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EUROPEAN GAS MARKET STRUCTURE

MILAN HUDAK

Abstract:

Focusing on the evolving roles of stakeholders and price-setting mechanisms, this paper sheds light on how the European Union gas market has shifted from dominant oil-linked contracts to a more diversified, market-driven system. Producers, TSOs, DSOs, shippers, traders, and consumers all contribute to a complex network in which efficient balancing is crucial to maintaining continuous gas flows. The maturing of gas hubs, particularly TTF and THE, has fostered spot and short-term trading, thereby offering enhanced liquidity and flexibility and introducing new forms of price volatility. EU-level policies, including unbundling requirements and harmonised network codes, have underpinned these developments, shaping transparent risk management strategies, derivatives trading, and storage usage. Although increased competition has yielded benefits in pricing and reliability, persistent regional discrepancies, such as varying infrastructure investment levels and differences in balancing practices, continue to influence

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1 Introduction

The European Union (EU) natural gas market plays an important role in meeting the energy needs of over 445 million consumers across its 27 Member States. Natural gas made up approximately 22% of the EU's total energy consumption in 2023, positioning it as the second-largest energy source after oil (34%) and ahead of coal (10%) and nuclear energy (13%)[1]. Over the past three decades, the EU gas market has undergone significant reforms and transformations, transitioning from a fragmented and monopolistic structure to a more open, competitive, and interconnected market fueled by a series of legislative actions between 1998-2009[2].

EU gas consumption reached 330 billion cubic meters (bcm) in 2023, marking a 20% decline compared to 2021 (European Commission, 2023). This reduction can be attributed to several factors, including the prolonged impact of high gas prices, mild weather conditions, and an accelerated shift toward renewable and low-carbon energy sources. Moreover, increasing geopolitical concerns have heightened the EU's focus on diversifying supply sources, such as Liquefied Natural Gas (LNG), to reduce reliance on single-supplier energy imports.

In 2023, the power generation sector remains the largest consumer of gas (32.4%), followed by households (25.5%), industry (24%), and services (11%). The slight uptick in industry and services can be traced to economic recovery and the transition to gas as a cleaner alternative to coal in certain industrial operations and heating systems.[3] However, there is growing interest in adopting innovative technologies, such as hydrogen-based processes and advanced heat pumps, that could gradually reshape these consumption patterns as envisaged by the EU's long-term hydrogen strategy and REPowerEU plan.

Looking ahead, EU gas demand is projected to continue its long-term decline, propelled by improvements in energy efficiency, electrification, and the ongoing expansion of renewable energy sources. Adopted in 2023, the "Fit for 55" package outlines a target to lower greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, necessitating a substantial reduction in fossil fuel consumption, including natural gas[4]. At the same time, initiatives such as the REPowerEU plan seek to reduce dependence on Russian fossil fuels, accelerate investments in renewables, and bolster Europe's overall energy resilience.

Despite these ambitious goals, the rate and extent of the decline in gas usage remains uncertain, influenced by factors such as economic growth, policy enforcement, technological breakthroughs, and public acceptance[5]. The EU gas market also faces emerging challenges and opportunities,

[1] https://www.acer.europa.eu/gas-factsheet (24.6.2024)

[2] First Energy Package (1998) - Directive 98/30/EC; Second Energy Package (2003) - Directive 2003/55/EC; Third Energy Package (2009) - Directive 2009/73/EC.

[3] https://www.consilium.europa.eu/en/infographics/eu-gas-supply/#0 (24.6.2024)

[4] Commission welcomes completion of key 'Fit for 55' legislation, putting EU on track to exceed 2030 targets. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4754 (23.6.2024).

[5] Changes in German Heating law created in 2022-2023 heated debate on gas heaters that were initially meant to be banned. However, compromised solution had to be found in order to pass the law. https://www.osw.waw.pl/en/publikacje/analyses/2023-09-14/germany-a-controversial-heating-law. (accessed on 3.1.2025).

including the integration of renewable and low-carbon gases (e.g., biomethane, hydrogen) and adapting gas infrastructure to the new energy landscape. Efforts to upgrade and expand energy storage facilities, particularly for LNG and hydrogen, are also underway, helping to ensure adequate supply in times of peak demand or supply disruptions.

Market integration and regulatory frameworks play a decisive role in shaping the future of the EU gas market. Institutions such as the Agency for the Cooperation of Energy Regulators (ACER) and the European Network of Transmission System Operators for Gas (ENTSOG) aim to harmonise rules, facilitate market coupling, and promote cross-border investments. These efforts include the development of interconnectors and LNG terminals, enhancing the region's supply and market liquidity security. Furthermore, digital innovation offers the potential to optimise network operations and integrate a growing share of intermittent renewables.

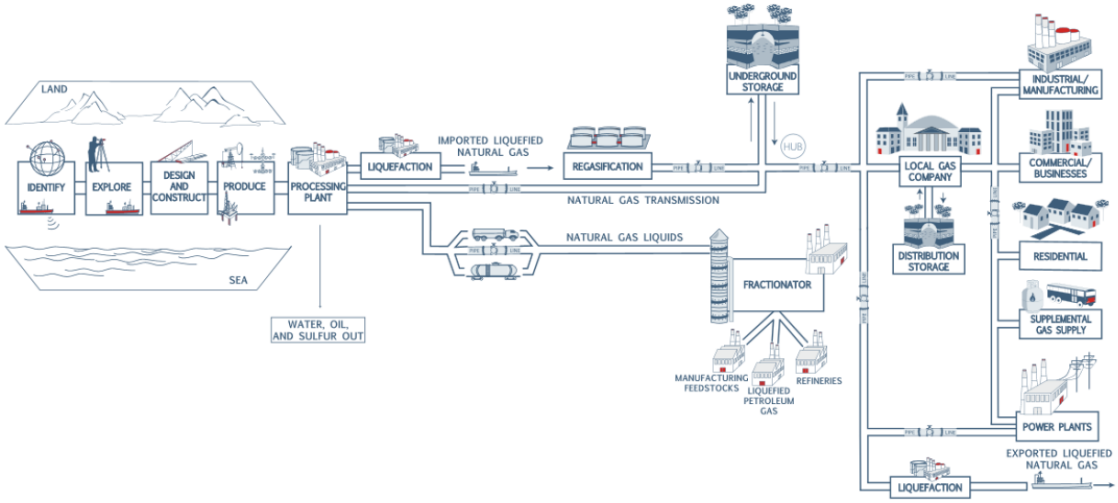
Current academic literature assessing a holistic view of the EU gas market is scarce. Miriello & Polo (2015) discuss the market structure for the major EU markets, while Hulshof et al. (2016) highlight the liberalised nature of the gas markets, underscoring market fundamentals as a driver of EU gas prices. With regards to EU markets, there is a large body of research focused on market integration, which largely concludes that EU gas markets are integrated, especially at the price level and within broader regulatory frameworks. (Asche et al., 2001, 2002, 2013, 2017; Broadstock et al., 2020; Dieckhöner et al., 2013; Dukhanina et al., 2019; Maltby, 2013; Newbery et al., 2013; Osička et al., 2018; Renou-Maissant, 2012) This paper aim to fill a void by analysing the EU gas market stakeholders, infrastructure and gas market organisation.

This paper is structured as follows. Following this introduction, section 2 examines the market structure and its stakeholders, including gas producers, TSOs, DSOs, shippers, traders, and consumers, while highlighting the evolving import dynamics and the increasing importance of LNG. In section 3, the paper explores gas trading and the rise of liquid market hubs, detailing the growth in spot and short-term transactions that supplement long-term contracts. Section 4 investigates various pricing mechanisms, ranging from oil-price indexation to gas-on-gas competition and the EU's gradual move toward more transparent, market-driven price signals. Section 5 focuses on balancing and flexibility requirements, an important element of the functioning of the physical gas markets, underlining the role of TSOs, short-term markets, and storage facilities. Finally, section 6 turns to the physical infrastructure, pipelines, LNG terminals, FSRUs, interconnectors, and storages, revealing ongoing challenges related to uneven regional development, infrastructure ageing, and the broader decarbonisation pathway. The paper concludes with a brief summary and policy observations.

2 Market Structure and Market Participants

This section outlines the structure of the EU gas market and its participants. We examine how market participants, infrastructure operators, and regulatory authorities carry out specific roles at different institutional levels and how their dynamic interactions shape the market's functioning and governance. Figure 1 illustrates the key stages of the gas supply chain in the gas market.

Figure 1. Gas Supply Chain



Source: American Petroleum Institute (API)

2.1 Gas Producers and Exporters

Producers are companies engaged in exploring, extracting, and processing natural gas from onshore or offshore fields. The EU's primary domestic producers are the Netherlands, Denmark, and Romania. However, domestic output has been steadily declining, dropping from about 125 bcm in 2010 to 38 bcm in 2023[6], mainly due to the depletion of older fields and the closure of the Groningen gas field in 2022 because of seismic risks. The EU relies heavily on imports, which accounted for about 89% of its consumption in 2021. This import dependency underscores the strategic importance of external suppliers.

The leading external suppliers to the EU between 2021 and 2023 were[7]:

- **Russia**: 41% of EU imports in 2021—mainly via pipelines (Nord Stream 1, Yamal-Europe, Brotherhood)—dropping to 15% in 2023 (from 150 bcm to 43 bcm)
- **Norway**: 16% of EU imports in 2021—via pipelines (Langeled, Europipe)—rising to 30% in 2023 (from 80 bcm to 88 bcm)
- **North Africa:** 14% in 2023—primarily through pipelines (Maghreb-Europe, Medgaz) and LNG
- **United States**: 7% in 2021, all LNG, jumping to 19.4% or 56.2 bcm in 2023
- **Qatar**: 5% in 2021, increasing to 5.3% or 15.5 bcm in 2023, entirely as LNG

Other important suppliers include Nigeria, Azerbaijan, and Trinidad and Tobago, predominantly via LNG. The EU has diversified its supply sources and routes to bolster energy security, notably through the Southern Gas Corridor and increased LNG infrastructure. Such initiatives ensure greater competition and help the EU adapt to evolving geopolitical landscapes.

[6] https://www.statista.com/statistics/265345/natural-gas-production-in-the-european-union/. (13.6.2024).

[7] Based on https://www.consilium.europa.eu/en/infographics/eu-gas-supply/#0 (13.6.2024).

2.2 Transmission System Operators (TSOs)

This section focuses on the pivotal role of TSOs in the EU market structure. TSOs oversee, maintain, and develop high-pressure gas transmission grids, linking producers to distribution networks and large consumers. They ensure secure and uninterrupted gas flow and guarantee non-discriminatory access. As of 2024, there are 45 TSOs in the EU[8], each subject to diverse regulatory conditions and ownership models. The list of the major TSOs by country is presented in Appendix 1.

TSOs must comply with strict unbundling rules based on the Third Energy Package, designed to foster market competition and avoid conflicts of interest by separating transmission from production and supply. They also cooperate through ENTSOG, established in 2009, to facilitate harmonised network codes and coordinate cross-border flow management. ENTSOG's publications (like the Ten-Year Network Development Plan, infrastructure data and Winter Supply Outlook) provide important data for market participants and policymakers, helping them anticipate supply-demand shifts and infrastructure needs.

2.3 Distribution System Operators (DSOs)

DSOs manage, maintain, and develop low-pressure networks delivering gas to end users: households, businesses, and smaller industrial enterprises. These operators are vital in ensuring continuous and efficient gas distribution while providing non-discriminatory access to suppliers and metering services. The EU is home to over 1,400 DSOs, mainly small to mid-sized, frequently under municipal or regional ownership. However, some DSOs—such as Italgas (Italy) or GRDF (France), operate across multiple regions, highlighting the diverse scope and scale within the sector.

DSOs are bound by unbundling requirements under the EU gas directives, mandating legal and functional separation of distribution and supply. Nevertheless, exemptions and flexibility for smaller DSOs (serving fewer than 100,000 customers) exist, designed to balance the goal of market liberalisation with the administrative and financial burdens on smaller networks. Collaboration through associations like Eurogas or Gas Infrastructure Europe (GIE) and GEODE[9] enables DSOs to share best practices, represent their collective interests, and influence EU policies and regulatory frameworks.

2.4 Shippers

Shippers are companies that lease capacity in both transmission and distribution networks to transport gas from producers to consumers. Shippers may include gas producers (e.g., Equinor), traders, or large end users with direct wholesale market access. They assume responsibility for balancing gas inputs and outputs within the network and cover transmission and distribution tariffs charged by the respective system operators. Shippers contribute significantly to the EU gas market by optimising the use of available capacity, as well as enhancing competition and liquidity

[8] The largest TSOs in terms of pipeline length and capacity are: Snam (Italy): 32,727 km of pipelines; ONTRAS (Germany): 7,414 km of pipelines; GRTgaz (France): 32,519 km of pipelines; Enagás (Spain): 11,000 km of pipelines; NET4GAS (Czech Republic): 3,973 km of pipelines; Fluxys (Belgium): 4,100 km of pipelines; Gasunie (Netherlands): 15,500 km of pipelines.

[9] https://www.geode-eu.org/.

in the wholesale market. They can trade gas through bilateral agreements or on organised exchanges, such as the European Energy Exchange (EEX), Intercontinental Exchange (ICE), or CEEGEX.

Moreover, shippers operate under EU network codes that govern capacity allocation, balancing, and interoperability. These codes aim to create universal pipeline access and usage standards across Member States. Shippers must also demonstrate sufficient financial strength and technical expertise to comply with regulatory and operator requirements, ensuring robust creditworthiness and operational reliability. This underscores the importance of formal rules and market-driven strategies in guiding shippers' activities and interactions with other stakeholders facilitated by associations like EFET, which provides contractual guidelines for trading and trading-related legal and commercial events. While EU network codes encourage consistency and efficiency, vibrant wholesale trading environments stimulate competition and market depth by providing liquidity.

2.5 Traders and Suppliers

Traders and suppliers undertake crucial roles in procuring, selling, and delivering gas to end users directly or via retail channels. Traders concentrate on the wholesale market, seeking arbitrage opportunities and price differentials, while suppliers focus on serving final consumers with competitive and reliable gas services. The EU hosts a large, dynamic market of over 3,000 traders and suppliers. Among the largest by gas sales volume are EDF, Engie (France), Vitol, Trafigura, Gunvor (Switzerland), Centrica (UK), Eni, ENEL (Italy), OMV (Austria), Uniper, RWE, SEFE, VNG (Germany), and Naturgy (Spain).

In securing gas, traders and suppliers draw on various sources, including long-term contracts with producers, short-term market transactions, or their own production and storage facilities. They frequently hedge market risks via derivatives such as futures, options, and swaps. In addition, suppliers must comply with licensing and consumer protection measures mandated by EU directives and national laws, ensuring transparent, competitive service provisions in the retail market. These rules oblige suppliers to offer clear, comparable information on tariffs and contractual conditions, facilitating smooth supplier-switching processes without undue cost or delays.

2.6 Consumers

Gas consumers in the EU are diverse segments, which can be categorised into three core groups:

- **Industrial Consumers**: Large users in sectors such as chemicals, steel, metallurgy, glass, ceramics, and food, accounting for ~24% of EU gas consumption in 2022. With an average usage of 10 million cubic meters per consumer annually, these industrial entities are highly price-sensitive and often secure their gas through direct wholesale market access or long-term supply contracts (BASF, YARA).
- **Power Generation**: Gas-fired power plants represent ~32.4% of total gas consumption in 2022, relying on gas as a flexible energy source to balance growing shares of intermittent renewables (wind, solar). The role of gas in electricity production may evolve in response to the EU's decarbonisation targets and the rise of low-carbon gases (e.g., biomethane, hydrogen). The role of the gas is discussed in Emery & Liu, 2001; Fabra, 2023; Kolb et al., 2020; Newbery et al., 2018; Philippou & Birkbeck, 2021; Zakeri et al., 2023.

- **Households and Commercial Users**: Smaller customers, including households, businesses, and public institutions, use gas for heating, cooking, and water heating[10]. Around 80 million EU households are heated by gas, collectively forming ~36.7% of total gas consumption. A typical household consumes about 5,000 cubic meters per year[11].

Based on the EU legislative acts listed in Appendix 2, market liberalisation has delivered notable consumer benefits, fueling competition, increasing choice, and improving service quality (Copenhagen Economics, 2005). Nonetheless, they still encounter price volatility, potential supply disruptions, and the financial impact of the "green transition." EU institutions and Member States have introduced measures like price caps, subsidies, energy-efficiency programs, and awareness campaigns to protect and empower consumers (Hidalgo-Pérez et al., 2022; Sgaravatti et al., 2024). As the EU advances toward climate neutrality by 2050–2055, the role of fossil gas will likely diminish, necessitating a shift to bio-based or low-carbon gases. However, gas is anticipated to serve as a "bridge fuel" in decarbonising the EU energy mix, with infrastructure gradually repurposed for renewable and "green" sources, such as hydrogen (e.g., the Kernnetz initiative in Germany).

3 Gas Trading and Market Hubs

This section focuses on gas trading and the role of trading hubs in the EU gas market structure. We examine how formal rules (e.g., regulations supporting the development of hubs) and market behaviour (e.g., the shift from long-term contracts to spot and short-term trading) at the levels of the institutional environment and governance influence the organisation and performance of gas trading.

Gas trading in the EU is conducted through a combination of long-term contracts, derivatives such as futures or options and short-term spot transactions in markets known as hubs (or Virtual Trading Points – VTPs). Long-term contracts, typically indexed to oil prices, have traditionally dominated the EU gas market, providing security of supply for consumers and stable revenues for producers. These contracts are increasingly indexed to major liquid hubs, primarily TTF and THE. However, the spot and short-term trading share has grown significantly in recent years, offering greater flexibility and market liquidity(ESMA, 2020).

[10] A complete overview is available at https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/heating-energy-consumption-by-energy-sources.html (June 16, 2024).

[11] https://www.consilium.europa.eu/en/infographics/eu-gas-supply/#0. (24.6.2024).

Map 1 Overview of Gas Hubs in the EU

Source: Heather (2024)

The EU has a network of Virtual Trading Points (VTPs) or market hubs, which are digital platforms enabling gas exchange (title transfer) among market participants without requiring physical delivery at a specific location or off-take point (point of consumption). These hubs have become key trading centers in the EU, providing price transparency, liquidity, and risk management tools for market participants. The hub overview on Map 1 from Heather (2024) shows the situation as of 2023 and classifies them based on criteria such as liquidity, number of market participants, traded products, churn ratio, and trading volumes (Heather, 2015). The most important gas hubs in the EU are:

- **Title Transfer Facility (TTF)** in the Netherlands: TTF is Europe's most liquid and widely used hub, accounting for about 75% of total gas trading volume in Europe in 2022. TTF prices continue to be used as a reference for gas contracts and derivatives across Europe (Jotanovic & D'Ecclesia, 2021), closely linked to global LNG prices. The Dutch gas grid operator, Gasunie Transport Services (GTS), operates TTF.
- **Trading Hub Europe (THE)** in Germany: After the merger of NCG and Gaspool in 2021, THE became the only hub in Germany, representing about 6% of total gas trading volume in Europe in 2022. THE is operated by ten German gas system operators[12].

[12] https://www.tradinghub.eu/en-gb/About-us/Company-Profile-Shareholder (accessed 3.1.2025).

- **Point d'Echange de Gaz (PEG)** in France: PEG is France's gas hub, accounting for about 3% of total gas trading volume in Europe in 2022. It is operated by the French transmission system operator GRTgaz.
- **Punto di Scambio Virtuale (PSV)** in Italy: PSV is Italy's gas hub, making up about 2% of total gas trading volume in Europe in 2022. It is operated by the Italian grid operator Snam Rete Gas.

The rise in spot and short-term trading in the EU gas market has been supported by several factors, including the development of more liquid and transparent market hubs, increasing flexibility and diversification of gas supply sources (e.g., LNG), and the growing need for market participants to manage price and volume risks in a more dynamic and uncertain market environment.

TTF's dominance as Europe's leading gas hub continued to grow (Heather, 2023), with its share of total gas trading volume in Europe rising from 70% in 2021 to 75% in 2023 (Heather, 2023). This can be attributed to TTF's increasing importance as a reference point for European gas prices and growing liquidity and trading activity at the hub (Jotanovic & D'Ecclesia, 2021). Globally, it serves as a reference price for Europe, and TTF also increasingly prices a large share of spot LNG headed for Europe. Other major hubs, such as THE, PEG, and PSV, have also seen slight increases in their share of total European gas trading volumes, contributing to the overall liquidity and efficiency of the European gas market (Heather, 2023). The trend toward higher spot and short-term trading in the EU gas market is expected to continue in the coming years as market participants seek to optimise their portfolios and manage their credit risks in an increasingly complex and rapidly changing market environment. At the same time, trading is expected to continue shifting from OTC to exchanges, driven primarily by the growth of speculative electronic trading, which narrows bid-offer spreads and the demise of oil-indexed long-term contracts.

Other significant EU gas hubs include the Central European Gas Hub (CEGH) in Austria, Zeebrugge Trading Point (ZTP) in Belgium, and Punto Virtual de Balance (PVB) in Spain.

Gas trading at the hubs involves a variety of products and contracts, ranging from intraday transactions to deliveries several years ahead. The most common products are:

- **Day-Ahead (DA):** Contracts for gas delivery the following day are usually traded daily.
- **Within-Day (WD):** Contracts for gas delivery on the same day are traded hourly with a 3-hour lead time on markets like THE, TTF, or CEGH (in Czechia or Slovakia, they are traded as 24-hour products).
- **Weekend (WE):** Contracts for gas delivery over the weekend are usually traded on Fridays. EEX allows trading starting from Thursday, but the OTC market can offer various time options.
- **BOM, WDNW, and BOW** are intra-month products that combine various segments such as part of a week, part of a month, or the next working week.
- **Month-Ahead (MA):** Contracts for gas delivery during the next calendar month, typically traded until the last day of the previous month.
- **Quarter-Ahead (QA):** Contracts for gas delivery in the next calendar quarter are usually traded in the last month of the previous quarter.
- **Season-Ahead (SA):** Contracts for gas delivery in the following summer or winter season, typically traded several months in advance.

- **Year-Ahead (CalY):** Contracts for gas delivery in the next calendar year, typically traded in the last quarter of the previous year.

Market participants can trade these products either bilaterally (over the counter, OTC) or on organised exchanges such as ICE Endex (the most liquid futures exchange), the European Energy Exchange (EEX), MIBGAS, TGE, and CEEGEX. Bilateral trading is more flexible but also less transparent and standardised than exchange-based trading. In addition to the physical gas market, the EU has a significant gas derivatives market, including futures, options, and swaps. Derivatives are financial instruments whose value is derived from the underlying gas price used for hedging, speculation, and arbitrage. According to Priolon (2019), the most commonly traded hedging gas derivatives in the EU are:

- **Futures**: Contracts obliging the buyer to purchase a specific volume of gas at a predetermined price in the future. Futures are used for hedging price risk and are traded on exchanges such as ICE Endex and EEX.
- **Options**: Contracts give the buyer the right, but not the obligation, to buy (call option) or sell (put option) a specific volume of gas at a predetermined price in the future. Options are used for hedging and speculation and can be traded on exchanges or bilaterally. They also serve as hedges via spread formations. A specific group includes quanto options.
- **Temperature derivatives**: Tools for managing hedging portfolios based on temperature, capturing the effect of temperature on gas demand.
- **Swaps**: Contracts involving the exchange of a fixed price for a floating price (or vice versa, Fix to Float) over a set period. Swaps are used to hedge price and volume risk and are mostly traded bilaterally.
- **Hub-to-hub spreads (location spreads)** allow simultaneous buying on one hub and selling on another national market, replacing the need to book physical transport capacities directly (done mainly via the Prisma platform or at the TSO booking platform).

The derivatives market plays a key role in the effective functioning of the EU gas market by providing insight into price formation, supporting risk management, and offering liquidity. In 2021, the volume of gas derivatives traded in the EU was more than five times the physical volume consumed, underscoring the market's significant financial dimension. This trend will continue with the growing involvement of banks and hedge funds (ESMA, 2020). The EU has implemented various regulations to increase transparency, integrity, and stability in the derivatives market, such as the European Market Infrastructure Regulation (EMIR) and the Markets in Financial Instruments Directive (MiFID).

4 Concepts of Natural Gas Pricing

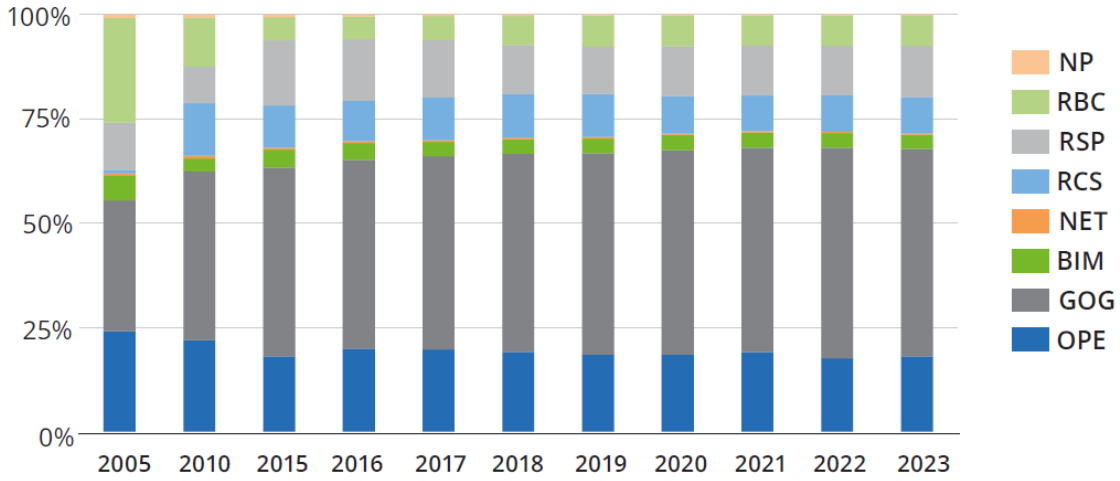
This section examines concepts of natural gas pricing in the EU. Natural gas pricing from the supply perspective is analysed annually by the International Gas Union. The classification of pricing mechanisms reflects price offers between natural gas producers and wholesale companies, or potentially natural gas traders. The graphs and the map below summarise the situation in the gas market based on the latest report from 2024, and the context and data are further discussed in Stern (2012), IGU (2023, 2024) and IGU & The Clingendael Institute (2006):

- **Oil Price Escalation (OPE):** This mechanism was historically dominant, particularly in long-term contracts. Gas prices are linked to oil or oil-product prices (or coal), often with a time lag. Although it supports price stability, it does not always mirror the actual supply-demand dynamics of the gas market. In recent years, many regions have shifted from OPE to more market-oriented mechanisms, most notably the EU.
- **Gas-on-Gas Competition (GOG):** This approach is increasingly prevalent, especially in developed markets such as the US and Europe. It allows flexible pricing that responds to real-time market conditions. The growth of liquid trading hubs has been instrumental in enabling this mechanism, though it can result in higher price volatility.
- **Bilateral Monopoly (BIM):** The price is set through bilateral negotiations between a major seller and a major buyer, with the price fixed for a certain period, typically one year. Sometimes, a written contract formalises this arrangement, but it is often established at the governmental or state enterprise level.
- **Netback from Final Product:** The supplier's revenue depends on the buyer's price for the final product using gas as a feedstock. This is common where gas is crucial for the chemical industry (e.g., ammonia) and represents the main variable cost in production.
- **Regulation: Cost of Service (RCS):** A regulatory body or ministry sets or approves the price established to cover the "cost of service," including a fair return on investment. However, this mechanism may not incentivise efficiency improvements and can lead to potential overinvestment.
- **Regulation: Social and Political (RSP):** The price is determined irregularly, based on political or social factors. While it can make gas more accessible for consumers, it also risks market distortions, discourages investment in gas infrastructure, and may cause supply shortages if set too low.
- **Regulation: Below Cost (RBC):** Similar to RSP but more extreme. The price is set deliberately below the average cost of extracting and transporting gas, often as a form of state subsidy. While it might boost economic growth in the short-term, it is typically unsustainable and can result in substantial market inefficiencies.
- **No Price (NP):** The produced gas is provided free to the population or industry, often when it is a byproduct of oil extraction. Although very rare and typically found only in state-controlled, resource-rich economies, it can lead to resource misallocation and insufficient conservation efforts.

The IGU survey tracks these trends over time and offers insights into ongoing shifts in the global gas market. Its most recent findings are presented in Graph 3, Graph 4, and Map 1, clearly illustrating the dominance of market-based pricing, its upward trajectory since 2005, and the fact that this mechanism largely prevails in advanced, OECD-member economies.

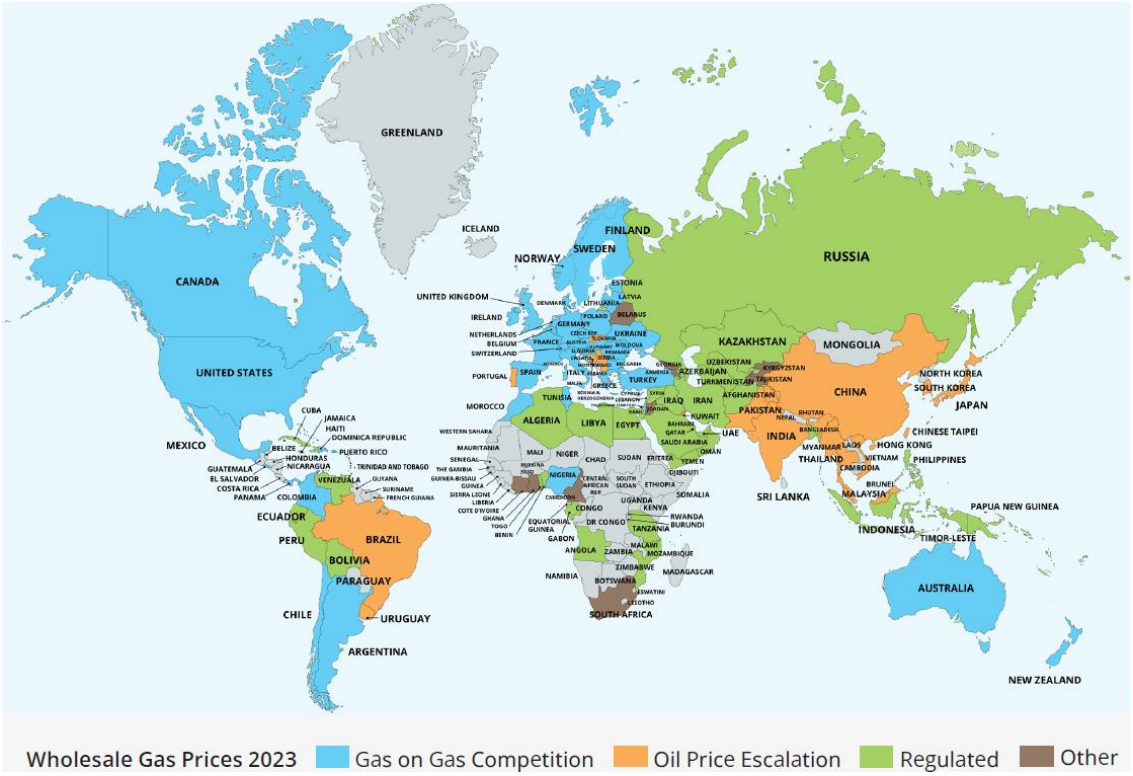
An analysis of natural gas pricing in the EU highlights a gradual shift from oil-linked mechanisms to competitive, market-driven models rooted in gas supply and demand dynamics. This development reflects institutional changes, particularly market liberalisation and deregulation, leading to more efficient and transparent price signals. Nevertheless, the persistence of certain legacy pricing mechanisms in specific segments shows that this transition remains incomplete and is also molded by informal institutions and historical relationships.

Graph 1: Gas Price Formation Since 2005



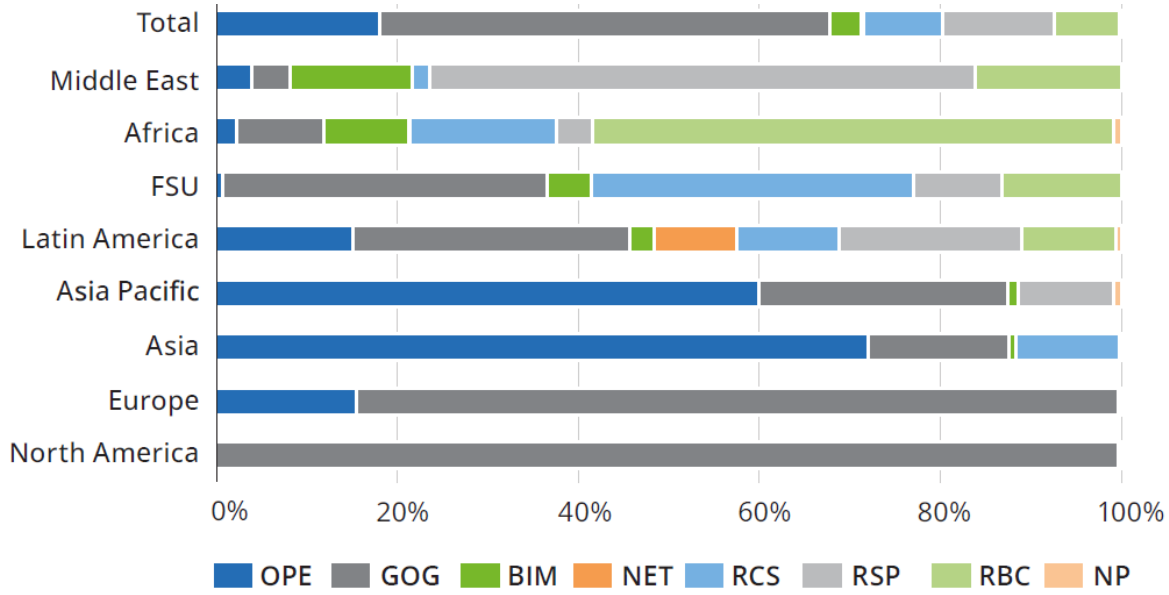
Source: IGU 2024

Map 2: Gas Price Formation



Source: IGU 2024

Graph 2: Regional Distribution of Gas Pricing



Source: IGU (2024)

5 Balancing and Flexibility

This section focuses on balancing and flexibility mechanisms in EU gas markets. Balancing refers to the process of maintaining a constant balance between the supply and consumption of gas in the gas system in terms of both volume and pressure. Balancing is essential for the safe, efficient, and reliable operation of the gas system because any significant imbalance may lead to supply disruptions, infrastructure damage, or gas leaks. In the EU, the responsibility for balancing primarily lies with transmission system operators (TSOs), who use a combination of market mechanisms and operational tools to maintain system integrity. However, market participants (shippers and suppliers) also play an important role in balancing their portfolios and minimising imbalances in their positions. The EU has a harmonised balancing regime in the Network Code on Gas Balancing (Regulation 312/2014[13]), which establishes rules and procedures for balancing across Member States. The main principles of the EU balancing regime are:

- **Market-based balancing:** TSOs should procure balancing services through short-term wholesale markets. This approach aims to increase competition, liquidity, and efficiency in the balancing market and to provide price signals for market participants to keep their portfolios in balance[14].

[13] Accessible at http://data.europa.eu/eli/reg/2014/312/oj (June 22, 2024).

[14] In addition to market balancing, TSOs also use operational balancing tools to ensure system stability and flexibility. These tools include: a) **Linepack**, which refers to the volume of gas stored in the pipeline network that can be used as a buffer zone to absorb short-term imbalances between supply and demand. TSOs can adjust pipeline pressure to increase or decrease linepack and maintain system balance. b) **Gas storage facilities**, such as depleted gas fields, aquifers, and salt caverns, which can be used to store excess gas during periods of low demand and to withdraw gas during periods of high demand. c) TSOs may **procure flexible services** from market participants—such as producers, consumers, and storage operators—to adjust their gas inputs or outputs in response to system needs. Flexible services can be contractually secured through market mechanisms such as auctions or tenders, or through bilateral agreements. d) TSOs may offer **interruptible capacity** to shippers, which the TSO can curtail or limit in the event of system

- **Daily balancing:** Balancing should occur daily, with shippers responsible for balancing their inputs and off-takes during one day (from 6:00 to 6:00 CET). Shippers can trade gas in the wholesale market to adjust their positions and thus avoid imbalance charges or fees.
- **Imbalance charges:** Shippers that are out of balance at the end of the day face imbalance charges that reflect the TSO's costs of system balancing. These imbalance charges are based on the marginal buy or sell price in the balancing market and include a cash-out factor that encourages shippers to balance their portfolios.
- **Neutrality:** TSOs should be financially neutral in relation to the balancing regime, meaning that any costs or revenues resulting from balancing activities should be passed on to shippers via imbalance charges or redistributed through neutrality charges.
- **Information transparency:** TSOs should provide transparent and timely information to market participants about their balancing status, imbalance charges, and system conditions, enabling them to make informed decisions and minimise imbalance risk.

The EU gas market has substantial flexibility and storage capacity, which has been critical in managing supply and demand variations and ensuring security of supply. In 2023, the EU had a total technical storage capacity of approximately 91 bcm (1,148 TWh) in 21 countries[15] associated with Gas Storage Europe (GSE)[16]. However, storage levels and capacity use vary significantly among EU Member States, depending on their geological conditions, market structure, and regulatory framework. In 2023, the average storage usage rate in the EU was around 80%, with some Member States (e.g., Germany, Italy) having higher usage rates above 90%, while others (e.g., Spain, Portugal) had lower usage rates below 70%. As of 2022, some Member States adopted so-called mandatory storage levels[17]. The volume of stored gas depends on the season and the regulatory environment. Storage facilities are usually emptied during winter and heating periods, while they are refilled in the summer. The spread between spot prices and the forward curve also plays an important role, given that the spread must be higher than the cost of storage capacity in order to attract the injection by storage capacity holders.

The EU is also working to improve the integration of its balancing and flexibility markets through initiatives such as the Network Code on Capacity Allocation Mechanisms (NC CAM) and the Network Code on Interoperability and Data Exchange (NC INT). These codes aim to harmonise rules and procedures for cross-border capacity allocation, congestion management, and data exchange to facilitate efficient and seamless gas flow across the EU[18].

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constraints or imbalances. Interruptible capacity provides additional flexibility to the system but also poses a risk for shippers who may pay for capacity they cannot use.

[15] https://www.gie.eu/publications/maps/gie-storage-map/ (22.6.2024).

[16] Inventory data and the development of the inventory in the EU storages are monitored at https://agsi.gie.eu/. For infrastructure events, such as unplanned or planned unavailability, data are available at https://iip.gie.eu/. For LNG related infrastructure information https://alsi.gie.eu/ offers in-depth overview.

[17] This targets are listed in Annex 1a of the Regulation (EU) 2022/1032, available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R1032 (accessed 2.1.2025).

[18] Nevertheless, some challenges and constraints persist. Notable examples include: a) Some balancing markets, especially in Eastern and Southern Europe, still have limited liquidity and trading activity due to the dominance of

An analysis of balancing and flexibility in the EU gas system highlights the key role of formal rules and governance methods in ensuring efficient and adaptable system operation. Harmonised balancing rules and the use of a combination of market-based and operational tools allow for managing variability in supply and demand, as well as responding to short-term fluctuations and disruptions.

6 Physical Infrastructure

This section examines the physical infrastructure of the EU gas system. The EU gas market is based on a large and complex physical infrastructure network that enables gas production, transmission, storage, and distribution throughout the continent. This network dates back to the local use of the town and coke gas since the end of the 19th century, further developed since the 1950s following the major gas discoveries in Europe. The origin of the gas infrastructure in Europe is vividly discussed in Gustafson (2020). This infrastructure includes:

- **Transmission pipelines**: High-pressure pipelines that transport gas from production areas or import points to consumption centers or distribution networks. The EU has about 200,000 km of transmission pipelines, operated by TSOs under national regulatory authorities (NRAs) supervision.
- **Distribution pipelines**: Medium- and low-pressure pipelines that deliver gas from transmission pipelines to final consumers, such as households, businesses, and industrial plants. The EU has around 2 million km of distribution pipelines operated by DSOs under the supervision of NRAs.
- **Compressor stations**: Facilities that regulate gas pressure in pipelines to allow long-range transportation. Compressor stations are typically located every 100–200 km along transmission pipelines and are operated by TSOs. The EU has over 20,000 compressor stations and pressure-adjusting facilities in the gas infrastructure.
- **LNG terminals and FSRUs**: Facilities that receive, store, and regasify liquefied natural gas (LNG) imported from abroad. LNG terminals are located in coastal areas and are connected to the transmission network. In addition to traditional onshore LNG terminals, the EU is increasingly using Floating Storage and Regasification Units (FSRUs) to expand import capacity and flexibility. FSRUs are offshore vessels that can be moored in coastal locations and connected to onshore gas networks, offering a faster and more flexible solution than building new onshore terminals. In 2024, the EU had a total of 39 major LNG terminals in operation[19], 14 of which are FSRUs, with a combined capacity of about 240 bcm per year, representing roughly 40% of the EU's gas consumption in 2023. This is an increase from 24 terminals with a capacity of 180 bcm/year in 2022, as the EU is working on expanding LNG import infrastructure to diversify its gas supply sources and reduce its dependence on Russian gas. In addition to onshore terminals, EU Member States had deployed 8 FSRUs by 2023, with a total capacity of about 40 bcm per year. These FSRUs are located in Germany

established suppliers and a lack of market participants. b) Despite progress in harmonizing balancing rules and procedures, there are still some differences and inconsistencies among EU Member States (e.g., hourly balancing in Germany vs. daily balancing in the Czech Republic).

[19] Data are available at https://www.raaey.gr/energeia/en/lng-terminals/ (accessed 3.1.2025).

(3), Italy (2), France (1), Spain (1), and the Netherlands (1), and were leased for periods ranging from 3 to 10 years. The deployment of FSRUs has been a key component of the EU's strategy to diversify gas supply sources and ensure the security of supply, particularly in the context of ongoing supply disruptions and price volatility[20].

- **Storage facilities:** Facilities that store gas for later use, balancing seasonal and short-term fluctuations in supply and demand. Storage facilities include depleted gas fields, aquifers, and salt caverns operated by Storage System Operators (SSOs). As of 2023, the EU has a total storage capacity of about 91 bcm, with a maximum withdrawal rate of about 6,500 GWh/day (590 mcm/day)[21].
- **Cross-border interconnection points**: Physical or virtual points where gas can flow between neighboring transmission systems or market areas. Interconnection points are essential for the integration and interoperability of the EU gas market, and they are subject to specific rules and procedures under EU network codes. In 2023, there were 92 cross-border interconnection points among EU Member States, with a total technical capacity of about 3,500 GWh/day (320 mcm/day)[22].

The EU gas infrastructure was built over several decades and has undergone significant changes and investments in recent years, but there are several challenges it currently faces. First, there is uneven development and usage. The level of infrastructure development and interconnection varies considerably among Member States: some regions (e.g., northwestern Europe) have a more integrated gas network than others (e.g., southeastern Europe), which creates obstacles and barriers to cross-border trade and market integration. At the same time, a significant portion of the EU's gas infrastructure is ageing and requires substantial investment in maintenance and modernisation. This is particularly challenging in the context of declining gas demand and increasing uncertainty about the future role of gas in the energy mix. The decarbonisation of the energy system and the transition to renewable biogases may further increase the potential underutilisation of some existing gas facilities. This raises questions about the optimal level and allocation of infrastructure investments and the fair distribution of costs and risks among market participants and consumers, especially considering the increasing TSO and DSO tariffs to cover operations costs once the network utilisation decreases. Related to this issue is the question of the future use of transportation pipelines such as Yamal, Nord Stream, and Brotherhood, which remain unused due to geopolitical changes. Lastly, EU gas infrastructure faces a variety of geopolitical and security risks, such as threats of supply disruptions, trade disputes, and cyberattacks.

7 Conclusion

Over the past three decades, the EU gas market has markedly evolved from a fragmented, monopolistic sector to one driven mainly by competitive and transparent price signals. The

[20] These data are compiled from three datasets: https://alsi.gie.eu/; https://ieefa.org/european-lng-tracker; https://www.gie.eu/publications/maps/gie-lng-map/ (accessed 21.6.2024).

[21] The data based on https://agsi.gie.eu/ (12.7.2024).

[22] These data were processed based on information from https://www.entsog.eu/sites/default/files/2024-02/ENTSOG_GIE_SYSCAP_2024_Update%20Feb.pdf (July 12, 2024).

transition from oil-indexed contracts to gas-on-gas competition, supported by liquid trading hubs such as TTF and THE, has lowered transaction costs and improved flexibility. At the same time, the harmonised balancing regime, unbundling requirements, and comprehensive network codes have reshaped the institutional landscape, encouraging cross-border coordination and greater participation by suppliers, traders, and shippers.

In recent years, the European gas market's gradual shift away from historically dominant oil-linked contracts toward more market-based pricing mechanisms has introduced a broad range of instruments, from long-term arrangements to spot and short-term trading. Although Gas-on-Gas Competition (GOG) continues to gain traction, legacy pricing models and divergent regulatory frameworks persist across EU Member States, underscoring the market's heterogeneity. At an operational level, balancing and flexibility regimes play fundamental roles in ensuring daily alignment between supply and demand, with storage capacity across the EU mitigating both seasonal and short-term fluctuations. Substantial infrastructure investments have diversified supply routes, including the deployment of LNG import terminals and floating storage regasification units (FSRUs). Yet, uneven development and ageing networks remain key concerns, especially against the backdrop of declining gas demand and ambitious decarbonisation goals.

From a policy perspective, strengthening harmonisation, investing in the modernisation of the infrastructure, and promoting low-carbon energy solutions are important for maintaining both efficiency and sustainability while preserving the network utilisation in the decarbonisation process. Harmonised market codes, refined capacity-booking procedures, and consistent imbalance charges can help narrow cross-border liquidity and transparency gaps. Simultaneously, integrated policy frameworks must address the evolving role of gas, whether as a transitional fuel or, increasingly, in connection with adaptation or retrofitting to hydrogen or biomethane. Moreover, ensuring the security of supply and managing cost allocation equitably, particularly for consumers, calls for continued alertness in the face of geopolitical risks and market volatility.

Appendix

A.1 Overview of the national regulators, exchanges and TSOs

Country	Transmission System Operator (TSO)	Exchange	Regulatory Authority
Austria	Gas Connect Austria, TAG	Central European Gas Hub (CEGH), EEX	Energie-Control Austria (E-Control)
Belgium	Fluxys	EEX	Commission for Electricity and Gas Regulation (CREG)
Bulgaria	Bulgartransgaz	Balkan Gas Hub	Energy and Water Regulatory Commission (EWRC)
Croatia	Plinacro	Croatian Energy Market Operator (HROTE)	Croatian Energy Regulatory Agency (HERA)

Cyprus	-	-	Cyprus Energy Regulatory Authority (CERA)
Czech Republic	NET4GAS	OTE, EEX	Energy Regulatory Office (ERÚ)
Denmark	Energinet	EEX	Danish Utility Regulator (DUR) / Forsyningstilsynet
Estonia	Elering	GET Baltic	Estonian Competition Authority
Finland	Gasgrid Finland	GET Baltic	Energy Authority / Energiavirasto
France	GRTgaz	Powernext Gas Spot/EEX	Energy Regulation Commission (CRE)
Germany	ONTRAS Gastransport, Open Grid Europe, Gasunie Deutschland, GRTgaz Deutschland	European Energy Exchange (EEX)	Federal Network Agency (BNetzA)
Greece	DESFA	Hellenic Energy Exchange	Regulatory Authority for Energy (RAE)
Hungary	FGSZ	CEEGEX, HUPEX	Hungarian Energy and Public Utility Regulatory Authority (MEKH)
Ireland	Gas Networks Ireland	-	Commission for Regulation of Utilities (CRU)
Italy	Snam Rete Gas	Italian Gas Market (MGAS)	Italian Regulatory Authority for Energy, Networks, and Environment (ARERA)
Latvia	Conexus Baltic Grid	GET Baltic	Public Utilities Commission (PUC)
Lithuania	Amber Grid	GET Baltic	National Energy Regulatory Council (NERC)
Luxembourg	Creos Luxembourg	-	Luxembourg Institute of Regulation (ILR)
Malta	-	-	Regulator for Energy and Water Services (REWS)
Netherlands	Gasunie Transport Services (GTS)	EEX, ICE Endex	Authority for Consumers and Markets (ACM)
Poland	Gaz-System	Polish Power Exchange (TGE)	Energy Regulatory Office (URE)
Portugal	REN Gasodutos	MIBGAS	Energy Services Regulatory Authority (ERSE)
Romania	Transgaz	Romanian Commodities Exchange (BRM)	Romanian Energy Regulatory Authority (ANRE)
Slovakia	Eustream	42 FS Broker	Regulatory Office for Network Industries (URSO)
Slovenia	Plinovodi	-	Energy Agency of the Republic of Slovenia (AGEN-RS)
Spain	Enagás	MIBGAS, EEX	National Commission for Markets and Competition (CNMC)
Sweden	Swedegas	-	Energy Markets Inspectorate

	(Ei)

Source: Author

A.2 Overview of the legal documents related the to EU gas market

Legal Document	Year	Key Objectives	Key Provisions
First Gas Directive (98/30/EC)	1998	Start of gas market liberalization.	Common rules for natural gas markets, third-party access (TPA), supply-transmission unbundling, national transposition by 2000.
Second Gas Directive (2003/55/EC)	2003	Accelerate market liberalization.	Legal/functional unbundling, independent regulatory authorities, expanded TPA, transparency, and market competition.
Security of Supply Directive (2004/67/EC)	2004	Protect natural gas supply security.	National emergency plans, gas storage capacity, diversification of sources, regional cooperation, and solidarity.
Regulation 1775/2005	2005	Strengthen internal gas market regulations.	Directly binding rules on access to transmission systems, tariff structures, capacity allocation, and cross-border trade facilitation.
Third Energy Package (Directive 2009/73/EC & Regulation 715/2009)	2009	Enhance market competition and integration.	Ownership unbundling, creation of ACER, and ensuring non-discriminatory network access.
Gas Security of Supply Regulation (994/2010)	2010	Improve resilience to supply disruptions.	N-1 infrastructure criterion, mandatory risk assessments, and regional cooperation.
REMIT (1227/2011)	2011	Increase transparency and integrity in wholesale gas markets.	Ban on insider trading/market manipulation, mandatory transaction reporting.
TEN-E Regulation (347/2013)	2013	Support strategic gas infrastructure projects.	Identification of PCIs, streamlined permitting, and financial support for interconnectors and LNG terminals.
LNG and Gas Storage Strategy (COM/2016/49)	2016	Promote LNG infrastructure and gas storage use.	Enhance diversification and flexibility of supply, improve access to global LNG markets.
Update of Gas Security of Supply Regulation (2017/1938)	2017	Strengthen crisis management.	Introduced solidarity principle, regional risk assessment groups.
Clean Energy Package (2018–2019)	2018–2019	Integrate renewable gases and improve energy system flexibility.	Focused on sector coupling and integration of renewable energy.
European Green Deal (COM/2019/640)	2019	Achieve climate neutrality by 2050.	Shift away from natural gas to decarbonized gases, sustainable economic strategies.
Taxonomy Regulation (2020/852)	2020	Guide sustainable investments.	Classified natural gas as transitional under certain conditions.
Hydrogen Strategy (COM/2020/301)	2020	Support hydrogen as a key energy source.	Large-scale hydrogen production, repurposing gas infrastructure, and shifting demand patterns.
Methane Strategy (COM/2020/663)	2020	Reduce methane emissions in the gas sector.	Monitoring, reporting, and managing methane emissions.

TEN-E Regulation Update (2022/869)	2022	Align infrastructure with Green Deal goals.	End support for natural gas projects; focus on hydrogen and smart grids.
REPowerEU (COM/2022/230)	2022	Reduce reliance on Russian gas.	Promote biomethane, renewable hydrogen, and energy diversification.
Emergency Intervention Regulation (2022/1854)	2022	Address energy price crisis.	Temporary measures for high prices, voluntary gas demand reduction target.
Gas Storage Regulation (2022/1032)	2022	Ensure gas supply security in winter.	Minimum gas storage levels (80% by 2022, 90% thereafter).
Gas Demand Reduction Regulation (2022/1369)	2022	Reduce winter gas demand.	Voluntary 15% reduction target, mandatory in emergencies.
Joint Gas Purchase Platform (C/2022/8036)	2022	Strengthen EU's negotiating power.	Joint procurement mechanism for better prices and supply conditions.
Renewable Energy Directive II & Revision (2018, 2022)	2018, 2022	Promote renewable energy, including renewable gases.	Set renewable energy targets and foster gas sector decarbonization.

Source: Author

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