EXECUTIVE SUMMARY

Storage: a vital segment of the gas chain

Natural gas storage plays a vital role in smoothing out fluctuations in seasonal and peak demand and ensuring reliable and secure gas supply. Natural gas market participants **all along the gas value chain** benefit from the capability to store natural gas until it is needed in response to market demands caused by weather or other events. Storage, such as underground gas storage (UGS) in depleted oil and gas fields, aquifers, salt caverns, built near market centers, are the most common ways in the main developed consuming countries to ensure reliable and secure gas supplies. The first commercial natural gas storage facility in the world commenced operations at the Zoar field near Buffalo, New York, United States, in 1916. **Today there are 680 UGS facilities operating in the world**. Each type of UGS has its own physical characteristics and economics (costs, deliverability rates, and cycling capability) which govern its suitability for particular applications. UGS facilities in aquifers and depleted oil and gas fields are better suited to meet seasonal adjustment needs and to constitute strategic reserves, because they can store a larger working volume than salt caverns. The installations built in salt caverns are designed to satisfy peak demand and trading purposes. Their advantage is their high deliverability and their ability to be cycled several times during the year.

While the most common and economical way to develop gas storage is UGS, due to geological and other considerations, **some countries rely on storage capacity built at liquefied natural gas (LNG) receiving terminals** to ensure reliable and secure gas supply. While this policy was first developed in Japan for geological and geographic considerations, the advent of the **Floating Storage Regasification Unit** (FSRU) technology since the middle of the 2000s, as well as growing volumes of flexible LNG on the international market, have driven a number of countries to build FSRUs, and postpone investment in UGS. The latter are more difficult to permit, have longer lead times, and in some cases difficult geology. This is illustrated by the numerous FSRUs built in Central and South America since 2010 to smooth out large swings in hydropower generation. Most Middle Eastern countries have followed the same path. Obviously UGS and LNG import terminals (onshore or FSRUs) do not serve the same functions. The main purpose of UGS is to shift supply and demand from one period to another, while LNG import terminals are built to access and/or diversify gas supplies. Their primary purpose is not to store LNG, but to inject gas into the transmission system.

Therefore, **one major difference between UGS and LNG storage is their storage capacity**. The working gas capacity of UGS in the world is more than twelve times higher than the storage capacity at LNG receiving terminals worldwide. The smaller LNG storage capacity is explained by the high cost of storing LNG compared with storage of gas underground. Despite their limited storage capacity, LNG terminals can quickly regasify LNG and inject it into the transmission system. This ability is key for reliable and secure gas supplies.

In liberalized markets, UGS competes with other flexibility tools

The role of UGS is not confined to solely smoothing out variations in gas demand. It also plays an important role for security of gas supply and for optimizing the whole gas value chain. The former is well illustrated by regulation at EU or national level in Europe which, in some national cases, mandate storage obligations or strategic storage. The latter is better illustrated by Russia and the United States and the development of UGS linked with the optimized sizing of long distance gas

pipelines. It is also well illustrated by the Netherlands and the growing role of UGS linked with decreasing swings in domestic production. With the development of renewable energy sources in the power sector, storage also plays a supplementary function to cover variability in gas demand when gas is used as a back-up to intermittent power supply. This is well illustrated by the development of salt caverns in the US Southern States, which are increasingly used to respond to short-term changes in power generation. **In liberalized markets, storage is also used as a financial tool to arbitrage price differentials between different points in time.**

There are several ways to meet seasonal and peak natural gas demand fluctuations, such as swings in production, flexibility in import contracts, line-pack (although limited), flexible LNG, spot gas and hub-related products in liberalized markets, and storage. With market liberalization, **flexibility markets develop** where market participants can buy their flexibility needs and balance their supply portfolio on a short term basis. Flexibility markets aggregate the needs of market participants and optimize the provision of flexibility. The contractual and physical delivery of flexibility tend to be separated. UGS is part of this flexibility market, and in regions where market liberalization has progressed and UGS is available (mainly North America and key markets in Europe), **UGS competes with other sources of flexibility in an increasingly competitive environment.** In both regions, the main incentive to develop new UGS is the summer-winter price spread which has fallen in both regions, leading to little investment in new capacities. The situation in Europe is exacerbated by the oversupply that has developed since gas demand started to fall after 2010. Not only the price signal to invest in new UGS has been removed, but there are ample competing sources of flexibility available at lower prices. However, despite bringing greater efficiency, the market finally needs flexible gas to be delivered in case of emergency situations (exceptional cold weather or disruption of gas supplies due to technical or geopolitical considerations). **The insurance role of UGS is a key function in Europe** which is increasingly dependent on external sources of supply. The North American market is different as a large share of UGS facilities are still owned and operated by local distribution companies (LDCs) to meet long-term customer contracts. Therefore, many UGS are regulated based on a cost-based tariff, providing a predictable, consistent environment and the ability to recover/payback investments for adding or expanding seasonal storage.

An important aspect of flexibility is the timing required: hourly, daily, weekly, monthly and annually. Different tools apply according to various timing. Not all flexibility tools are available for the same timing while combining the different types of storage makes UGS adapted to all requirements. Flexibility requirements and mechanisms differ greatly from one region to another, and from one country to another, depending on the degree of market liberalization, the demand structure, the share of gas in the energy mix, the existence and size of national gas resources, and the diversification of supply. Moreover, flexibility needs and mechanisms are not static. They evolve with time. For instance, flexibility in supply declines as a major gas field is depleting. The case of the Dutch Groningen field is a striking example.

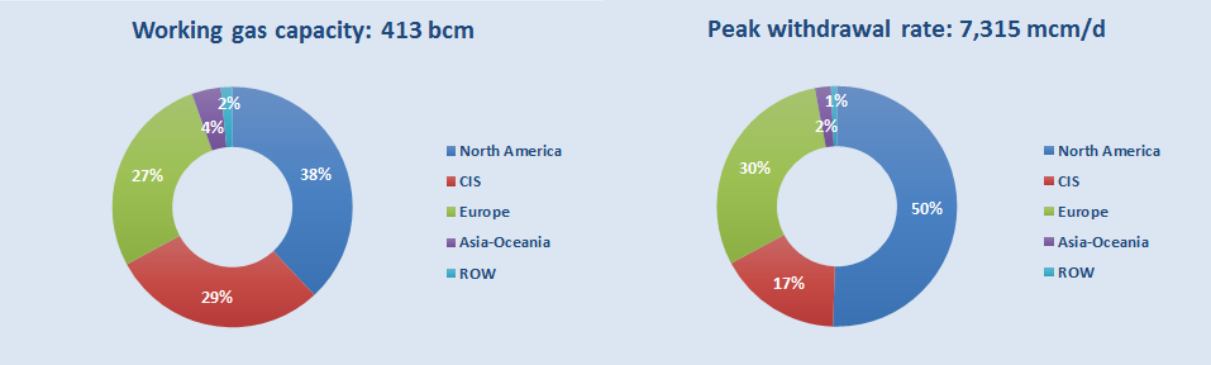
The capacity of LNG receiving and regasification terminals worldwide offers large spare capacity to allow flexible operation of these facilities. Flexible LNG (spot cargoes and short-term LNG supplies) and ample regasification capacity play a significant role in balancing supply and demand in several LNG importing countries. **LNG therefore competes with UGS in the provision of short term flexibility**. The issues with LNG flexibility are the timing of the availability of supplies, prices and uncertainty on future availability of flexible spot cargoes. LNG is a global commodity competing on

the international market. While additional supplies may be available at LNG export terminals, they will go to the highest-price market.

Global underground gas storage trends: Asia and the Middle East drive the growth

There were 680 UGS facilities in operation in the world at the end of 2015, representing a working gas capacity of 413 billion cubic meters (bcm). Most of the capacity is concentrated in the three developed gas markets: North America, the CIS and Europe. The new and growing gas markets, Asia-Oceania and the Middle East, represented only 6% of global UGS capacity. Global peak withdrawal rates (or deliverability) reached 7,315 million cubic meters per day (mcm/d) at the end of 2015. **UGS working gas capacity has increased significantly since 2010**, up 14%, mainly under the impetus of Europe. The growth in other regions was also pronounced and one additional region, the Middle East (Iran), took part in this development. Global deliverability rates increased even faster, up 21% from 2010.

Figure 1: Global UGS capacity by region, end of 2015



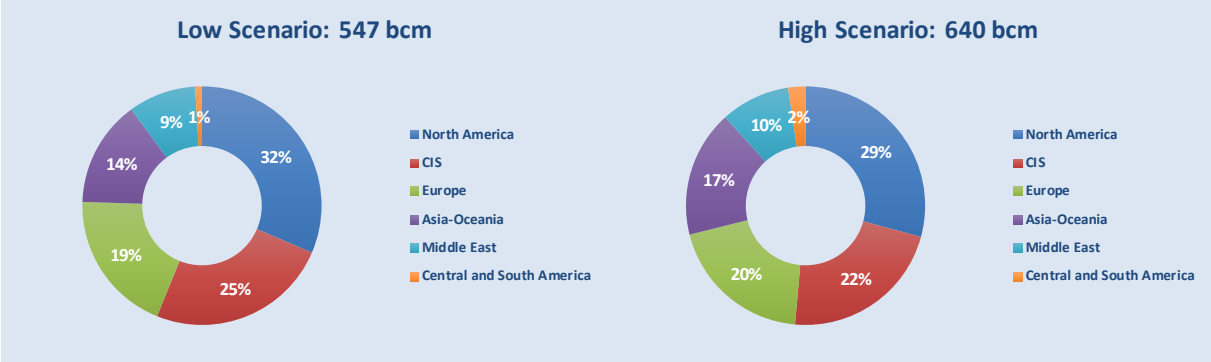
Source: CEDIGAZ

Global natural gas demand increased at an annual average rate of 2.5% during the past 20 years and growth is expected to continue, but at a slower rate (1.6%/year on average over the period 2014-2035). Global gas demand is expected to rise to 4,760 bcm by 2035 mainly under the impetus of the growth in global electricity demand and gas-fired electricity generation. Thanks to its environmental advantage, gas is expected to replace coal in several countries, a trend accentuated by the agreement reached at COP21 in Paris, and to play a key role to facilitate the development of intermittent renewable energy sources. As observed in recent years, the largest growth in gas demand, in both absolute and relative terms, is expected in Asia-Oceania and the Middle East. These two regions account for two-thirds of the global additional demand by 2035.

Global UGS capacity is expected to increase from 413 bcm in 2015 to 547-640 bcm by 2035. The incremental growth in UGS capacity requires sustained investment all over the period: €100 billion to 170 billion will need to be invested by 2035. The growth is much smaller than observed in the past 20 years (an annual average growth of 1.4% to 2.2% over the period 2015-2035 compared with 2.6%/year in the past 20 years) and reflects the maturity of the storage market in the main storage regions. The range of future additions to storage capacity, 134 bcm to 227 bcm by 2035, is also much larger than foreseen in past CEDIGAZ storage outlooks due to the uncertainty on the availability of appropriate geology, economic and financial constraints, and competition with alternative sources of flexibility in the new storage regions. Many storage projects, planned for years, have not materialized and several countries (mostly in South Asia, Southeast Asia and Central and South America) have

chosen to build LNG regasification terminals instead and use flexible LNG imports to provide their flexibility needs.

Figure 2: Global UGS working gas capacity by 2035



Source: CEDIGAZ

The evolution in UGS capacity is significantly contrasted between regions. New storage markets, Asia-Oceania, the Middle East, and potentially Central and South America, account for most of the growth expected by 2035. The large differences seen in the development of the natural gas industry worldwide are reflected on the expected evolution of the regional underground gas storage markets. In countries where the gas industry is still in its early days, storage projects are mainly linked to seasonal and peak balancing needs, optimization of the main long distance gas transmission pipelines and security of supply. Large volumes are needed but also peak deliverability to cope with increasing demand. Conversely, in mature markets (North America, most of Europe, the CIS), the growth in working capacity is limited, and could even be negative (EU). In the liberalized markets, the gas industry has undergone massive changes, largely impacting the storage activity which is increasingly geared to trading and managing gas price fluctuations. New storage needs are linked to the development of trading activity and to the use of natural gas as a back-up of intermittent renewable energy sources in the power sector. The focus is on increasing peak deliverability rather than storage volumes. UGS also plays a major role for security of supply in Europe where import dependence increases.

The gas industry is willing to continue investing in this key asset to support the expansion of global gas markets and accompany the trend towards more intermittent energy sources, provided the right economic and regulatory framework is in place. **At worldwide level, projects currently under construction add 36 bcm of working capacity and mainly relate to expansions of existing facilities.** There are 18 new UGS facilities under construction worldwide. In addition, **planned and potential projects add another 61 bcm of working capacity if all built.** In mature markets, planned projects are well identified and only require a conducive investment climate to go ahead. In the new storage markets, the need for storage is well identified, but the geological potential often needs to be further investigated. Competition with flexible LNG, and especially FSRUs, as well as geological constraints, will limit the development of UGS in a number of new gas consuming countries.

FSRUs allow a growing number of countries to access the LNG market

After four years of stagnation due to the tightness of LNG supplies, **LNG trade is slated for a new phase of expansion**. A new wave of LNG export capacity is entering the market with huge capacities built in Australia and the US. Rising supply is coming to market at a time when oil, natural gas, and

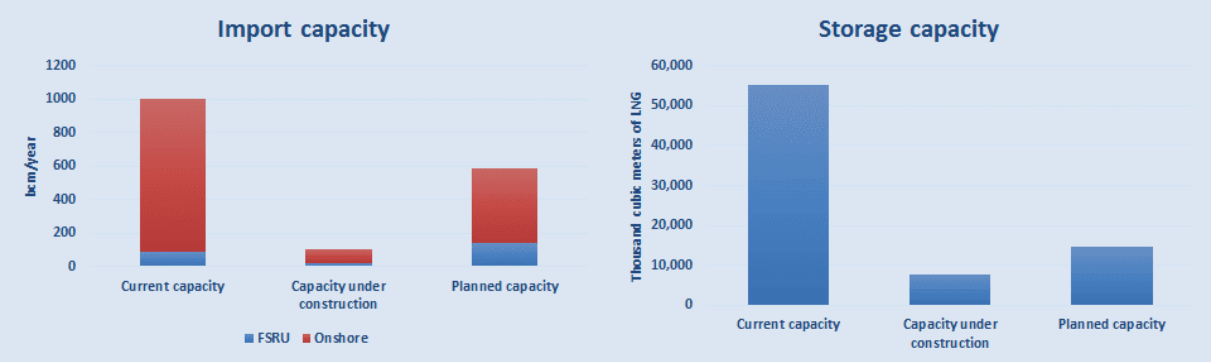
LNG prices have collapsed, making LNG more affordable for a number of new consuming countries, and creating new opportunities for existing LNG importing countries.

The number of LNG importing countries has expanded significantly over the past ten years, from 18 in 2005 to 35 in 2015. A wider range of LNG supply options, flexible shipping strategies, the growth of the spot and short-term market and FSRU technology have helped a growing number of countries to become LNG importers. This includes traditionally export-oriented regions (such as the Middle East and North Africa) facing burgeoning gas demand, emerging economies with growing energy needs (in Southeast Asia and Central and South America), and countries seeking greater energy security and diversification (mainly in Europe). **The global regasification market has expanded at a strong rate, having more than doubled in the past ten years**, with capacity growth coming from new and 'traditional' importers alike. The FSRU technology has enabled new countries to secure an accelerated access to the global LNG market, while existing importers have often focused on bringing online larger terminals with increased send-out, berthing and storage capacity. **As of beginning of 2016, 118 LNG import terminals (including 17 FSRUs) and 429 LNG storage tanks existed worldwide.** Global import capacity stood at 1,000 bcm/year at the beginning of 2016. In 2015 alone, 11 new terminals (of which five FSRUs) and two expansions of existing plants came online. With a global share of 54%, Asia is the number one region for regasification capacity. However, its dominance has decreased notably since 2005 when it accounted for a much larger 65% of global regasification infrastructure. Such a decrease highlights the steady emergence of new LNG consumers. This trend is expected to continue going forward with 20 new countries planning to add LNG import capacities.

There are currently 16 new terminals under construction, of which four FSRUs. In addition, 12 terminals are being expanded. These projects will add a combined capacity of over 100 bcm/year by 2018/19. **In addition, there are more than 100 potential and speculative projects** (expansions and new terminals) adding almost 600 bcm/year of import capacity worldwide. Asia-Oceania drives the expansion, with three quarters of the current capacity under construction and half of the planned capacity located in the region, but new LNG importing countries are entering the LNG market.

The FSRU technology facilitates this trend thanks to the lower cost of FSRUs compared with traditional onshore plants, their shorter lead time and less difficult permitting. At the beginning of 2016, there were 17 FSRUs in operation globally. Floating import capacity was 88 bcm/year, accounting for about 9% of the world's total. **In 2015 alone, five FSRUs came online and four additional FSRUs are set to start operations in 2016 and 2017. With 41 FSRU projects under consideration globally**, both the volume (a combined capacity of 145 bcm/year) and share of FSRU capacity are likely to increase further. Asia still dominates the planned and announced FSRUs projects. However, 40% of the additional capacity is outside Asia. FSRUs are particularly popular in Central and South America, Europe, and Africa.

Figure 3: Global LNG import and storage capacity (current, under construction and planned as of beginning of 2016)



Source: CEDIGAZ

Global LNG storage capacity amounted to 55.3 million cubic meters (mcm) of LNG at the beginning of 2016, equivalent to 33.2 bcm in gaseous form. The LNG import terminals under construction or expansion will increase current LNG storage capacity by 14%, while planned terminals could increase it by a further 40%.

The average onshore terminal storage size equals 520,000 cm of LNG. **Onshore terminals in Asia generally have larger storage capacity** to allow for greater flexibility and security of LNG supply during periods of peak seasonal demand. As it is the case for liquefaction trains, onshore terminals and above-ground **LNG tanks tend to become larger**. South Korea's Samcheok LNG terminal, which started operations in the third quarter of 2014, will have the world's largest LNG storage tanks, with a unit capacity of 270,000 cm. Similarly, although they offer smaller storage capacity, typically between 125,000 and 170,000 cm, **larger FSRUs are being built**. With a storage capacity of 263,000 cm, Uruguay's GNL del Plata FSRU – set to come online in 2016 – will become the world's largest FSRU to enter operations.