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**Energy security as a public  
good: the economic impact of  
the EU gas Storage Regulation  
after the 2022 energy crisis**

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## **Abstract**

This thesis investigates the role of natural gas storage in ensuring energy security within the European Union, focusing on the regulatory and economic implications of the emergency measures adopted following the 2022 energy crisis. The central research question guiding the study is twofold: was the Regulation (EU) 2022/1032 necessary to guarantee energy security, and was it economically efficient? The hypothesis is that while Regulation (EU) 2022/1032, which introduced binding 90% filling targets for underground gas storage, successfully ensured supply security, its design and implementation generated significant economic distortions and a financial burden that was ultimately socialised across Member States.

To address this twofold research question, the thesis first examines the structural vulnerabilities of the European energy system, particularly its dependence on imported fossil fuels and the strategic function of gas storage infrastructure. It then analyses the regulatory evolution triggered by the 2022 supply shock and reviews the academic debate on the market implications of mandatory storage targets. The core of the study is a comparative analysis of four major European economies based on Eurostat data and national sources. By reconstructing import volumes, price trends, and expenditure patterns, the thesis assesses how the financial costs of compliance were distributed across private operators, state-linked entities, and ultimately society at large. The findings reveal that while the Regulation (EU) 2022/1032 achieved its primary security objective, the lack of coordination among Member States and the reactive nature of

national support instruments led to significant inefficiencies and a widely socialised economic burden.

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## **INTRODUCTION**

This thesis investigates the role of natural gas storage within the European Union's energy system, with particular attention to the policy and economic implications of the 2022 energy crisis. The sharp reduction in Russian gas supplies exposed structural vulnerabilities in the European energy model, notably its high dependence on external suppliers and the limited coordination of strategic reserves across Member States. In this context, underground gas storage emerged as a central instrument for ensuring security of supply, prompting unprecedented regulatory intervention at the European level. The thesis examines both the effectiveness and the economic efficiency of this intervention, with a focus on the Regulation (EU) 2022/1032 introduced in 2022 and its impact on markets, public finances, and private actors. Against this background, the thesis is organised into four main analytical chapters, followed by a final chapter that presents the overall conclusions.

Chapter One provides the analytical and empirical background by describing the structure of the EU energy system. Drawing on Eurostat data, it analyses the energy mix of the industrial and household sectors, the evolution of domestic production, and the growing reliance on energy imports. The analysis focuses on the role of fossil fuels, especially natural gas, and the persistent heterogeneity across Member States in terms of energy consumption patterns and efficiency. The chapter highlights how limited domestic resources and dependence on a small number of external suppliers constitute a structural weakness for the European Union, shaping its exposure to external shocks.

Building on this context, Chapter Two focuses on the dynamics of natural gas demand, prices, and infrastructure. It examines the seasonal and volatile nature of gas consumption, distinguishing between long-term and

short-term drivers, and analyses the evolution of prices for different categories of consumers, in particular households and non-household users such as industrial and commercial sectors. The chapter demonstrates the inelastic nature of natural gas demand, which responds only modestly to price signals, particularly in the short term. It also explores the physical architecture of the European gas system, including pipeline networks, LNG import terminals, and underground storage facilities, highlighting their complementary roles. Significant attention is given to storage as a strategic asset, including its operational functioning and its essential role in reducing seasonal demand fluctuations and reinforcing supply security.

Chapter Three turns to the regulatory dimension, tracing the evolution of the European framework governing gas storage. It first examines the pre-2022 approach, in which storage was primarily governed by Regulation (EU) 2017/1938, and was characterised by limited harmonisation and a reliance on national responsibility and regional risk assessments. It then analyses the turning point represented by the 2022 energy crisis, which led to the adoption of Regulation (EU) 2022/1032 and the introduction of binding storage filling targets. The chapter further reviews the academic and policy literature, discussing both the benefits of the Regulation (EU) 2022/1032 in terms of enhanced security of supply, such as its role as a volatility-dampening mechanism capable of reducing extreme price spikes and improving market predictability, and its potential drawbacks, namely increased market pressure, adverse price effects, and the risk of reinforcing fossil fuel dependence through new infrastructure investments.

Chapter Four addresses the central research question of the thesis: did the EU Storage Regulation represent an efficient policy instrument for guaranteeing energy security, or could its objectives have been achieved at a lower economic cost? The work seeks to understand whether the binding regulatory requirements distorted an already stressed natural gas

market, forcing companies and states to purchase more gas than needed to fill storages and incurring significant losses, merely to stock additional reserves rather than to meet immediate supply needs. To answer this, the chapter provides a comparative empirical assessment of the Regulation's economic consequences across four major European economies, namely Germany, Italy, France, and Spain, analysing how differences in infrastructure, market design, and policy choices influenced storage strategies. It examines the evolution of gas import volumes and expenditures during the crisis, the role of private and state-linked actors in procuring gas under extreme market conditions, the fiscal and regulatory measures implemented to protect consumers and firms, and how the financial burden was ultimately distributed across society through public budgets, taxation, and energy prices.

The thesis concludes by synthesising the main findings and reflecting on the broader implications for European energy policy. It shows that the EU Storage Regulation (EU) 2022/1032 was highly effective in achieving its primary objective of strengthening energy security, ensuring adequate storage levels, and reducing price volatility. However, this success came at a significant economic cost, as the evidence suggests that the mandatory storage targets contributed to amplifying short-term price pressures by prompting simultaneous procurement by Member States during a period of already constrained supply. As a result, the financial burden associated with securing energy supply was ultimately socialised across society, through public spending, regulatory mechanisms, and higher consumer costs. These findings highlight a fundamental trade-off between security of supply and economic efficiency. Nevertheless, this assessment is limited by the absence of a clearly defined counterfactual: the costs appear significant even because the winter of 2022-2023 was mild and the most extreme supply shocks did not materialise. The relevance of this limitation

is underscored by ongoing disruptions in the Gulf, including the closure of the Strait of Hormuz and constraints on Qatari LNG supplies, which remind us that adverse scenarios remain a persistent reality. These considerations point to the need for more coordinated and forward-looking policy frameworks capable of achieving similar security outcomes at lower economic cost.

# **CHAPTER ONE – THE ENERGY MIX OF EUROPEAN COUNTRIES**

## **1.1 Introduction**

This chapter establishes the context of the European Union’s energy system. Drawing primarily on Eurostat data, it outlines the current energy landscape of the European Union by analysing the energy mix of key sectors, particularly industry and households, alongside domestic production capacities and the Union’s resulting dependence on energy imports. The analysis highlights the EU’s heavy reliance on fossil fuels and the limited availability of indigenous resources, underscoring the energy security concerns that arise from this structural dependency.

Section one focuses on the industrial and household sectors as primary drivers of energy demand, accounting for more than half of the total. The varying energy mixes observed across the selected Member States illustrate the significant heterogeneity that characterizes the European energy supply for these two crucial sectors, which remains largely supported by electricity and natural gas as primary energy sources, as detailed at the end of this section. Furthermore, the concept of energy efficiency, closely related to energy productivity for the industrial sector, is explained in this section, showing how the top five European economies rank differently on this significant indicator during 2023.

Section two underscores that the limited domestic availability of fossil fuels within most European countries represents a structural weakness, explaining the EU's significant reliance on imports. The utilization of nuclear power, where politically admissible, and the strategic push for renewable energy sources are key strategies to mitigate this external dependency. However, as shown in Figure 4, the focus on renewables and

biofuels in the industrial sector during the decade 2013-2023 has resulted in only a slight increase in their consumption across the EU-27 countries.

The third section turns to energy imports, providing an overview of total energy, natural gas, and oil and petroleum product imports for the EU-27 and for Italy specifically over the decade 2013-2023. What emerges is the EU's high dependence on foreign countries, particularly for natural gas and other fossil fuels. A closer examination of Europe's primary natural gas suppliers, distinguishing between pipeline gas and LNG, is presented at the end of the section. This analysis highlights Europe's key energy partners while revealing how reliance on a limited number of foreign suppliers creates a critical structural vulnerability. This vulnerability was first exposed during the 1973 oil crisis, which showed Europe's exposure to external suppliers and shaped the concept of energy security in the minds of Europeans.

## **1.2 Energy landscape in Europe**

This section provides an overview of the European energy landscape, focusing on sectoral energy mixes across the Union. Table 1 presents the volume and sectoral distribution of energy demand in the EU for 2023. The analysis then turns to the industrial sector: Figure 1 illustrates the energy mix of the five largest European economies, highlighting their continued reliance on fossil fuels (particularly natural gas) and cross-country differences in renewable energy adoption. At the EU-27 level, the data reveal the persistent predominance of fossil fuels and the still marginal role of renewables. Finally, the section examines the link between energy consumption and industrial productivity, with Table 2 presenting energy productivity indicators for the EU and its five largest economies in 2023.

Europe is one of the most important components of the world's economic and energy systems, due to its substantial population, high levels of consumption, and major contribution to global GDP. With six of the top twenty global economies in 2024 being European nations, the continent delivers advanced products and services worldwide. According to Eurostat (nrg\_bal\_s, 2025) and as presented in Table 1, the total final energy consumption of the EU-27 in 2023 amounted to 873 Mtoe, distributed across four main economic sectors: industry, transport, households, and commercial and public services. The transport sector accounted for the largest share, consuming 279 Mtoe (32%), followed by households at 229 Mtoe (26%) and the industrial sector at 214 Mtoe (25%). Commercial and public services represented 117 Mtoe (14%), while other minor uses accounted for 32 Mtoe (4%). This distribution highlights the substantial energy demand to meet European consumption, underscoring the importance of sector-specific strategies for energy efficiency and decarbonisation within the EU.

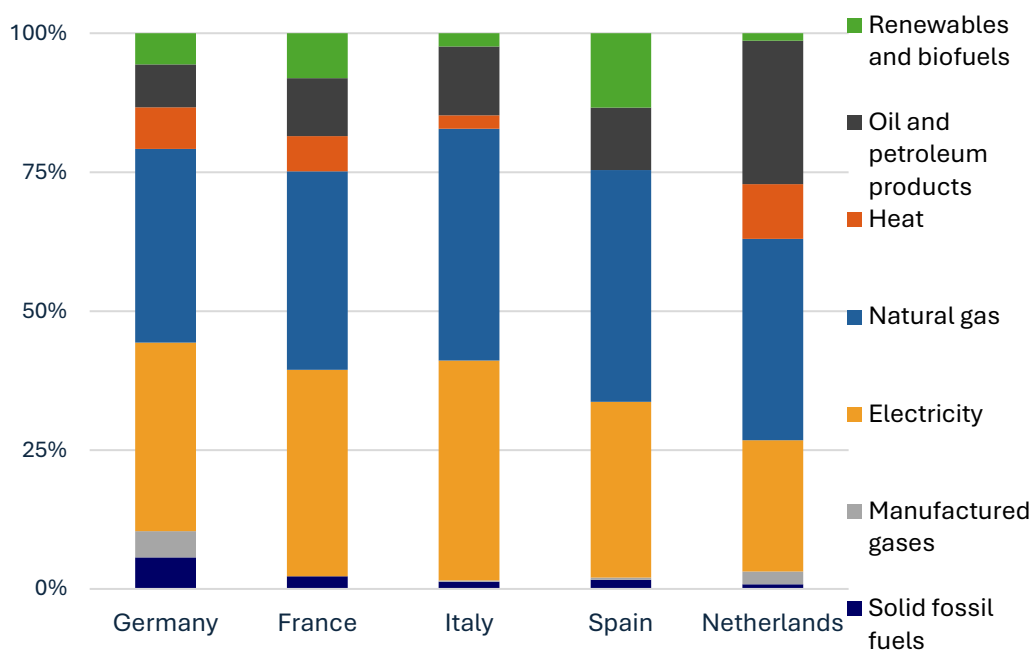
Full Year 2023	Mtoe/yr	SHARE
<b>Final consumption - energy use</b>	<b>873</b>	
Transport sector	279	32%
Industry sector	214	25%
Households	229	26%
Commercial and public services	117	14%
<i>Others</i>	32	4%

**Table 1** Final energy consumption by sector in the European Union, full year 2023. Unit of measure: Million tonnes of oil equivalent per year (Mtoe/yr). Data source: Eurostat, nrg\_bal\_s, (2025).

The European energy landscape is characterised by a high degree of heterogeneity, reflecting substantial differences across Member States in terms of population size, economic structure, and the availability of

domestic energy resources. These disparities are further amplified by geographical characteristics, uneven access to natural endowments, and divergent national policy choices, particularly about the role of nuclear energy, which ranges from active expansion in some countries to complete phase-out or prohibition in others. As a result, the energy mix of each country, defined as the combination of primary energy sources used to meet its energy needs, varies considerably across the Union. Over time, this mix has undergone profound transformations, especially since the mid-twentieth century, shaped by shifting policy priorities such as sustainability, economic competitiveness, and energy security. More recently, these objectives have been increasingly influenced by climate commitments and decarbonisation targets, further accelerating the transition towards renewable energy sources while simultaneously raising new challenges related to system integration, reliability, and dependence on external suppliers.

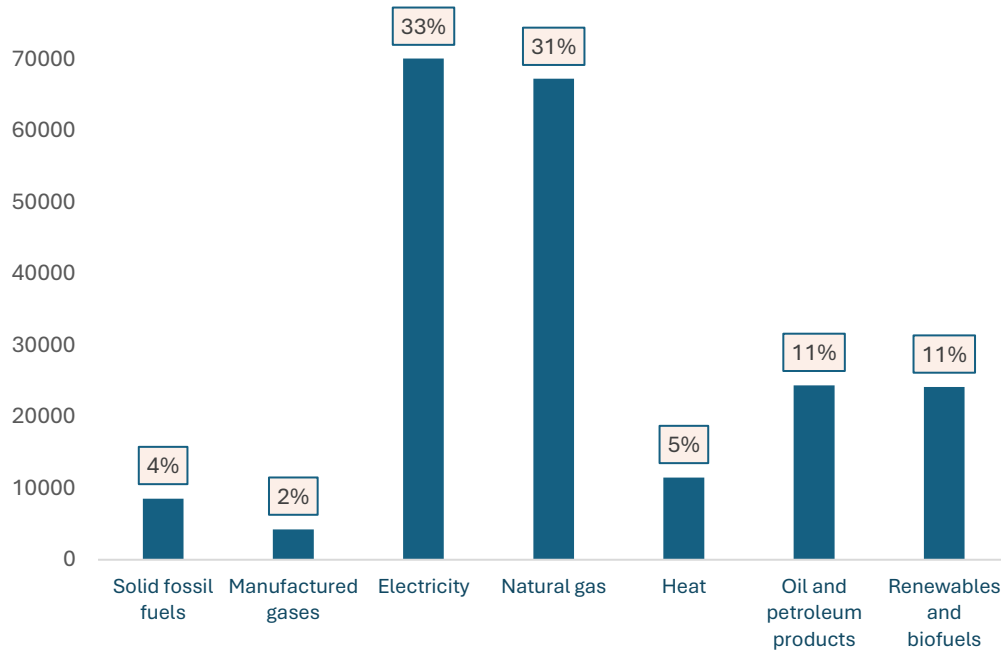
As a primary driver of energy demand and a backbone of the European economy, the industrial sector provides crucial insights into the region's evolving energy mix. Its energy consumption patterns not only reveal the relative importance of different energy sources, but also highlight the challenges associated with improving efficiency, reducing emissions, and maintaining international competitiveness in the context of the ongoing energy transition. Eurostat data (nrg\_bal\_s, 2025) on the industrial sector of the EU's five largest economies identify natural gas and electricity as the predominant energy sources, while consumption of solid fossil fuels and manufactured gases is comparatively limited. This consumption structure signals a progressing energy transition yet also a continued strategic dependency on natural gas, with the share of renewables and biofuels remaining marginal in most of these pivotal countries, despite demonstrating variance from 1% to 13%.



**Figure 1** National Energy Mix in Selected Countries – Industrial sector, full year 2023. Note: data represent the share of each energy source in the national total. Data source: Eurostat, nrg\_bal\_s, (2025).

In aggregate, the industrial sector of the European Union consumed 214 Mtoe in 2023 (Eurostat, nrg\_bal\_s, 2025), accounting for about one-quarter of the EU's total final energy consumption. As shown in Figure 2, electricity and natural gas dominate the industrial energy mix, each accounting for approximately one-third of total final consumption (33% and 32%, respectively). Oil and petroleum products make up 12%, followed by renewables and biofuels at 11%, with the remaining sources accounting for around 12%. This high reliance on natural gas within the industrial sector underscores a critical vulnerability: disruptions to gas supply directly threaten industrial production, competitiveness, and employment across the EU. Understanding the composition of industrial energy consumption is therefore essential to assessing the potential

economic impact of gas supply shocks and the rationale behind the EU's emergency energy policies.



**Figure 2** Final energy consumption by energy source in the European Union – Industrial sector, full year 2023. Unit of measure: Thousand tonnes of oil equivalent per year (Ktoe/yr). Data source: Eurostat, nrg\_bal\_s, (2025).

Energy productivity measures the economic output generated per unit of gross available energy; a higher value means a country produces more euros for each kilogram of oil equivalent consumed. These values are intrinsically tied to a nation's energy efficiency, which brings a variety of benefits, including reduced greenhouse gas emissions, lower demand for energy imports, diminished dependence on fossil fuel suppliers, decreased energy bills for individual households, and cost savings at an economy-wide level (Hancher et al., 2022, p. 92). Enormous opportunities for improvements in energy efficiency can be found in all sectors of the economy, from buildings to transport, industry and energy, according to Hancher et al. (2022, p92).

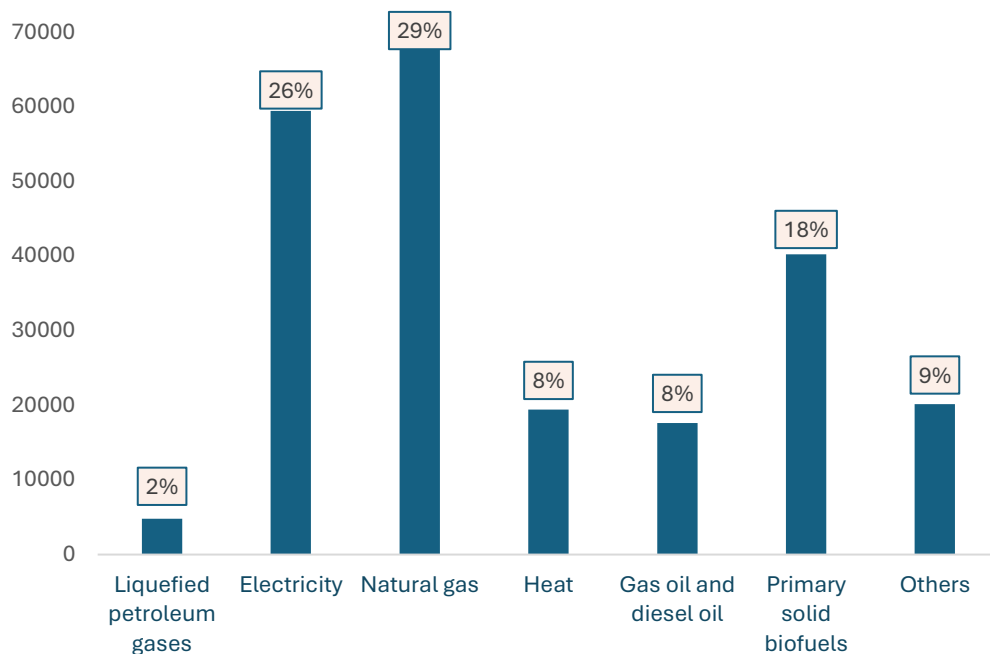
## Energy Productivity

COUNTRY	Full Year 2023
<b>EU - 27 countries</b>	<b>9.84</b>
Germany	11.84
Italy	11.80
Netherlands	10.46
France	10.23
Spain	9.94

**Table 2** Energy productivity in the European Union and Top 5 Economies, full year 2023. Unit of measure: Euro per kilogram of oil equivalent per year (KGOE/yr). Data source: Eurostat, nrg\_ind\_ep, (2024).

As observed by Thomas & Rosenow (2020), industrial sector energy consumption remained flat during the period of economic growth leading up to 2020, as the impact of production increases was offset by efficiency gains while the structure of the sector changed very little. The pick-up in industrial production volumes between 2013 and 2020 was accompanied by only a very small rise in energy consumption.

The household sector is the second major source of energy demand in Europe (see Table 1) and primarily relies on natural gas and electricity to meet its needs for heating, cooling, cooking, and appliances; a dependency clearly illustrated by the sector's energy mix, as shown in Figure 3. The histogram details the amount and relative shares of energy sources consumed for final household energy consumption in the EU-27 for the full year 2023.



**Figure 3** Final energy consumption by energy source in the European Union – household sector, full year 2023. Unit of measure: Thousand tonnes of oil equivalent per year (Ktoe/yr). Data source: Eurostat, nrg\_bal\_c, (2025).

A notable finding is the share held by primary solid biofuels (18%), highlighting their prominence as a renewable source for household heating. Solid biofuels cover solid organic, non-fossil material of biological origin (also known as biomass) which may be used as fuel for heat production or electricity generation, such as fuelwood, wood residues, wood pellets, animal waste, vegetal material, and others.

### 1.3 Energy production capacity across the EU

This section demonstrates that domestic production capacity for key energy resources, particularly natural gas and crude oil, is limited across European countries, revealing a structural dependence on external sources to meet national demand. It then examines the role of nuclear power in

European energy systems, presenting data on its contribution to total energy production and discussing the political and regulatory constraints that limit its expansion, while also considering how increasing the share of renewables could reduce dependence on imported fossil fuels. However, as Figure 4 illustrates through the ten-year trend in renewable energy consumption in the EU industrial sector, this transition has yet to gain substantial momentum.

The EU's indigenous production and extraction of coal, oil, and natural gas is insufficient to meet its domestic consumption needs, creating a significant dependency on external suppliers, especially for natural gas and petroleum. Turning specifically to electricity generation, these fossil fuels have historically been the dominant energy sources. Although renewable energy has gradually come into play due to increasing environmental awareness, the position of fossil fuels in electricity production remains unshakable (Farnoosh, 2022, p. 112).

Unit of Measure:	Billion cubic metres per year	Million tonnes per year
EU-27   Full Year 2023	Natural gas	Oil and Petroleum products
Indigenous production	39	19
<i>Imports</i>	358	785
Production/ Imports	11%	2%

**Table 3** EU-27 Indigenous production and imports of natural gas and oil, full year 2023. Data source: Eurostat, nrg\_cb\_gas (2025).

Table 3 illustrates this dependency with striking figures: in 2023, the EU-27 produced only 39 billion cubic metres of natural gas domestically, while net imports reached 358 billion cubic metres. The situation for oil and petroleum products is even more pronounced, with domestic

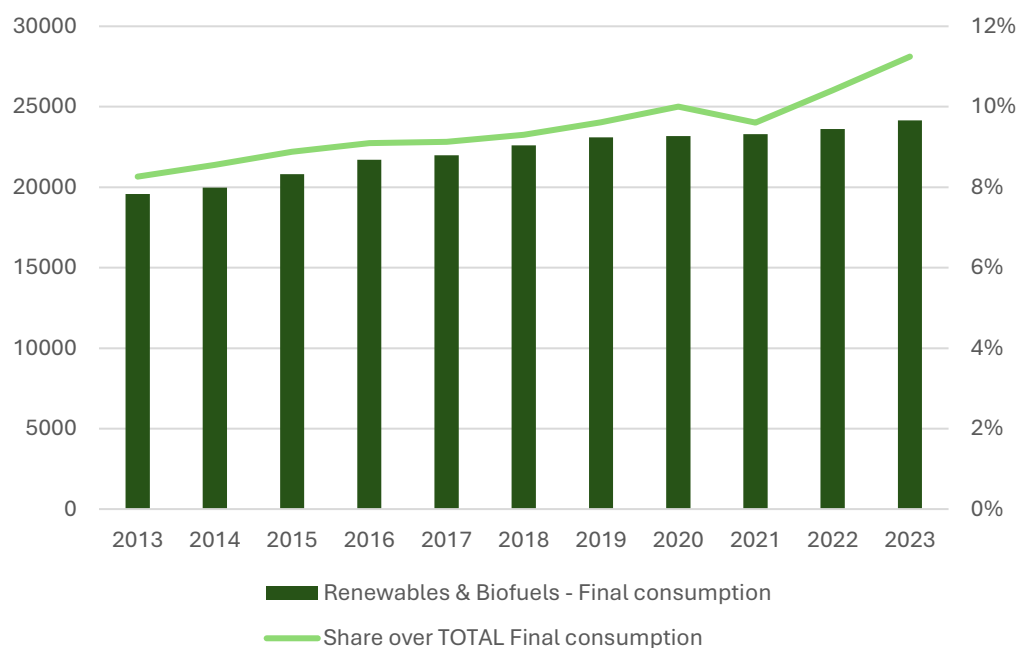
production of 19 million tonnes representing only a small fraction of the 785 million tonnes imported (Eurostat, nrg\_cb\_gas, 2025).

Nuclear power plants generated around 22.8% of the total electricity produced in the EU in 2023, increasing by 1.7% compared with 2022 (Eurostat, nrg\_inf\_nuc, 2025). In 2023, as reported by Eurostat, nrg\_inf\_nuc (2025), 12 EU countries had operational nuclear reactors: Belgium, Bulgaria, Czechia, Spain, France, Hungary, the Netherlands, Romania, Slovenia, Slovakia, Finland and Sweden. As evidenced by Hafner & Luciani (2022, p. 112), nuclear is recognized as a low-carbon energy source, along with renewables and fossil fuels with carbon capture and sequestration.

According to Eurostat (nrg\_ind\_ren, 2026), the EU reached a 24.5% share of its gross final energy consumption from renewable sources in 2023, around 1.5 percentage points higher than 2022 and almost three times higher than 2004 (9.6%). This remains well below the EU's 2030 renewable energy target of 42.5%, highlighting the scale of the transition still ahead. Wind and hydro power accounted for more than two-thirds of the total electricity generated from renewable sources (38.5 and 28.2% respectively). The remaining one-third of electricity generated was from solar power (20.5%), solid biofuels (6.2%) and other renewable energy sources (6.6%) (Eurostat, nrg\_ind\_ren, 2026). Directive (EU) 2018/2001, which provides the legal framework for renewable energy in the EU, defines 'renewable energy' under its Article 2 to include a range of sources such as solar, geothermal, and ambient energy; tide, wave, and other ocean energy; hydropower; and various forms of biogas and biomass.

Renewable energy sources have demonstrated steady growth over the past decade, increasingly displacing fossil fuels in electricity generation. Although different countries are progressing at different speeds, overall, the European continent is displaying a positive evolution in its efforts to

speed up the energy transition (Puertas & Marti, 2022). This trend, however, is not fully reflected in the industrial sector, where between 2013 and 2023 only a slight increase occurred in both the absolute consumption of renewables and biofuels and their share of the total energy mix (see Figure 4). By 2023, renewables and biofuels accounted for just 11% of the industry's final energy consumption, representing a volume of 24 million tonnes of oil equivalent (Mtoe).



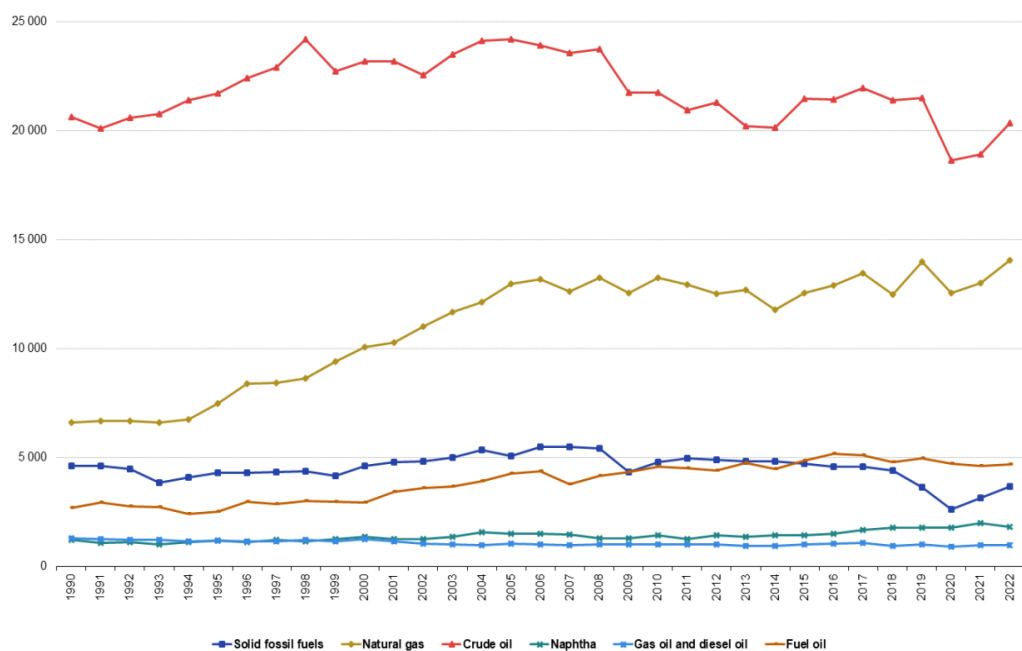
**Figure 4** Consumption trend of renewables and biofuels in the EU-27 Industrial Sector, 2013-2023. Unit of measure: Thousand tonnes of oil equivalent per year (Ktoe/yr). Data source: Eurostat, nrg\_bal\_s, (2025).

#### 1.4 Energy Imports and EU's energy security

This section offers a deeper examination of European energy imports, highlighting the EU's high dependence on external suppliers and the resulting energy security vulnerabilities. Historical supply shocks illustrate how such dependence can significantly amplify systemic risk. In this context, the section presents data on the share of total natural gas and

LNG imports by supplier country, revealing the EU’s continued reliance on a limited number of external partners to meet its energy needs.

EU Member States rely heavily on energy imports, as domestic production does not sufficiently cover internal demand. This makes stable access to external energy sources a critical concern for the Union (Carfora et al., 2022, p. 1). The energy dependency rate, defined as the share of net imports in gross inland energy consumption, provides a useful indicator of a country's reliance on external energy sources.



**Figure 5** Imports of selected energy products in the European Union, year 1990-2022. Unit of measure: Petajoule per year (PJ/yr). Note: data for imports include intra-EU trade. Source: Eurostat, nrg\_bal\_c, (2025).

According to Figure 5, the quantity of imported natural gas more than doubled over the period 1990-2022, reaching the record level of 14,056 petajoule (PJ). It is the second largest imported energy product, after crude oil, with 20,320 PJ imported in 2022.

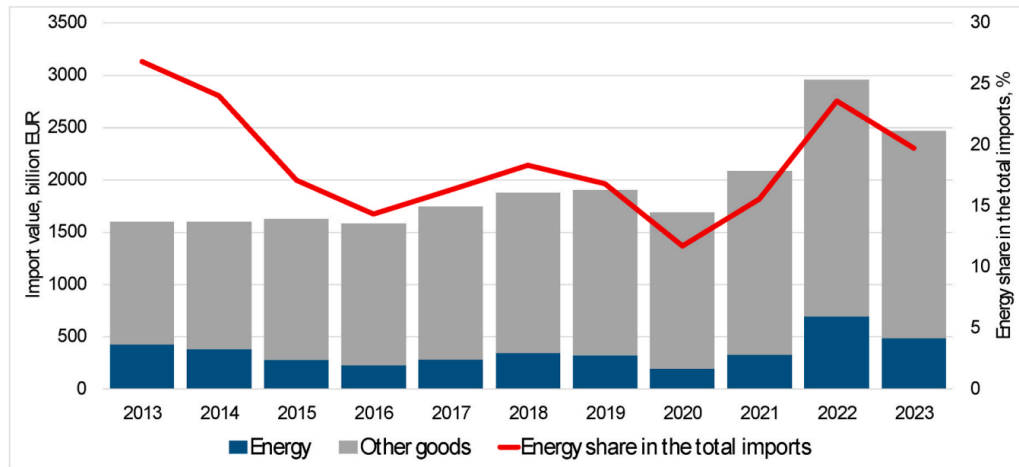
Data from Eurostat, nrg\_ind\_d, (2026), illustrating the energy import dependency of EU-27 and Italy, reveal a structural and persistent reliance

for total energy, natural gas and oil on external suppliers, which is significantly more pronounced for Italy. This dependency is near total for strategically important fossil fuels, with import levels averaging 82% for natural gas and 95% for oil and petroleum products over the decade 2013-2023.

IMPORTS	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
<b>TOTAL ENERGY</b>	AVG (2013 - 2023): EU-27 = 57%   IT = 76%										
EU-27	54%	54%	56%	56%	58%	58%	60%	57%	56%	63%	58%
ITALY	77%	76%	77%	78%	77%	76%	77%	73%	73%	79%	75%
<b>NATURAL GAS</b>	AVG (2013 - 2023): EU-27 = 82%   IT = 93%										
EU-27	68%	72%	74%	76%	80%	83%	90%	84%	84%	98%	90%
ITALY	88%	90%	90%	92%	92%	93%	95%	93%	94%	99%	96%
<b>OIL &amp; PETROLEUM PRODUCTS</b>	AVG (2013 - 2023): EU-27 = 95%   IT = 90%										
EU-27	94%	94%	97%	95%	94%	95%	97%	97%	92%	98%	95%
ITALY	91%	89%	89%	91%	92%	90%	93%	89%	84%	93%	89%

**Table 4** Yearly share of imported energy in total supply: EU-27 and Italy, 2013-2023. Data Source: Eurostat, nrg\_ind\_d, (2026).

Italy's even higher import shares exemplify the acute exposure faced by individual Member States within this broader European context. Furthermore, the stability of these high import levels over ten years highlights a deeply entrenched challenge that has proven difficult to mitigate. Over the decade 2013-2023, total imports of goods amounted to EUR 1.6-3 trillion, of which EUR 0.2-0.7 trillion were energy and fuel imports. The share of energy and fuel imports ranges from 12% to 27%. As energy demand changes relatively slowly, the share of energy imports in the total value of imports depends mainly on the dynamics of energy prices, as indicated by the highest values of this indicator during periods of high energy prices (Lekavicius et al., 2024, p. 6).



**Figure 6** Dynamics of imports to the EU in 2013-2023. Source: Lekavicius et al. (2024, p. 6).

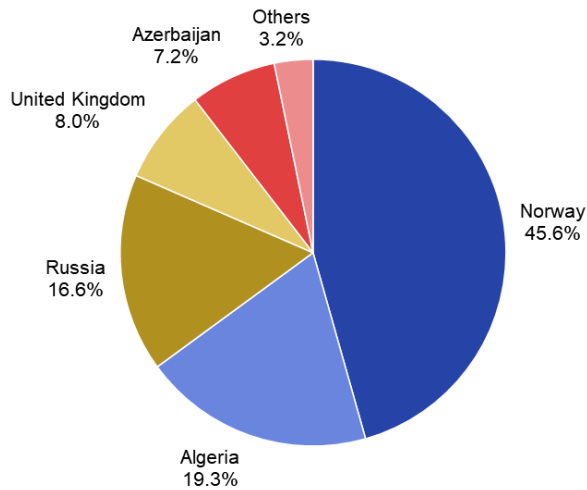
The energy import bill is an overall macroeconomic indicator that shows the costs for the EU of its reliance on fossil fuels, because most of these energy sources are imported. In recent years, EU’s energy imports have become more diversified, especially since 2022, when sanctions began to be imposed on Russia (Lekavicius et al., 2024, p. 13). In this context, Lekavicius et al. (2024, p. 1) assert that energy diversification is one of the main challenges to energy security in the twenty-first century and is a key tool in energy security policy making. Reorienting imports toward greater supply diversity and more reliable suppliers is an obvious risk mitigation measure that reduces the likelihood of supply disruptions but may involve higher costs for imported goods (Lekavicius et al., 2024, p. 1).

The high dependency on natural gas imports presents a fundamental energy security challenge for European countries. In Europe, the high levels of Russian gas imports have always been considered a potential threat to energy security, indeed, prior to 2022, the European Union's natural gas supply was characterized by a high import dependency and a critical reliance on Russia. In 2020, imports accounted for 84% of the EU's gas consumption, with Russia alone supplying over 40% of this total volume (Di Bella et al., 2024). Remarkably, Russia accounts for the largest

import volumes not only of natural gas but also of crude oil and coal where no security concerns are generally voiced. This is due to the global nature of the market for oil and coal, while gas remains mainly a regional market dependent on existing import infrastructure, primarily pipelines in the case of Russia-EU gas trade.

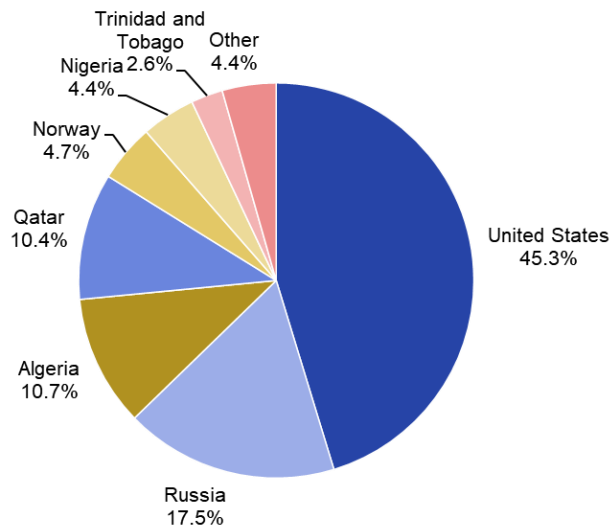
Pie charts provided by Eurostat database (Comext) and Eurostat estimates (2026), depicting the EU's natural gas import portfolio for 2024, reveal a distinct supplier structure: a primary reliance on Norway for pipeline gas and on the United States for liquefied natural gas. Despite this dominance, Di Bella et al. (2024) evidence that the composition of the remaining imports underscores a strategic diversification across multiple other partners. Russian pipelines enter Europe through Germany (Nord Stream I and II), Poland (Yamal), Ukraine, and Türkiye. Norwegian gas enters via Germany, the Netherlands, Belgium, the UK, and Denmark since the completion of the Baltic Pipe to Poland in November 2022. To a far lesser extent, gas from Northern Africa and Azerbaijan enter through Spain, Italy, Türkiye, and Greece.

In total, as of early 2022, non-Russian pipelines accounted for 30% of total gas import capacity, while Russian pipelines accounted for 42% and LNG import terminals for another 28% of import capacity (Di Bella et al., 2024). However, natural gas markets are also becoming increasingly globalized, driven by growing availability of liquefied natural gas, whose supply is much more flexible than pipelines (Hafner & Raimondi, 2022, p. 742). This shift toward LNG enhances diversification and resilience in supply sources while introducing greater exposure to global market competition and price volatility, fundamentally reshaping the dynamics of European gas security.



**Figure 7** Annual percentage share of gaseous natural gas in total EU import value, by partner country (2024). Source: Eurostat database (Comext) and Eurostat estimates (2026).

Natural gas markets are also becoming increasingly globalized, driven by growing availability of liquefied natural gas (LNG), which is much more flexible than pipelines (Hafner & Raimondi, 2022, p. 742).



**Figure 8** Annual percentage share of liquefied natural gas in total EU import value, by partner country (2024). Source: Eurostat database (Comext) and Eurostat estimates (2024).

Consistent with the previous analysis, the high dependency on energy imports and the huge gap between energy consumption and production capacity make the European Union vulnerable to crises in the energy markets. The 1973 oil crisis shocked the European importing countries, showing their vulnerability to external suppliers. The crisis substantially shaped the concept of energy security in the mind of Europeans, and started to be considered a key theme for European countries, becoming a pillar of the European energy policy, with European countries addressing energy security issues through national strategies and energy conservation policies, mostly involving the development and increase of nuclear energy and the establishment of domestic reserves (Hafner & Raimondi, 2022, p. 736). The continuous efforts and policies of European Commission in promoting renewable energy and energy efficiency among the Member States yield successful aggregated results. Investment on RE reduces the need for importing fossil fuels and direct electricity, which leverages the energy security at EU level. However, each EU country has a unique energy regime and apply different RE promotion policies, which resulted in diverse performance in RE (Gökgöz & Güvercin, 2018).

## **1.5 Conclusions**

The analysis of the European energy landscape presented in the first chapter clearly demonstrates why energy security is a predominant theme for EU Member States and the Union itself. With an energy mix predominantly reliant on fossil fuels, notably natural gas and petroleum products, imports from foreign suppliers become crucial for meeting demand across all sectors. This dependency raises significant challenges for policymakers responsible for safeguarding Europe's energy security, given the limited domestic extraction capacity for fossil fuels, the constrained availability of alternative energy sources such as nuclear

power, which is restricted or prohibited in several Member States, and the still marginal role played by renewable energy in the energy mixes of the industrial and household sectors. A further analysis of the share of imported fossil energy sources in both Europe and Italy shows that Italy's level of dependence exceeds the European average, particularly with respect to natural gas imports, thereby placing the country in a more vulnerable position from an energy security perspective. In this context, industrial energy productivity across Europe and among the five largest EU economies represents a key parameter for assessing the amount of energy required to sustain industrial output. Countries with higher levels of energy efficiency tend to require less energy per unit of production, which reduces their exposure to supply disruptions and price volatility. As a result, greater energy productivity contributes to enhanced resilience to energy shortages, although it does not necessarily imply full energy self-sufficiency.

Renewable energy sources represent one of the most promising alternatives to fossil fuels for enhancing energy independence, as they can be produced domestically through the development of new infrastructure. Despite this potential, the analysis presented in Figure 4 on trends in energy consumption in the European industrial sector between 2013 and 2023 indicates that the share of renewables and biofuels in total final consumption increased only modestly over the decade, reaching approximately 11% by the end of 2023.

The extraction of fossil fuels across Europe is severely constrained by the limited availability of domestic natural reserves. This structural condition compels the continent to rely heavily on external suppliers to meet its energy demand. Figures 7 and 8 illustrate the composition of Europe's natural gas and liquefied natural gas (LNG) imports by supplier country. Pipeline-based natural gas imports depend on fixed physical connections

and therefore primarily involve geographically proximate suppliers, such as Norway, Algeria, and Russia in 2024. By contrast, LNG imports offer greater flexibility and allow for a broader diversification of supply sources, including more distant countries. As shown in Figure 8, the United States emerged as the EU's principal LNG supplier in 2024, followed by Russia, Algeria, Qatar, and other exporters. Reliance on a limited number of exporting countries poses a significant risk to Europe's energy security, as historically illustrated by episodes such as the 1973 oil crisis. For this reason, diversifying both the portfolio of supplier countries and the modes of supply between pipeline natural gas and LNG, enhances the continent's energy security and supply stability, and has become a central strategy for mitigating this persistent vulnerability.



## **CHAPTER TWO – NATURAL GAS: DEMAND, SUPPLY AND STORAGE ACROSS THE EUROPEAN UNION**

### **2.1 Introduction**

Understanding the nature and evolution of natural gas demand in Europe is essential to explaining the strategies underlying gas storage and its utilisation by Member States across months, seasons, and years. In this context, Section 2.2 introduces the concepts of seasonality and volatility in natural gas demand, differentiating between long-term and short-term consumption. The former is primarily influenced by economic and demographic factors, while the latter is mainly driven by weather-related and calendar effects. The section illustrates the pattern of natural gas consumption across 2023 and 2024, alongside the evolution of its wholesale price. The key findings highlight a peak season during colder months, driven by household demand for heating, and demonstrate that prices reflect this seasonality. The data further reveal how prices are susceptible to external shocks, as exemplified by the market disruption in 2022.

A further part of the section presents annual natural gas consumption in Italy from 2012 to 2023, showing how major events, such as the European sovereign debt crisis, the decline in industrial activity and mobility during the 2020 pandemic, and the 2022 supply disruption, contributed to reductions in overall consumption. The analysis then turns to natural gas price trends for household and non-household consumers over the period 2008–2025, underscoring differing demand patterns across seasons. Finally, it highlights the relationship between gas prices and import volumes, showing that, given the relatively inelastic nature of demand, the sharp price increases observed in 2022 did not lead to a proportional decline in consumption.

Having detailed the magnitude, volume, and pattern of European natural gas import demand, the third section of this chapter delves into the physical infrastructure, technologies, and partners that supply it. Specifically, it examines the pipelines for gaseous natural gas, the terminals for liquefied natural gas (LNG), and the underground gas storage facilities that constitute the strategic reserves of the Member States. Two maps representing the operating gas pipelines in Europe and LNG import terminals are provided, together with data provided by the Global Energy Monitor (2024) of the capacity of the European infrastructures.

The strategic role of European natural gas storage for energy security is treated in the final section of this chapter, which first explains how these facilities operate in terms of gas injection and withdrawal. As expected, their usage reflects the seasonality of demand: storage is replenished during warmer months and drawn upon during winter. To illustrate the scale across the top five European economies, data from the International Gas Union (2025) report the number of underground gas storage facilities in these countries; accompanied by a brief explanation of the different types of storage (depleted hydrocarbon fields, aquifers, and salt caverns) and their distinct characteristics, operational principles, and functionalities.

## **2.2 European natural gas demand: seasonality and volatility**

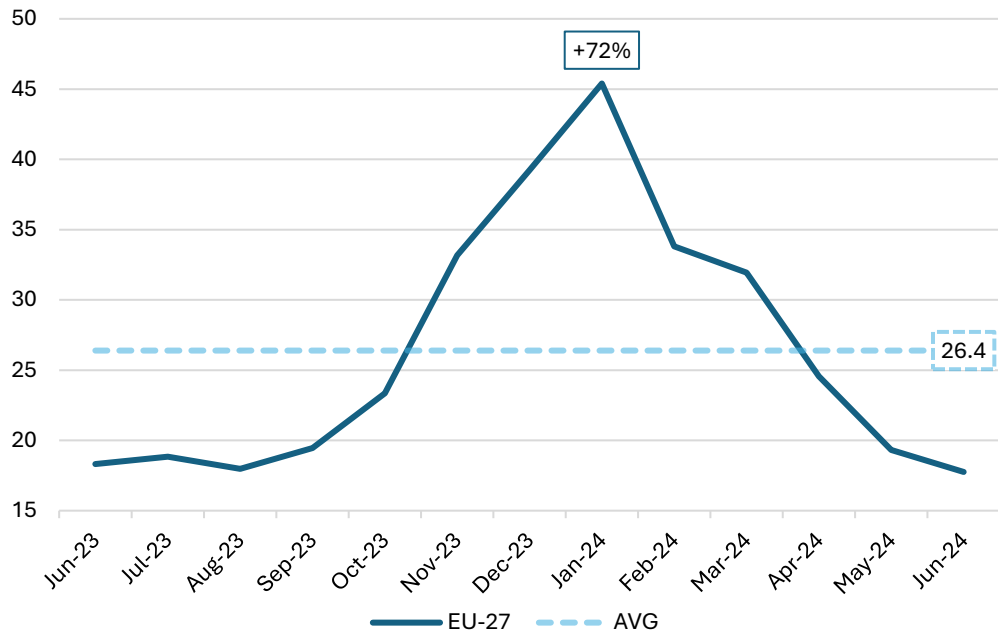
This section explains the typical patterns of natural gas demand across the EU-27, highlighting its historical evolution and inherently volatile nature, with prices particularly sensitive to supply shocks and shortages. The analysis focuses on the industrial and household sectors, showing their distinct demand patterns: industry is influenced by production cycles, while households are driven by seasonal and weather factors. Consequently, prices are directly influenced by the intensity of demand

throughout the year. Furthermore, the essential inelastic nature of natural gas demand is illustrated by the sharp price surge during the 2022 crisis, which did not result in a proportional decline in consumption despite dramatically rising prices.

Natural gas demand in Europe is intrinsically volatile, driven by strong climatic seasonality and fluctuating economic activity, making accurate consumption forecasts essential for operational efficiency, energy conservation, and cost reduction. Ding et al. (2023) observe that industrial consumption is significantly affected by production planning and scheduling and exhibits great fluctuations. Commercial customers mainly consume natural gas for heating, which is characterized by seasonal variation (peak and off-season); medium to long-term consumption is mainly affected by economic and demographic factors such as GDP, price, household income and general population; while short-term consumption is more influenced by weather-related factors, such as temperature, and calendar factors, such as holidays and weekends (Ding et al., 2023).

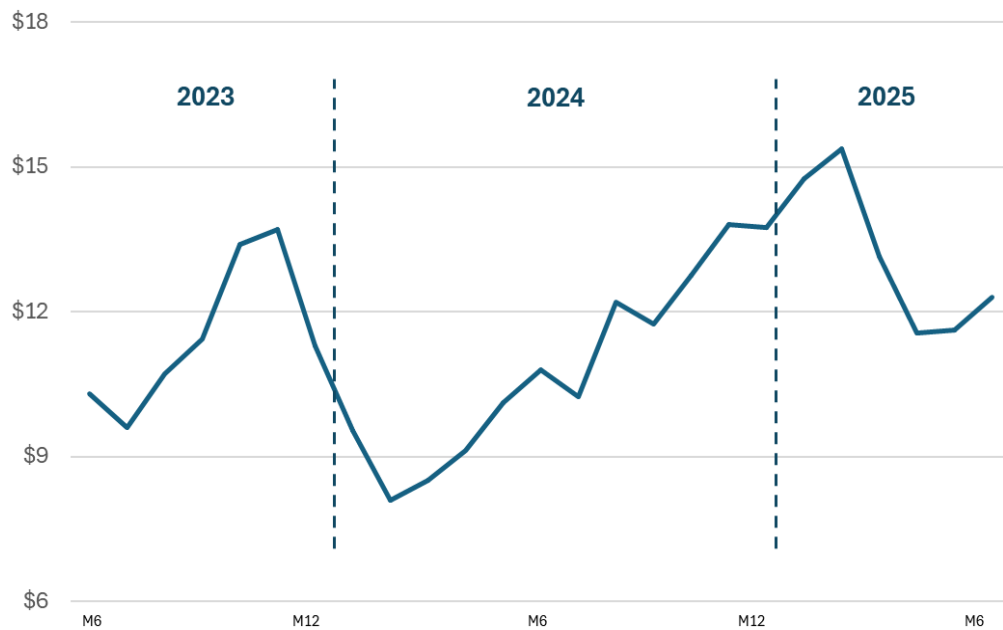
Inland gas consumption, defined by Eurostat's Monthly Oil and Statistics (MOS) as total natural gas available within a country's borders (primary production plus recovered products plus imports minus exports and international maritime bunkers), confirms expected seasonal patterns when applied to the EU-27 (Eurostat, nrg\_cb\_gas, 2026). Peak demand coincides with winter as a consequence of colder temperatures and heating needs, with volumes surging up to 39 bcm per month, 72% above the monthly average of 26 bcm. As suggested by Erias & Iglesias (2022), during the October-February period, when heating represents a higher

share of demand, gas price is not a determinant factor, showing inelastic demand, especially in the short term.



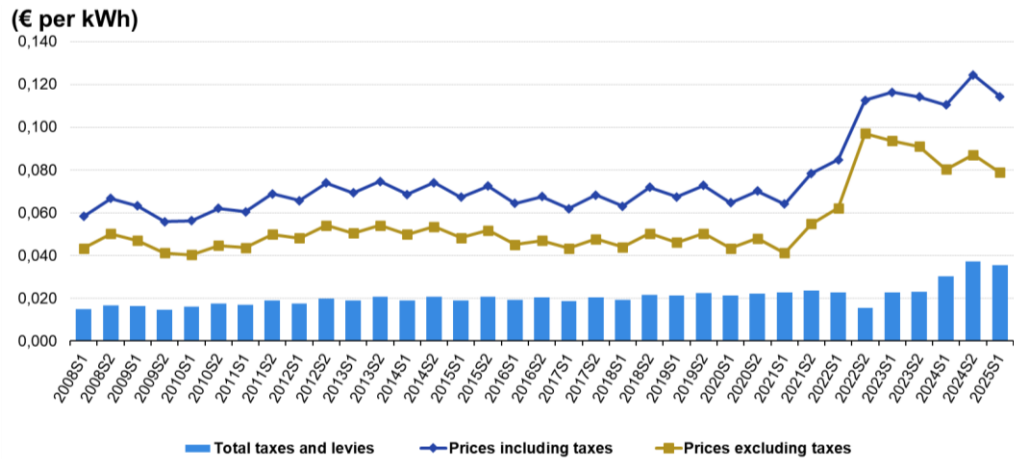
**Figure 9** Monthly trend of natural gas consumption in the EU-27 (June 2023 - June 2024) Unit of measure: Billion cubic metres per month (Bcm/mth). Data source: Eurostat, nrg\_cb\_gas (2026)

The seasonality of natural gas demand is directly reflected in its price pattern. Data from the International Monetary Fund via Federal Reserve Bank of St. Louis (2026) on European natural gas wholesale prices for the period 2023-2025 clearly demonstrates this cyclical pattern, with price peaks consistently occurring during the coldest winter months and the lowest prices registered in the warmer seasons. Despite the geopolitical shocks of recent years, the structural seasonality of gas demand remains the dominant short-term price driver, primarily due to heating needs. The persistence of this pattern, even in a volatile market, highlights the critical role of storage.



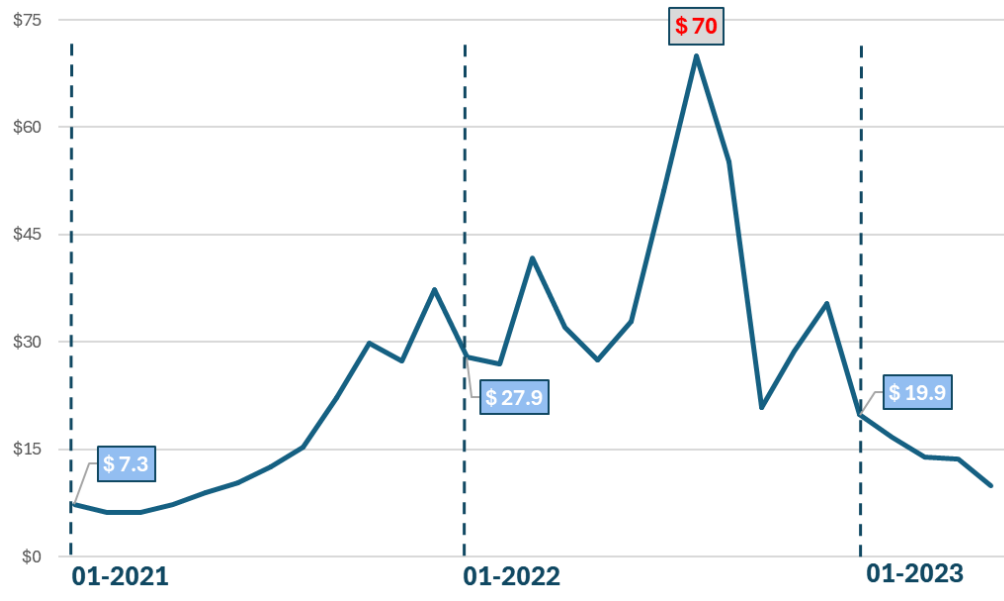
**Figure 10** Monthly trend of the global natural gas wholesale price (June 2023 - June 2025). Note: Price is in U.S. dollars per million British thermal units (USD/MMBtu). Source: International Monetary Fund via Federal Reserve Bank of St. Louis (2026).

Natural gas prices for household consumers generally follow a clear seasonal pattern, rising during the winter heating period and declining in the summer months. This cyclical behaviour mirrors demand dynamics (see Figure 9) and is illustrated by the pronounced fluctuations in Figure 11, which depicts the evolution of household gas prices between 2008 and 2025.



**Figure 11** Seasonal development of Natural Gas Prices for household consumers in the European Union (2008 - 2025). Note: data are presented in six-month seasons (semesters): S1 refers to the first half of the year (January-June), and S2 refers to the second half (July-December). Source: Eurostat, nrg\_bal\_s (2025).

While natural gas prices are inherently cyclical and typically follow well-defined seasonal patterns, they remain highly vulnerable to external geopolitical shocks. This vulnerability was starkly illustrated by the Russian invasion of Ukraine in 2022, which triggered an unprecedented price surge that far exceeded normal seasonal fluctuations. As shown in Figure 12, the TTF (Title Transfer Facility) benchmark for European natural gas rose sharply, reaching a peak of approximately \$70 per MMBtu within months of the invasion, thereby highlighting the extreme sensitivity of the market to sudden supply disruptions (as discussed in Section 1.4). This episode demonstrates how structural dependence on external suppliers can rapidly translate geopolitical risk into severe market instability.

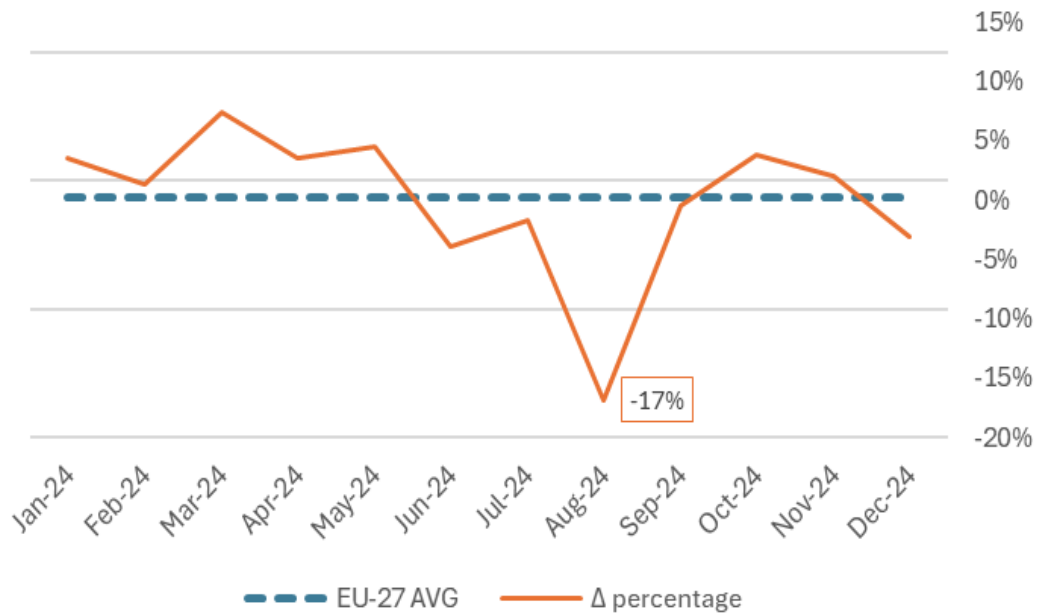


**Figure 12** Monthly trend of the global natural gas price (2021-2023). Note: Price is in U.S. dollars per million British thermal units (USD/MMBtu). Source: International Monetary Fund via Federal Reserve Bank of St. Louis (2026).

The European industrial sector represents a meaningful case of demand fluctuations driven by economic factors, as evidenced by the monthly consumption pattern observed in 2024. Throughout the year, natural gas demand remained relatively stable, averaging around 1.8 billion cubic metres per month, yet it exhibited pronounced deviations during specific periods. A significant contraction occurred during the summer months, with the sharpest decline recorded in August, reflecting widespread production slowdowns and temporary plant closures associated with the holiday season across much of Europe.

This pattern highlights the close link between industrial activity and energy demand, illustrating how short-term variations in production cycles

can generate noticeable fluctuations within a stable annual trend, as displayed by Figure 13.



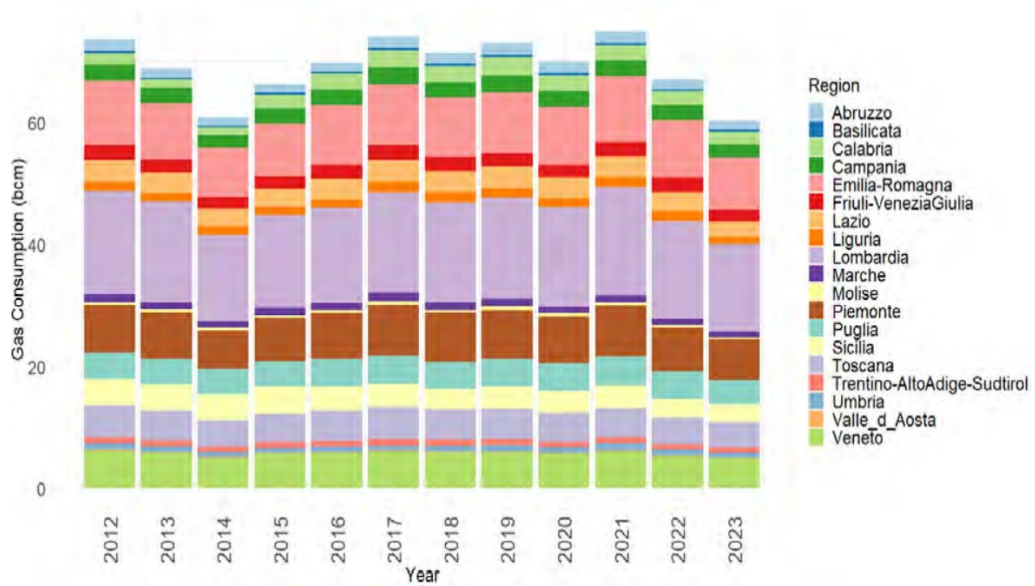
**Figure 13** Monthly trend of natural gas consumption in the EU-27 industrial sector, 2024. Note:  $\Delta$  Percentage = deviation of monthly consumption from the mean. Calculated as  $(\text{Monthly Value} - \text{Mean}) / \text{Mean}$ . Data source: Eurostat, nrg\_bal\_s (2025). The average monthly consumption is approximately 1.8 bcm/mth.

The natural gas demand in Italy is described by Banca D’Italia (Emiliozzi & Favero, 2025) utilizing a comprehensive dataset provided by Snam, which captures monthly gas consumption, over the period from January 2012 to December 2023. This longer time horizon is particularly instructive because it allows for the identification of structural demand patterns predating the 2022 crisis, providing a baseline against which the disruption caused by the energy shock can be assessed. Italy is a significant case: it is one of the EU's largest gas consumers, possesses substantial storage infrastructure, and experienced a dramatic increase in import costs during the crisis. The residential sector and small to medium-sized enterprises in the industrial and tertiary sectors are typically served by

distribution networks, and these categories are gathered under Local Distribution Consumption (LDC), which refers to the consumption of natural gas by residential, industrial, and commercial users within a local distribution network.

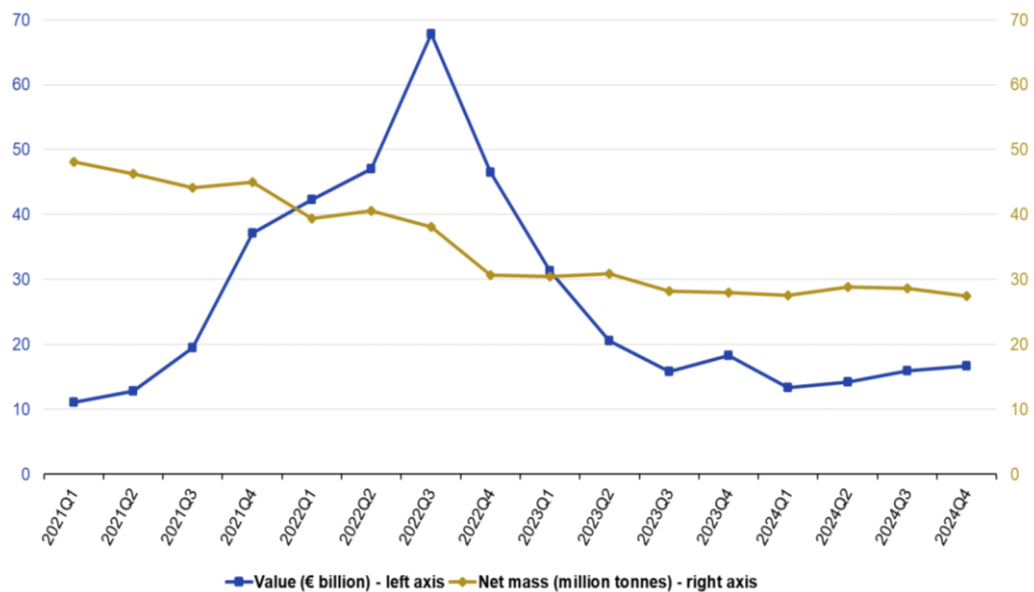
The annual gas consumption in billions of cubic meters per year from January 2012 to December 2023 exhibits a marked reduction in gas usage. This decline coincides with the aftermath of the European sovereign debt crisis, which constrained economic activity across Italy, and an unusually warm autumn-winter season (Emiliozzi & Favero, 2025). While 2020 experienced a decline in gas consumption, coinciding with reduced industrial activity and mobility due to the COVID-19 pandemic, Emiliozzi & Favero (2025) highlight that 2021 brought a swift recovery as economic activity resumed. From 2022 onward, the gas data indicate a new phase of contraction in gas consumption, coinciding with supply constraints caused by geopolitical tensions and rising natural gas prices, particularly after issues surrounding the Nord Stream 1 pipeline between Germany and Russia began in summer 2021. The situation further deteriorated following the Russian invasion of Ukraine in February 2022, which led to a sharp reduction in Russian gas supplies, drastically altering the European energy landscape (Emiliozzi & Favero, 2025).

Overall, these developments highlight the strong exposure of natural gas demand to external shocks and structural changes in the broader economic and geopolitical environment. Rather than following a purely market-driven trajectory, consumption patterns over the period appear closely tied to disruptions in economic activity, shifts in supply conditions, and climate variability, underscoring the complexity of forecasting demand in an increasingly uncertain energy landscape.

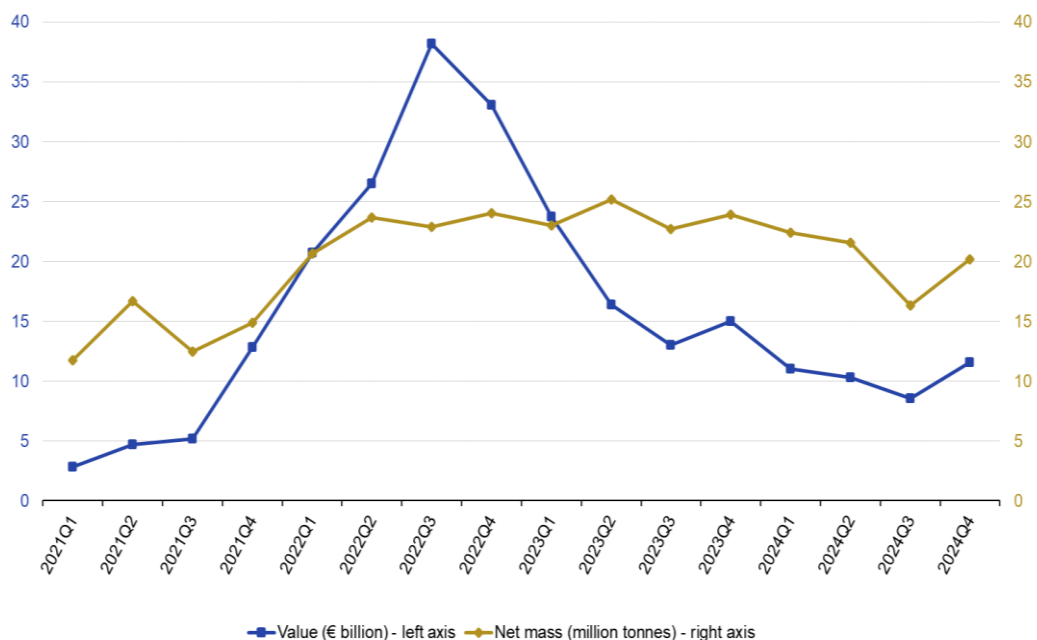


**Figure 14** Italy annual gas consumption by region from 2012 until 2023. Unit of measure: Billion cubic metres per year (Bcm/yr). Source: Emiliozzi & Favero (2025).

The price and reliability of energy supplies are key elements in a country's energy supply strategy. Natural gas prices are of particular importance for international competitiveness, as natural gas may represent a significant proportion of total energy costs for industrial enterprises and the services sector (e.g., retail, hospitality, transport, and commercial activities) (Eurostat, nrg\_bal\_s, 2025). Substantial price changes can disrupt the classic seasonal price pattern, as experienced by EU countries since the first half of 2022, when a sharp decrease in natural gas import volumes (both gaseous and liquefied) was overshadowed by a massive increase in total cost in euros, as shown in Figures 15 and 16. This divergence between price and volume underscores the profound inelasticity of natural gas demand, as it is essential for non-discretionary uses such as household heating and critical industrial processes, leaving the EU unable to reduce consumption substantially in the short term despite soaring costs.

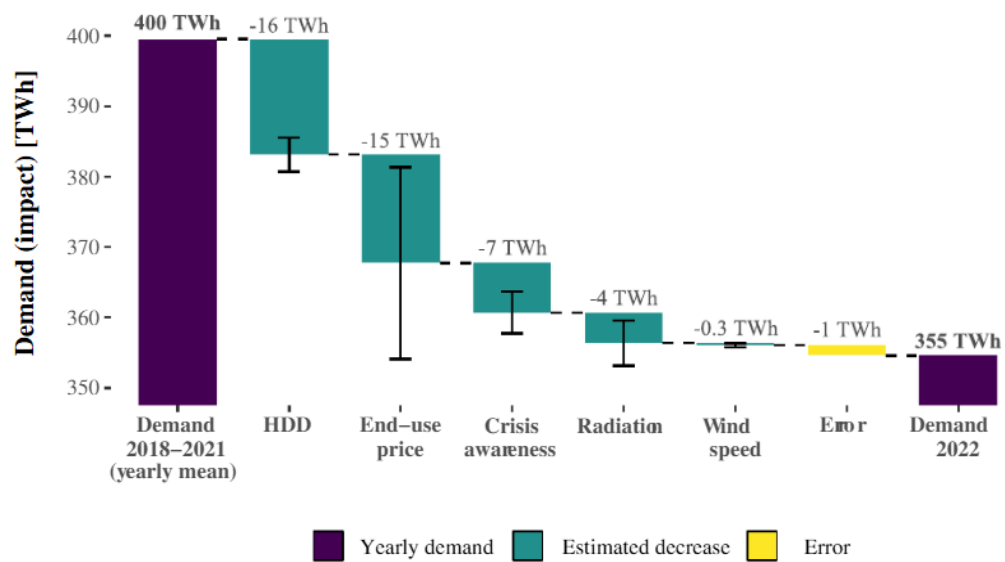


**Figure 15** Evolution of EU gaseous natural gas imports by volume and monetary value, quarterly (2021-2024). Source: Eurostat database (Comext) and Eurostat estimates (2026).



**Figure 16** Evolution of EU liquefied natural gas imports by volume and monetary value, quarterly (2021-2024). Source: Eurostat database (Comext) and Eurostat estimates (2026).

A study conducted by Jamissen et al. (2024) on Germany illustrates that natural gas demand of small consumers is highly inelastic in response to both retail and wholesale prices, with a price elasticity of -0.012 both on the daily frequency and monthly frequency, a 1% increase in wholesale prices leads to a demand reduction of 0.012%. The average wholesale price rose by a remarkable 433% in the crisis year 2022 compared to 2018-2021 (Jamissen et al., 2024). As observed by Jamissen et al. (2024), the largest reducing effect on natural gas demand in 2022 came from the lower number of cold days (HDD) which contributed with 16 TWh (35%) to the total reduction of 45 TWh (approximately 4.5 bcm). The higher prices observed in that year contributed to a similar extent (15TWh, 33%).



**Figure 17** Decomposing the demand reduction in the crisis year 2022. Source: Jamissen et al. (2024).

To elucidate the factors affecting natural gas demand, the U.S. Energy Information Administration (EIA, 2023) demonstrates that the strength of the economy is a primary driver. During periods of economic growth, heightened demand for goods and services from the commercial and industrial sectors leads to increased natural gas consumption. Furthermore, residential and commercial demand for heating is highly

dependent on winter weather conditions, as the arrival of unexpected cold weather can intensify price effects given that supply often cannot react swiftly to short-term demand spikes, an impact magnified when the natural gas transmission system operates at or near full capacity. When supply disruptions occur during peak demand periods, they can lead to price increases that exceed expectations, and in this context, storage plays a critical role in balancing the market by helping to meet both seasonal and sudden demand increases that domestic production and imports cannot immediately cover. Consequently, the volume of natural gas in underground storage fields is a major determinant of overall supply security and price stability (U.S. Energy Information Administration [EIA], 2023).

### **2.3 The Flow of Natural Gas across the European Network: Infrastructures, Technologies and Partners**

This section introduces the different infrastructures essential for sustaining the supply and final delivery of energy sources, providing a brief overview of their function. Pipelines and liquefied natural gas terminals constitute the critical infrastructure enabling the import of natural gas from the supplier countries. Their geographical distribution across the European continent is illustrated by two maps (see Figures 18 and 19) provided for the year 2024.

The gas value chain begins at the point of production, or wellhead, from which gathering pipelines deliver raw gas to nearby processing plants. These processing plants separate out natural gas liquids NGL, water, carbon dioxide and other inert gases, and various impurities, and then feed a homogenous finished gas product consisting primarily of methane, ethane, and propane, into long-distance transmission pipelines, which transport the gas to various end users (Oliver, M., 2021). As evidenced in

Figure 7, the European Union imports pipeline gas primarily from Norway, Algeria, Libya, Azerbaijan, Russia and the UK, accounting for 62% of total gas imports. The other 38% is LNG imports (Strategic Perspectives, 2024), with Figure 8 displaying United States, Russia, Algeria, Qatar and Norway as the main import partners. The transport segment alone can account for over 50% of the costs occurring through the value chain of internationally traded natural gas. Consequently, natural gas remained for a long time a local commodity, consumed relatively close to its production centres. LNG exports more than tripled since the beginning of the twenty-first century and accounted for just over half of international gas trade in 2018 (Molnar, 2022, pp. 23-24).

Gas pipelines, together with LNG terminals and underground gas storage facilities, are the hardware supporting market integration, competition, and enhancing the security of supply in an efficient and sustainable way. If coupled with electricity, gas infrastructure can also support the energy transition towards a less carbon-intensive, and eventually carbon-neutral future (ACER, 2023). European countries are developing 248.7 billion cubic meters per year in new LNG import capacity and 16,491 kilometres in new gas transmission pipelines, which include cross-border pipelines capable of importing a further 46 bcm/year of gas into Europe (Rozansky & Hassan, 2024). The Global Energy Monitor (2024) estimates that the total capital expenditure in new European gas infrastructure could be €44.4 billion for LNG terminals and €39.7 billion for gas pipelines, for a total of €84.1 billion; with Germany, Italy and Greece, which are developing the most gas infrastructure in Europe, together responsible for half of these plans (€45.3 billion).

Modern pipeline systems, most often constructed from steel, can transport natural gas over several thousand kilometres from the wellhead to the burner tip of end consumers. The movement of natural gas within pipelines

is driven by pressure differentials between two points, requiring compressor stations to compress incoming gas and release it at a higher pressure to maintain sufficient pressure and ensure continuous flow. In addition to compressor stations, pipeline systems include other non-linear components such as metering stations, which measure gas flows and allow operators to monitor and manage the transmission of natural gas throughout the network (Molnar, 2022, pp. 26-27).

The natural gas pipeline transmission network in Europe counts hundreds of thousands of kilometres across the Member States, a system whose scale is exemplified by the extensive infrastructure of Germany (over 40,000 km), Italy (over 33,000 km), and France (over 38,000 km), which represent some of the largest national grids on the continent (European Network of Transmission System Operators for Gas [ENTSOG], 2023). Among the most crucial and largest infrastructures were the Nord Stream 1 and Nord Stream 2 pipelines, and the Yamal-Europe pipeline traversing Belarus and Poland. From the South, the Trans-Mediterranean Pipeline (Transmed) system has long been a cornerstone of supply, channelling gas from North Africa to Italy via Sicily. Beyond their sheer scale, these pipeline networks play a fundamental role in ensuring the continuous and cost-efficient transport of natural gas across borders, enabling market integration and supporting the security of supply within the European energy system. At the same time, their fixed nature and dependence on specific transit routes create structural rigidities, potentially exposing the system to geopolitical risks and supply disruptions, as highlighted during the 2022 energy crisis.

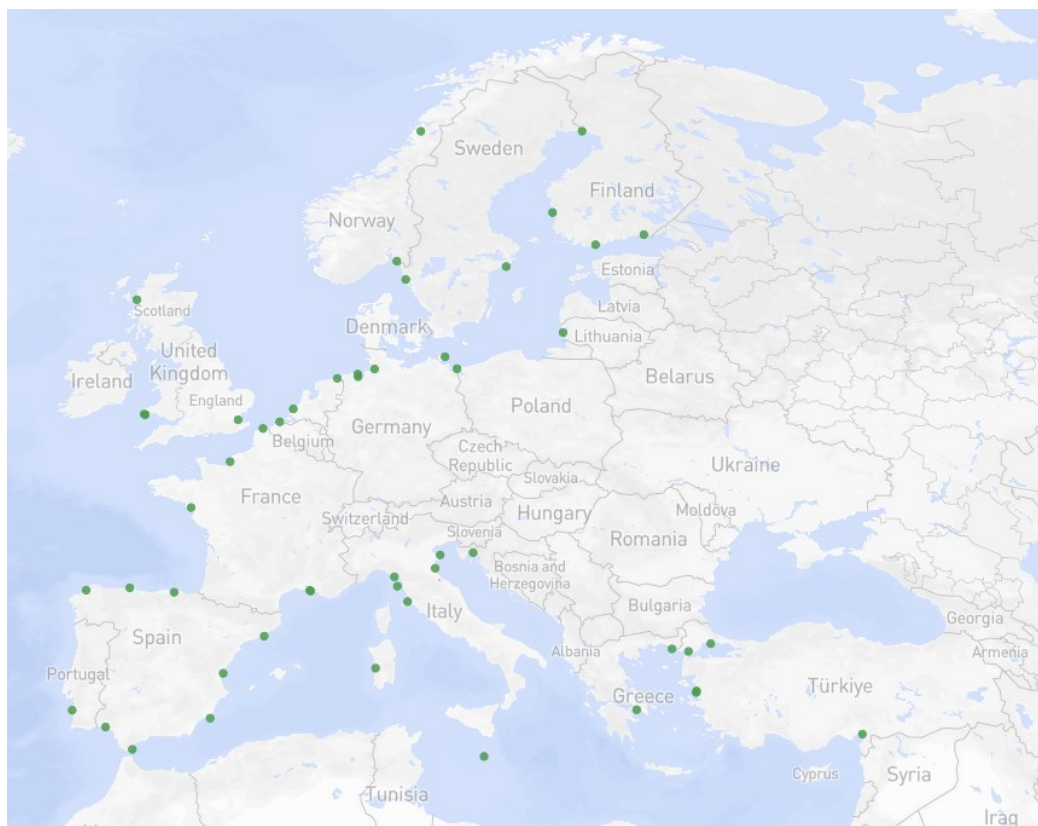


**Figure 18** Operating transmission gas pipelines map in Europe, 2024. Source: Global Energy Monitor (2024).

As detailed by Hafner & Raimondi (2022, p. 740), LNG is produced by cooling down methane to  $-162^{\circ}\text{C}$ . This effectively reduces its volume by around 600 times and as such allows for a more flexible way of transportation than through pipelines which have a fixed route. Internationally traded LNG is transported via LNG carriers, while smaller volumes of liquefied natural gas are also moved by trucks or railroad, typically serving local markets as "virtual pipelines". Liquefaction terminals are arguably the most complex and most costly components of the LNG value chain, accounting for over half of total investment costs and operating expenses, when excluding upstream development (Hafner & Raimondi, 2022, p. 740).

Liquefied natural gas plays a fundamental economic and geostrategic role in the EU energy security strategy by enabling diversification of the energy

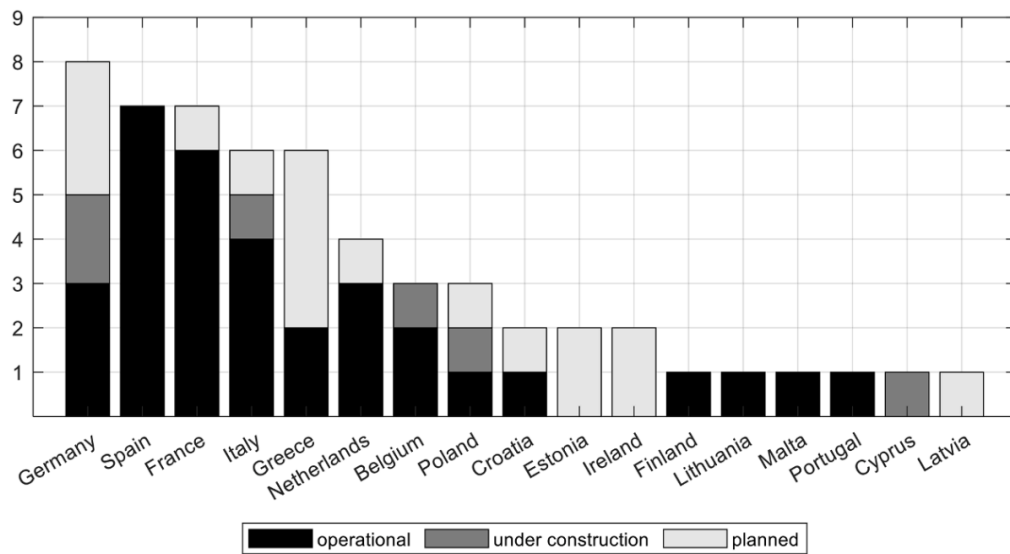
mix and reducing dependence on Russian pipeline gas under the European Green Deal. According to Casagrande & Dallago (2025), before 2022 the EU was the main importer of Russian gas mostly by pipeline through Nord Stream (via the Baltic Sea) and Yamal (via Belarus and Poland and Ukraine). The global LNG market expanded by 68% between 2013 and 2023 to the detriment of pipeline gas, with France, Spain, the UK, the Netherlands, Italy and Belgium as the top LNG importers in 2022 (Casagrande & Dallago, 2025).



**Figure 19** Operating liquefied natural gas (LNG) import terminals in Europe, 2024. Source: Global Energy Monitor (2024).

Global Energy Monitor's data (2024) on infrastructure plans paired with demand forecasts reveal a widening gap between import capacity and demand. In terms of LNG capacity alone, Europe's import capacity in 2023 (318.7 bcm/year) exceeded its LNG demand (167 bcm) by nearly a factor of two. If all the import capacity in development were built by 2030,

Europe's LNG import capacity (567.5 bcm) would exceed the forecast for LNG demand (134.7 bcm) from IEEFA (the Institute for Energy Economics and Financial Analysis, a non-profit research organisation focused on energy markets) by over a factor of four. Europe already has sufficient import capacity, as evidenced by its successful pivot away from piped Russian gas imports. New import projects would only widen the gap between gas demand and capacity (Global Energy Monitor, 2024, p. 12).



**Figure 20** Number of LNG import terminals and their status in EU-27 countries. Source of data: Gas Infrastructure Europe (GIE) LNG Database 2025. Elaboration by Casagrande & Dallago (2025).

As detailed by Casagrande & Dallago (2025) geography has a central importance when comparing between LNG and pipeline gas, since the transport segment alone can account for over 50% of the costs occurring through the value chain of internationally traded natural gas; the greater the distance between sellers and buyers, the greater the convenience of LNG compared to pipeline gas, especially for small volumes (Casagrande & Dallago, 2025). Driven by this economic rationale alongside energy security and supply reliability concerns, European countries are making significant investments to expand their LNG import terminal network.

It should be noted, however, that an apparent surplus of LNG regasification capacity does not necessarily translate into effective supply security across the entire European gas system. Excess LNG import capacity may be of limited relevance when the pipeline supply it is intended to replace is geographically distant and internal gas transmission interconnections are weak. This structural mismatch helps explain why, despite the existence of substantial regasification capacity at the European level, episodes of gas scarcity were observed in specific regions of the system. Constrained west-east transport capacity within the continent limited the ability to move regasified LNG from coastal entry points in the west to landlocked and eastern markets, thereby exposing bottlenecks in internal transmission infrastructure rather than a lack of aggregate import capacity.

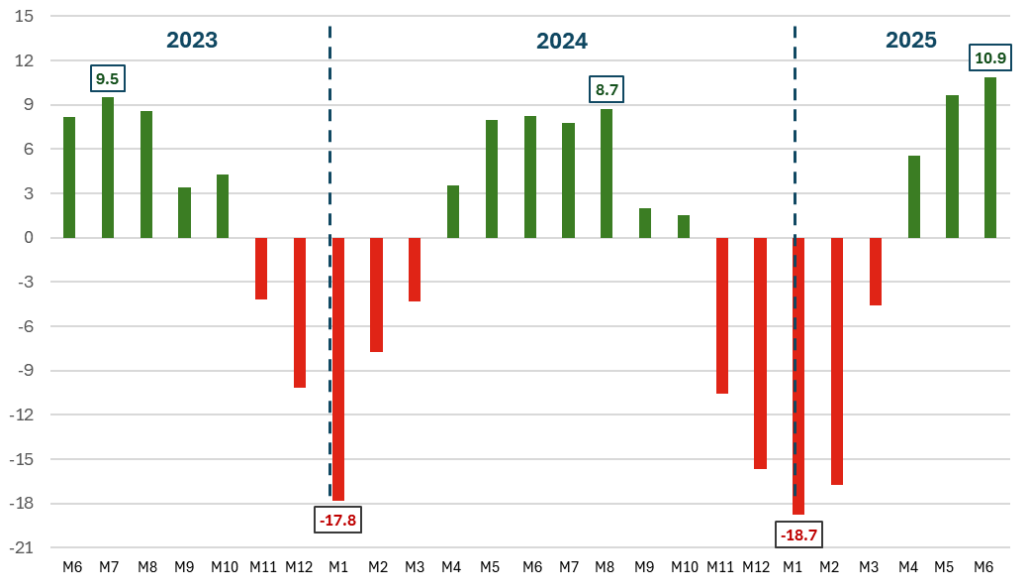
## **2.4 The strategic role of natural gas storage in the EU**

Underground natural gas storage facilities play a critical role in ensuring energy security by balancing seasonal fluctuations in gas demand. The data presented in this section illustrate the operational dynamics of storage facilities, which typically follow the cyclical pattern of injection during periods of lower demand and withdrawal during peak consumption. This section provides a technical overview of underground gas storage, explaining key operational parameters such as cushion gas, working gas, and injection and withdrawal rates. It also outlines the main types of underground storage currently in use, including depleted hydrocarbon fields, aquifers, and salt caverns. The section concludes with an analysis of the strategic importance of gas storage, highlighting its role during the 2022 gas supply crisis triggered by the Russia-Ukraine conflict.

Storing energy is becoming increasingly interesting in a framework of high efficiency energy systems, allowing better management and

mitigating the imbalances between demand and production. Gas storage represents a surplus of gas that can be used in case of supply problems, such as upstream or downstream failures, balancing the demand evolution and making a country or company able to better negotiate prices (Guelpa et al., 2019). Locating gas storage facilities near consumption hubs not only reduces the need for costly network reinforcements, but it also decreases the reliance on flexibility mechanisms within the power system mechanisms that are often constrained in both scale and duration. As a result, gas storage helps avoid substantial capital expenditures and curbs future operational costs, contributing to a more efficient and resilient energy system (International Gas Union, 2025).

As displayed in Figure 21, natural gas stock changes clearly reflect the seasonality of demand, with storage facilities replenished during warmer months and drawn upon to meet supply requirements during winter. This pattern is evident in the alternating sequence of positive (injection) and negative (withdrawal) values: injections peak during late spring and summer, as shown by the strong positive values around mid-2023, mid-2024, and mid-2025, while withdrawals intensify during the winter months, reaching particularly pronounced lows in early 2024 and early 2025. Consequently, aggregate storage fill levels follow a predictable annual cycle, peaking just before winter and reaching their lowest point after the colder months have passed. To achieve this, both private market participants and state-backed entities engage in significant purchases of natural gas beginning in the spring, capitalising on lower spot prices during periods of subdued demand to meet both commercial and strategic storage obligations. This behaviour not only allows operators to exploit seasonal price differentials but also plays a crucial role in stabilising the system by ensuring adequate reserves ahead of peak demand, thereby mitigating the risk of supply shortages during the winter season.



**Figure 21** Monthly Change in EU Natural Gas Stocks (June 2023 - June 2025). Unit of measure: Billion cubic metres per month (Bcm/Mth). Data source: Eurostat, nrg\_cb\_gasm (2025).

The primary types of underground gas storage are depleted hydrocarbon fields, aquifers and salt caverns. The key defining parameters for storage operation are the cushion gas volumes, working gas volumes, injection rates and withdrawal rates. Cushion gas refers to the gas permanently stored in the underground structure during the lifetime of the site, serving to maintain the conditions always required for adequate storage operation. Working gas is the amount of gas that can be injected into and withdrawn from the storage in one cycle. Injection and withdrawal rates determine the maximum gas flow rate in and out of the asset. In general, the more working gas is withdrawn, the lower the storage pressure and the withdrawal rate (Cihlar et al., 2021, p. 19). For storage, natural gas is filtered, measured, compressed, and pressed under high pressure into the facility, where the resulting overpressure facilitates subsequent withdrawal. Two processes are necessary before gas can be fed into supply networks. First, the gas, which has cooled down considerably due to

pressure loss, must be reheated in the conveyor system. Second, the gas must be dried in drying towers to remove water absorbed during storage.

Salt caverns are man-made cavities created within underground rock salt formations through a process known as solution mining or leaching, whereby water is injected to dissolve the salt and form the desired storage space, with depths in Europe ranging from 300 to 1,800 metres. Depleted gas reservoirs are underground geological structures that naturally contained hydrocarbons for millions of years and can be used to store natural gas once they have been depleted. They have multiple wells located throughout the site, sometimes remaining from when it was operational for gas production and sometimes drilled strategically to improve the operation of the storage facility. Unlike salt caverns, the injection and withdrawal rates of porous rock structures are limited by the permeability of the rock. Aquifers are similar structures to natural gas reservoirs in that they are porous sedimentary rock structures, but they contain water instead of natural gas. As with depleted gas fields, the average cushion gas volume is approximately 50% of the total gas volume. Aquifers are common for natural gas storage, representing about 13% of existing capacity in Europe (Cihlar et al., 2021, pp. 42-48).

Russia's full-scale military invasion of Ukraine in February 2022 and its attempted weaponisation of Europe's energy supply clearly demonstrates the crucial role of stored gas for EU energy security which highlighted the EU's over-dependence on a single, unreliable supplier for almost half of its gas imports (European Commission, 2025). The EU's actions against the Kremlin triggered an acute shortage of imported gas, as Russia imposed restrictions on natural gas exports in response to EU sanctions, exposing systemic challenges in EU energy security (Chen et al., 2026). As Russia was the EU's predominant energy partner, the sudden supply disruption exposed an acute vulnerability: the continent's energy security

was at risk. Without the substantial reserves held in storage, widespread shortages and an inability to meet core demand would have been inevitable, making the crisis the ultimate empirical validation of storage as an essential security asset that confirmed the necessity not only of maintaining the infrastructure but also of ensuring it was filled to a sufficient level. This rationale directly underpinned the EU's subsequent regulatory intervention, which mandated minimum storage fill levels. The policy's core objective was to transform storage from a passive market buffer into an active instrument of sovereignty, thereby preventing future supply crises and mitigating their severe economic consequences.

## **2.5 Conclusions**

European natural gas demand is highly volatile and largely inelastic, particularly in the residential and commercial sectors. Consumption in these segments increases significantly during colder months due to heating needs, and demand remains relatively insensitive to price changes given the essential nature of the service. As a result, price dynamics for household consumers tend to reflect these seasonal demand patterns, with higher prices typically observed during peak winter periods and lower prices during warmer months when consumption declines. Because of this inelasticity, external shocks and unexpected supply reductions translate rapidly into price surges and inflationary pressures, as documented during the 2022 Russian supply shock and the subsequent period.

In parallel, European countries primarily import natural gas in gaseous form through an extensive network of pipelines connecting the continent to external suppliers as well as linking Member States to one another. However, the physical constraints of pipeline infrastructure, together with the strategic objective of diversifying supply sources, have led to a growing role for liquefied natural gas imports by sea. In recent years, the

number and capacity of LNG import terminals across the European Union have increased, reflecting the need to access more distant global suppliers and reduce reliance on geographically concentrated pipeline routes. While LNG provides greater flexibility in sourcing natural gas from global markets, its effective integration into the European energy system depends on adequate internal transport infrastructure; once regasified at coastal terminals, the gas must be transported inland through the pipeline network to reach final consumers. Consequently, the expansion of LNG imports requires not only regasification capacity but also sufficient cross-border pipeline connectivity to distribute the gas efficiently across European markets.

Underground gas storage systems across the European Union follow a seasonal operational logic closely aligned with demand patterns, with gas generally injected during warmer months, when consumption and prices are lower, and withdrawn during colder months to meet increased demand. This cyclical pattern of storage filling and withdrawal mirrors the seasonal fluctuations in demand and price that characterise the European natural gas market. In this context, the maintenance of adequate storage levels becomes a critical instrument for moderating price volatility and ensuring supply security, particularly during periods of peak demand. By injecting gas into storage during the low-demand season, States and energy operators can build strategic reserves that act as a buffer against future supply constraints. These stored volumes can then be withdrawn during high-demand periods, helping to stabilise supply conditions and mitigate potential price spikes by covering part of the additional consumption. In this way, the operational cycle of underground gas storage closely follows the seasonal pattern of demand described above, as illustrated by Figure 21.

## **CHAPTER THREE – EU GAS STORAGE MEASURES IN RESPONSE TO THE 2022 ENERGY SHOCK: A LITERATURE AND POLICY REVIEW**

### **3.1 Introduction**

This chapter provides an overview of the evolution of the regulatory framework governing underground gas storage in the European Union, both before and after the 2022 energy crisis. It highlights the significant shift in the approach adopted by EU authorities: while underground gas storage had previously received relatively limited regulatory attention, the supply disruptions triggered by the crisis led to a renewed recognition of its strategic importance. This change in perspective subsequently translated into the introduction of binding regulatory requirements concerning minimum storage filling levels.

Section 3.2 examines the distribution of underground gas storage infrastructure across EU Member States, analysing both the number of facilities and the total storage capacity available at the national level. Table 5 focuses on the five largest EU economies, which rank among the countries with the most extensive storage capacities, reflecting the central role these infrastructures play in their energy systems. Spain represents a notable exception within this group, as it possesses limited underground storage capacity and instead relies heavily on liquefied natural gas import terminals and maritime supply routes, supported by its extensive coastal infrastructure.

The regulatory framework in place prior to the 2022 energy crisis is described at the end of Section 3.2. It highlights the rationale under which underground gas storage was addressed at the EU level: storage facilities were primarily regarded as instruments to mitigate the effects of severe

supply disruptions within the Union. While solidarity mechanisms among Member States were established, the responsibility for ensuring adequate storage levels remained largely delegated to national authorities and network operators. These responsibilities were guided by regional risk assessments rather than by a fully coordinated EU-wide strategy, and the events of 2022 revealed the limitations of this approach. When the war in Ukraine began, storage levels across the Union were relatively low, raising concerns about the continent's ability to guarantee adequate energy security in the event of prolonged supply disruptions. This situation suggested that underground gas storage facilities, despite their strategic importance, had not been sufficiently leveraged by Member States within a broader security-oriented framework.

Section 3.3 examines the impact of the disruption of natural gas supplies from Russia, historically the European Union's main external supplier, by analysing trends in import volumes before and after the sanctions imposed on the country. The data clearly illustrate the sharp decline (represented by Figure 23) in this supply relationship and the resulting implications for the EU's reliance on Russian gas. The evolution of filling levels in European underground gas storage facilities is illustrated in Figure 24, which highlights the particularly vulnerable position of the Union at the onset of the crisis. Storage levels were exceptionally low, further aggravating the risks associated with the sudden reduction in Russian supply and prompting the need for urgent regulatory intervention by EU authorities to ensure higher and more reliable storage levels.

In response, the European Union adopted Regulation (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022, amending Regulations (EU) 2017/1938 and (EC) No 715/2009 with regard to gas storage. Through this measure, the European Commission formally recognised the strategic "insurance value" of underground gas storage

facilities. The Regulation introduced, for the first time, binding filling targets, requiring Member States to ensure that storage facilities on their territory reach at least 90% of their capacity ahead of the winter season. The Regulation also allowed Member States, under specific conditions, to consider stocks of liquefied natural gas stored in LNG facilities when assessing their security-of-supply obligations.

Section 3.4 presents a review of the literature on the European emergency Regulation (EU) 2022/1032 introduced in 2022, providing a critical assessment of the REPowerEU plan and the emergency regulatory measures adopted by the European Union in response to the 2022 gas supply shock, with particular attention to their implications for energy security and market stability. First, literature review examines if the expansion of capital-intensive infrastructures, such as pipeline networks and LNG import terminals, has generated concerns about potential lock-in effects in fossil fuel infrastructure, which could slow down or complicate the energy transition. Moreover, the increased reliance on LNG imports from geographically distant suppliers entails additional environmental costs associated with longer transport routes and related emissions. At the same time, the diversification of gas imports away from Russia has required the European Union to strengthen energy relationships with alternative supplier countries, including Israel, Qatar, Egypt, and Azerbaijan, some of which raise political and governance concerns due to their geopolitical positions or domestic political systems.

The section examines the effects of the binding storage filling requirements introduced by the EU following the 2022 gas supply shock, with particular attention to their implications for market dynamics and price formation. The literature highlights that the coordinated effort by Member States to procure large volumes of natural gas within a short period, while simultaneously striving to meet the storage targets

established by the Storage Regulation, contributed to additional demand pressure in an already strained market environment. The involvement of state-backed buyers operating under security-of-supply obligations may have reduced price sensitivity in the market. In pursuing mandatory storage targets, these actors were less responsive to price signals, potentially intensifying competition for available supplies during the injection season. As a result, the regulatory framework designed to strengthen energy security may also have contributed to short-term price pressures in the European gas market. It is therefore highly likely that, in the absence of such interventionist behaviour by Member State governments, gas prices would not have reached the same extreme levels.

The analysis by Fernández-Blanco et al. (2023), presented at the end of Section 3.4, examines the price impact of mandatory storage levels using the EU consumption-weighted average price. Their findings underscore the role of storage obligations as a volatility-dampening mechanism, effectively reducing price spikes, lowering tail risk, and improving overall market predictability. This empirical evidence provides a crucial counterweight to the critique of regulatory costs, suggesting that the storage mandate also delivered measurable stability benefits.

### **3.2 Underground Natural Gas Storage in the European Union: Distribution, Ownership, and Regulatory Framework before the 2022 Crisis**

This section presents an overview of the distribution and capacity of underground natural gas storage facilities across the European Union, highlighting the Member States that dominate in terms of both the number of installations and total storage capacity. It then examines the regulatory framework governing gas storage prior to 2022, as established by EU legislation. Under Regulation (EU) 2017/1938, responsibilities were

delegated to national authorities, with an emphasis on risk assessment and voluntary measures rather than binding EU-wide storage targets. This analysis provides a necessary baseline for assessing the effectiveness and strategic objectives of the regulatory reforms introduced in 2022, which imposed stronger and more binding requirements on Member States.

Gas storage has mostly been treated as a national competence, since it forms part of the 'structure of energy supply' that Article 194 TFEU enshrines as the 'right' of Member States (Boehm & Wilson, 2022). Consequently, storage capacities vary considerably across the EU, revealing deep disparities. This uneven distribution, shaped by geological conditions and historical investment patterns, means that countries without storage must rely on cross-border infrastructure and regional solidarity, effectively making storage a shared resource despite its legal framing as a national competence.

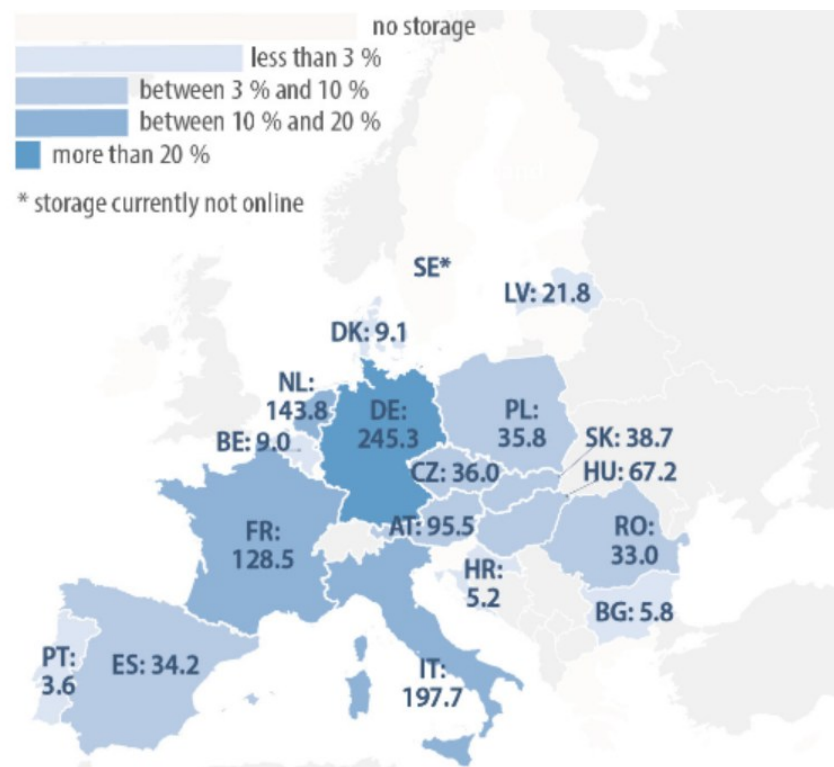
NATION	NO. OF UGS FACILITIES	WGV (BCM)	PWR (MCM/D)
Germany	44	22.49	631
France	14	11.77	220
Italy	13	17.66	244
Netherlands	5	13.74	283
Spain	1	2.41	21

**Table 5** Number of Underground Gas Storage Facilities in the top 5 EU economies, 2025. Data Source: International Gas Union (2025).

As shown in Table 5 and Figure 23, this capacity is heavily concentrated: five countries, namely Germany, Italy, France, the Netherlands, and Austria, account for nearly three-quarters (73%) of the EU's total capacity (European Council, 2026a). Germany possesses by far the largest storage capacity, with 44 facilities offering a working gas volume of 22.49 bcm,

while France, Italy, and the Netherlands also maintain significant strategic reserves. Several Member States have no storage capacity of their own and would therefore have to rely on facilities in neighbouring countries (Boehm & Wilson, 2022). According to Conti (2022), total EU-27 gas storage capacity amounts to approximately 1,147 TWh (around 100 bcm), equivalent to roughly one-quarter of the EU's annual gas demand.

Spain represents a distinctive case: its underground gas storage capacity is markedly limited, which could be interpreted as a potential vulnerability in terms of supply resilience. However, the country has developed the largest LNG regasification capacity in Europe, with multiple terminals distributed along its coastline. This extensive LNG infrastructure provides a high degree of flexibility through continuous imports and short-term supply adjustments, thereby reducing the perceived need for large-scale seasonal underground gas storage.



**Figure 22** Share of EU storage capacity (TWh and share), 2022. Source: Boehm & Wilson (2022).

Before the 2022 energy crisis, the EU’s regulatory framework for natural gas security of supply was established by Regulation (EU) 2017/1938 of the European Parliament and of the Council of 25 October, that aimed to “safeguard the security of gas supply” across Member States by ensuring uninterrupted gas availability in the internal market and a clear allocation of responsibilities among authorities and market players. The concept of a binding filling target for underground gas storage was not part of the 2017 text as originally adopted, which referred to: “a solidarity mechanism as an instrument to mitigate the effects of a severe emergency within the Union in which gas supply to solidarity protected customers, as an essential security need and a necessary priority is at stake in a Member State. In the event of a Union emergency, an immediate response ensures that Member States can provide enhanced protection to customers” (European Parliament and Council, 2017). The Regulation (EU) 2017/1938 focused on general security-of-supply measures, highlighting the importance of storage in security planning. Responsibilities for ensuring adequate storage levels were primarily delegated to national authorities and network operators, guided by a regional risk assessment. Rather than fixed numerical targets, Regulation (EU) 2017/1938 emphasised infrastructure classification, requiring clear identification and integration of storage assets in national risk and emergency planning, and reporting and monitoring, Member States were expected to monitor supply trends and report relevant operational conditions, including storage levels, to competent authorities as part of their preventive action and emergency frameworks. The Regulation included also a solidarity mechanism, underlining that Member States should support one another in the face of a serious supply shortage.

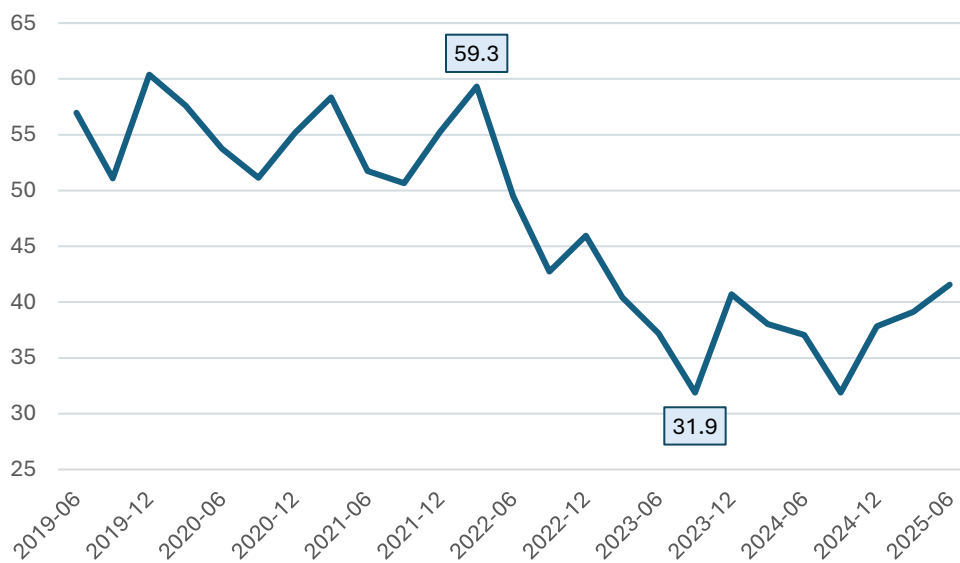
However, Regulation (EU) 2017/1938 also contributed to a fragmented and insufficiently coordinated approach to natural gas storage across the

Union, which resulted in structurally low storage levels at the outset of the 2022 crisis (see Figure 25). By relying primarily on regional risk assessments, voluntary preventive measures, and market-based incentives rather than binding EU-wide storage filling obligations, the Regulation left significant discretion to Member States regarding the use and management of storage facilities. As a result, storage adequacy varied widely across countries, reflecting divergent national strategies, infrastructure endowments, and market conditions. These provisions constituted the regulatory baseline for Member States' planning and cooperation on gas storage prior to 2022, and their limitations became evident once gas supply conditions deteriorated sharply, prompting the subsequent introduction of mandatory storage filling targets in response to the energy market shock.

### **3.3 The 2022 Energy Shock Triggered by the Russian Invasion of Ukraine**

This section examines the consequences of the Russian invasion of Ukraine and the subsequent sanctions imposed by the European Union. The first observable effect was a significant reduction in natural gas imports from Russia, which fell by approximately half (see Figure 23). A detailed breakdown of EU natural gas imports by supply route is then provided to illustrate the regional and infrastructural dimensions of this decline. Compounding the 2022 supply shock, natural gas storage levels were at historically low values prior to the crisis, as documented by Conti (2022). The section concludes with an analysis of the new underground gas storage Regulation introduced in 2022 under the REPowerEU plan. As shown in Figures 25 and 26, the mandatory 90% storage targets were successfully met in the years following the crisis, demonstrating the impact of the regulatory reforms on EU gas security.

The abrupt disruption of Russian natural gas, which represented the EU's primary supplier, exposed critical European vulnerabilities. It created an immediate and urgent imperative to replace these lost supplies through two primary channels: securing new international partners and strategically leveraging existing natural gas reserves in storage. As detailed in Section 2.4, the impact of Russian export restrictions imposed in response to EU sanctions, is clearly reflected in the evolution of European natural gas import volumes displayed in Figure 23.



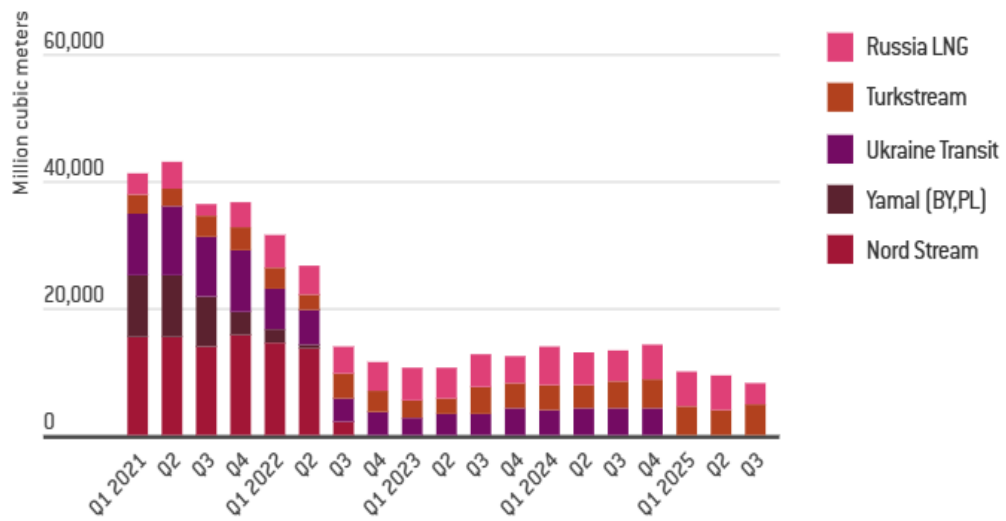
**Figure 23** Quarterly imports of natural gas to the European Union, 2019-2025. Unit of measure: Billion cubic metres per quarter (bcm/quarter). Data source: Eurostat, nrg\_cb\_gasm (2025).

Before the 2022 invasion, total EU imports were sustained at a relatively high level, reaching a peak of 59.31 bcm in the first quarter of 2022. However, following the sanctions and the withdrawal of Russian pipeline gas, this previously stable import level began a structural decline. The steady, non-seasonal reduction that followed, which reached a low of 31.89 bcm by the third quarter of 2023, signals that the bloc was unable to fully replace the lost Russian volumes through alternative suppliers in the

short term. This direct correlation confirms that the reduction in Russian imports was reflected in the bloc's total import volumes.

European authorities intensified their focus on the continuity of natural gas supply and on broader energy security concerns. As described in paragraph 2.3, the presence of gas storage facilities across European countries became a crucial source of resilience for sustaining natural gas demand in the various sectors. The aim was to leverage this infrastructure to achieve greater energy supply independence by storing natural gas imported in advance, increasing Europe's energy sovereignty. The conflict has exposed Europe's fragile reliance on external energy supplies, triggering a severe energy crisis characterized by soaring domestic energy prices and concerns over supply stability, which, in turn, have led to higher inflation and dampened economic growth (Gueye et al., 2025). As global energy supply tightened and imports to the EU decreased, EU gas and electricity prices skyrocketed, affecting entire economic sectors and especially the welfare of poorer citizens (Siddi, M., 2022).

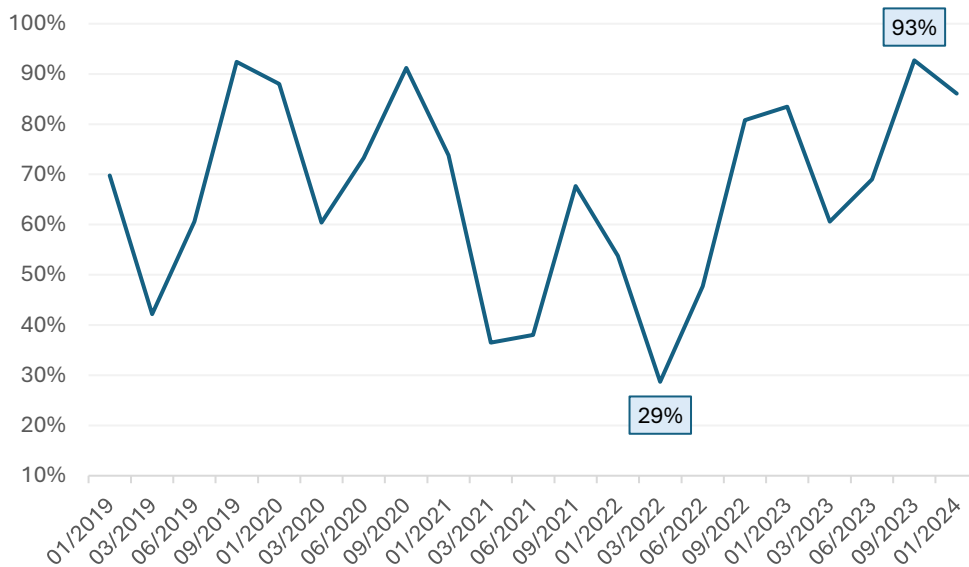
Since May 2022, the EU has taken a range of actions to eliminate its reliance on Russian fossil fuel imports by saving energy, diversifying supplies and accelerating the roll-out of renewable energy production in Europe. The data underscore the effectiveness of the sanction's regime: imports of Russian natural gas plummeted from 45% of the EU supply in 2021 to 13% in 2025, while oil imports fell from 27% to below 3% over the same period (European Council, 2026b). The shock triggered a structural decline in EU natural gas imports via Russian routes, a trend clearly documented by Figure 24.



**Figure 24** Quarterly EU imports of natural gas by supply route, since Q1 2021. Data source: (Keliauskaitė et al., 2026)

When the energy crisis started, at the end of summer 2021, gas storage levels in Europe were way below the 5-year average. More gas than usual had been used during the spring and summer because gas demand had risen more than expected (due to economic, weather-driven factors and other more structural reasons). At the same time, re-filling levels were quite heterogeneous, notably with countries that had a strictly regulated regime for storage achieving higher filling levels. These considerations, jointly with the fear of rising gas prices and the ghost of a real scarcity of supply, attracted policy makers' attention towards gas storage as a potential guarantee for security of gas supply and at the same time as a price catalyser against the crisis (Conti, 2022). Fernandez-Blanco et al. (2023) report that on 1st November 2021, gas in underground gas storages in the EU reached its lowest level in the past 11 years, with a storage filling level of 77%, compared to 88.5% on the same day during the years 2016-2018, corresponding to 852 TWh in 2021 and 976 TWh in 2016-2018. The Agency for the Cooperation of Energy Regulators (ACER) identified several factors that led to higher gas withdrawals from UGSs in 2021 than in 2019, such as: a high gas demand driven by post-pandemic economic

recovery, reduced power generation from wind and hydropower, which increased the need of gas fired generation in the electricity system, a decline in EU indigenous gas production, and a decrease in liquefied natural gas and pipeline gas supply to the EU, primarily from Norway, Russia, and Trinidad and Tobago (Fernandez-Blanco et al., 2023). Luckily, the mild winter of 2021-2022 prevented the UGSs from becoming even more depleted and provided some relief to the gas markets. Data from the Aggregated Gas Storage Inventory (Gas Infrastructure Europe, 2025) reveal that, despite the usual seasonal filling pattern, the lowest inventory level across the EU was reached in March 2022. This indicates that stored gas was actively drawn upon to meet demand following the withdrawal of Russian supply routes. In response to this evidence, European Regulations subsequently mandated higher fill targets.



**Figure 25** Evolution of quarterly fill levels for EU natural gas storage, 2019-2024. Note: Values represent the fill level as a percentage of total working gas capacity at the end of each quarter. Data source: Aggregated Gas Storage Inventory (Gas Infrastructure Europe, 2025).

In 2021, the EU-27 gas storage capacity amounted to 1,147 TWh across 18 Member States or an equivalent of approximately 27% of the EU-27's yearly consumption (ACER & CEER, 2022). In May 2022, the Commission presented the REPowerEU plan to rapidly reduce the EU's dependence on Russian fossil fuels before 2030, by fast-forwarding the clean transition and joining forces to achieve a more resilient energy system with a true energy Union. A key part of the plan involved ensuring secure and affordable energy supplies by diversifying supply routes. With the Regulation (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022 amending Regulations (EU) 2017/1938 and (EC) No 715/2009 about gas storage, for the first time, the EC recognised the insurance value of UGSs.

The Regulation (EU) 2022/1032, Art. 5 explicitly notes that: “based on the Commission’s analysis of, inter alia, the adequacy of measures to secure gas supply and the Union-wide reinforced risk preparedness analysis carried out in February 2022 by the Commission and the Gas Coordination Group (the ‘GCG’) established by Regulation (EU) 2017/1938, each Member State should, in principle, ensure that the underground gas storage facilities that are located on its territory and directly interconnected to a market area of that Member State are filled to at least 90 % of their capacity at Member State level by 1 November of each year (filling target)” (European Parliament and Council, 2022, Art. 5). The legal design of Regulation (EU) 2022/1032 also provides for intermediate filling trajectories to smooth injections throughout the year, specifying: “a series of intermediate targets for each Member State in May, July, September and February (filling trajectory) of the year thereafter” (European Parliament and Council, 2022, Art. 5). The Regulation then provides for exemptions for Member States with disproportionately large storage capacity, noting that: “some Member States that have significant underground storage

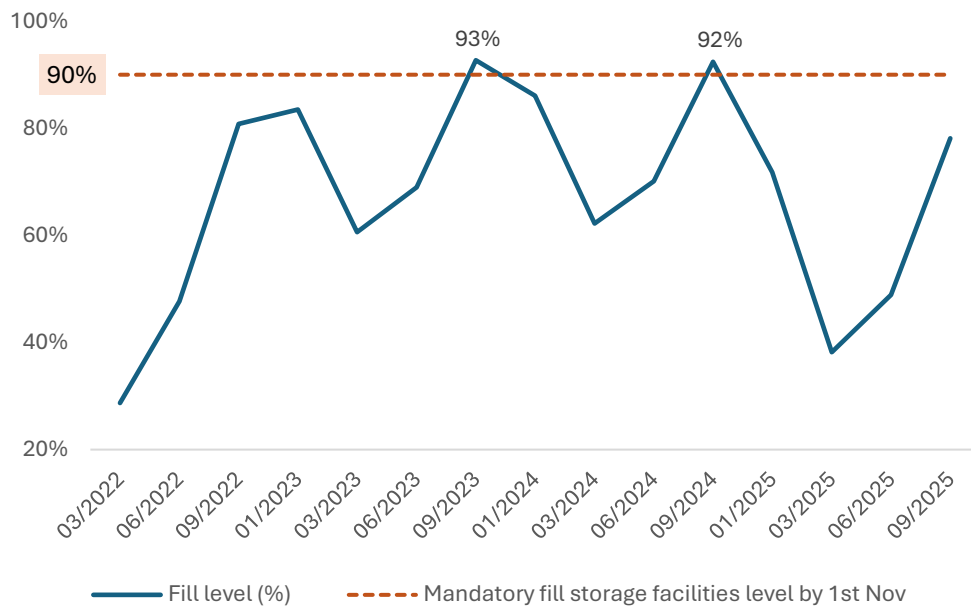
capacity would be disproportionately affected by the obligation to meet the filling target for the underground gas storage facilities on their territory. In order to reflect that situation, the obligation to fill their underground gas storage facilities should be reduced to 35 % of their average annual gas consumption over the preceding five years” (European Parliament and Council, 2022, Art. 5).

Regulation (EU) 2022/1032, Art. 5 further clarifies that filling targets are not limited to underground storage alone, stating that: “Member States should be able to decide, subject to conditions, to partially meet the filling target by counting liquefied natural gas stocks stored in LNG facilities” (European Parliament and Council, 2022, Art. 5). The primary objective of the Regulation is to ensure that consumers across the EU are adequately protected against gas supply shortages. As stated in the text of the Regulation: “the filling targets are necessary to ensure that consumers in the Union are adequately protected against gas supply shortages” (European Parliament and Council, 2022, Art. 5).

The Commission allowed a transitional arrangement for 2022, recognising that the Regulation had entered into force after the start of the storage filling season. As noted in the Regulation (EU) 2022/1032, Art. 3: “for 2022, a lower filling target of 80 % and a reduced number of intermediate targets should apply, taking into account the fact that this Regulation is to enter into force after the start of the storage filling season and that Member States will have limited time to implement it” (European Parliament and Council, 2022, Art. 3).

This coordinated effort by Member States produced a direct and tangible result: by September 2023, aggregate EU storage levels had peaked at a historic 93% (1,057 TWh), as shown in Figure 26. This peak concretely reflects the new strategic priority placed on storage security, confirmed by

the subsequent, consistent attainment of the 90% target by the 1 November deadline in 2024.



**Figure 26** Quarterly EU Natural Gas Storage: Fill Levels vs. Regulatory Target, 2022-2025. Note: Values represent the fill level as a percentage of total working gas capacity at the end of each quarter. Data Source: Aggregated Gas Storage Inventory (Gas Infrastructure Europe, 2025).

The Regulation (EU) 2022/1032, Art. 6c recognises that some Member States lack underground storage infrastructure and therefore cannot physically satisfy the 90 % filling target within their own borders. To address this, Article 6c establishes that such Member States must ensure access to storage volumes in other Member States corresponding to at least 15 % of their annual gas consumption by 1 November each year, through arrangements agreed with storage-holding Member States and confirmed by the Gas Coordination Group (European Parliament and Council, 2022, Art. 6c). This mechanism is designed not only to guarantee that all Member States participate in collective supply security, but also to

distribute the financial and logistical burden of filling obligations more equitably. In practice, this requires coordination between countries with limited storage capacity and those with larger facilities, facilitating access to gas reserves without requiring new infrastructure in every Member State. The solidarity provisions thus reinforce the internal market's resilience by supporting mutual assistance and shared risk-management in the face of supply shocks.

In response to evolving market conditions and concerns that the original storage targets might contribute to market stress and higher prices, EU institutions agreed in 2025 to extend and refine the Regulation (EU) 2022/1032 on gas storage for an additional two years, until the end of 2027. Under the amended framework, the 90 % annual filling target is retained, but Member States are granted greater temporal and quantitative flexibility in how they meet it. Rather than a fixed deadline on 1st November, the target may now be reached at any point between 1st October and 1st December, giving governments and market participants a wider purchase window that can reduce the risk of simultaneous buying and associated price spikes (Council of the European Union, 2025). Additionally, the amended rules introduce a 10 percentage points flexibility margin in cases of difficult market conditions, such as indications of market manipulation or trading behaviour that impede cost-effective filling (European Parliament and Council, 2025, Art. 6a(5b)), and empower the Commission, through a delegated act, to expand this margin by up to an additional 5 percentage points if unfavourable conditions persist (European Parliament and Council, 2025, Art. 6a(5c)). Intermediate storage targets are also made indicative, rather than binding, allowing Member States and operators to plan refilling more opportunistically throughout the year (Council of the European Union, 2025). These amendments seek to maintain robust energy security while

improving market efficiency and cost-effectiveness, mitigating the distortions caused by rigid deadlines and ensuring that gas storage continues to play a central role in securing winter supply.

### **3.4 Literature review on EU Emergency Regulation**

This section reviews the existing literature on the multifaceted consequences of the EU's emergency energy measures adopted in response to the 2022 crisis. It first analyses the geopolitical and environmental paradoxes of the REPowerEU plan, which, while aiming to accelerate the energy transition, has led to increased fossil fuel infrastructure investment and new dependencies on illiberal states (Siddi, 2022; Vezzoni, 2023). It then assesses the market impact of the mandatory gas storage Regulation (EU) 2022/1032, exploring how uniform filling targets created inelastic demand, price spikes, and fragmented procurement competition among Member States. Finally, the section evaluates the price-stabilising benefits of storage obligations through the empirical lens of Fernández-Blanco et al. (2023), weighing short-term costs against long-term gains in volatility reduction and market predictability.

The European Commission framed the REPowerEU plan as an instrument to accelerate the energy transition. However, in the short and medium term, the policy of phasing out Russian fossil fuels and the decrease in Russian gas supplies have led to a switch from gas to coal in some contexts and to a rapid increase in imports of LNG over long distances. Coupled with plans to build additional infrastructure for LNG imports and new pipeline connections, these developments risk delaying the climate agenda by distracting resources and, at worst, producing new dependencies and carbon lock-in (Siddi, 2022). Vezzoni (2023) argues that the new course of EU energy policy may paradoxically increase the continent's dependence on raw materials and lock in investments in fossil fuel

infrastructure. While the EU formally presents its strategy as both a defence of liberal democratic principles and an acceleration of the energy transition, these policy choices may produce unintended consequences. In particular, the crisis response has led to a renewed reliance on nuclear and fossil energy sources, including the reactivation of coal plants and increased investment in liquefied natural gas terminals and gas pipelines. Furthermore, the diversification of supply may strengthen ties with politically sensitive partners such as Israel, Qatar, Egypt, and Azerbaijan. At the same time, the growing reliance on LNG imports, especially from distant suppliers like the United States and Qatar, raises environmental concerns, due to both higher transport-related emissions and the significant methane emissions associated with LNG production and distribution (Siddi, 2022).

Following the establishment of the gas storage Regulation (EU) 2022/1032, leaders expressed concern about the market's ability to meet fill targets amid exceptionally high gas prices and, critically, the negative winter-summer price spreads in forward markets. These spreads offered no commercial incentive for market players to refill storage, as doing so would incur a financial loss. In response to this market failure, ACER and CEER (2022) proposed a framework of targeted and temporary public intervention. They argue that financial support for storage obligations should be conceived as an insurance policy: a deliberate reallocation of price and volume risk from storage operators to the public sector, reflecting the treatment of storage as a security-of-supply instrument rather than a purely commercial activity.

To protect market participants and consumers, they identify contracts for difference (neutralising the risk of selling at a loss) and negative storage auction prices as the preferred instruments. The associated costs could be financed through levies or taxes on domestic consumers and taxpayers. In

their view, such support may be necessary in Member States where the costs of implementing the storage obligations, particularly the procurement and injection of gas at high market prices, are unaffordable, and dedicated EU funding could be required. This approach entails a socialisation of costs, justified by security-of-supply objectives: sharing the financial burden across society treats gas storage as a public good rather than a purely commercial activity, preventing the unsustainable risks that would otherwise lead to supply shortages and extreme price spikes.

Since the Russian invasion of Ukraine in February 2022, security of supply has been a top priority, and some Member States, panicking alongside the Commission, even purchased gas on behalf of their national utilities comply with storage targets. Indeed, the gas storage provisions of Regulation (EU) 2022/1032 likely contributed to upward pressure on gas prices, particularly during the third quarter of 2022, as Member States simultaneously entered the market to procure gas in an already constrained supply environment in order to meet binding storage targets. Arguably, EU-mandated storage filling requirements were among the factors that helped push European gas prices to record highs in late August 2022, alongside the sharp reduction in Russian gas supplies (Elliott, 2022). Mandatory filling targets transformed demand into inelastic, deadline-driven demand: storage operators and governments became forced buyers, regardless of price levels.

While it is not possible to precisely isolate the contribution of the Regulation itself to the observed increase in gas prices, the involvement of state-backed buyers with less binding budget constraints significantly reduced price discipline in the market. Acting under storage obligations and security-of-supply concerns, these buyers were less responsive to price signals, thereby amplifying demand pressure during the injection

season. It is therefore highly likely that, in the absence of such interventionist behaviour by Member State governments, gas prices would not have reached the same extreme levels.

Thus, although the impact on prices was relatively short-lived, there is little doubt that the original storage Regulation (EU) 2017/1938 interfered with market functioning under the exceptional conditions prevailing in 2022 (Yafimava, 2025). Looking ahead, Yafimava (2025) argues that the amended storage Regulation is unlikely to exert a lasting upward pressure on prices, as the effect of binding storage targets is highly contingent on market conditions. In an oversupplied market, the presence of surplus gas allows companies to procure volumes well ahead of the target deadline and to spread injections over time, thereby reducing the need for price-insensitive buying. Under such conditions, even mandatory storage targets are unlikely to result in significant price distortions.

To analyse the price impact of mandatory storage levels, Fernández-Blanco et al. (2023) use the EU consumption-weighted average price (WAP) as the outcome variable. Their analysis is performed using METIS, a linear programming model that simulates the European gas system and market as a mass-balance model, considering technical and economic constraints over daily time periods. To account for uncertainty, the authors consider four uncertain parameters (natural gas demand, UGS boundary conditions, maximum storage filling levels, and minimum storage obligations), each treated as statistically independent random variables. They employ Latin Hypercube sampling (LHS) to generate 100 test cases, ensuring that sample points are evenly distributed across the most probable range of uncertainty. For each test case, the model checks the technical feasibility of storage obligations against UGS injection capacity curves before running the simulation. Applying this framework, the authors find that implementing storage obligations by 1 November results in an annual

WAP of 39.5 €/MWh. Examining the injection and withdrawal seasons provides insight into this effect. During the injection season, average prices increase by 3.2 %, reflecting the short-term cost of the policy as demand is artificially increased and buyers are less price responsive. However, this increase generates economic benefits during the withdrawal season, with average prices falling from 53.6 to 40.5 €/MWh (-32.3 %) due to higher storage levels mitigating scarcity risk, thereby reducing the winter premium over summer prices.

Another significant finding is that storage obligations yield robust results, as evidenced by a decrease in the standard deviation of WAP from 10.4 to 3.9 €/MWh when considering the annual basis. This effect is even more pronounced during the withdrawal season, where the standard deviation decreases by 60 % when accounting for minimum storage levels (from 21.3 to 7.8 €/MWh), as evidenced by Fernandez-Blanco, R. et al (2023). These results highlight the role of storage obligations as a volatility-dampening mechanism, reducing price spikes, lowering tail risk, and improving market predictability. Overall, although storage obligations impose a short-term cost, they generate longer-term welfare gains by redistributing prices across seasons, increasing prices during injection while substantially reducing both price levels and volatility during withdrawal periods.

### **3.5 Conclusions**

The short-term consequences of the 2022 energy shock also raised significant concerns among experts regarding the implications for energy transition and sustainability. In response to the sudden reduction in gas supplies, some governments, including Germany, temporarily increased reliance on alternative fossil fuels, notably by reactivating coal-fired power plants to compensate for energy shortages. At the same time, the

rapid expansion of LNG imports following the crisis led to substantial investments in new infrastructure, including import terminals and regasification facilities. Although these developments contributed to diversifying supply sources and strengthening the resilience of the European energy system, they may also create potential constraints for the energy transition. The large fixed and sunk capital costs associated with such infrastructure risk generating lock-in effects, potentially prolonging the role of fossil fuels within the European energy mix beyond what would be required under long-term decarbonisation objectives.

The literature review assesses the impact of Regulation (EU) 2022/1032, which introduced binding filling targets for underground gas storage across Member States with the objective of strengthening energy security in an increasingly unstable global environment. In particular, the debate in the literature focuses on the potential effects of these requirements on natural gas prices. By mandating high storage filling levels within a limited time frame, the Regulation effectively compelled European countries to procure large volumes of natural gas to meet regulatory targets, even when such quantities were not immediately required to satisfy current consumer demand.

This situation occurred in an already strained market context, as gas prices had reached historically high levels following the outbreak of the war in Ukraine and the subsequent disruption of Russian supply. The simultaneous and largely uncoordinated procurement of gas by multiple Member States may therefore have intensified competition for available supplies. A few studies suggest that this surge in precautionary demand during the storage injection season could have contributed to additional upward pressure on prices beyond the levels already driven by the geopolitical shock. As observed by Fernández-Blanco et al. (2023): “it is highly likely that, in the absence of such interventionist behaviour by

Member State governments, gas prices would not have reached the same extreme levels”.

However, the regulatory framework cannot be assessed solely on its short-term price impact. The same analysis provided by Fernández-Blanco et al. (2023) highlights the role of storage obligations as a volatility-dampening mechanism, reducing price spikes, lowering tail risk, and improving market predictability. Thus, while mandatory storage targets impose a short-term cost, exacerbating price peaks during the injection season, they generate longer-term welfare gains by redistributing prices across seasons and substantially reducing both price levels and volatility during withdrawal seasons.



## **CHAPTER FOUR – THE ECONOMIC IMPACT OF STORAGE REGULATION (EU) 2022/1032 ON MEMBER STATES, PRIVATE OPERATORS AND SOCIETY**

### **4.1 Introduction**

This chapter assesses the impact of the Storage Regulation (EU) 2022/1032 on Member States, examining the extent to which they were compelled to purchase natural gas in an exceptionally adverse market context to meet mandatory storage filling targets. The burden imposed by the Regulation differed significantly across countries due to variations in underground gas storage (UGS) infrastructure and available capacity, which directly influenced the volume of gas each state was required to procure and the corresponding financial exposure during the price peak of 2022.

Section 4.2 examines the evolution of natural gas imports and expenditures in four major European economies, namely Germany, Italy, France, and Spain during the crisis period. By analysing import volumes and associated costs between 2021 and 2022, the section highlights how the sharp increase in gas prices dramatically raised total expenditure despite relatively stable import volumes. Particular attention is devoted to the distinctive position of Spain, whose limited underground storage capacity contrasts with its extensive LNG regasification infrastructure and strategic role as a transit and re-export hub for liquefied natural gas within Europe.

Section 4.3 analyses how the financial burden generated by emergency gas procurement was distributed across the energy system, focusing on the role played by private and semi-public operators that were required to purchase gas at exceptionally high prices to secure supply and meet storage obligations. The section proceeds to illustrate the contrasting approaches

adopted by Germany and Italy in managing these risks: the former exemplifies the severe financial pressures borne by private market actors during the crisis, epitomised by Uniper's near-collapse, while the latter highlights a different model in which state-linked entities, namely Snam and GSE, intervened as last-resort buyers to ensure that storage injection targets were met.

Section 4.4 addresses the central research question of this thesis: was the EU Storage Regulation an efficient tool for guaranteeing energy security, and how were its costs ultimately distributed across society? To answer this question, the section first introduces the concept of energy security as a public good, illustrating how, during emergency situations such as the 2022 energy crisis, its provision necessitated government intervention through economic and fiscal measures. These interventions served to spread the impact of the crisis across society, rather than allowing it to fall disproportionately on private actors, such as energy importers, or on consumers exposed to unregulated retail price increases. The Section then provides an overview of the emergency measures adopted by four selected Member States, namely Germany, Italy, France, and Spain, which are summarised in Table 9. This is followed by an analysis of the economic impact of these measures, detailing the yearly evolution of the general government deficit/surplus for the EU-27 and the selected countries, as presented in Table 10.

In addressing the central research question, Section 4.4 concludes by illustrating the positive contributions of the EU Storage Regulation, while also highlighting the negative market distortions generated by its binding storage target. As the analysis shows, these distortions exacerbated pressures on an already strained natural gas wholesale market, with the resulting costs ultimately distributed across society.

## **4.2 National strategies and the economic cost of storage compliance**

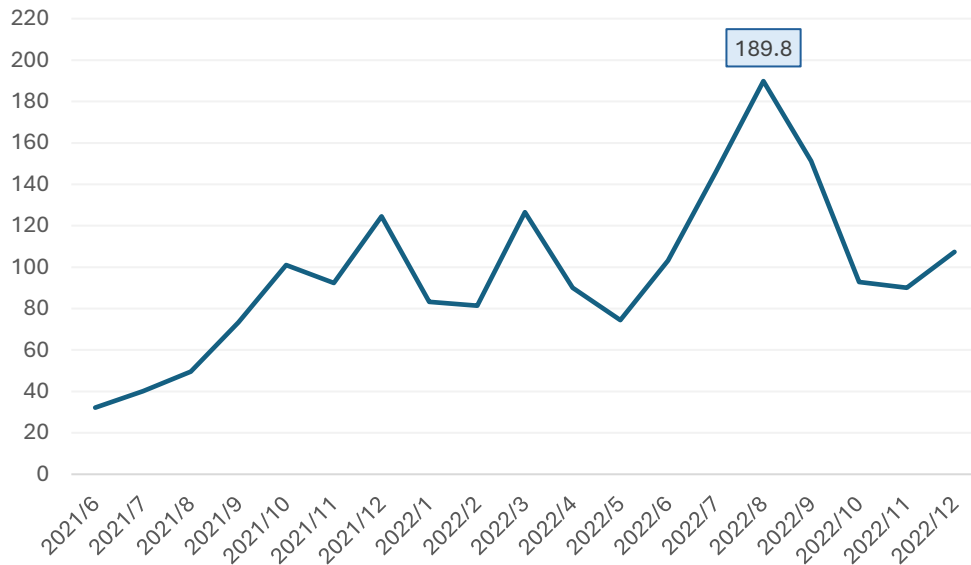
This section examines the quantity and cost of natural gas imported by selected Member States in response to the 2022 energy shock and the subsequent EU Storage Regulation. It then analyses the divergent strategies adopted by four of Europe's largest economies – Germany, Italy, France, and Spain – to achieve compliance with the regulatory targets, highlighting the key differences in their approaches. These countries are selected due to their central role in the European gas system, as reflected in their substantial storage capacities and market size (as shown in Table 5). While Spain has relatively lower storage capacity compared to the other cases, it is included due to its distinctive position as a major importer of liquefied natural gas and its strategic role in diversifying European gas supply. The clearest result emerging from the analysis is the unprecedented surge in Member States' expenditure on natural gas in 2022, particularly when compared to 2021 and subsequent years. This finding substantiates the central thesis of this chapter: the combination of record-high prices and mandatory procurement to meet storage obligations under the EU Regulation imposed a significant economic burden on European countries during the first year of the crisis.

Energy security holds fundamental strategic importance for Europe, given its near-total reliance on imported energy sources to meet domestic demand (see Table 4), a structural dependency that has positioned the European Union in a state of strategic vulnerability. Prior to the 2022 Regulation, the seasonal dynamics of natural gas demand and pricing were primarily driven by market-based storage operations, reflecting both the cyclical nature of consumption and the commercial practice of purchasing and injecting gas during warmer months when prices were lower. As detailed in Section 3.2, the preceding European framework, Regulation (EU) 2017/1938, did not mandate specific storage fill targets, allowing

Member States and network operators to self-regulate their purchasing strategies and inventory levels, guided by commercial factors such as seasonal natural gas prices and projected consumption forecasts. This regulatory and market context precipitated a critical situation by late 2021: as documented by Fernandez-Blanco et al. (2023), the aggregate fill level of EU underground gas storage sites on November 1st, 2021, had fallen to its lowest point in over a decade. This historic shortfall triggered a dual crisis. First, it created an immediate, desperate need for imports from new and distant suppliers, such as the United States, with higher associated costs for liquefied natural gas and long-distance shipping. Second, it rendered the subsequent 2022 storage mandate, which introduced a mandatory 90% target, both more difficult and more expensive to achieve. Unlike in previous years, spot market prices failed to drop significantly after the winter of 2021-2022 but remained at historically elevated levels, forcing EU Member States to procure gas at great expense to comply with the new Regulation.

According to data from the World Integrated Trade Solution, in 2022 the European Union imported a total of approximately 85.4 billion kilograms of gaseous natural gas, at a total cost of \$118 billion. The main partner countries were Algeria (22.2 billion kg), the Russian Federation (19.6 billion kg), the United Kingdom (16.8 billion kg), and Norway (14.9 billion kg), together accounting for \$96.8 billion of the total import value. LNG imports have also increased significantly since 2022, driven by the EU's strategic objective of ending its dependency on Russian fossil fuels. In the three years following the presentation of the REPowerEU plan (May 2022), the EU installed ten floating storage and regasification units and expanded seven existing LNG terminals (Institute for Energy Economics and Financial Analysis, 2025). In response to the supply shock, EU LNG imports surged from approximately 105 bcm in 2021 to 167 bcm in 2022,

a 59% increase according to Kpler and Eurostat data (Jaller-Makarewicz, 2023). This rapid influx of LNG, while crucial for replacing lost Russian pipeline volumes, occurred against a backdrop of record-high and volatile prices, as evidenced by the surge increase of LNG prices reported by the line represented in Figure 27.



**Figure 27** Evolution of Natural Gas Wholesale Prices – LNG Spot, Northwestern Europe, 2021-2022. Data Source: European Commission (2024). Note: Prices are expressed in Euros per Megawatt-hour (€/MWh).

Together, these factors imposed a substantial economic burden on European countries as they sought to maintain energy security during the crisis while simultaneously meeting the mandatory storage fill levels introduced by the subsequent Regulation (EU) 2022/1032 detailed in Section 3.3, making it instructive to examine how individual Member States responded to the 90% storage target. Such analysis reveals divergent national strategies and highlights the varying economic impact of compliance across the Union.

One of the most significant structural asymmetries within the EU concerned the distribution of underground gas storage capacity (see Table

5). Member States such as Germany, Italy, France, and the Netherlands possess large storage facilities, often representing a substantial share of their annual consumption. In contrast, other Member States, particularly in Eastern and Southern Europe, have little or no domestic storage capacity. This imbalance created a dual burden: storage-rich countries bore the physical and financial responsibility of filling large volumes, while storage-poor countries relied on the access mechanism established by Article 6c of the Regulation, which granted them the right to store up to 15% of their annual consumption in other Member States' facilities. However, such access was not free of charge: it required the conclusion of contractual arrangements with storage operators and entailed the payment of storage tariffs and associated costs, which could in turn be subject to financial compensation mechanisms under the Regulation (Regulation (EU) 2022/1032, Article 6c).

The abrupt shift away from Russian pipeline gas compelled EU Member States to rapidly diversify their supply sources. Norway and the United States emerged as pivotal new partners, alongside significant contributions from Algeria, Qatar, Azerbaijan, the United Kingdom, and others. This diversification unfolded unevenly across the continent: countries with established pipeline connections to Norway and North Africa continued to rely on this infrastructure, benefiting from comparatively stable and often cheaper gas, yet their supply remained constrained by the physical limits of transport capacity. LNG acquired unprecedented strategic importance, with Spain, France, Italy, the Netherlands, and Belgium becoming the EU's primary LNG entry points, equipped with regasification terminals. By contrast, Member States lacking direct access to LNG infrastructure were forced to depend on pipeline gas or cross-border flows from neighbouring countries, a dependency that limited their supply flexibility and, in some

cases, exposed them to higher costs and greater vulnerability during peak demand.

According to the Bundesnetzagentur (2023), Germany imported a total of 1,449 TWh of natural gas in 2022, a decrease from 1,652 TWh in 2021. The report documents the extreme price volatility that characterized the year: “the price of wholesale gas has quadrupled since March 2022, reaching a temporary record high (€315.9/MWh) at the end of August on the EEX energy exchange. At that level, wholesale gas prices were around four times what they were before the outbreak of the Russian war in Ukraine. By November prices fell again significantly and were at the year's lowest level on 1 November 2022 (€22.4/MWh). At the end of the year, the wholesale price was €63.8/MWh, which was slightly below the expected wholesale price for 2023, most recently forecast at €88.7/MWh” (Bundesnetzagentur, 2023).

Statistics Bundesamt (Destatis) (2026) reporting yearly natural gas imports in Germany between 2021 and 2024 clearly show the impact of exceptionally high gas prices during the 2022 energy crisis: although the quantity imported declined substantially compared to 2021, total expenditure more than doubled. As shown in Table 6, imports fell from 4,219,158 TJ in 2021 to 2,837,775 TJ in 2022 (-33%), yet the value of imports increased by 123%, reaching €67.9 billion. The average import price surged from €7.21 per TJ in 2021 to €23.92 per TJ in 2022, more than a threefold increase. For reference, 1 TJ is equivalent to approximately 0.0278 bcm, meaning that 4,219,158 TJ corresponds to roughly 117 bcm.

Year	Imported Natural Gas	Total Cost	Delta	Weighted Price
	<b>Terajoule (TJ)</b>	<b>1K Euro</b>	<b>Δ vs Y-1</b>	<b>Euro / TJ</b>
<b>2024</b>	1,686,855	17,435,344	-29%	10,336
<b>2023</b>	2,042,738	24,402,828	-64%	11,946
<b>2022</b>	<b>2,837,775</b>	<b>67,878,692</b>	<b>123%</b>	<b>23,920</b>
<b>2021</b>	4,219,158	30,431,509		7,213

**Table 6** German natural gas imports by volume, cost, and weighted price, 2021-2024. Note: Volume in terajoules (TJ); cost in thousand euros (1K Euro); weighted price in euros per terajoule (Euro/TJ). Delta indicates percentage change in total cost from the previous year. Source: Statistisches Bundesamt (Destatis) (2026).

Luckily, Germany's natural gas consumption declined significantly in 2022, falling by approximately 14% compared with the average consumption of the previous four years (Bundesnetzagentur, 2023). Weather conditions played a substantial role in this reduction, as temperatures in 2022 were on average 1.1°C higher than the mean annual temperature observed between 2018 and 2021, contributing to lower heating demand. These temperature dynamics, combined with behavioural adjustments and industrial demand reduction, contributed to a marked contraction in gas consumption. As reported by Bundesnetzagentur (2023), the legal storage level requirements for storage facilities on 1 October (85%) and 1 November (95%) were each surpassed. Storage was already 85% full at the beginning of September and reached 95% on 12 October, reflecting Germany's stricter national requirements, which exceed the EU targets of 80% and 90% under Regulation (EU) 2022/1032. Introduced via the Gas Storage Act (*Gasspeichergesetz*) in April 2022 following the cessation of Russian gas deliveries, the stricter approach proved successful: by 1 October storage reached 91%, and by 1 November 99%. The German case demonstrates that the economic burden of the 2022

energy crisis was primarily driven by unprecedented price escalation rather than increased physical import volumes.

Italy's natural gas import volumes remained relatively stable before and after the 2022 crisis, according to Table 7. However, the total cost of these imports more than quadrupled during the energy shock, reflecting the extreme price surge rather than a change in quantity (Istat, 2024).

Year	Imported Natural Gas	Total Cost	Delta	Weighted Price
	Terajoule (TJ)	1K Euro	Δ vs Y-1	Euro / TJ
<b>2023</b>	2,355,483	29,230,000	-53%	12,409
<b>2022</b>	<b>2,765,731</b>	<b>62,430,000</b>	<b>363%</b>	<b>22,572</b>
<b>2021</b>	2,781,130	13,470,000		4,843

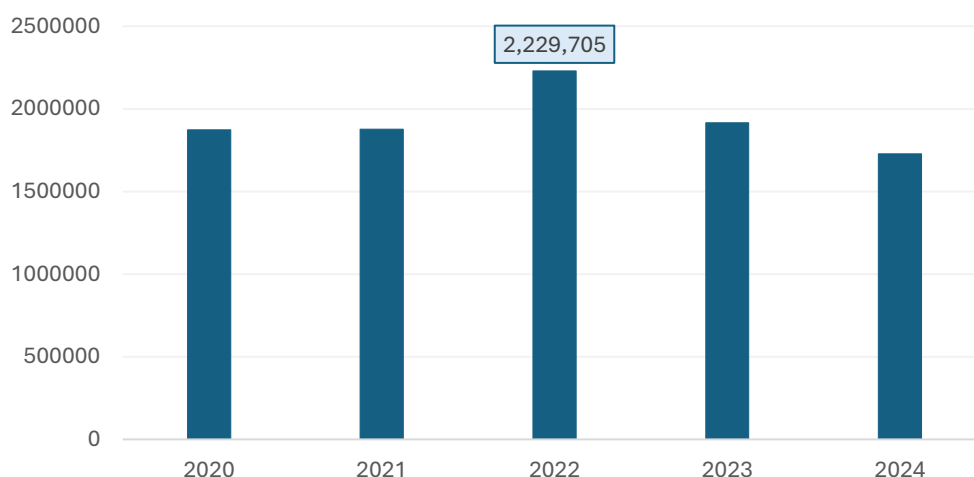
**Table 7** Italian natural gas imports by volume, cost, and weighted price, 2021-2023. Note: Volume in terajoules (TJ); cost in thousand euros (1K Euro); weighted price in euros per terajoule (Euro/TJ). Delta indicates percentage change in total cost from the previous year. Sources: Eurostat, nrg\_ti\_gas (2026); ISTAT (2024).

One key factor explaining why Italy's natural gas imports remained stable in 2022, despite record-high prices, was the binding effect of EU Regulation (EU) 2022/1032. Italy's storage capacity is among the largest in the European Union (see Table 5), making it directly subject to the Regulation's mandatory fill targets. This obligation was compounded by critically low storage levels at the outset of the crisis. According to GIE (2022), Italian storage facilities were only 35% full in the first half of 2022, compared to 42% during the same period in 2021: a trend consistent with the broader European situation described in Section 3.2.

Gas demand in Italy declined by 10% in 2022 to 68.7 bcm, driven down by a lower consumption in all sectors. Gas consumption contracted in the residential and tertiary sector (-16%), because of warmer weather than in

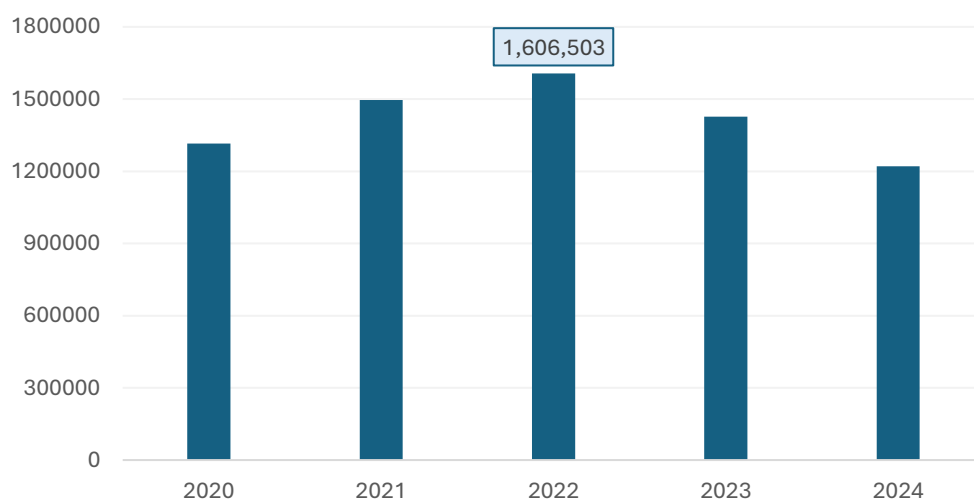
2021, and energy conservation efforts. It also decreased in the industrial sector (-14%) due to the effect of the increase in commodity prices and the unstable macroeconomic situation that led to a drop in industrial production in some energy-intensive sectors. Gas consumption was cut in the power generation sector (-3%) as a result of higher gas prices, despite the drop in hydro production caused by extreme drought. If the weather were the same as the previous year, Italian gas demand would have decreased only by 8% (Enerdata, 2023a). This pattern underscores the binding impact of EU Regulation (EU) 2022/1032, which compelled Italy to maintain high import volumes despite falling domestic demand and record prices. Faced with critically low storage levels and a binding 90% fill target, Italy was forced to continue purchasing gas despite historically high prices. The result was a substantial financial burden for both private operators and the State, arising from the sharp divergence between the high prices paid during mandatory summer injections and the significantly lower prices at which the stored gas was eventually sold when withdrawn for consumption.

The French case is comparable to the German and Italian ones, given its substantial UGS capacity (see Table 5). Meeting the EU's mandatory fill targets required significant physical imports during the injection season, particularly LNG and pipeline gas from Norway. As Jaller-Makarewicz (2023) observes: “France paid about €32 billion for imported LNG in 2022, a record high, according to Eurostat. The largest amounts were paid to the U.S. (€16.0 billion), Russia (€5.4 billion), Qatar (€3.2 billion), Algeria (€2.4 billion), Angola (€1.4 billion) and Norway (€1.2 billion)”. As in Germany and Italy, France also recorded a significant decline in gas consumption. GRTgaz reported a 9% drop in 2022, attributed to milder weather, high prices, and lower household use (Jaller-Makarewicz, 2023).



**Figure 28** France – Annual natural gas imports, 2020-2024. Note: Volume in Terajoules (TJ). Source: Eurostat, nrg\_ti\_gas (2026).

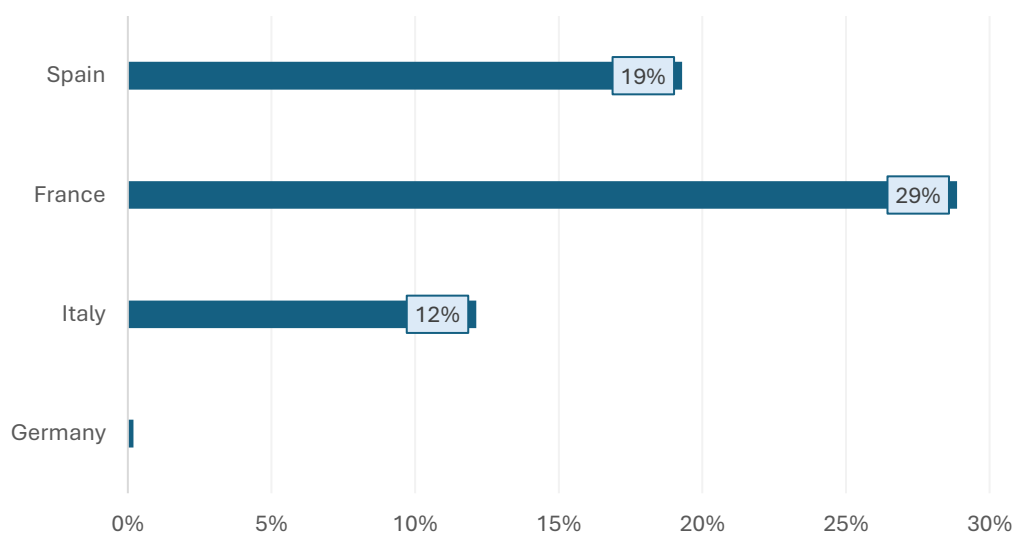
Given Spain’s very limited UGS capacity (see Table 5), its 2022 natural gas import peak – measured in Terajoules – cannot be explained primarily by storage obligations, but rather by its infrastructure position within the European gas system.



**Figure 29** Spain – Annual natural gas imports, 2020-2024. Note: Volume in Terajoules (TJ). Source: Eurostat, nrg\_ti\_gas (2026).

Based on ACER (2025) data on LNG regasification capacity in EU Member States (2021-2025), Spain functions as Europe's principal LNG

gateway in terms of infrastructure, with the largest capacity in the EU (60 bcm/year), followed by France (39 bcm/year). In 2022, as Russian pipeline flows to Europe declined sharply, LNG cargoes were redirected toward European markets offering premium prices, and Spain’s infrastructure positioned it as a key entry point. Although Spain became an important LNG re-export and transit hub during the crisis, limited pipeline interconnection capacity with France constrained its ability to transmit large volumes into Central Europe. According to the World Integrated Trade Solution (2026), Spain imported 21.6 billion kilograms of liquefied natural gas in 2022, at a total cost of \$22.6 billion. This volume was nearly double that of Italy (11.5 billion kg) but considerably lower than that of France (29.6 billion kg). As shown in Figure 30, Spain accounted for approximately 19% of total EU LNG imports in 2022, while France accounted for 29%.



**Figure 30** Share of EU LNG Imports by Member State, 2022. Source: World Integrated Trade Solution (2026).

The Iberian gas market (MIBGAS) price for Spain rose from slightly more than €19/MWh, on average, between 2016 (the year in which the index was created) and 2019, to well over €200/MWh on several occasions in

2022, peaking at an all-time high of €225/MWh on 29 August. However, in 2023, prices have fallen significantly, with the latest prices on both markets standing at around €30/MWh. These wholesale price developments are passed through in part to retail prices, depending on the taxes and fixed charges paid by agents and the type of contract they have with retailers (Matea, 2023). Demand for gas from households and SMEs in Spain was 5.1% lower in the first half of 2022 and 30.8% lower in the second half compared with the 2017–2021 average. According to the Banco de España (2023), the decline in the first half can be largely explained by relatively high temperatures, while up to one-third (approximately 10 percentage points) of the reduction in the second half may be attributable to other factors, including the sharp increase in retail prices. At the same time, as reported by Matea (2023), demand for gas among firms (excluding SMEs) fell by 8% in the first half of 2022 and by 34% in the second half. The structure of gas supply contracts varies across sectors: among firms overall, 30% are fixed-rate and 28% are indexed, while in industry the share of indexed contracts rises to 42%, reaching 49% in gas-intensive industries.

#### **4.3 The cost of energy security on private operators: financial losses and government support mechanisms**

European governments faced the imperative of procuring natural gas to comply with the Storage Regulation (EU) 2022/1032, even under the most unfavourable price conditions in history. This section examines how this burden was managed through private and state-owned energy organisations. It first analyses the German case of Uniper, whose forced procurement of gas at record-high prices led to severe economic losses and near-collapse. It then turns to the Italian experience, where the main actors were the partially state-owned entities GSE and Snam. Although they also

incurred substantial expenditure, their losses were better absorbed through government protection mechanisms, which compensated for the gap between high purchase prices and the comparatively lower prices at which the gas was eventually sold.

Under Regulation (EU) 2022/1032, the legal obligation to meet minimum storage filling levels was formally imposed on Member States, though in practice the operational burden fell on storage system operators and market participants across most European countries. Private energy companies and gas traders, including major utilities, mid-stream traders, and integrated energy groups such as Uniper and (formerly) Gazprom Germania in Germany, Eni and Edison in Italy, Engie in France, and various supplier companies across Europe, were the actors purchasing gas on global markets to fill storage and meet domestic demand. These private actors were the ones bidding in spot and forward markets during 2022, when prices reached historical highs, and in many cases, they were among the main buyers of gas destined for both storage and consumption.

As a result, private operators were required to secure substantial quantities of natural gas irrespective of prevailing market conditions, often purchasing volumes that exceeded short-term consumption needs to comply with mandatory filling trajectories. Storage decisions that would ordinarily be guided by seasonal price spreads and commercial optimisation were therefore reshaped by regulatory imperatives and security-of-supply considerations. In countries such as Germany and Italy, private companies holding storage capacity were effectively compelled to inject gas regardless of prevailing price levels, bound by mandatory injection schedules that remained binding even when forward price spreads were unfavourable.

From a strictly commercial perspective, purchasing gas at the peak prices observed in mid-2022 was economically unfavourable for many private

operators. In several Member States, retail tariffs were regulated or subject to political constraints, and long-term supply contracts with industrial clients limited the immediate pass-through of wholesale price increases. Consequently, gas acquired on the spot market at historically elevated prices could not be resold domestically at equivalent margins, implying negative expected returns on storage injections. Operators were therefore aware that procurement under these conditions would severely strain their balance sheets, yet abstaining from purchases was not a viable alternative. Regulatory storage obligations, contractual delivery commitments, and the systemic risk associated with supply shortages compelled firms to secure volumes despite adverse price signals. In this context, behaviour that might seem commercially irrational was, in fact, a constrained rational response to a regulatory and geopolitical emergency that subordinated profitability to security of supply.

#### **4.3.1 Germany: Uniper and the cost of mandatory storage filling**

One of the most illustrative cases of the impact of the 2022 gas crisis on private energy operators is Uniper, Germany's largest gas importer. The company's experience is particularly relevant to understanding the costs and strategies associated with mandatory storage filling, as it operated simultaneously in two capacities: as a storage customer legally obliged to meet Germany's filling targets, and as a storage operator managing critical infrastructure. In the German regulatory framework, the legal obligation to meet storage filling targets rests primarily on storage users (i.e. market participants holding storage capacity rights), rather than on storage system operators themselves, which are instead responsible for providing and managing the infrastructure.

When Russian gas volumes were sharply reduced and then cut off in mid-2022, Uniper was forced to secure replacement gas on the spot market at historically high prices in order to fulfil long-term customer contracts.

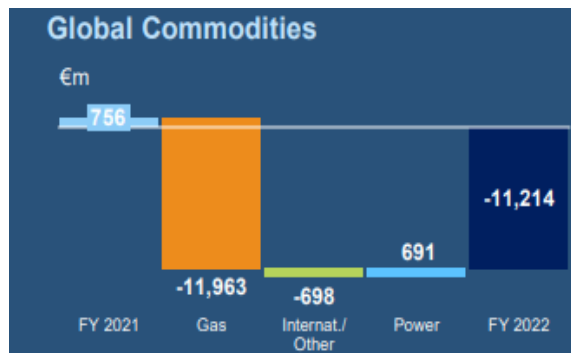
Crucially, Uniper also faced the additional burden of Germany's mandatory storage filling targets under the Gas Storage Act (Gasspeichergesetz). In its role as a storage customer, the company was required to meet legally binding filling targets of 85% by 1 October and 95% by 1 November 2022, at a time when spot market prices were exceptionally high. The combination of these regulatory obligations and existing supply commitments placed significant financial strain on the company, contributing to its economic distress.

In February 2023 The German energy group Uniper has released its 2022 results, posting a €19 billion net income loss due to additional costs of gas procurement, compared to a €4.1 billion net income loss in 2021, and an adjusted EBIT loss of €10.8 billion; the economic debt increased from €0.32 billion in 2021 to €3.05 billion in 2022 (Uniper Full Year 2022 Results, 2023). The company recorded one of the largest corporate losses in German history with adjusted EBIT deeply negative as procurement costs skyrocketed. As a result, in December 2022 the European Commission approved state aid to Uniper subject to certain conditions.

In December 2022, Germany nationalised Uniper through a financial stabilisation package approved by the European Commission. The Federal Republic provided approximately €13.5 billion in financial resources during the 2022 financial year through capital increases (Uniper, 2025), effectively becoming the company's main shareholder with a 99.1% stake. This followed the acquisition of the previous 80% shareholding from Fortum and the injection of fresh equity (Enerdata, 2023b). According to Uniper's (2025) official statement: “the financial support from the German government was necessary because Uniper had to procure gas elsewhere at high cost due to a lack of gas supplies from Russia and was therefore in financial difficulties. With the help of the stabilization measures, Uniper was able to meet its supply obligations and reliably deliver gas to

municipal utilities and German industry”. The stabilization measures included liquidity support, extended credit facilities via the state bank KfW, and other backstops to ensure Uniper could continue trading and fulfilling supply contracts.

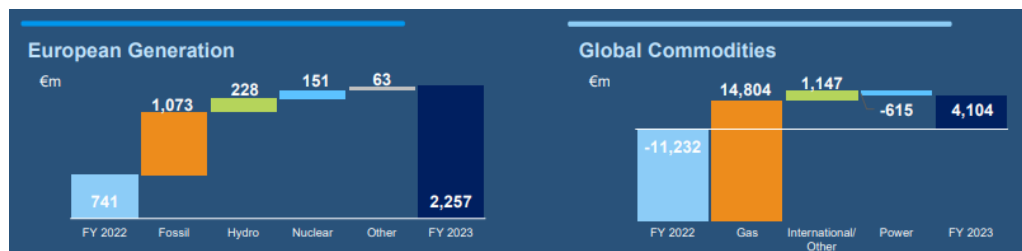
Uniper's Full Year 2022 Results Presentation (2023) identifies natural gas as the primary driver of the company's negative Adjusted EBIT. As shown in Figure 31, it was the most significant loss-contributing segment in the overall reconciliation. The company commented on this gas result as follows: “substantial additional costs for procuring replacement gas volumes due to Russian curtailments, partly offset by strong optimization results in volatile markets and hedging transactions for futures gas deliveries in the current year” (Uniper's Full Year 2022 Results Presentation, 2023).



**Figure 31** Adjusted EBIT – Development by sub-segment, year 2022. Source: Uniper Full Year 2022 Presentation (2023).

In 2023, Uniper returned to positive adjusted earnings, posting around €6.4 billion in adjusted EBIT and €4.4 billion in adjusted net income, largely driven by its gas business and European fossil generation (Uniper Full Year 2023 Results, 2024). The company attributes this recovery primarily to the disappearance of losses related to replacement procurement costs. This dynamic is particularly relevant in the context of storage obligations: the severe losses recorded in 2022, amounting to

€13.2 billion, were closely linked to the need to procure high-cost gas both to fulfil long-term supply contracts and to meet mandatory storage filling requirements. As market conditions normalised in 2023, these extraordinary costs declined significantly, contributing to a reduction in losses of approximately €2.3 billion, despite a lower contribution from portfolio optimisation activities. As illustrated in Figure 32, the gas segment played a decisive role in driving the company’s financial recovery, highlighting how the economic burden associated with storage obligations was largely concentrated during the peak of the crisis.



**Figure 32** Adjusted EBIT – Development by sub-segment, year 2023. Source: Uniper Full Year 2023 Presentation (2024).

#### 4.3.2 Italy: Public intervention as buyer of last resort

The Italian case illustrates how governments relied on private or semi-public operators to implement security-of-supply policies, including storage filling and the diversification of imports. During spring 2022, market incentives for storage injections were weak because the gas forward curve was in backwardation, meaning that spot prices exceeded winter futures prices. Under such conditions, purchasing gas for storage implied a negative expected margin, since operators risked selling the stored gas later at a lower price. As a result, commercial actors were reluctant to inject additional volumes into storage.

Unwilling to impose a mandatory storage obligation on commercial operators (for example, proportional to their historical or expected sales in the residential sector), the Government and Arera (*Autorità di Regolazione*

*per Energia Reti e Ambiente*), the Italian regulatory authority for energy, networks and the environment, decided to attempt to break the deadlock by introducing in April 2022 a pair of incentives: a storage premium and a two-way Contract for Difference (CfD), the latter serving as a form of insurance against price volatility for gas purchases intended for storage (Goldoni & Repetto, 2022).

The storage premium consisted of a financial incentive granted to operators injecting gas into storage facilities during the summer injection season. The objective was to partially compensate market participants for the risk associated with purchasing gas at very high spot prices in order to store it for future use. The two-way Contract for Difference (CfD), instead, acted as a risk-sharing mechanism between the state and the storage operator. Under this arrangement, if the market price of gas at the time of withdrawal was lower than the purchase price, the operator would receive compensation for the difference; conversely, if market prices increased, the operator would return part of the gains. In this way, the scheme aimed to reduce price uncertainty and encourage storage injections despite the highly volatile market environment.

However, as Goldoni & Repetto (2022) documented, even these measures failed to ensure the desired regular progress in filling storage facilities in the months preceding the formal adoption of the EU Storage Regulation in June 2022. Faced with persistently low utilisation rates of injection capacity and growing uncertainty over market participants' willingness to inject gas at high prices, the Italian government intervened in June 2022 through a decree by the MiTE (Ministry of Ecological Transition), authorising two state-linked entities, Snam, Italy's gas transmission and storage infrastructure operator, and GSE (*Gestore dei Servizi Energetici*), a public company responsible for energy-related public services and incentives, to begin purchasing gas from the end of that month. This

measure effectively established a last-resort service, aimed at guaranteeing progress towards storage targets in a context where market-based incentives alone were not delivering the required volumes.

As reported by GSE (2023) in its 2022 Annual Report: “Article 5-bis of Decree-Law No. 50 of 17 May 2022 (the so-called '*Decreto Aiuti*'), coordinated with the Conversion Law No. 91 of 15 July 2022, established that GSE, also through agreements with companies directly or indirectly controlled by the State and through close coordination with the main transmission company, shall provide a last-resort filling service through the purchase of natural gas for storage purposes and subsequent sale by 10 November 2023, within a limit of €4 billion”. GSE's 2022 Annual Report documents the entity's role as last-resort gas purchaser during the critical summer months of 2022. Between 25 July and 19 September, GSE purchased and stored a total of 17,878 GWh of natural gas through bilateral contracts with Eni (8,633 GWh) and Snam (9,245 GWh). The total cost of these operations amounted to €3,995 billion, nearly reaching the €4 billion limit authorized by the *Decreto Aiuti* (GSE, 2023). According to GSE (2023), total operator demand for gas from the storage facility reached 5,679 GWh, a volume that accounted for approximately 32% of the total gas stored by GSE as part of the state-backed filling initiative.

Examining specific income statement items from GSE's 2022 Annual Report, particularly revenues, costs, and the impact of energy and gas operations over the 2021-2022 period, reveals the dramatic financial impact of the energy crisis on Italy's last-resort purchaser, as illustrated by Table 8.

€ thousand	2021	2022	Δ% vs Y-1
REVENUE from sales and services	54,401,461	120,624,414	122%
o/w From energy and gas sales	42,206,109	109,953,734	161%
Share of total Revenues	78%	91%	14 pp
COSTS for purchase of raw materials	42,791,063	111,816,597	161%
o/w Of energy and gas purchases	38,434,061	106,655,245	178%
Share of total Costs	90%	95%	5 pp

**Table 8** GSE revenue and procurement costs: the impact of energy and gas operations, 2021-2022. Source: GSE, 2022 Annual Report (2023).

Total revenue from sales and services more than doubled, surging from €54.4 billion in 2021 to €120.6 billion in 2022 (+122%). As detailed in GSE's 2022 Annual Report (2023), a significant portion of the entity's revenue came from energy and gas sales conducted through GME (*Gestore dei Mercati Energetici*). The report specifies that this revenue stream, amounting to €63.6 billion, was: “attributable both to the sharp increase in trading prices on the electricity and natural gas markets, and to the higher volumes intermediated” (GSE, 2023). This explicit acknowledgement from GSE itself confirms that the revenue explosion was driven by two simultaneous factors: the extraordinary price surge and the increased volumes that GSE was compelled to intermediate under the last-resort purchasing mechanism.

On the cost side, the financial statement reveals an even more dramatic shift. Total costs for raw materials purchases increased by €69.1 billion, from €42.8 billion in 2021 to €111.8 billion in 2022 (+161%). As GSE (2023) explains, this variation is primarily attributable to two factors. First, and most significantly, the costs of energy and gas purchases on GME-managed markets rose by €64.2 billion, driven by “both the increase in prices on the electricity and natural gas markets, and the higher volumes

intermediated”. Second, the report explicitly acknowledges the impact of the regulatory mandate: the figure includes “gas purchases made by GSE in the second half of 2022 for the last-resort filling service, as regulated by Decree-Law 50/2022 (€3,980,089 thousand), which were not present in the previous financial year” (GSE, 2023).

The losses associated with the gas purchased for storage during the 2022 crisis, estimated at around €4.8 billion, were not eliminated but rather redistributed across the gas system. This figure does not refer to the initial budget allocated to individual intervention instruments, such as the approximately €4 billion mandate granted to GSE, but to the ex-post losses generated by purchasing gas at exceptionally high prices and subsequently valuing or releasing it under significantly lower market conditions. Through the neutrality charge mechanism introduced by the Italian regulator ARERA, the financial burden linked to the emergency procurement carried out by entities such as GSE and Snam was spread over time and across all gas users. In practice, the exceptional costs generated by purchasing gas at peak market prices were socialised through the tariff system rather than being absorbed by individual operators. This mechanism illustrates a broader feature of the crisis response: when market incentives failed to ensure sufficient storage injections, the State effectively assumed the role of buyer of last resort and redistributed the associated financial risk across the entire gas system. While this approach safeguarded security of supply ahead of the 2022-2023 winter, it also implied that the economic burden of the crisis was ultimately borne by end users through regulated charges.

### **4.3.3 Summary**

The EU Storage Regulation of 2022 established binding targets for gas storage filling levels but left Member States discretion over the economic instruments used to achieve them. National governments were therefore

responsible for designing support mechanisms or regulatory measures to ensure that market participants injected sufficient gas into storage facilities. Germany relied primarily on State intervention and direct financial support to market actors, while Italy initially relied more on market incentives before moving to direct state intervention when injections proved insufficient. In Germany, authorities combined mandatory storage targets with strong public involvement in the gas market, including the empowerment of the market area manager, a state-mandated entity responsible for ensuring the operational functioning of Germany's gas market, to procure gas if private injections proved inadequate and the provision of extensive financial support to key gas importers.

A contrasting dynamic can be observed in the German case involving Uniper when compared with the Italian framework. Unlike the Italian approach, where financial risks linked to emergency procurement were anticipated and distributed through regulatory mechanisms, Uniper initially absorbed the impact directly at the corporate level. As a major gas importer bound by long-term supply obligations to utilities and industrial customers, the company was forced to replace missing Russian pipeline deliveries with significantly more expensive spot market purchases. Because these higher procurement costs could not be immediately passed through to customers, the company accumulated substantial losses during 2022, eventually requiring a large-scale rescue and nationalisation by the German government. In Italy, by contrast, the authorities first introduced market incentives, such as a storage premium and a two-way Contract for Difference, to encourage injections, and later authorised State-linked entities such as Snam and GSE to intervene as buyers of last resort when market responses proved insufficient.

The comparison between the two cases highlights different institutional approaches to managing the crisis: in Italy, the financial risks associated with emergency gas procurement were largely socialised ex-ante through regulatory mechanisms, whereas in Germany the shock initially manifested itself as a corporate solvency crisis before ultimately being absorbed by the State.

#### **4.4 Energy security as a public good: assessing the efficiency of the storage Regulation (EU) 2022/1032 and its social cost**

This section begins by framing energy security as a public good, before turning to an analysis of the economic interventions carried out by the European Union and the governments of selected Member States during the recent energy crisis. It explores the variety of policy instruments deployed to support private actors, most notably energy importers, and to shield consumers from the most acute effects of price shocks. The section thus highlights how the economic burden of the crisis was socialised across society, evidenced by the significant fiscal impact of increased government expenditure and persistently high budget deficits. Table 10 illustrates this point by presenting the general government deficit/surplus for the EU-27 and selected countries, demonstrating the negative fiscal impact of the energy crisis and the subsequent mitigating measures adopted by these governments. While the storage Regulation (EU) 2022/1032 proved highly effective in securing supply and stabilising markets in the wake of the Russian supply shock, this section ultimately questions its economic efficiency, examining how uncoordinated national implementations amplified price surges, created market distortions, and resulted in a significant fiscal burden that was ultimately socialised across European society.

Energy security can be interpreted as a public good, as its benefits are both non-excludable and non-rival, with its positive external impact constituting the primary value of such a good. Although consumers are not required to pay directly for a public good, it is not without cost; public goods, particularly those provided by the state (though not necessarily produced by it), are typically funded through taxation. In seeking to guarantee energy security during the critical period of the 2022 energy price crisis, European Member States and EU institutions intervened through multiple channels, implementing large-scale fiscal measures to stabilise energy markets and secure gas supply. These interventions confirm that private market actors did not bear alone the costs of ensuring energy security during the crisis, including the purchase of vast natural gas quantities to meet the EU's 90% storage requirement. Governments provided financial support to private organisations that were required to purchase natural gas at record-high prices to fill storage facilities, and in some cases directly intervened in the market through state-owned or state-linked companies (see Section 4.3).

At the same time, additional economic instruments were introduced to shield households and industries from the sharp increase in retail gas prices. As a result, the financial burden generated by the crisis was largely transferred from individual market participants to the public sector and the wider economy. In practice, this redistribution occurred through three main fiscal channels: increased public borrowing, which expanded government debt; adjustments to taxation, particularly through reductions or reallocation of energy-related taxes; and the use of tariff charges and regulated levies applied within energy systems, ultimately borne by energy consumers.

As reported by Sgaravatti et al. (2023), since September 2021, €651 billion has been allocated and earmarked across European countries to shield

consumers from rising energy costs, including €540 billion from EU Member States. A significant portion of this funding was directed toward ensuring energy security through gas storage, which became a central pillar of the EU's crisis response following the adoption of Regulation (EU) 2022/1032. Governments intervened to support storage filling through various mechanisms: direct procurement by state-owned or state-linked companies, loan guarantees for utilities facing liquidity constraints due to storage obligations, and the creation of last-resort procurement frameworks to meet binding storage targets. Beyond storage, the remaining funding addressed three distinct policy objectives in the period September 2021 to January 2023. First, governments allocated resources to protect households and firms from rising energy prices and their consequences on the cost of living. Second, support was provided on a per capita basis, ensuring a minimum level of assistance across populations. Third, significant sums were directed toward utilities to meet their liquidity needs through loans, bailouts, and fully fledged nationalisations (Sgaravatti et al., 2023).

According to the 2024 Report on Energy Subsidies in the EU, “total energy subsidies in the EU jumped from €213 billion in 2021 to €397 billion in 2022 and decreased by 10% to €354 billion in 2023 – equivalent to 2.10% of GDP, down from 2.37% in 2022” (Directorate-General for Energy, 2025). The report further notes that crisis measures to protect consumers from high prices accounted for an estimated €145 billion in 2023, with households receiving €121 billion in direct support between 2021 and 2023, more than industry (€30 billion) and transport (€28 billion) combined. Cross-sectoral support reached €125 billion. This category includes measures such as general tax reductions and price caps, which were applied across the economy rather than targeted at specific sectors.

Meanwhile, fossil fuel subsidies declined by 18% from their 2022 record, totalling €111 billion in 2023.

The fiscal and regulatory response to the 2022 energy crisis varied across EU Member States, reflecting differences in institutional frameworks, energy systems, and fiscal capacity. Governments intervened extensively through fiscal transfers, price controls, and regulatory mechanisms to ensure that storage obligations were met and that energy markets remained stable. Although the specific instruments differed across countries, a consistent pattern emerges: the economic burden associated with guaranteeing energy security was ultimately redistributed across society through a combination of public spending, regulatory charges, and market interventions affecting both taxpayers and energy consumers. The following cases, namely Germany, Italy, France, and Spain, illustrate the diversity of policy tools used to finance these interventions during the crisis.

At the end of September 2022, as part of an "economic defence shield against the consequences of the Russian war of aggression", the German Federal Government announced that it would provide the Economic Stabilisation Fund (WSF) with a credit authorisation of €200 billion. The reorientation of the fund originally set up to deal with the economic consequences of the coronavirus pandemic is intended to finance the measures to overcome the energy crisis up to and including the year 2024. These measures included the financing of the gas price brake and the electricity price brake (German Council of Economic Experts, 2022). Germany's intervention to support energy-related companies was unprecedented in scale. This was due, in large part, to the country's possession of Europe's largest gas storage capacity (see Table 5), which entailed particularly high costs for filling storage facilities. In April and May 2022, the federal government placed Gazprom Germany under

trusteeship, transitioning the previous trustee appointed under foreign trade law to a new mandate under the Energy Security Act. Concurrently, it prevented the company's insolvency, triggered by Russian sanctions, through a loan of €9-10 billion (Sgaravatti et al., 2023). In July 2022, the government further committed a €17 billion rescue package to bail out the utility company Uniper, as discussed in Section 4.3

In Italy, the government adopted a broad package of fiscal and regulatory measures to mitigate the impact of the energy crisis and support the functioning of the gas system. In addition to its direct intervention through Snam and GSE in gas procurement and the introduction of storage incentives such as the storage premium and the two-way Contract for Difference, already discussed in Section 4.3, Italy's initial response to rising energy prices consisted of short-term measures worth nearly €3 billion, approved in September 2021 to offset expected retail power price increases until the end of the year. The package was split into €2 billion to eliminate general system charges in the electricity sector and €480 million to reduce general charges on gas bills (Sgaravatti et al., 2023). These early measures, however, represented only a fraction of the total fiscal support that the Italian government would ultimately deploy over 2022 and 2023.

According to Nascia, et al. (2023, p. 107), the Italian government's response to the energy crisis comprised a series of fiscal interventions. These included reducing the value-added tax (VAT) on gas for civil and industrial use to 5%, which cost approximately €4 billion, and eliminating general system charges for electricity and gas, at a cost of €21 billion for 2021, 2022 and the first quarter of 2023. Furthermore, between March and December 2022, cuts in excise duties on petrol, diesel and gas were introduced, alongside a reduction in VAT on gas for transportation, amounting to a further €9 billion. In January 2022, the Draghi government introduced a temporary windfall tax on companies that had benefited from

the increase in energy prices. This measure established an additional rate of 10% for companies that import, distribute and sell gas or electricity, as well as those that produce, extract, distribute and sell petroleum products, and which had increased their profits by at least 10%, or at least 5 million euros, between October 2021 and March 2022 compared to the same points twelve months previously (Nascia et al., 2023, pp. 108-109).

The introduction of this measure reflected the highly uneven economic effects of the energy crisis across the energy sector. While some companies faced severe financial stress due to their exposure to rapidly increasing procurement costs and contractual supply obligations, other market participants experienced substantial increases in revenues as wholesale and retail energy prices surged. Firms involved in energy production, extraction, or trading, particularly those not constrained by fixed-price supply commitments, were able to sell energy at significantly higher market prices, generating extraordinary profits during the crisis period. The windfall tax was therefore designed to capture part of these unexpected gains and use them to support broader public interventions aimed at mitigating the economic impact of the energy shock.

As a result, the financial burden generated by the crisis response was ultimately distributed across several channels: public debt borne by taxpayers, extraordinary taxation on energy producers, and tariff adjustments within the energy system that were indirectly passed on to consumers. This combination of fiscal intervention and regulatory redistribution reflects the broader pattern observed across Europe, whereby the costs of ensuring energy security during the crisis were largely socialised across society rather than absorbed by private market actors alone.

France and Spain also implemented extensive fiscal and regulatory measures to mitigate the impact of the energy crisis and stabilise energy

markets during the period of exceptionally high gas prices. In France, the government introduced a comprehensive package centred on the so-called tariff shield, initially adopted in late 2021 and extended throughout the crisis. This mechanism capped increases in regulated gas and electricity tariffs for households and small businesses, limiting retail price increases and compensating energy suppliers through transfers from the State budget. In addition, the French government implemented direct financial support measures for vulnerable households and energy-intensive firms and strengthened its intervention in the electricity sector, including the full nationalisation of the utility EDF in 2022. According to estimates compiled by Bruegel, France allocated approximately €70 billion in energy crisis support measures between 2021 and early 2023, reflecting one of the largest fiscal responses among EU Member States (Sgaravatti et al., 2023).

Spain adopted a somewhat similar strategy, combining fiscal transfers with regulatory interventions aimed at limiting the transmission of wholesale gas prices to electricity consumers. One of the most prominent measures was the so-called Iberian exception, introduced jointly with Portugal in 2022 with the approval of the European Commission. This mechanism imposed a temporary cap on the price of natural gas used in electricity generation, reducing wholesale electricity prices and partially insulating consumers from the surge in gas costs. Overall, Spain mobilised energy crisis support measures estimated at around €35-40 billion between 2021 and early 2023 (Sgaravatti et al., 2023).

COUNTRY	ESTIMATED PUBLIC SUPPORT	KEY POLICY MEASURES	MAIN FINANCING SYSTEMS
Germany	Up to €200 billion	Gas and electricity price brakes; nationalisation and financial support for energy companies (e.g. Uniper); liquidity support for utilities; trusteeship and stabilisation of Gazprom Germania	Primarily financed through public borrowing and state guarantees via the Economic Stabilisation Fund
Italy	Over €50 billion in crisis-related measures (2021–2023)	Reduction of VAT on gas (to 5%); elimination of general system charges; tax credits for energy-intensive firms; excise duty reductions on fuels; storage incentives (CfD and storage premium); state intervention through Snam and GSE	Combination of public borrowing, windfall taxes on energy companies, ETS revenues, and tariff adjustments within the energy system
France	~€70 billion (2021–2023)	Tariff shield ( <i>bouclier tarifaire</i> ) limiting gas and electricity price increases; direct subsidies to households and firms; nationalisation of EDF; compensation to energy suppliers for regulated price caps	Primarily financed through state budget transfers and increased public spending
Spain	~€35–40 billion (2021–2023)	Iberian gas price cap mechanism for electricity generation; tax reductions on electricity and energy bills; direct support for households and firms; tariff interventions	Combination of public budget support, electricity system adjustments, and regulated compensation mechanisms

**Table 9** Main national measures adopted in response to the 2022 energy crisis. Source: Sgaravatti et al. (2023); Nascia et al. (2023); German Council of Economic Experts (2022); European Commission reports.

Fiscal data confirm that the response to the 2022 energy crisis had a measurable impact on public finances across the European Union. Energy-related support measures increased government expenditure and contributed to maintaining relatively high budget deficits in several Member States during 2022 and 2023. Although the magnitude of the intervention differed across countries, the evidence suggests that a substantial share of the costs associated with ensuring energy security was ultimately absorbed by national budgets and therefore borne, directly or indirectly, by taxpayers. Data from the European Central Bank confirm the scale of public intervention: discretionary fiscal support enacted by euro area governments in response to the energy crisis and high inflation is estimated at approximately 1.9% of GDP in 2022. This value remained largely stable at 1.8% in 2023, before declining sharply to 0.5% in 2024 (Checherita-Westphal & Dorrucchi, 2026).

As a direct consequence of the substantial fiscal effort documented above encompassing support for households, industries, and energy utilities, public finances came under increased pressure. This impact is reflected in the evolution of the general government balance, defined under the Maastricht framework as general government net lending (+) or net borrowing (–) according to the European System of Accounts (ESA). The general government sector includes central, regional, and local administrations as well as social security funds, thereby providing a comprehensive measure of the fiscal stance of a country. As illustrated in Table 10, after the exceptional deficits recorded during the COVID-19 pandemic in 2020 and 2021, government balances remained significantly negative in 2022 and 2023. This persistence of large deficits coincides with the period during which European governments implemented extensive fiscal measures to mitigate the impact of the energy crisis.

YEAR	2019	2020	2021	2022	2023	2024
Germany	47	-151	-117	-76	-105	-115
Spain	-38	-112	-82	-63	-50	-51
France	-58	-207	-165	-126	-152	-170
Italy	-26	-157	-164	-162	-153	-74
EU-27	-65	-908	-684	-511	-593	-566

**Table 10** General government deficit/surplus in selected EU countries, 2019-2024 (billion euros). Source: Eurostat, gov\_10dd\_edpt1 (2025).

While the COVID-19 pandemic remains the primary driver of the exceptionally large deficits observed in 2020 and 2021, the persistence of elevated fiscal imbalances in 2022 and 2023 reflects the continuation of expansionary policies, including the extensive public support measures introduced to mitigate the economic consequences of the energy crisis. In this sense, it is instructive to examine the cases of Germany and France, whose fiscal positions worsened from 2022 to 2023, with energy crisis support measures constituting a significant contributing factor. In this sense, it is instructive to examine the cases of Germany and France, where energy crisis support measures contributed significantly to fiscal deterioration. According to the OECD (2022), Germany's energy support packages were estimated at EUR 95 billion (2.6% of GDP), while France's direct energy support amounted to EUR 45.3 billion (1.6% of GDP) in 2023 (OECD, 2023).

The central question that emerges from this analysis concerns the efficiency of the EU Storage Regulation introduced in 2022. While the policy clearly succeeded in its primary objective of ensuring a high level of storage filling ahead of the winter seasons following the Russian supply shock, as illustrated in Figure 26, the broader question is whether the 90% storage target represented the least-cost strategy for guaranteeing energy

security. In other words, could the same outcome have been achieved with lower economic costs and fewer distortions in the energy market?

From a security-of-supply perspective, the Regulation can be considered highly effective, as the mandatory filling targets were reached by Member States within a relatively short timeframe, restoring confidence in the European gas system after the severe disruption caused by the reduction of Russian pipeline imports. High storage filling levels provided an important buffer against further supply interruptions and contributed to stabilising expectations in the gas market. As suggested by Fernández-Blanco et al. (2023), the presence of large strategic reserves can also function as a volatility-dampening mechanism, reducing the risk of extreme price spikes and improving the predictability of supply conditions during periods of high demand and limited supply.

However, the Regulation also generated significant economic costs and market distortions, one of the main issues being the lack of coordination among Member States during the initial implementation phase. Because all countries were simultaneously required to meet binding storage targets in a context of already constrained supply, governments and market participants entered the market at the same time to procure large volumes of gas. This contributed to intense bidding competition and likely amplified the price surge observed during the summer of 2022. Although it is difficult to isolate the precise effect of the Regulation on price dynamics, the simultaneous procurement pressure created by national compliance efforts probably pushed prices above the level that would have prevailed under a more coordinated strategy. Given the short-term inelasticity of gas demand, whereby storage obligations left buyers with limited ability to delay purchases, the additional demand generated by uncoordinated national filling efforts likely translated into a proportionally

larger price increase than would have occurred under a coordinated approach.

A second limitation of the Regulation (EU) 2022/1032 concerns the fragmented nature of national support instruments. As discussed throughout the chapter, the Regulation left Member States significant discretion in designing the economic mechanisms used to reach the storage targets. While this flexibility allowed governments to tailor policies to national circumstances, it also resulted in a patchwork of interventions, including direct state purchases, price caps, subsidies, and financial guarantees, that were largely designed reactively rather than as part of a coordinated European framework. This fragmentation increased the overall economic cost of the crisis response and generated uneven fiscal impacts across countries.

Finally, the analysis suggests that the financial burden associated with guaranteeing energy security was ultimately socialised across society. Although the immediate costs were initially borne by specific actors like gas importers, utilities, or state-owned companies, these costs were subsequently redistributed through public spending, regulatory charges, and taxation. As a result, the economic impact of the storage policy was ultimately absorbed by a combination of taxpayers, energy consumers, and public budgets. The fiscal data analysed in this chapter confirm that government deficits remained elevated during the peak years of the crisis, reflecting the extensive public intervention required to stabilise energy markets.

Taken together, these findings suggest that the storage Regulation (EU) 2022/1032 was effective but not necessarily efficient, highlighting the intrinsic nature of energy security as a public good. In conclusion, the Regulation should be understood as a crisis-driven policy that prioritised security over economic efficiency. While the 90% storage target proved

successful in restoring confidence and stabilising the gas system, future policy design could benefit from stronger coordination mechanisms at the European level and from ex-ante frameworks capable of achieving similar security outcomes at lower economic cost.

#### **4.5 Conclusions**

The impact of the 2022 storage Regulation (EU) 2022/1032 on Member States is represented by the extent to which they were required to procure natural gas under exceptionally adverse market conditions in order to meet mandatory storage filling targets. The burden associated with these obligations varied significantly across countries, largely reflecting differences in underground gas storage infrastructure and available capacity. These structural factors influenced both the volume of gas each country had to purchase, and the total expenditure incurred during the price peak of 2022.

The analysis of four major European economies, specifically Germany, Italy, France, and Spain, reveals that the quantity of natural gas they imported remained broadly stable despite the sharp escalation of gas prices between 2021 and the summer peak of 2022. As shown in Tables 6 and 7, the direct consequence was a dramatic increase in total expenditure: import costs more than doubled for France and nearly quadrupled for Italy compared to 2021. This apparent stability in import volumes, despite unprecedented price increases, reflects a combination of supply-side obligations and demand-side insulation. The Storage Regulation (EU) 2022/1032 compelled Member States to secure large quantities of gas for storage, ensuring sustained import volumes regardless of price. Simultaneously, governments across Europe intervened to protect final consumers from soaring energy costs through price caps, tax reductions,

and direct subsidies, preventing the sharp demand contraction that would normally accompany such extreme price spikes.

Spain represents a distinctive case within this group. Whereas Germany, Italy, and France faced significant procurement pressure due to their storage filling obligations under the Regulation, Spain's limited underground gas storage capacity meant it was not subject to comparable mandatory targets. Nevertheless, its import volumes remained stable. This outcome reflects its strategic geographical position and extensive LNG regasification infrastructure, which enabled Spain to function as a key entry point and re-export hub for LNG destined for other European markets. In Spain's case, therefore, stable imports were driven primarily by its role in facilitating European LNG supply rather than by domestic storage requirements.

Turning to how the economic costs of emergency gas procurement were distributed across the energy system, the German case clearly illustrates the financial vulnerability of private market actors operating under extreme market conditions. In particular, the experience of Uniper demonstrates how a major gas importer and storage operator was forced to purchase large volumes of gas at exceptionally high prices in order to maintain supply and fulfil storage obligations, generating substantial financial losses. The recovery observed in the following year was only made possible through the intervention of the German government, which nationalised the company through a large-scale financial stabilisation package. By contrast, the Italian case followed a different trajectory. After initial market-based incentives proved insufficient to ensure adequate storage injections, State-linked entities (Snam and GSE) were authorised to intervene directly in the market and purchase natural gas as buyers of last resort. The analysis of key financial indicators highlights the significant increase in procurement costs faced by these entities during

2022, accompanied by a parallel rise in revenues from sales and services that allowed the company to withstand the immediate financial impact. At the system level, however, the financial burden associated with these emergency purchases was not eliminated but redistributed. The losses generated by the gas procured at peak prices were spread across the gas system through a neutrality charge mechanism introduced by the Italian energy regulator ARERA, effectively distributing the cost of the crisis over time and across all gas users.

The conceptualisation of energy security as a public good, with its distinctive characteristics, helps explain why European Member States responded to the energy crisis by deploying extensive social and fiscal measures aimed at supporting private actors and final consumers. Against this backdrop, the thesis ultimately seeks to address a critical research question: was the EU Storage Regulation an efficient tool for guaranteeing energy security, and how were its costs ultimately distributed across society? The underlying assumption is that a binding and demanding natural gas storage target was, in certain respects, beneficial to Member States, thereby providing an important buffer against further supply interruptions and helping to stabilise expectations in the gas market. On the other hand, the massive and concerted purchasing of natural gas from alternative suppliers (in place of Russian imports), undertaken by Member States compelled to meet the Regulation's targets, distorted market dynamics and contributed to further price increases. This occurred during a period when demand was not particularly intensive, yet the sheer volume of gas required for storage injection, procured at historically high prices and without any guarantee of recovering costs through future sales, placed significant strain on both markets and public finances.

## CHAPTER FIVE – CONCLUSIONS

### 5.1 Summary of Findings

The energy shock that began with the Russia's invasion of Ukraine in 2022 left European Member States in a dramatic situation, exposing their dependence on a dominant supplier for imports of natural gas and petroleum: crucial primary sources upon which energy generation and the functioning of all sectors of the EU economy and society depended. This event brought to the fore the concept of energy security, revealing its multifaceted nature, which encompasses not only the physical availability of supplies but also their affordability, reliability, and the resilience of the systems designed to safeguard them. Given the massive annual energy consumption required to sustain Europe's main economic sectors, combined with the continent's limited capacity to extract and produce fossil fuels domestically due to resource scarcity, European countries used to rely on a seemingly stable arrangement: constant imports of natural gas and petroleum from neighbouring producers, supplemented by a buffer of stored energy to guard against temporary supply interruptions and seasonal fluctuations.

The 2022 energy shock exposed two fundamental vulnerabilities in this model. First, the dominant import partner, Russia, proved politically unreliable, revealing the risks of overreliance on a single supplier. Second, the storage levels that Member States had maintained as a safety buffer proved inadequate to prevent dramatic price increases once supply uncertainty materialised. The crisis thus laid bare the fragility of an energy security framework built on steady imports and limited reserves. Indeed, despite the fundamental strategic relevance of natural gas storage for energy availability and independence, the pre-crisis regulatory framework (Regulation (EU) 2017/1938) proved too light-touch. It left risk

assessment and the responsibility for ensuring adequate storage levels to national and regional authorities, resulting in insufficient coordination. Consequently, when supply shortages emerged in 2022, storage facilities in major European countries were far below adequate fill levels. This revealed that, at least in that specific period, Member States had relied on continuous import flows rather than on building substantial reserves through strategic procurement, compounding the challenges of an already critical situation and underscoring the need for a binding, coordinated approach to storage obligations.

The sharp increase in natural gas prices documented by Eurostat data following the onset of the crisis was driven primarily by global instability and supply disruptions. However, the lack of adequate natural gas reserves across Member States likely compounded the phenomenon: with storage levels far below adequate thresholds, European countries were forced to purchase massive quantities of gas on the spot market precisely when prices were peaking, thereby amplifying the upward pressure on prices. In this context, the inadequacy of the pre-2022 European regulatory framework on gas storage is perhaps best evidenced by the immediate shift to a new, more stringent regime following the crisis. Regulation (EU) 2022/1032, adopted on 29 June 2022, amended the existing Security of Gas Supply Regulation (EU) 2017/1938 by introducing, for the first time, binding storage filling targets across Member States. Under the new rules, EU countries were required to fill underground gas storage facilities to 80% of capacity by 1 October and 90% by 1 November each year, with intermediate targets established to ensure a steady build-up of reserves throughout the summer. The Regulation also introduced a solidarity mechanism requiring Member States without domestic storage to store a share of their consumption in other countries and established a mandatory

certification process for storage operators to safeguard critical infrastructure from external influence.

Through these provisions, the European Commission explicitly recognised the strategic value of underground gas storage as an instrument of energy security, a recognition that had been largely absent from the previous framework. Data from Eurostat confirm that Member States successfully met the Regulation's storage targets, while the literature review carried out in Chapter 3 underscores the undeniable utility of the Regulation in terms of energy security. The Regulation proved an effective instrument for reducing price spikes and limiting price volatility, generating welfare gains by redistributing prices across seasons.

To meet the regulatory storage requirements, Member States intervened by providing economic support to market operators procuring gas for storage, thereby enabling compliance with binding targets. However, state intervention during the crisis was not limited to economic support for market operators procuring gas for storage. Governments implemented a wide range of measures to support society, including reductions in national taxes on energy products, price caps, and direct support for households and firms. These interventions reflected the massive economic effort and public resources deployed to overcome the emergency, confirming that the costs of ensuring energy security were ultimately socialised across European society.

## **5.2 Answering the Research Question**

This thesis has examined both the effectiveness and the economic consequences of Regulation (EU) 2022/1032, adopted in the wake of the 2022 energy crisis. On the one hand, the Regulation (EU) 2022/1032 effectively strengthened European energy security and reduced

dependence on external suppliers by ensuring adequate storage levels ahead of winter. On the other hand, it required a massive economic effort from Member States and, consequently, from private market participants to comply with its binding storage targets. The crucial question is whether the mandatory targets triggered a reactive and massive purchasing of natural gas by Member States during the worst historical period in terms of wholesale natural gas prices, thereby pushing them even higher than they would have been without this imposition. In this sense, the contribution of such procurement behaviour to price amplification is already supported by the literature review, particularly by Fernandez-Blanco et al. (2023), who assessed that: "it is highly likely that, in the absence of such interventionist behaviour by Member State governments, gas prices would not have reached the same extreme levels".

This finding directly addresses the central research question of this thesis. The evidence indicates that the mandatory storage targets did indeed compel Member States to enter the natural gas market at a moment of peak prices, and that this collective procurement pressure amplified the very price surge that Regulation (EU) 2022/1032 sought to mitigate. In other words, the instrument designed to guarantee energy security carried with it a significant economic cost in the short term. To add further evidence on this point, the analysis of the annual reports of Uniper for Germany, and of Snam and GSE for Italy, three of the main energy market participants in their respective countries, is particularly instructive. These companies engaged in a behaviour that, from a purely economic perspective, was not fully rational: they purchased vast quantities of natural gas at peak prices, not only to guarantee supply to society but also to stock national reserves in compliance with the Regulation. This led to massive procurement costs that were difficult, if not impossible, for market operators to recoup without state intervention. The underlying challenge was that gas

purchased at historically high prices for storage purposes would inevitably be sold in a subsequent period when prices had fallen, making the recovery of costs unattainable through normal market mechanisms alone.

The aim of EU authorities in adopting Regulation (EU) 2022/1032 was to strengthen energy independence and guarantee energy security across all sectors of European society, from industry to households. However, given that energy security functions as a public good, its provision during a crisis inevitably carries significant costs. For a continent as resource-poor as the European Union, natural gas storage represents a crucial instrument for defending against political shocks, unexpected disruptions, and ensuring a survival buffer even in the absence of continuous import flows. From this perspective, the European legislator's decision to update the regulatory framework was strategically sound.

The critical issue lies not in the objective of the Regulation but in the timing and manner of its implementation. Adopted immediately after the onset of the crisis, the Regulation triggered a wave of uncoordinated and massive gas purchases on the market, sustained by governments that were less constrained by budgetary concerns in the face of an emergency. This collective procurement pressure contributed to pushing wholesale natural gas prices to record levels between the second half of 2022 and the end of that year, driven by legitimate fears that without such intervention, shortages during the following winter could have materialised had the supply situation worsened.

It is important to acknowledge, however, that this assessment is inevitably influenced by the benefit of hindsight. The economic costs associated with the implementation of Regulation (EU) 2022/1032 appear particularly significant when evaluated ex post, in a context where the winter of 2022-2023 turned out to be relatively mild and where the most extreme supply disruption scenarios did not materialise. Under different conditions, such

as a significantly colder winter or a complete interruption of Russian gas flows, the same regulatory intervention might have been perceived as not only justified but economically efficient, given the potentially much higher costs of severe shortages or rationing. This highlights the inherent difficulty of evaluating crisis-driven policies without a clearly defined counterfactual, as the true value of precautionary measures depends on adverse scenarios that ultimately did not occur.

The evidence from Germany and Italy further illustrates that the financial burden generated by these emergency procurement efforts was not ultimately borne by private operators alone. In both cases, the costs of complying with the storage targets were socialised, either through public spending or through regulatory charges ultimately passed on to consumers. Indeed, the German government's nationalisation of Uniper through a large-scale financial stabilisation package, together with the neutrality charge mechanism introduced by ARERA to support GSE and Snam, confirms that the Regulation, while succeeding in securing supply, transformed what might have been isolated corporate losses into a collective economic burden shared across society.

### **5.3 Limitations and avenues for future research**

This thesis has adopted a two-tier analytical structure. The early chapters establish the broader EU context by examining the energy mix, industrial consumption, import patterns, and the evolution of the regulatory framework. This contextual analysis draws on EU-wide data to illustrate the structural vulnerabilities and policy challenges that shaped the crisis response. For the core analysis of the Regulation's economic implications, specifically the costs of storage compliance and the distribution of financial burdens, the thesis then narrows its focus to four selected Member States: Germany, Italy, France, and Spain. While this approach

allows for an in-depth examination of contrasting national strategies, several limitations should be acknowledged.

First, the selection of four countries, although representing the largest gas markets and most significant storage capacities within the EU, may not fully capture the diversity of responses across smaller Member States or those with different energy system characteristics. Future research could extend the comparative analysis to cover all EU Member States, enabling a more comprehensive assessment of how national storage infrastructure, market structures, and policy frameworks influenced the costs and effectiveness of the Regulation.

Second, the study's empirical analysis is confined to a relatively short timeframe around the crisis, covering the immediate pre-crisis period, the acute shock, and the initial implementation of the Regulation, but not extending far enough to assess longer-term economic consequences or structural trends. It remains unclear whether the costs incurred will be recouped over time, whether the price patterns observed represent a temporary deviation or a lasting shift in market dynamics, and what the full cost-benefit balance of the Regulation might be. Without a longer-term perspective, the overall assessment of the Regulation's efficiency remains necessarily partial.

A further limitation concerns the absence of a formal counterfactual analysis to rigorously evaluate the costs and benefits of the mechanism introduced by Regulation (EU) 2022/1032. In particular, the thesis does not simulate what market outcomes would have been in the absence of mandatory storage targets, nor does it quantify how such a precautionary policy instrument may have altered price dynamics, security of supply, or welfare outcomes. As a result, while the analysis documents the significant short-term costs associated with compliance, it does not provide a systematic assessment of potential long-term benefits that could offset

these costs, such as lower price volatility in subsequent periods, avoided costs of more severe shortages, or the value of enhanced market confidence. A more robust evaluation would require a formal cost-benefit framework combined with counterfactual modelling. A longitudinal and quantitative approach of this kind would allow future research to better isolate the causal impact of the Regulation and to assess its overall efficiency in a more comprehensive manner.

Third, this thesis relies primarily on qualitative and descriptive quantitative analysis of national policy responses, corporate financial reports, and aggregated import data. A more precise assessment of the price impact of simultaneous procurement, such as estimating the price elasticity of gas demand during the filling season and modelling the marginal effect of the storage obligation, would be necessary to isolate the precise effect of the Regulation (EU) 2022/1032 on price dynamics. Such quantitative analysis, however, would require advanced econometric techniques that lay beyond the scope of this work. Future research could usefully employ these methods to determine the exact magnitude of the price impact and to assess whether the Regulation (EU) 2022/1032 amplified price surges beyond what would have prevailed under a more coordinated strategy.

Addressing these limitations would not only strengthen the evidence base for evaluating the Regulation (EU) 2022/1032 but also provide valuable lessons for the design of future energy security instruments, particularly as the EU accelerates its transition toward decarbonised energy systems and hydrogen storage infrastructure. This need is further underscored by ongoing geopolitical tensions, such as the disruptions observed in early 2026 linked to escalating instability in the Gulf region, including the temporary closure of the Strait of Hormuz and the resulting constraints on LNG supplies from Qatar, which is one of the EU's key gas suppliers and

accounted for 10.4% of LNG imports in 2024 (see Figure 8). The current crisis in the Gulf thus offers a powerful lesson: the true value of the EU Storage Regulation cannot be assessed solely against the benign conditions of 2022-2023. Rather, it must be evaluated against the full range of plausible adverse scenarios, including the one unfolding today, where the cost of unpreparedness would have been immeasurably higher.



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