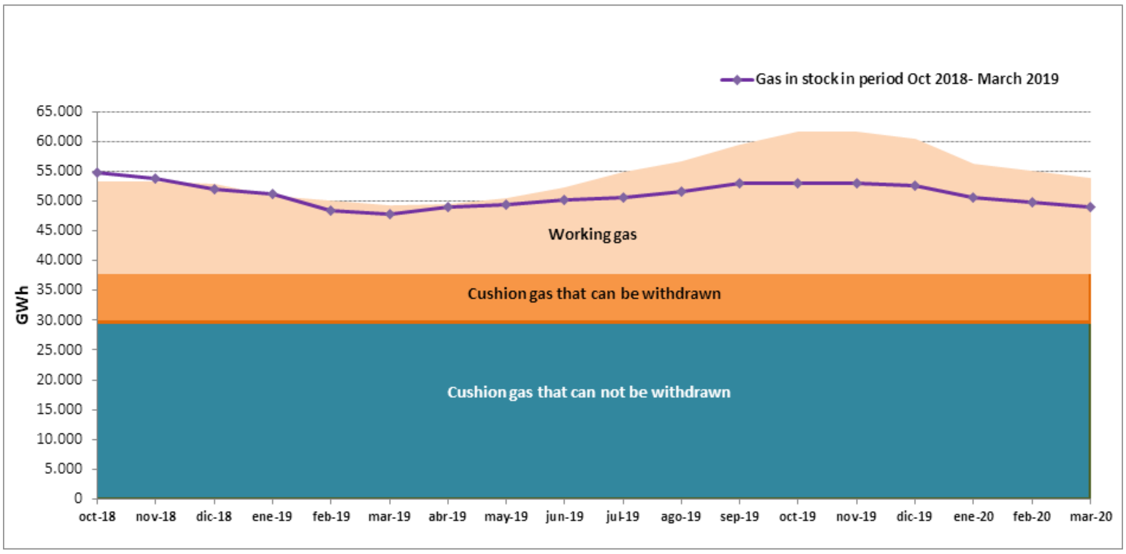

Figure 6 – Gas volumes in underground storage in Spain (Source: CNMC)

[19] All data provided by the Spanish NRA, CNMC, unless otherwise noted.

[20] Enagás GTS is also responsible for the correct functioning and operation of the whole gas system.

At the beginning of the year, the storage operator provides all information about firm demand in the previous year corresponding to each retailer with final clients (each one has the obligation to store 20 days of its annual firm sales to final consumers always). After that, users indicate how much strategic storage capacity they want to contract in the underground storage, and capacity is directly allocated to users which requested it. This gas is injected from the beginning of April each year (annual contracts go from April year n to March year n+1). In order to use strategic gas stocks, the Ministry must declare a state of emergency , something that has never happened up to date.

Moreover, retailers who supply the residential market (household consumption) have the right to contract capacity for storage of up to 60 days of this demand with direct allocation. The remainder of the retailers could also ask for ten days' worth of storage capacity of their firm customer demand base.

3. Storage for price arbitrage and flexibility: capacity allocation via market-based mechanism

The remaining capacity (not allocated by the direct allocation mechanism) is allocated through normalised products in auction procedures organised by Enagás GTS, under the supervision of CNMC. This regime was first established by the Royal Decree 984/2015 and Ministerial Order ETU/1977/2016. However, in January 2019, competences regarding access to gas infrastructures were assigned to CNMC, which approved Circular 8/2019, in application as from April 2020.

Currently, there are three types of capacity related to underground storage (storage, injection, and withdrawal) that are allocated in yearly, quarterly, monthly, daily and intraday products. From yearly to monthly products, storage, injection and withdrawal capacity are offered as a bundled product (users only request storage capacity and injection and withdrawal capacity are allocated to them proportionally to their contracted storage capacity). Daily and intraday storage, injection and withdrawal capacity are offered in an unbundled way. 100 GWh of storage and 10% of the injection and withdrawal capacity are reserved to be offered as unbundled daily products. In case all the firm capacity is allocated, daily/intraday interruptible injection and withdrawal capacity can be offered.

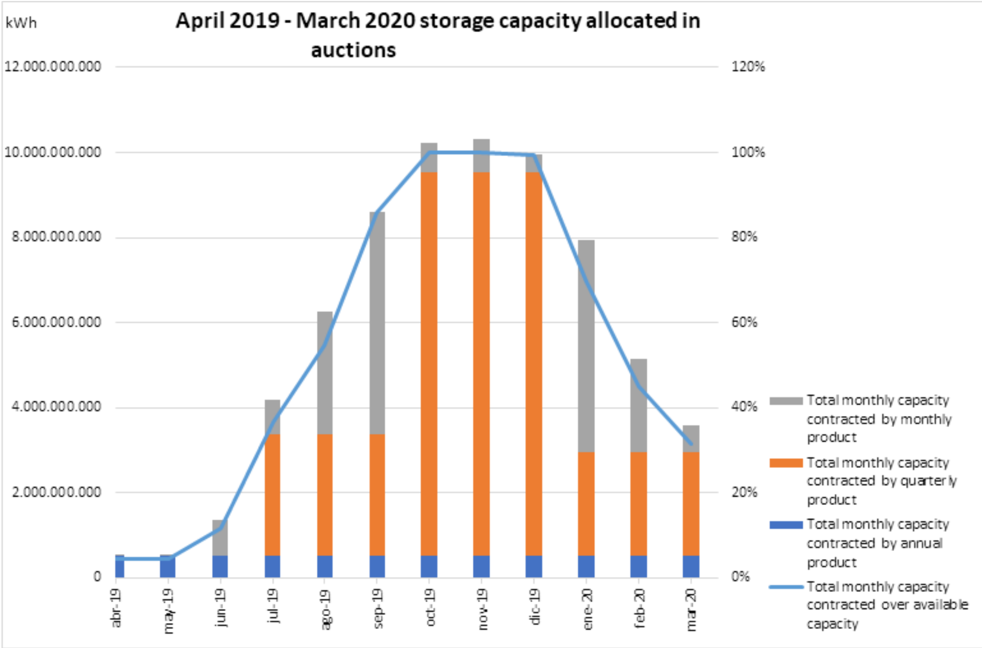

Figure 7 – Gas storage capacity allocated in auctions in Spain, April 2019-March 2020

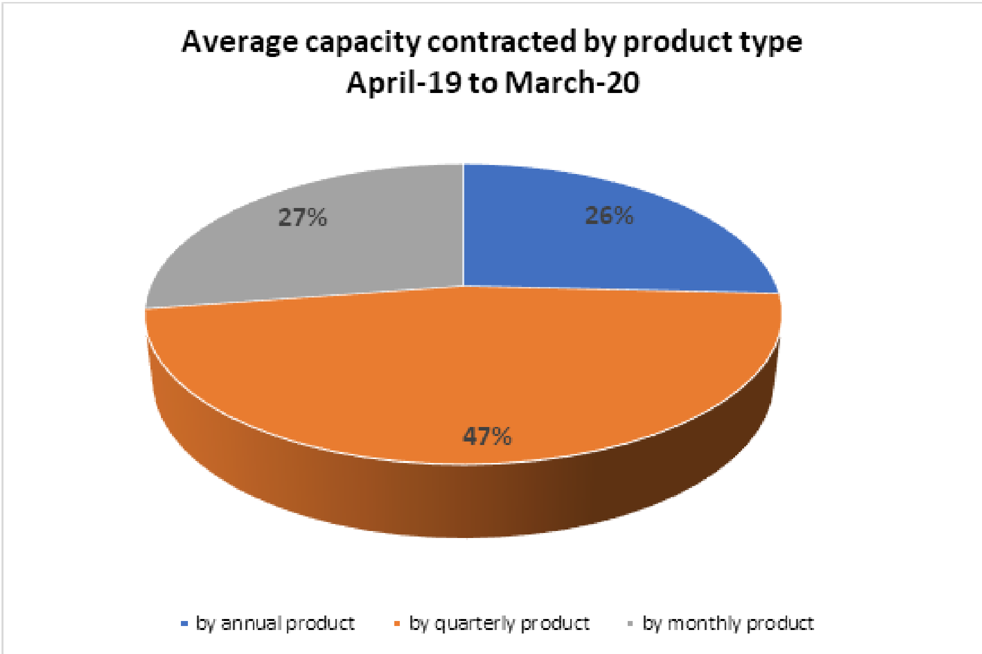

Figure 8 – Average capacity contracted by product type in Spain, April 2019-March 2020[21]

4. Storage for a better system operation

Storage sites are conducted as a single operation. Users request and contract capacity in underground storage without indicating the specific site where they want their gas to be stored, injected and/or withdrawn. They only request and contract quantities in the virtual storage. It is Enagás GTS which decides the location of the stored gas and the distribution of nominations

[21] More information about storage capacity auctions is available at https://www.cnmc.es/expedientes/isde03020.

among the storage sites according to their technical characteristics and to an economic and efficient operation of the whole gas system, and in particular, of the pipeline network. CNMC supervises the correct operation of underground storage facilities and their access management by Enagás GTS.

Enagás GTS is also allowed to use underground storage capacity to facilitate the gas system operation (for example, to allocate operational balancing account (OBA) gas), as long as it does not interfere with the use of these infrastructures by users or reduce the capacity offered to the market.

5. Storage tariffs and cost recovery

The Ministry for the Ecological Transition and the Demographic Challenge is the competent authority for setting TPA tariffs to access underground storage[22].

[22] More information about storage tariffs is available at https://www.boe.es/eli/es/o/2020/12/29/ted1286.

Annex 8 – Great Britain[23]

1. Storage usage among flexibility sources

The supply of gas to Great Britain (GB) comes from a number of sources: indigenous production almost exclusively from the United Kingdom Continental Shelf (UKCS), imports from Norway, imports of LNG and imports from continental Europe via two interconnectors.

Historically, until around 2004, when it came to natural gas the United Kingdom (UK) was broadly self-sufficient[24]. At present, the UK's dependency on imported gas is around 54%. This is expected to grow to around 63% in the next five years and remain stable at this level until around 2050[25].

Due to significant indigenous gas production in the UK and a diversity of sources of supply, GB gas storage had a limited role in assuring security of supplies. This role became even smaller after the Rough storage facility was closed in 2017, which accounted for around 70% of the UK's working storage gas volume and around 25% of the UK's daily deliverability. The figure below shows the impact of the Rough closure on UK gas storage deliverability (assuming all capacity started full).[26]

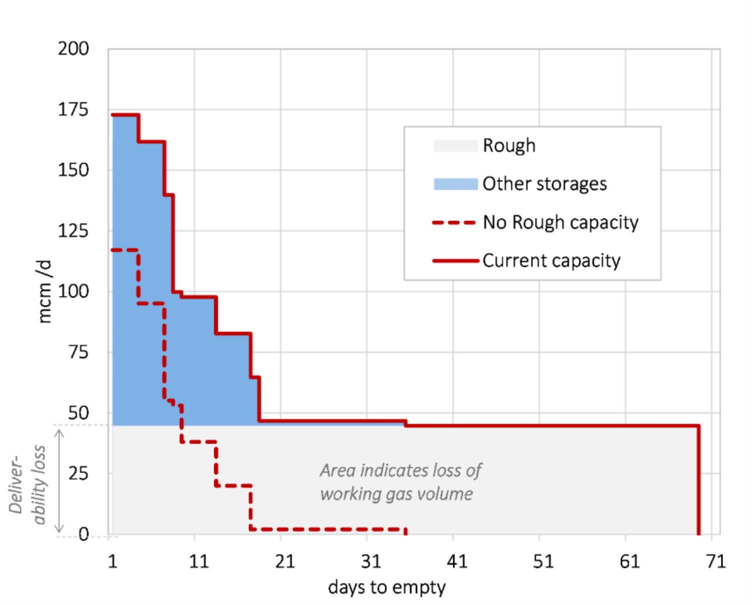

Figure 9 – Number of days to empty storage facilities in GB (Source: Timera Energy (based on data from National Grid) published in April 2017)

[23] All data provided by the British NRA, Ofgem, unless otherwise noted.

[24] UK Government, "Gas statistics", https://www.gov.uk/government/collections/gas-statistics

[25] Statista, "UK projected gas import dependency 2020-2050", https://www.statista.com/statistics/749101/projected-uk-gas-import-demand/

[26] Timera Energy, "The UK gas market without Rough", https://timera-energy.com/the-uk-gas-market-without-rough/

In 2021, the total gas storage in GB was nearly 1.5 bcm, which is less than 2% of GB annual gas consumption, with a maximum deliverability rate to the national transmission system of 117 Mcm/day[27].

Of the seven GB gas storage facilities, the largest, Stublach, has around 400 Mcm capacity and the smallest one, Hill Top Farm, is around 59 Mcm.

The annual gas demand in GB is significantly larger than the storage capacity. In guaranteeing a seasonal security of supply of gas to GB, storage facilities compete with other sources of supply, which have much higher delivery capacity than GB's storage facilities. However, at times of maximum gas demand, storage facilities may play some role in stabilising the maximum price when there are demand peaks or help to avoid such peaks.

Facility	Estimated working gas volume (mcm)	Approx. Max. production rate (mcm/d)	Approx. max injection rate (mcm/d)	Withdrawal duration from full assuming max. rate (days)	Start date	Owner
Facilities operating under nTPA rules						
Hornsea (Atwick)	285	12	3	20	1979	SSEHL Hornsea Limited
nTPA exempt facilities that are currently operational						
Hatfield Moor	70	2	2	60	2000	Scottish Power
Humbly Grove	243	7	8	34	2005	Humbly Grove Energy
Aldbrough	205	31	29	6	2009	SSEHL Hornsea Limited / Equinor
Holford	237	22	26	19	2011	Uniper
Hill Top Farm	59	13	13	5	2011	EDF
Stublach	400	30	30	13	2014	Storengy

Table 3: Current detailed gas storage facilities information in GB[28]

[27] There are seven gas storage facilities: Hornsea (Atwick), Hatfield Moor, Humbly Grove, Aldbrough, Holford, Hill Top Farm and Stublach. Source: Ofgem, GB Gas Storage Facilities 2021. Retrieved from: https://www.ofgem.gov.uk/publications/gb-gas-storage-facilities-2021

[28] Source: Ofgem, GB Gas Storage Facilities 2021. Retrieved from: https://www.ofgem.gov.uk/publications/gb-gas-storage-facilities-2021

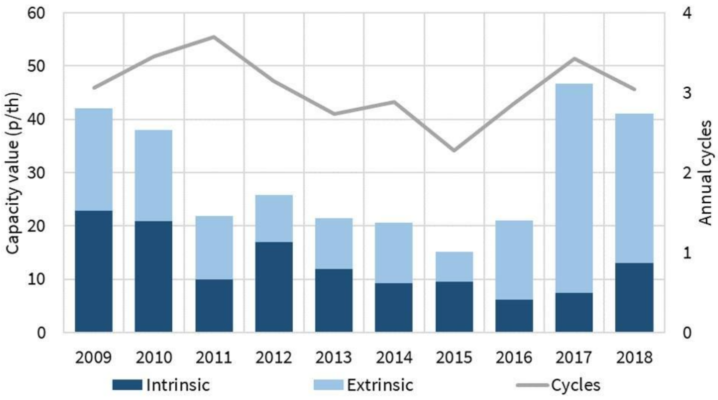

Figure 10: Decline and increase of gas storage value in GB (Source: [Timera Energy](#))

Between 2009 and 2015, there was a decline of GB gas storage value from around 42 pence (p)/therm to around 16 p/therm. In 2012, there were 13 proposed or planned gas storage facility projects with total capacity of around 13 bcm, none of which was developed[29]. Instead, in 2017 Rough storage facility of 3.31 bcm was shut down.

Since 2015, as GB gas demand recovered, especially in the power sector, and also due to closure of the Rough facility, the value of gas storage recovered to above 40 p/therm in 2017 and 2018.

2. Access to European storage facilities

GB is connected with mainland Europe by two interconnectors, Interconnector Limited and Balgzand Bacton Line. These interconnectors allow GB gas shippers to use storage facilities in mainland Europe on a commercial basis.

Compared to GB, the Netherlands, France and Germany have significant gas storage facilities. With the use of interconnectors, GB can access and be a part of the gas supply balancing market arrangements in mainland Europe.

The figure below compares GB gas storage capacity and deliverability with other European countries.

[29] Reuters, TABLE-Planned UK gas storage facilities. Retrieved from: https://www.reuters.com/article/britain-gas-storage-idUKL6E8IC5WX20120724 (accessed on 21 July 2021)

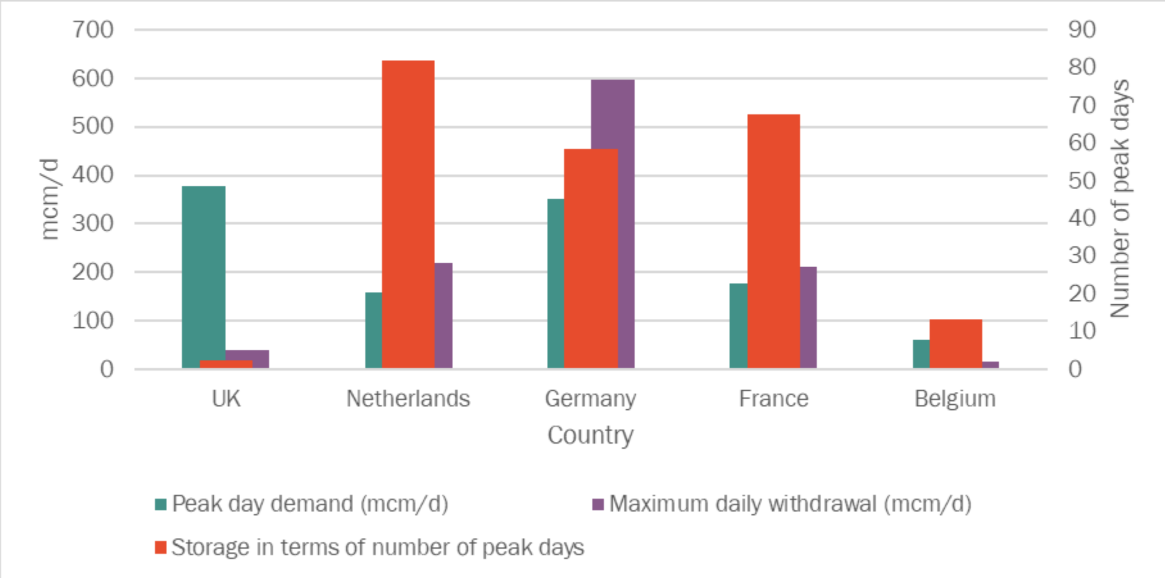

Figure 11 –GB gas storage capacity and deliverability compared with other EU countries (Source: Ofgem 2021 based on agsi.gie.eu)

3. Legal and regulatory framework of gas storage in GB

The GB storage and regulatory framework is based on the Gas Act of 1986, in particular Sections 8R, 8S and relevant parts of Section 19. Gas storage facilities owners are responsible for developing access arrangements which must be, since 3 March 2011, compliant with the EU Third Energy Package, the directly applicable provisions of the Gas Regulation and the relevant provisions of the Gas Directive as transposed into UK legislation.

The default access regime for a gas storage facility in GB is that it is operated under nTPA compliant arrangements[30].

GB's energy regulator Ofgem developed guidance on the regulatory regime for gas storage facilities in GB, which aims to provide greater clarity around the operation of the TPA framework and associated measures. Below is a summary of some elements of this framework:

- Capacity allocation

  Owners of gas storage facilities in GB should offer the maximum technical storage capacity of their facility(s). Market based mechanisms such as auctions and open seasons are considered to increase the likelihood of the allocation mechanism meeting the requirements of the Gas Regulation.

- Main commercial conditions and service mix

  Storage facility owners are expected to conduct open and transparent processes for consulting the market when developing (or amending) their main commercial conditions. Storage owners are considered to be responsible for determining the appropriate level of consultation/market testing.

- Unbundling and the management of commercially sensitive information

[30] The nTPA requirements are set out in s.19B of the Gas Act and s.17D of the Petroleum Act. Broadly, the storage provisions in the Gas Act cover onshore and territorial waters whilst the Petroleum Act sets out the off-shore requirements.

Gas storage owners that are subject to nTPA are expected to be legally unbundled from relevant affiliates. They are also expected to ensure that their facility is operated independently and in a way that protects commercially sensitive information through separation of managers and senior officers, and by implementing and monitoring appropriate measures on staff. Owners are required to publish a compliance report on an annual basis. All storage owners, even those with a minor facilities nTPA exemption, must manage commercially sensitive information appropriately.

- Monitoring and enforcement

  Ofgem has adopted a mix of monitoring and industry engagement to determine whether or not owners of GB gas storage facilities are complying with the relevant regulatory requirements.

The above provides only a very brief summary of some details of the guidance. The full guidance can be found on the Ofgem website[31].

4. Minor facilities exemption (MFE)

A storage facility can apply for a minor facilities exemption under section 8S of the Gas Act 1986. When considering an application for an exemption from the nTPA requirements for minor gas storage facilities, Ofgem considers, on a case-by-case basis, whether nTPA is technically and/or economically necessary for providing efficient access to the system for the supply of customers.

There is no single test that Ofgem considers should be relied upon to demonstrate whether an exemption should be granted. Instead, it is likely to examine a series of indicators to help come to a view on whether an exemption should be granted. Note also that Ofgem would expect that applicants for an exemption should also have considered these indicators and to have provided an assessment against them (where possible) before submitting an exemption application to Ofgem. In addition, any further analysis that storage operators may consider supports their application is welcomed.

As part of ongoing market surveillance activities, Ofgem will continue to look at the effects of exemptions on the market. Minor facility exemptions may be amended or revoked if Ofgem considers that offering nTPA at the facility becomes technically and/or economically necessary for providing efficient access to the system for the supply of customers.

One can see Ofgem's Gas Storage Minor Facility Exemptions Open Letter for further guidance on the criteria that is used to consider exemption applications[32].

5. Future role of storage

The UK Government's Energy White Paper 'Powering our Net Zero Future'[33] published in December 2020 indicates that by 2050 they expect low-carbon options, such as clean hydrogen and long-duration energy storage, to satisfy the need for peaking capacity and ensuring security of supply at low cost, with a view to progressively reduce the reliance on energy generation from natural gas.

[31] Ofgem. Guidance on the regulatory regime for gas storage facilities in Great Britain. Retrieved from: https://www.ofgem.gov.uk/publications/guidance-regulatory-regime-gas-storage-facilities-great-britain-version-2

[32] Ofgem. Gas Storage Minor Facility Exemptions Open Letter. Retrieved from: https://www.ofgem.gov.uk/publications/gas-storage-minor-facility-exemptions-open-letter

[33] UK Government. Energy White Paper: Powering our Net Zero Future, December 2020. Available here.

GB's natural gas storage facilities will continue to play an important role to provide a source of flexibility and ensure security of gas supply alongside the development of alternatives for hydrogen and other low-carbon gases. Hydrogen storage is also likely to be an essential part of growing the UK hydrogen economy. However, it is not yet clear at what scale and in what time frame such storage will be needed as the UK energy system decarbonises.

The Department for Business, Energy & Industrial Strategy (BEIS) continues to explore the future role of storage in meeting the net zero target. The UK Hydrogen Strategy[34] considers the role of hydrogen storage in greater detail and whether further regulation or support mechanisms are needed.

In addition, BEIS' Call for Evidence on the Future of the Gas System, which is expected to be published before the end of 2021, also seek stakeholders' views on the continued need for natural gas storage facilities and potential changes to current storage facilities as work progresses on low-carbon options. Feedback received on the Call for Evidence will determine next steps; for example, whether the UK Government will issue a formal consultation or strategy on the future of the gas system.

[34] UK Government, UK Hydrogen Strategy. August 2021. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

Annex 9 – About CEER

The Council of European Energy Regulators (CEER) is the voice of Europe's national energy regulators. CEER's members and observers comprise 39 national energy regulatory authorities (NRAs) from across Europe.

CEER is legally established as a not-for-profit association under Belgian law, with a small Secretariat based in Brussels to assist the organisation.

CEER supports its NRA members/observers in their responsibilities, sharing experience and developing regulatory capacity and best practices. It does so by facilitating expert working group meetings, hosting workshops and events, supporting the development and publication of regulatory papers, and through an in-house Training Academy. Through CEER, European NRAs cooperate and develop common position papers, advice and forward-thinking recommendations to improve the electricity and gas markets for the benefit of consumers and businesses.

In terms of policy, CEER actively promotes an investment friendly, harmonised regulatory environment and the consistent application of existing EU legislation. A key objective of CEER is to facilitate the creation of a single, competitive, efficient and sustainable Internal Energy Market in Europe that works in the consumer interest.

Specifically, CEER deals with a range of energy regulatory issues including wholesale and retail markets; consumer issues; distribution networks; smart grids; flexibility; sustainability; and international cooperation.

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More information is available at www.ceer.eu.