LITHUANIAN ENERGY AGENCY

ENERGY SECURITY CHANGES IN THE BALTIC REGION IN 2022-2024

Document	ENERGY SECURITY CHANGES IN THE BALTIC REGION IN 2022-2024
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Abstract	The main aim of the study is to analyze the energy security situation in the Baltic Sea Region. After Russia started the war in Ukraine there were changes implemented in national policies, which are aimed to change the energy security landscape in the region. This led to a construction of new gas terminals in the region, change of main energy suppliers and increased adoption of RES (Renewable Energy Sources). There were a number of events or accidents which affected the energy infrastructure in the region, raising concerns on how energy infrastructure and links can be protected, and how the energy sector may function in case of such accidents. In the light of these developments EUSBSR PA Energy project represented by Lithuanian Energy Agency performed a comprehensive analysis of the energy security landscape in the Baltic Sea region, focusing on Lithuania, Latvia, Estonia, and Finland during 2022-2024. It highlights the region's transition from reliance on Russian energy imports to diversified and integrated energy systems, emphasizing infrastructure development, renewable energy adoption, and strategic policy shifts. The study on energy security aims to analyze best examples and address main issues of energy security in the region, such as: • Energy security transformation; • Electricity generation shifts: • Gas demand and supply changes • Electricity grid integration • Infrastructure resilience challenges • Oil sector dynamics • Affordability and market volatility • Nuclear energy role • Hydrogen and decarbonization efforts • Regional cooperation and future outlook The study also provides a comprehensive analysis of energy security through the 4A's principle by introducing accessibility, affordability, acceptability, and availability within each of the sectors, such as gas, electricity, oil, hydrogen and etc.
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1. Introduction

Over the past decade, the energy security situation in the Baltic region has been shaped by drive towards energy supplies diversification and independence from reliance on Russian energy imports. This was accompanied by necessary infrastructure development, construction of new energy connections, increased market integration with Europe, and an aim for increasing decarbonization of the energy sector. The main aim of this study is to analyze the energy security situation in the Baltic Sea Region, focusing on Baltic States and Finland.

Historically Russia has been a major energy resources supplier to the Baltic States and Finland. This historical reliance coming from the times of soviet occupation has given Russia leverage, which it has used and still trying to use as a political tool to influence new EU and NATO members.[1] The Baltic States have historically relied on Russian electricity grids being part of the IPS/UPS energy network, while gas supply was dominated by Russian Gazprom and its subsidiaries. Russia is known for using its former monopoly to unilaterally increase gas price, threatened to reduce or to cut off natural gas supplies to exert political pressure.[2]

Formerly occupied by Soviet Union, predecessor of current Russian Federation, Baltic States inherited a heavily centralized energy infrastructure linked to Russia. Railroads, oil and natural gas pipelines, and electricity grids were connected to Russian system, leading to infrastructural and supply dependency. However, the firm actions taken during the past two decades led to significant progress in diversifying energy sources and developing infrastructure that reduces this dependency. Finland has also relied on Russian natural gas and electricity, though to a lesser extent than the Baltic States, its energy mixture has been rather well diversified, with a mix of nuclear and renewable energy sources.[3]

The Baltic States and Finland have undertaken the significant efforts to enhance energy security and reduce reliance on Russian energy. Some key developments include two new LNG terminals in the region for import of non-Russian LNG. New electricity connections, such as EstLink, NordBalt and LitPolLink increased the security of an electricity sector. In 2025 synchronization with continental European grid will cut ties with Russian-controlled synchronous transmission grid.[4] Increasing share of renewable resources in electricity and heating sectors as well as new nuclear power unit (Olkiluoto 3) in Finland will reduce dependency on Russian imports and fossil fuels in general.[5] Overall, the past decade has seen significant progress in reducing the energy security risks posed by Russian influence in the Baltic States and Finland. Ongoing projects and policies are set to further enhance regional energy security and resilience.

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[1] Korteweg, R. (2018). *Energy as a tool of foreign policy of authoritarian states, in particular Russia*. European Parliament. https://www.europarl.europa.eu/RegData/etudes/STUD/2018/603868/EXPO_STU(2018)603868_EN.pdf

[2] Korteweg, R. (2018). *Energy as a tool of foreign policy of authoritarian states, in particular Russia*. European Parliament. https://www.europarl.europa.eu/RegData/etudes/STUD/2018/603868/EXPO_STU(2018)603868_EN.pdf

[3] Vadén, T., Majava, A., Korhonen, J. M., & Eronen, J. T (2023). *Energy without Russia: The consequences of the Ukraine war and the EU sanctions on the energy sector in Europe (Country Report Finland).* Friedrich-Ebert-Stiftung. https://collections.fes.de/publikationen/ident/fes/20613

[4] Ministry of Climate of the Republic of Estonia (2024). *Hundred-Days' Countdown to Baltic Synchronization with the European Electricity Grid*. https://kliimaministeerium.ee/en/news/hundred-days-countdown-baltic-synchronization-european-electricity-grid

[5] Vadén, T., Majava, A., Korhonen, J. M., & Eronen, J. T (2023). *Energy without Russia: The consequences of the Ukraine war and the EU sanctions on the energy sector in Europe (Country Report Finland).* Friedrich-Ebert-Stiftung. https://collections.fes.de/publikationen/ident/fes/20613

The Russian invasion of Ukraine has had significant consequences for the whole European energy sector not excluding Baltic region. In natural gas sector, the loss of piped Russian gas supplies caused extreme volatility of gas prices (TTF reached more than €340/MWh in March 2022 and August 2022), which led to search of alternative supply sources, especially LNG. This increased LNG imports, transforming Europe into the primary destination for flexible LNG cargoes, particularly from the United States.[6] However, to ensure the capability to accept gas from other suppliers, large investments in infrastructure projects were necessary. Finances flowed to new LNG terminals and interconnectors which improved the flexibility of Europe's gas transmission network. The ever-changing landscape has led to an increased pace of gas sector policy changes in Europe. In this sense, the Baltic region is a good example of fast adaptation of changed political and gas supply reality.

Other sectors followed a similar pathway. Disturbed prices of natural gas directly affected wholesale electricity prices due to marginal pricing mechanism. While prices have fallen significantly from their 2022 peaks, the market remains fragile and subject to volatility due to its new reliance on global LNG balances, with European prices still double their historical average in 2023.[7] This put pressure on consumers and businesses but also encouraged investments in renewable energy sources in order to reduce reliance on fossil fuels. Some European countries revived interest or increased the pace of their nuclear energy implementation program. The start of the war in Ukraine led to a price shock in the oil sector, which stabilized in half a year. Meanwhile, sanctions on Russian oil and its products made many European states change their import sources – most of them turning to other continents for supply. Thanks to these sanctions, the EU successfully reduced the share of Russian oil and petroleum products in its imports from 21% in 2022 to just 4% in 2023.[8] Increased costs of fuels also directly affected the costs of heating in homes and businesses, affecting energy poverty and economic competitiveness. This led to increased use of energy efficiency measures and the use of alternative fuels to avoid the transfer of high gas prices to the heating sector.

Between 2022 and 2024, the Baltic Sea region experienced several significant disruptions to energy infrastructure, raising concerns about the security and resilience of critical systems as well as the need to enhance protection of this infrastructure. Main incidents were Nord Stream Pipeline Explosions in September 2022[9], BalticConnector gas pipeline damage in October 2023[10], undersea internet cables incidents in November 2024 and Estlink 2 power cable disruption in December 2024[11]. Moreover Estlink 2 was not operational in between January and September 2024 due to a cable failure.

Overall, the Russian aggression in Ukraine has accelerated changes in the European energy sector, especially in Russian neighborhood – Baltic region, even more highlighting the need for diversification, energy security, and a more rapid transition to renewable energy sources. The increased importance of more active protection of critical energy infrastructure, especially undersea energy interconnections, is also a problem which will have to be addressed in the near future.

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[6] International Energy Agency (2024). *What drives natural gas price volatility in Europe and beyond?* *https://www.iea.org/commentaries/what-drives-natural-gas-price-volatility-in-europe-and-beyond*

[7] International Energy Agency (2024). *What drives natural gas price volatility in Europe and beyond?* *https://www.iea.org/commentaries/what-drives-natural-gas-price-volatility-in-europe-and-beyond*

[8] Kouam, A. (2025). *Russian fossil fuel phase-out: An imperative for the European Union*. Strategic Perspectives. https://strategicperspectives.eu/russian-fossil-fuel-phase-out/

[9] Brown, C. (2024). This Ukrainian diver is the only person charged in the Nord Stream pipeline explosions. He says he's a scapegoat. CBC News. https://www.cbc.ca/news/investigates/nord-stream-pipeline-explosion-ukraine-diver-1.7296527

[10] Cooban, A. (2023). *Suspected sabotage shuts another European gas pipeline. Here's what you need to know*. CNN. https://edition.cnn.com/2023/10/11/energy/baltic-pipeline-explainer

[11] ERR. (2024). *Estonian-Finnish undersea power link Estlink 2 down again due to fault*. ERR News. https://news.err.ee/1609560328/estonian-finnish-undersea-power-link-estlink-2-down-again-due-to-fault

Moreover, the Ukrainian experience showed the fragility of centralized energy system. This should be considered during energy transformation and decarbonization.

To understand regional changes better the need for summarizing energy security study arises, especially in the light of Russian aggression against Ukraine. The main aim of this study is to analyze the current energy security situation and ongoing changes in the Baltic Sea Region, focusing on Baltic States and Finland.

2. Energy security

Definitions of energy security are given by different sources however they are very similar. E.g. energy security is defined by IAE as the uninterrupted availability of energy sources at an affordable price [12]. EU defines it as a stable access to energy sources on a timely, sustainable and affordable basis[13]. OECD definition stands as avoidance of unanticipated disruptions in energy production or imports, as well as price stability and continuation of historical price levels[14].

To sum up, definition of energy security covers the availability, sustainability, reliability and affordability of energy sources and systems. For a state or region, it means the possibility to ensure uninterrupted access to energy sources at affordable prices, while maintaining resilience against various risks or disruptions. Different quantitative indicators can be used to assess energy security such like energy self-sufficiency, energy diversity index, electricity system reliability metrics, price (price fluctuations) of energy resources or renewable energy share in the energy mix[15][16].

These indicators also point to the pathways how to ensure acceptable level of energy security: aim for energy self-sufficiency, increasing energy diversity, maintaining resilient and reliable electricity system securing a stable prices of energy resources, and increasing share of RES in primary energy mix. Other factors such as increasing energy efficiency, ensuring the existence of sufficiently diversified strategic energy reserves, ensuring physical security of energy system and keeping adequate infrastructure investment levels also should not be forgotten.

Different sectors in the regions face different challenges, however the main direction towards regional integration and common market with EU is underway in the Baltic States, while Finland is currently better integrated in common markets of EU.

Several risks can threaten energy security, including:

- Geopolitical Conflicts: Disruptions in energy supply due to international disputes or conflicts, often related to oil and gas – typical example may be wars in Middle East, threatening oil and gas supply. Russian war in Ukraine caused disruptions and uncertainties of energy supply as well.
- Natural Disasters: Natural events like floods, droughts, forest fires, extreme heat or cold spells that may disrupt energy infrastructure. This can affect countries relying mostly on renewable energy resources with events affecting energy supply, while infrastructure could be affected by extreme events.
- Technical Failures: Breakdowns in energy systems due to aging infrastructure or inadequate maintenance.

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[12] International Energy Agency (2022). *World Energy Outlook 2022*. https://www.iea.org/reports/world-energy-outlook-2022

[13] European Commission (2000). *Green Paper - Towards a European strategy for the security of energy supply*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52000DC0769

[14] OECD (2008). *Energy Security and Competition Policy*. https://www.oecd.org/en/publications/energy-security-and-competition-policy_6eaf285b-en.html

[15] Siksnelyte-Butkiene et al. (2024). *Comprehensive Analysis of Energy Security Indicators and Measurement of Their Integrity.* Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2023.123167

[16] Karpavicius, Balezentis, and Streimikiene (2024). *Security Indicators for Sustainable Energy Development: Application to Electricity Sector in the Context of State Economic Decisions*. Sustainable Development. https://doi.org/10.1002/sd.3190

- Cyberattacks: Increasing risks of cyber threats to energy systems, including power grids and pipelines. Unsafe equipment from third countries, e.g. inverters of solar panels, could also be a target for hybrid attacs.
- Economic Fluctuations: Rapid changes in energy markets or global economies that impact energy prices and availability – changes in expectations and uncertainty about the future affects availability and price of energy supplies.
- Regulatory and Policy Risks: Unpredictable changes in government policies, regulations, or international agreements that affect energy production and consumption.

3. Recent energy security reviews in the Baltic sea region

In recent years, there has been increased interest about energy security in the Baltic Sea region, this interest is covered in various studies and scientific papers, covering different aspects of the topic. Key studies and research papers covering this topic are:

- Energy Security in the Baltic Sea Region (2022)

This Danish Institute for International Studies Report provided a brief overview of the energy security situation in the Baltic Sea Region, zooming in on eight country cases (Denmark, Sweden, Finland, Estonia, Latvia, Lithuania, Poland and Germany). By locating the national energy policies in a historical context that shaped choices of energy infrastructure and technology, the analysis suggests how the energy policy and energy mix of each country was affected by cutting the energy ties with the Kremlin following the outbreak of war in 2022.

- Analysis of Energy Security Level in the Baltic States Based on Indicator Approach (2020)

This study by Lithuanian researchers provides analysis of the Baltic States regarding the performance of energy security level based on indicators. It provides a comparative assessment of energy security across Estonia, Latvia, and Lithuania. The analysis covers 2008–2016, in which the Baltic States faced essential changes in the energy sector. The methodology, based on indexes, is adopted for an integral measure of energy security level. The system of indicators is proposed, which considers technical, economic, geopolitical and sociopolitical aspects of energy security.

- Energy Security in the Baltic Sea Region: Regional Coordination and Management of Interdependencies (2015)

The study maps changing energy relations in the Baltic Sea region in the aftermath of two events – the 2004 EU enlargement that has changed the political and institutional/regulatory landscape of the region and the 2014 Russian aggression in Ukraine that has put the issue of energy security – and security in more general terms – very high on the European political agenda.

Smaller scale papers that analyzes energy security situation in the region gives less comprehensive view but focuses on some more particular issues:

- Development of Energy Security in Finland and in the Baltic States since 1991 (2020)

Aalto University (Finland) researchers in their paper analyzed trends in self-sufficiency, carbon intensity, and affordability in Finland and the Baltic States from 1991 onwards. It highlights the significant changes in the Baltic energy systems compared to Finland's more stable development.

- Energy security in the Baltic-Black Sea region: energy insecurity sources and their impact upon states (2012)

This paper examines the problems related to the energy security of Lithuanian, Belarus and Ukraine. The main energy problem areas discussed are oil and natural gas resources

- Transatlantic Energy Security From a Baltic Perspective (https://www.fpri.org/article/2024/11/transatlantic-energy-security-from-a-baltic-perspective/_ (2024)

Article discusses the transformation of the Baltic region into a European energy security stronghold, highlighting the success story of the Baltic States in enhancing their energy independence.

Research papers Energy citizenship in energy transition: the case of the Baltic states (2024) and Energy Security Innovation in the Baltic Sea Region (2024) analyzes social perception of Energy security and “energy citizenship” cases in the region.

4. Study Approach

4.1. Research Structure

This study adopts a thematic and cross-country analytical structure rather than a traditional country-by-country narrative. This approach is based on the fact that the energy systems of Lithuania, Latvia, Estonia, and Finland are not isolated units but components of an increasingly integrated subregional ecosystem. As noted in the foundational premise of this research, energy security in this region cannot be meaningfully assessed through national statistics alone; operational stability is determined by the aggregate behavior of the entire Baltic–Nordic subregion. It is shaped by common infrastructural dependencies, shared weather patterns, and market coupling via NordPool.

Consequently, the specific technical and market variables identified in the preliminary research – such as generation structures, cross-border balances, and synchronization obligations – are synthesized into the "4 A’s" framework. This synthesis allows the study to highlight not only national trajectories but also the systemic interactions and frictions that define the region's post-2022 security landscape. The main goal of this study is to understand how the Baltic-Finnish energy systems have adapted to external shocks, particularly the Russian invasion of Ukraine, and to evaluate their evolving energy security policies within the broader Baltic Sea region’s and EU energy policy frameworks. The following research questions guide the study:

- How did Russian aggression against Ukraine impact various energy sectors in the selected countries?
- How secure are the selected countries energy sectors’ post-invasion?
- What measures were taken to strengthen energy security in a pivot away from Russia?
- What are long-term goals and strategies to strengthen energy security in the present and beyond?

To provide analytical rigor and a consistent structure, this study adopts a dual framework that defines both the thematic scope and the analytical lens of the research. Thematic in a sense that each major energy sector is covered, and analytical in the scope of this study which is defined by the aforementioned “4 A’s” of energy security. This framework is utilized by organizations like the Asia Pacific Energy Research Centre.[17] It ensures that all critical dimensions of energy security are addressed comprehensively. The four A's are:

- **Availability,** the main, foundational dimension of energy security, concerned with the physical presence and robustness of energy supplies. It evaluates a nation‘s resilience against physical or geopolitical disruptions. Availability measures dependency on imports, the diversity of suppliers, the share of domestically produced energy in the final consumption. A high degree of availability signifies low risk of supply shortages.[18] In the context of the energy transition, Availability is expanded to include the capacity of renewable energy technologies (RETs) to replace fossil baseloads. This includes analyzing the intermittency of renewable sources and the necessity of "system resilience and redundancy measures".[19] For

[17] Asia Pacific Energy Research Centre (2007). *A Quest for Energy Security in the 21st Century: Resources and Constraints.*https://aperc.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf
[18] Asia Pacific Energy Research Centre (2007). *A Quest for Energy Security in the 21st Century: Resources and Constraints.*https://aperc.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf
[19] Bain, R. J. (2025). *Making Energy Transitions Work: Defining Success and Metrics for Tracking Progress.* RAND Corporation. https://www.rand.org/pubs/working_papers/WRA3116-2.html

the Baltic region, this dimension examines the rapid shift from Russian fossil fuel dependence to global LNG markets and the acceleration of domestic renewable production capacities.

- **Accessibility** measures the physical and market-based connectivity of selected country's energy system. It measures the ability to access the resources, and assesses the adequacy of infrastructure, such as cross-border electricity interconnectors and gas pipelines, which allow a nation to access regional markets. Accessibility means integration which prevents a nation becoming an energy island. Through good access, import in the times of need is possible while also allowing the export of surpluses, thus enhancing stability and operational costs of a country's energy system.[20] Post-2022, Accessibility in this region is heavily influenced by "securitization," where energy is moved from the realm of normal politics to security politics due to existential threats.[21] This dimension analyzes the geopolitical "break" from Russian grids and the prioritization of national sovereignty over market efficiency.[22] It also includes the physical "grid modernization" required to handle bidirectional power flows from distributed renewable sources.[23]
- **Affordability** is the economic aspect of energy security. It focuses on the cost burden for households and business alike. It measures the final price of essential energy commodities, natural gas, and transport fuels.[24] Affordable energy is key in preventing energy poverty, ensuring social and political stability while maintain the competitiveness of the national economy. This study views Affordability through the lens of "energy poverty rates" and "price volatility indices" exacerbated by the decoupling from Russian supplies.[25] It also considers the macro-economic competitiveness of the region, noting that while energy security is positively correlated with economic growth, the transition costs must be balanced against the risk of "lost development opportunities" due to high energy prices.
- **Acceptability** evaluates the long-term environmental impact and sustainability of the energy system. For the energy transition to be acceptable, energy system must align with climate goals, and have high public opinion. This includes progress toward renewable energy targets, carbon efficiency of the economy, and the adoption of circular economy in practice. In other words, high acceptability equates to a social license to operate, in addition, being resilient to future climate-related policy changes.[26] This dimension is broadened to include "energy justice" and the "social impacts" of transition, such as the equitable distribution of costs and benefits among populations.[27] It also incorporates the concept of the "circular economy transition," examining how energy systems interact with resource cycles and waste minimization.[28] Furthermore, it addresses the "riskification" of energy decisions, where long-

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[20] Asia Pacific Energy Research Centre (2007). *A Quest for Energy Security in the 21st Century: Resources and Constraints.*https://aperc.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf

[21] Sivonen, M. H., & Kivimaa, P. (2024*). Securitization of Energy Transitions in Estonia, Finland and Norway.* International Political Sociology. International Political Sociology. https://doi.org/10.1093/ips/olae017

[22] Sivonen, M. H., & Kivimaa, P. (2024*). Securitization of Energy Transitions in Estonia, Finland and Norway.* International Political Sociology. International Political Sociology. https://doi.org/10.1093/ips/olae017

[23] Bain, R. J. (2025). *Making Energy Transitions Work: Defining Success and Metrics for Tracking Progress..* RAND Corporation.https://www.rand.org/pubs/working_papers/WRA3116-2.html

[24] Asia Pacific Energy Research Centre (2007). *A Quest for Energy Security in the 21st Century: Resources and Constraints.*https://aperc.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf

[25] Bain, R. J. (2025). *Making Energy Transitions Work: Defining Success and Metrics for Tracking Progress..* RAND Corporation.https://www.rand.org/pubs/working_papers/WRA3116-2.html

[26] Asia Pacific Energy Research Centre (2007). *A Quest for Energy Security in the 21st Century: Resources and Constraints.*https://aperc.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf

[27] Bain, R. J. (2025). *Making Energy Transitions Work: Defining Success and Metrics for Tracking Progress..* RAND Corporation.https://www.rand.org/pubs/working_papers/WRA3116-2.html

[28] Bain, R. J. (2025). *Making Energy Transitions Work: Defining Success and Metrics for Tracking Progress..* RAND Corporation.https://www.rand.org/pubs/working_papers/WRA3116-2.html

term precautionary governance (e.g., regarding nuclear power or land use for wind farms) interacts with immediate security threats.[29]

The main body of this report is structured on a 4A's sector-by-sector basis to provide a coherent narrative for each nation's specific energy security transformation. Within each country chapter, the key energy sectors (e.g., electricity, natural gas, oil) are reviewed. After each sectoral analysis, we provide the Energy Security indicators.

4.2. Sources and Data collection

To address the research questions regarding the adaptation of Baltic-Finnish energy systems to external geopolitical shocks, this study relies on a qualitative document analysis of primary and secondary sources published between 2018 and 2025. The data collection strategy was designed to ensure a comprehensive coverage of the "4 A's" (Availability, Accessibility, Acceptability, Affordability) by triangulating data from international organizations, national government strategies, Transmission System Operators (TSOs), and academic literature. For indicators, main data points were selected as of 2024, while some were chosen of earlier period due to unavailability of concrete data.

4.2.1. Indicator Framework

4.2.1.1. Availability

In the context of the post-2022 Russian invasion into Ukraine, this dimension helps identify whether Baltic States and Finland can function independently of Russian supply chains. This assessment relies on three core indicators:

- **Energy Import Dependency** measures the extent to which a country relies on imports to meet its energy consumption. It is calculated as the share of imports minus exports (net imports) in gross inland energy consumption.
    - **It is measured in percentages (%).**
    - **Its relevance to energy security** is encapsulated by a fact that import dependency is a primary proxy for exposure to geopolitical risk. A high percentage indicates that the national economy is vulnerable to external supply disruptions. Low percentage, on the other hand, implies a high degree of energy self-sufficiency.
    - **Contextually,** this indicator is critical following the sprint away from Russian fossil fuels. This indicator regards self-sufficiency while highlighting vulnerabilities of nations that lack domestic fossil fuel.
    - Scores are assigned based on the level of self-sufficiency, where a lower dependency percentage results in a higher energy security score.
        - **5 (Excellent):** < 20% (High Self-Sufficiency)
        - **4 (Good):** 20% – 40%
        - **3 (Adequate):** 40% – 60% (Around EU Average)
        - **2 (Below Average):** 60% – 80%
        - **1 (Poor):** > 80% (High Vulnerability)

[29] Sivonen, M. H., & Kivimaa, P. (2024*). Securitization of Energy Transitions in Estonia, Finland and Norway.* International Political Sociology. International Political Sociology. https://doi.org/10.1093/ips/olae017

- **Electricity Generation from Low Carbon Sources** measures the "home-grown" security of the electricity sector. It assesses the annual electricity generated from domestic low-carbon sources (including wind, solar, hydro, biomass, and nuclear) as a percentage of total domestic electricity generation,
  - **It is measured in percentages (%).**
  - **Its relevance to energy security** is a high share of domestic low-carbon generation that reduces reliance on imported fossil fuels (gas/coal) for power production. It reflects supply-side security and resilience.
  - **Contextually,** this indicator varies across the region. It captures Finland's robust baseload security provided by nuclear power (approx. 40 % of the mix) and Latvia's reliance on hydropower (approx. 54 %). It also accounts for the security challenges posed by variability of wind and solar RES. They require a stable baseload or storage capacity to ensure continuous availability.
  - Scores are assigned based on the dominance of domestically available clean energy in the generation mix.
    - **5 (Excellent):** > 85 % of total generation
    - **4 (Good):** 65 % – 85 % of total generation
    - **3 (Adequate):** 45% – 65% of total generation
    - **2 (Below Average):** 25% – 45% of total generation
    - **1 (Poor):** < 25% of total generation
- **Supply Source Diversification Index (HHI)** measures the market concentration using the formula of Herfindahl-Hirschman Index This index is applied to the aggregated imports of Crude Oil, Natural Gas, and Electricity. The index is calculated as the sum of the squared market shares of each supplier country.
  - **It is measured in index value (0 to 10 000), and calculated with a formula:**

    $$HHI = \sum(s_i^2)$$

    Where S*i* = each firm's market share (expressed as a whole number, not a decimal).

      - < 1 500 is highly diversified meaning low risk;
      - 1 500 – 2 500 is moderately concentrated;
      - > 2 500 is highly concentrated meaning high risk.
  - **Its relevance to energy security** is the hedge against the weaponization of energy. A low HHI socre indicates a healthy mix of suppliers. It ensures that the loss of one partner does not cripple the system. A high score is more dangerous as it indicates reliance on a low number of suppliers.
  - **Contextually,** this indicator highlights the structural trade-offs of the post-2022 era. While the Baltic States successfully eliminated Russian supplies, they have started to overrely on other partner countries. HHI highlights such cases.
  - Scores are determined by standard market concentration thresholds, penalizing high dependency on limited suppliers.
    - **5 (Excellent):** < 1,500 (Unconcentrated)
    - **4 (Good):** 1,500 – 2,000
    - **3 (Adequate):** 2,000 – 2,500 (Moderately Concentrated)
    - **2 (Below Average):** 2,500 – 4,000 (Highly Concentrated)
    - **1 (Poor):** > 4,000 (Extremely Concentrated/Monopoly)

4.2.1.2. Accessibility

This dimension is particularly significant for the Baltic States as they finalize their synchronization with Continental European Network (CEN). This dimension is measured by these indicators:

- **Cross-Border Electricity Interconnection Capacity** measures the total bidirectional transmission capacity avaliable for the trade of electricity with surrounding countries. It is expressed through a percentage of the country's national peak demand.
  - **It is measured in percentages (%)**
  - **Its relevance to energy security** is that high interconnection capacity is the prerequisite for a functioning common market. It is one of the main stabilizers of electricity system: importing when there is a deficit, exporting when there is a surplus. The EU regulations have set a target for Member States to make at least 70 % of their cross-border available for trade by 2025.[30]
  - **Contextually,** Baltic States are at the forefront of this exceptional performance as ratios are driven by infrastructure build out required for the synchronization with CEN. On the other hand, Finland's ratio is also high, however, in percentage terms it is lower due to its significantly higher industrial peak demand.
  - Scores are assigned based on the capacity ratio, rewarding infrastructure that exceeds basic EU targets to ensure maximum flexibility during the synchronization process and various emergency situations that require cross-border interconnections.
    - **5 (Excellent):** > 50% of peak demand
    - **4 (Good):** 25% – 50% of peak demand
    - **3 (Adequate):** 15% – 25% of peak demand (EU Interconnection Target)
    - **2 (Below Average):** 5% – 15% of peak demand
    - **1 (Poor):** < 5% of peak demand
- **Gas Interconnector Capacity (N-1 Rule Compliance)** is an indicator, which is a standard measure for gas infrastructure redundancy. It calculates the percentage of total daily gas demand that can be satisfied on a day when an exceptionally high consumption occurs, even if the largest gas infrastructure element fails (for this case: LNG terminals).
  - **It is measured in percentages (%)**
  - **Its relevance to energy security** is that it shows whether gas system of a nation is resilient or not. Scores above 100 % indicate that it can withstand major supply interruptions. This is critical for assessing resilience against technical failure or geopolitical sabotage.
  - **Contextually,** following the cessation of Russian gas imports, this indicator measures the capacity of alternative routes. Latvia and Finland lead the region due to the massive buffer provided by the Inčukalns underground gas storage, and the Inkoo LNG terminal, respectively. Lithuania is also present in this calculation.
  - Scores are determined by the level of redundancy above the mandatory EU compliance threshold (100%).
    - **5 (Excellent):** > 160% (High Redundancy)
    - **4 (Good):** 120% – 160% (Strong Buffer)
    - **3 (Adequate):** 100% – 120% (Compliant)
    - **2 (At Risk):** 80% – 100% (Non-Compliant)
    - **1 (Poor):** < 80% (Critical Vulnerability)

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[30] European Union (2019). *Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast)*. https://eur-lex.europa.eu/eli/reg/2019/943/oj/eng

- **Grid Reliability (SAIDI)** is an indicator that measures System Average Interruption Duration, which represents the average total duration of power outage (in minutes) experienced by a customer over the course of the year.
    - **It is measured in minutes per customer per year.**
    - **Its relevance to energy security is that** it measures the "last mile" security, meaning a low SAIDI value indicates weatherproof, well-maintained grid that supports economic continuity. High values indicate vulnerability to storms and aging infrastructure.
    - **Contextually,** there is a sharp regional divide. Finland has achieved a world-class standard due to extensive underground cabling. In contrast, the Baltic States face significantly higher outage times, with Lithuania almost crossing 400 minutes mark due to a major storm in spring of 2024. Overall, Baltic States are in need for modernization investments to replace overhead line in forested areas.
    - Scores are benchmarked against international best practices for grid reliability, where lower outage times indicate superior infrastructure resilience.
        - **5 (Excellent):** < 30 minutes (Weatherproof/Underground Grid)
        - **4 (Good):** 30 – 75 minutes
        - **3 (Adequate):** 75 – 150 minutes (Standard Overhead Grid)
        - **2 (Below Average):** 150 – 250 minutes
        - **1 (Poor):** > 250 minutes (Significant Infrastructure Deficit or a Major Event)

4.2.1.3. Affordability

This dimension is critical for ensuring social stability, preventing energy poverty, and maintaining economic competitiveness within the region. This dimension is measured by these indicators:

- **Household Electricity Price** measures the final, all-inclusive price paid by residential consumers for electricity, including the energy component, network costs, taxes, and levies.
    - It is measured in **Euros per kilowatt-hour (EUR/kWh)**.
    - **Its relevance to energy security** is that it acts as a direct measure of market efficiency and the risk of energy poverty. Competitive electricity prices indicate a well-functioning market integration and efficient grid management, while high prices can suppress economic activity and burden vulnerable households.
    - **Contextually,** he Baltic States and Finland operate within the common Nord Pool spot market. Theoretically, this should lead to price convergence. Contextually, this indicator reveals how differences in national taxation, distribution network tariffs, and the level of effective interconnection capacity influence the final price paid by the consumer, despite the shared wholesale market.
    - Scoring logic is based on the final price relative to the regional peer group, rewarding lower costs for consumers.
        - **5 (Excellent):** < 175 EUR/MWh
        - **4 (Good):** 175 – 195 EUR/MWh
        - **3 (Adequate):** 195 – 215 EUR/MWh
        - **2 (Below Average):** 215 – 235 EUR/MWh
        - **1 (Poor):** > 235 EUR/MWh
- **Average Household Gas Price** measures the annual weighted average price paid by residential consumers for natural gas, which is a primary fuel for heating in the region.
    - It is measured in **Euros per kilowatt-hour (EUR/kWh)**.

    - Its relevance to energy security is tied to the cost of heating and the competitiveness of alternative energy sources. Affordable gas prices reflect successful diversification strategies (e.g., access to global LNG) that prevent monopolistic pricing, whereas high prices can force consumers toward more polluting solid fuels.
    - **Contextually,** following the cessation of Russian gas imports, the region now relies on LNG terminals (Klaipėda in Lithuania, Inkoo in Finland). This indicator contextually measures the effectiveness of these new supply chains and the ability of national retailers to secure competitive cargoes from the global market.
    - Scores are assigned based on comparative affordability within the region:
        - **5 (Excellent):** < 80 EUR/MWh
        - **4 (Good):** 80 – 100 EUR/MWh
        - **3 (Adequate):** 100 – 120 EUR/MWh
        - **2 (Below Average):** 120 – 150 EUR/MWh
        - **1 (Poor):** > 150 EUR/MWh
- **Transport Fuel Prices (Affordability)** measures the affordability of mobility by calculating the average annual expenditure on road transport fuels (gasoline and diesel) as a share of a household's net median income.
    - It is measured in **percentages (%) of net yearly median income**.
    - **Its relevance to energy security** lies in the impact of global oil volatility on the domestic economy. Since transport fuels are globally priced, security is measured by the domestic capacity to pay. A high percentage indicates that mobility costs are consuming a disproportionate share of income, limiting economic mobility and increasing the cost of goods.
    - **Contextually,** this indicator highlights the structural economic disparities within the Baltic Sea region. It accounts for the fact that while a liter of petrol may cost roughly the same in Helsinki and Riga, the economic impact of that purchase is vastly different due to the gap in median income levels between the Nordic and Baltic economies.
    - Scoring logic evaluates the relative financial burden on the average household:
        - **5 (Excellent):** < 4.0% of annual income
        - **4 (Good):** 4.0% – 5.0% of annual income
        - **3 (Adequate):** 5.0% – 7.0% of annual income
        - **2 (Below Average):** 7.0% – 9.0% of annual income
        - **1 (Poor):** > 9.0% of annual income

4.2.1.4. Acceptability

The **Acceptability** dimension evaluates the long-term environmental and social sustainability of the energy system. It measures the extent to which the energy sector aligns with national and European climate goals, thereby securing the "social license to operate." A system that fails to decarbonize or manage resources efficiently faces regulatory risks, financial penalties, and public opposition. This dimension is measured by three core indicators:

- **National Energy and Climate Plan (NECP) Compliance Target Achievement** measures the progress a country has made towards its binding national target for the share of renewable energy sources (RES) in gross final energy consumption by 2030. It compares the most recent verified data against the 2030 goal set in the country's NECP.
    - It is measured in **percentages (%) of the 2030 target achieved**.

    - Its relevance to energy security lies in policy stability and future-proofing. High performance indicates that a country is successfully implementing its transition strategy, reducing the risk of drastic regulatory interventions or failure to meet EU climate obligations.
    - Contextually, this indicator reveals the gap between political ambition and infrastructure execution across the region. While the Baltic Sea region is collectively viewed as a leader in the green transition, this metric exposes which nations have successfully translated early investments (in wind, hydro, or bioenergy) into tangible progress, versus those that risk falling behind due to permitting delays or slower deployment rates.
    - Scores are assigned based on the percentage of the 2030 goal already realized, rewarding early action and high implementation rates.
        - **5 (Excellent):** > 80% of target achieved
        - **4 (Good):** 65% – 80% of target achieved
        - **3 (Adequate):** 50% – 65% of target achieved
        - **2 (Below Average):** 35% – 50% of target achieved
        - **1 (Poor):** < 35% of target achieved
- **Greenhouse Gas (GHG) Emissions Intensity of the Economy** measures the carbon efficiency of economic production. It is calculated as the total national greenhouse gas emissions divided by the Gross Domestic Product (GDP).
    - It is measured in **grams of CO2 equivalent per Euro of GDP (gCO2e/€)**.
    - Its relevance to energy security is the measurement of "decoupling." A low and declining value indicates that economic growth is no longer tied to increased pollution. This makes the economy more resilient to carbon pricing (ETS) and stricter environmental regulations.
    - Contextually, this indicator highlights the deep structural legacies of national economies. It differentiates between nations with advanced, high-tech industrial bases powered by low-carbon baseloads (such as nuclear) and those still managing the transition away from carbon-intensive legacy industries (such as oil shale). It serves as a proxy for how vulnerable a nation's economic competitiveness is to rising carbon prices.
    - Scores are benchmarked against the EU average (~270 gCO2e/€), rewarding high carbon efficiency.
        - **5 (Excellent):** < 220 gCO2e/€
        - **4 (Good):** 220 – 270 gCO2e/€
        - **3 (Adequate):** 270 – 320 gCO2e/€
        - **2 (Below Average):** 320 – 400 gCO2e/€
        - **1 (Poor):** > 400 gCO2e/€
- **Circular Material Use Rate** measures the share of material recovered and fed back into the economy (from recycled products and waste) relative to the total overall material use.
    - It is measured in **percentages (%)**.
    - Its relevance to energy security is tied to resource independence. A circular economy reduces the need for extraction and importation of primary raw materials, lowering the energy intensity of the supply chain and enhancing sustainability.
    - Contextually, this indicator exposes the statistical distortions caused by differing industrial structures. It illustrates how nations with massive primary extraction sectors (forestry or mining) may appear statistically "linear" due to the sheer volume of virgin materials processed, regardless of their recycling efficiency. Conversely, it highlights

cases where specific industrial byproducts (like ash) can artificially inflate circularity statistics without necessarily reflecting a broadly circular consumer society.

- Scores are based on performance relative to the EU average (~11.5%).
  - **5 (Excellent):** > 15% (Significantly above EU avg)
  - **4 (Good):** 10% – 15% (Around EU avg)
  - **3 (Adequate):** 7% – 10%
  - **2 (Below Average):** 4% – 7%
  - **1 (Poor):** < 4% (Highly Linear Economy)

4.2.2. Data Sources

To understand the broader geopolitical context of energy weaponization and the EU-level response, the study utilizes reports from supranational bodies. Assessments of authoritarian influence on energy markets are drawn from the European Parliament, while the imperative for a fossil fuel phase-out is analyzed through strategic perspectives on EU policy. Broad economic impacts and policy coherence are evaluated using recent reviews from the OECD and the International Energy Agency's country-specific policy reviews.

The analysis of national-level strategic pivots is grounded in official government documents. For the selected countries, data is derived from the National Energy and Climate Plans (NECP) updates submitted to the European Commission by the relevant ministries in Estonia, Finland, Latvia, and Lithuania. Furthermore, critical milestones regarding grid synchronization and desynchronization from the BRELL ring are analyzed using official announcements and reports from the respective ministries.

Technical data regarding infrastructure stability, generation capacity, and cross-border flows are sourced directly from industry annual reports, market overviews, and system development plans produced by the Transmission System Operators (TSOs). Key sources include:

- Finland: Fingrid and Gasgrid Finland;
- Estonia: Elering;
- Latvia: AST and Conexus;
- Lithuania: Litgrid and Amber Grid.

To assess the developing hydrogen sector, the study utilizes specific industry roadmaps and feasibility studies, such as the *Clean Hydrogen Economy Strategy for Finland* and the *Estonian Hydrogen Roadmap*

To substantiate official data with critical analysis, the study incorporates peer-reviewed literature and independent expert reports. This includes assessments of energy security indicators, the consequences of the Ukraine war and sanctions on the Finnish energy sector, and specific analyses of nuclear energy governance and legislation.

For the calculation of specific indicators, data was gathered using a non-probability purposive sampling method to ensure the selection of comparable and authoritative quantitative metrics that align with the defined "4A" framework. The majority of data points utilized in the research are from

2024; however, where 2024 data was unavailable (e.g., specific heating degree days or consolidated annual consumption figures), 2023 data was substituted to ensure empirical accuracy.

To guarantee that the methodology for calculation was identical across all four nations, indicators regarding prices (EUR/MWh), import dependency, and emissions were extracted from harmonized European databases, specifically Eurostat and ACER. Indicators covering interconnection capacity and grid reliability (e.g., NTC, SAIDI) were extracted directly from the TSOs or consolidated ENTSO-E platforms. Metrics relying heavily on unique national definitions without EU-level standardization were excluded to maintain cross-border comparability.

4.2.3. Operationalization of Data within the 4 A's Framework

The collected data is systematically mapped to the four dimensions of energy security to ensure a holistic evaluation of the region's strategic pivot.

Availability
Data regarding the structural shift from Russian fossil fuel dependence to domestic generation is derived from production statistics and impact reports. The physical capacity of new renewable installations is analyzed using output records—such as the solar and wind production milestones reported by Elering and Enefit—and development plans for major offshore projects like ELWIND. The availability of stable baseload power is assessed through operational data from nuclear facilities, specifically the Olkiluoto 3 unit in Finland, and reports on the strategic reserve role of oil shale in Estonia.

Accessibility
This dimension focuses on the physical and geopolitical ability to access energy flows. The study analyzes the critical synchronization of the Baltic grids with Continental Europe using technical data from ENTSO-E and countdown reports from national ministries. Infrastructure vulnerabilities and hybrid threats are examined through investigative reports on the Balticconnector damage and the Nord Stream sabotage. Furthermore, accessibility to global LNG markets is evaluated using operational data from the FSRU *Independence* and the Inkoo LNG terminal.

Affordability
The economic dimension is analyzed using market data to identify the drivers of price volatility, particularly following the decoupling from Russian supplies. Drivers of natural gas volatility are contextualized using IEA analyses, while regional electricity price dynamics are derived from market summaries by national competition authorities and energy agencies. The economic impacts on end-users are further evaluated using Eurostat price statistics and European Commission cost assessments.

Acceptability
Social license and environmental standards are evaluated using recent survey data on public attitudes toward energy transitions. This includes specific data on the high support for nuclear power in Finland and the public feasibility studies for Small Modular Reactors (SMRs) in Estonia. Broader support for renewables is assessed through surveys by the Lithuanian Wind Energy Association and the Latvian Wind Energy Association. Conversely, environmental constraints and industry friction are analyzed through developer feedback regarding 2030 climate targets.

4.3. Scope and Limitations

Geographically, this research zooms in on the Baltic States, Estonia, Latvia, and Lithuania, and Finland. These four nations were selected not merely for their proximity, but because they represent a distinct geopolitical cluster that effectively served as the "frontline" for the European Union's energy decoupling from Russia. Historically tethered to Soviet energy infrastructure and once characterized as an "energy island" within the EU, this region offers a unique window into how energy systems react to forced, rapid reorganization. The study examines the deep interconnectivity between these nations, focusing on shared infrastructure like the Balticconnector and the synchronization with the Continental European grid, while excluding broader Nordic or Central European market dynamics unless they directly determine the security outcomes of this specific cluster.

Temporally, the research isolates the critical transition period between 2022 and 2024. This timeframe was chosen to capture the full arc of the initial crisis: from the immediate shock following the invasion of Ukraine in February 2022, through the extreme volatility of the subsequent heating seasons, to the stabilization efforts observed by late 2024. This specific window allows the analysis to distinguish between immediate crisis management measures, like the emergency leasing of FSRUs, and the implementation of medium-term strategic pivots. Data preceding 2022 serves only as a baseline for pre-war dependence, while projections beyond 2024 are treated as strategic outlooks rather than empirical evidence.

It is important to acknowledge that analyzing energy security in such a volatile context comes with inherent limitations. First, as Strojny et al. (2023) note, the very concept of energy security is currently in flux. The data from 2022 represents an outlier year defined by crisis anomalies rather than stable market trends; consequently, conclusions regarding long-term economic affordability drawn from this period must be interpreted with caution. Second, the "securitization" of the energy sector described by Sivonen and Kivimaa (2024)[31] creates a barrier to transparency. As energy infrastructure moves from a commercial concern to a matter of national defense, specific details regarding the protection of offshore assets or subsea interconnectors are increasingly redacted or classified. This naturally limits the granularity of our analysis regarding physical infrastructure safety. Finally, the study must navigate the definitional ambiguity highlighted by Bain (2025)[32]. Concepts like "energy independence" or "net zero" are often used inconsistently across different national jurisdictions; to ensure valid comparisons, this research strictly standardizes these terms based on the APERC framework.

[31] Sivonen, M. H., & Kivimaa, P. (2024*). Securitization of Energy Transitions in Estonia, Finland and Norway.* International Political Sociology. International Political Sociology. https://doi.org/10.1093/ips/olae017

[32] Bain, R. J. (2025). *Making Energy Transitions Work: Defining Success and Metrics for Tracking Progress.* RAND Corporation.https://www.rand.org/pubs/working_papers/WRA3116-2.html

5. Multidimensional Energy Security Assessment

5.1. Availability

In the conceptual hierarchy of energy security, **Availability** is the foundational tier. Defined by the International Energy Agency (IEA) as "the ability to provide steady and sufficient access to energy"[33], it refers strictly to the physical existence of energy carriers independent of thei cost or the infrastructure required to transport them. For the Baltic Sea region, the period between 2022 and 2024 represented a traumatic stress test of this fundamental attribute.

Prior to February 2022, the region's availability equation was dangerously asymmetric. While domestic electricity generation capacity existed–hydropower in Latvia, oil shale in Estonia, and nuclear in Finland - it was insufficient to meet peak demand without external support. The "gap" was structurally filled by the Russian Federation. For example, Russia accounted for 75% of Finland's natural gas imports and 51% of its electricity net imports in 2021, and acted as the *de facto* balancing authority for the Baltic electrical grid.[34] The physical availability of energy in the region was thus predicated on the political stability of its eastern neighbor.

The Russian invasion of Ukraine and the subsequent cessation of energy trade in mid-2022 created an immediate "availability vacuum." The central challenge for policymakers in Helsinki, Tallinn, Riga, and Vilnius was not only price management, but also how to ensure energy supply from other suppliers. The region's response was a forced, rapid reconfiguration of its supply baseload, shifting from a model of "eastern dependency" to one of "strategic self-sufficiency and western integration."

This chapter analyzes how the four nations filled this vacuum. The analysis reveals a stark divergence in national strategies, dictated by geology, legacy infrastructure, and political choices.

- **Finland** successfully transitioned from a deficit market to a surplus market, securing availability through the deployment of massive, centralized nuclear baseload (Olkiluoto 3) and wind power.
- **The Baltic States**, lacking such large-scale domestic options, adopted a hybrid resilience strategy. They secured gas availability by pivoting to global Liquefied Natural Gas (LNG) markets via new terminals, while electricity availability remains precarious, reliant on a combination of intermittent renewables and the retention of carbon-intensive fossil fuel plants as strategic reserves.

The following sections dissect the specific mechanisms used to secure energy supply across the region, highlighting how the "availability gap" was closed not through new interconnections alone, but through a restructuring of domestic generation portfolios.

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[33] Jacek Strojny , Anna Krakowiak-Bal, Jarosław Knaga, Piotr Kacorzyk (2023). *Energy Security: A Conceptual Overview*. *Energies.* *https://doi.org/10.3390/en16135042?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle*
[34] International Energy Agency (2023). *Finland 2023: Energy policy review*. https://www.iea.org/reports/finland-2023

5.1.1. Electricity sector

In the Baltic–Nordic region, the concept of electricity availability has undergone a radical geopolitical and structural redefinition between 2022 and 2025. Historically, the availability of baseload power in the Baltic States was underwritten by the BRELL ring, which provided physical balancing and frequency stability from the Russian and Belarusian systems. The cessation of commercial electricity trade with Russia in May 2022, followed by the full synchronization with the Continental European Network in February 2025, ended this era. Availability is now strictly defined by domestic generation capacity and the adequacy of flows from the Nordic and Continental European markets. The region has transitioned from a model dependent on fossil–fuel generation and connections with the East (BRELL) to inclusion in European electricity markets. While the physical availability of electricity is secure from a geopolitical standpoint, the retirement of fossil baseload capacity (oil shale in Estonia, gas in the wider region) and the rapid expansion of wind and solar have made availability increasingly sensitive to meteorological conditions.

5.1.1.1. Electricity Generation Structure

The generation structure of Lithuania, Latvia, Estonia and Finland has shifted significantly over the past five years, reshaping not only national electricity balances but also the stability of the interconnected Baltic–Nordic system. Although the four countries share similar decarbonisation imperatives, their resource endowments, policy choices and infrastructural legacies differ sharply. These differences create distinct vulnerabilities and strengths, which increasingly interact under conditions of regional synchronisation and market integration. These structural differences are reflected in the current distribution of installed generation capacities across the four countries. **Figure 5.1.** illustrates the contrasting renewable energy portfolios of Lithuania, Latvia, Estonia and Finland, highlighting the asymmetric roles of wind, solar, hydro and biomass within the regional power system.

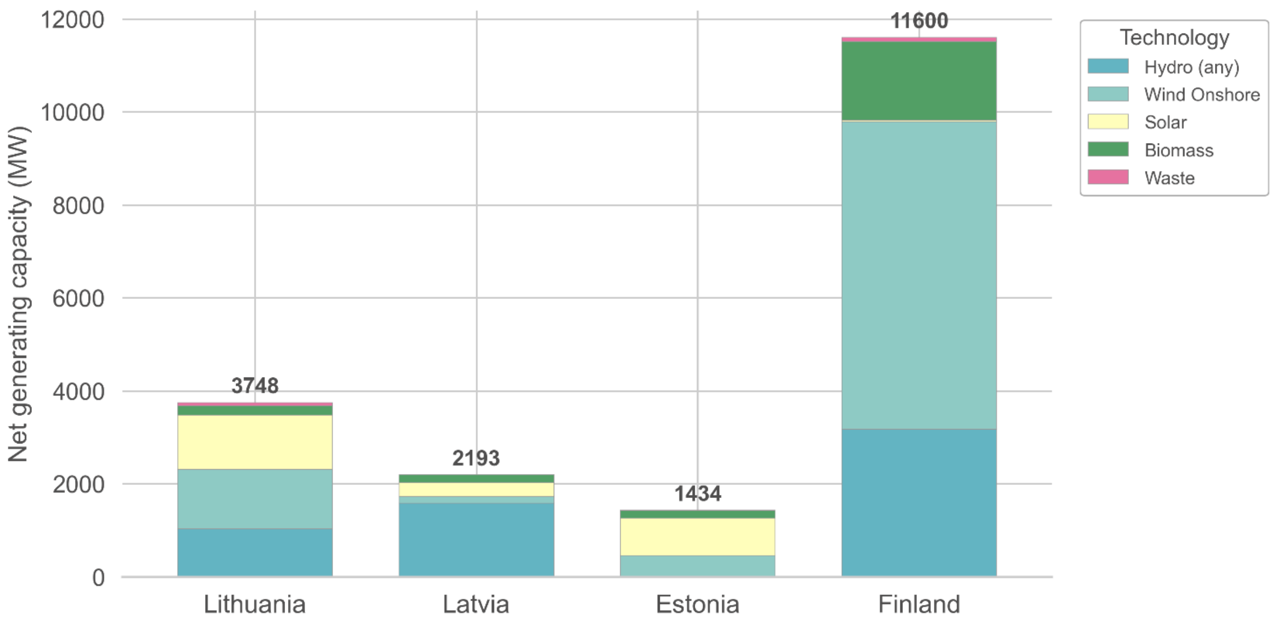

Figure 5.1. Net generating capacity by technology in 2024 (ENTSO-E data)

Lithuania has undergone one of the most rapid transitions in the region. Accelerated deployment of wind and solar has transformed its generation base, lifting domestic production to 7.76 TWh in 2024, the highest level since the closure of the Ignalina Nuclear Power Plant. Wind generation reached 3.49 TWh in 2024, a 38% increase from the previous year, while solar output doubled to 1.27 TWh, reflecting the emergence of a large prosumer and independent producer segment[35]. Hydropower contributed 0.97 TWh and biomass around 0.23 TWh, yet the defining feature of the Lithuanian supply structure is its growing dependence on weather-sensitive renewables. This has increased intra-day and seasonal variability, prompting a parallel investment push into system flexibility. In practice, Lithuania moderates weather-driven volatility through the 1 GW Kruonis pumped-hydro storage plant, a strategic asset unique in the Baltic States, and through a rapidly expanding battery storage ecosystem, including four 50 MW/50 MWh "Energy Cells" battery parks totalling 200 MW/200 MWh, now the largest such system in the Baltic countries. National plans envisage deploying more than 4 000 MWh of storage capacity in the coming years, further strengthening the system's ability to manage RES variability and reinforcing flexibility.[36] At the same time, offshore wind is emerging as Lithuania's largest untapped resource: the National Energy Independence Strategy (NENS) foresees 1.4 GW by 2030 (two 700 MW projects), although the second auction was cancelled in 2025 due to insufficient bidders.[37] The first 700 MW project, developed by the Ignitis–Ocean Winds consortium, continues under market conditions, but has been met by challenges decreased profitability rising costs which since 2023 jumped by 27 % to 2.7 billion euros.[38] These developments strengthen Lithuania's long-term adequacy prospects but also deepen its structural shift toward weather-dependent generation.

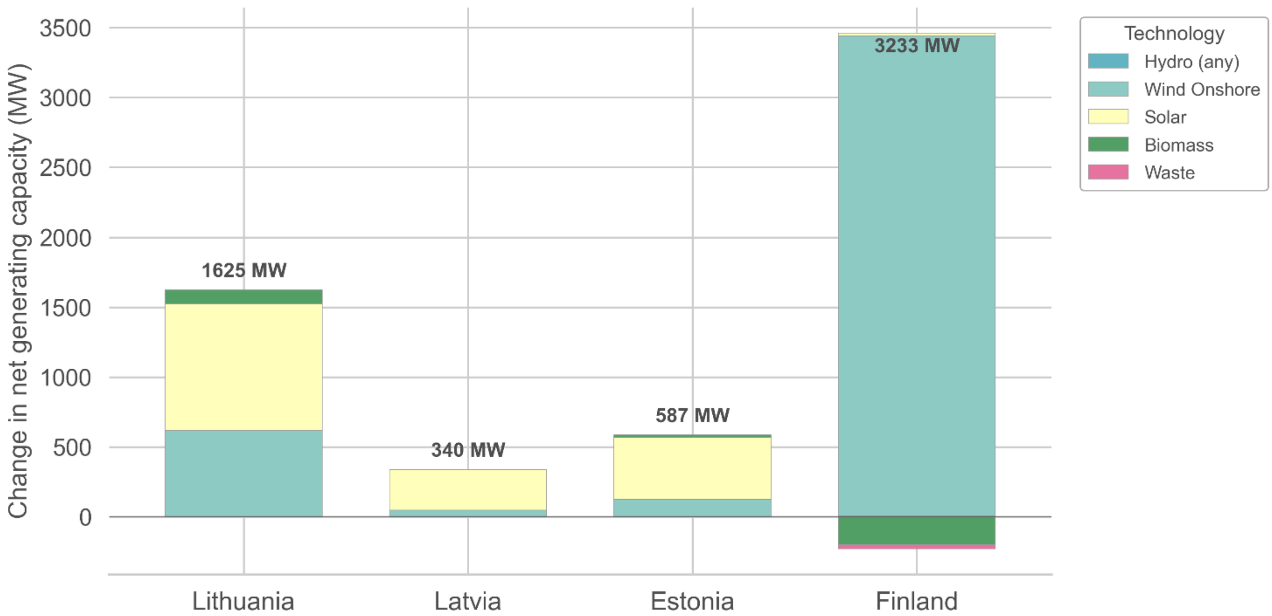

Figure 5.2. Change in net generating capacity by technology, 2022–2024 (ENTSO-E data)

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[35] Litgrid (2024). *Lithuanian electricity generation data for 2024.*

[36] Interreg Baltic Sea Region (2025). *Energy accumulation and storage development in Lithuania,* Energy Equilibrium Project. https://interreg-baltic.eu/project-posts/energy-equilibrium/energy-accumulation-and-storage-development-in-lithuania/

[37] BNS (2025). *Lithuania's second offshore wind farm tender declared void with only one bid received*. LRT. https://www.lrt.lt/en/news-in-english/19/2705304/lithuania-s-second-offshore-wind-farm-tender-declared-void-with-only-one-bid-received

[38] BNS (2025). Audit: Lithuania's first offshore wind project plagued by rising costs and mounting risks. LRT. Audit: Lithuania's first offshore wind project plagued by rising costs and mounting risks - LRT

Latvia presents a contrasting profile, defined primarily by its hydrological resources. With a combined hydropower capacity of roughly 1.56 GW across the Pļaviņas (908 MW), Rīga (402 MW), Ķegums (248 MW), and other small hydro (31.14 MW) plants[39], Latvia retains the most flexible and dispatchable renewable generation fleet in the region. Latvia's hydropower generation varies strongly by year. In 2023, hydro generation reached 3.78 TWh, accounting for about 62% of the country's total electricity generation, while its share of the national power balance fluctuates substantially across hydrologically different years, reflecting Latvia's dependence on annual water inflow conditions rather than a fixed generation level[40]. Dauguva and Rigshalea plants alone can produce 2.78 TWh, and 1,54 TWh respectively. This hydro dominance enhances Latvia's ability to balance regional flows and provide flexibility to neighbouring systems, yet it also exposes the country, and by extension the Baltic synchronised area, to hydrological volatility.

While wind and solar remain smaller components of the mix, they have still been expanded considerably. Solar has effectively transitioned from a niche source to a substantial market participant. In 2022, total solar generation capacity connected to DSOs (Distribution System Operator) was around 100 MW. This figure tripled in 2023 and more than doubled again to reach 660 MW by the end of 2024.[41] That is reflected in the solar production which rose from 2.1% in 2023 to 6.7% in 2024, reaching record-high monthly generation of 66 GWh in August of 2024, thus becoming the third-largest source of electricity.[42] Onshore wind in Latvia expanded more steadily than solar: wind generation increased by about 42.5% in 2023[43], which is linked to the first full year of output from the Tārgale Wind Park (alongside windy conditions). In 2024, wind generation injected into the grid rose by around 2% year-on-year (about 276 GWh), and a new monthly record of 38 GWh was set in December.[44] Despite these additions, wind remains at early stages of development, especially concerning offshore wind. Estimated potential is at 15 GW, yet alike in other Baltic States no capacity is installed[45]. However, Estonia and Latvia have launched the ELWIND project with environmental impact procedures in progress. Auction should be launched in 2026.[46] In May 2023, Latvia recorded its highest-ever share of renewable electricity at 99.9%, driven by exceptional renewable generation that month.[47]. These additions improve diversification but do not fundamentally alter the hydro-centric profile of the system. It raises additional concerns of system instability, including 184 hours of negative prices in 2024, while also creating balancing issues due to variability.

Estonia has a long anchored oil-shale sector in the generation of electricity, however, due to tightening EU climate policy and the need to decarbonize, oil shale generation capacity has fallen from 1.97 GW

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[39] AST (2025). *Transmission System Operator's Annual Report*. https://www.ast.lv/sites/default/files/editor/PSO_Zinojums_2025_ENG.cleaned.pdf
[40] AST (2023). *Latvian Electricity Market Overview 2023.* https://www.ast.lv/en/electricity-market-review
[41] AST (2025). *Transmission System Operator's Annual Report*. https://www.ast.lv/sites/default/files/editor/PSO_Zinojums_2025_ENG.cleaned.pdf
[42] AST (2024). *Latvian Electricity Market Overview 2024.* https://www.ast.lv/en/electricity-market-review
[43] LSM. *Latvia generated 44% more renewable energy in 2023.* https://eng.lsm.lv/article/economy/economy/02.07.2024-latvia-generated-44-more-renewable-energy-in-2023.a559205/
[44] AST (2025). *Transmission System Operator's Annual Report*. https://www.ast.lv/sites/default/files/editor/PSO_Zinojums_2025_ENG.cleaned.pdf
[45] Balticwind (2023). *LWEA: Unlocking the potential of Latvian offshore wind.https://balticwind.eu/lwea-unlocking-the-potential-of-latvian-offshore-wind/*
[46]Tõnn Tuvikene (2023). *Estonian - Latvian hybrid offshore wind project.* ELWIND. https://www.ena.lt/uploads/TT-projektai/BOWE2H/2023-06-05/5-Estonia-and-Latvia%E2%80%93ELWIND.pdf
[47] AST (2023). *Latvian Electricity Market Overview 2023. https://www.ast.lv/en/electricity-market-review*

in 2019[48] to 1.3 GW by 2024, largely due to the closure of older blocks and environmental restrictions.[49] In spite of this reduction, Estonian government prioritizes security of supply in the energy system. TSO, Elering, notes that market mechanisms alone are currently insufficient to guarantee firm capacity. Consequently, strategic reserves and support measures are being used to keep older, uncompetitive dispatchable generation capacity operational as a backstop until at least 2026 or 2027.[50] In 2024, Estonia's domestic electricity production totalled 5.25 TWh, while domestic consumption (including network losses) reached 8.15 TWh, leaving a shortfall of about 2.90 TWh that was covered by net imports.[51]

In place of fossil fuels, Estonia as other Baltic States, has witnessed a rapid expansion of renewables. In 2023 alone, for the first time, renewable energy sources produced more electricity than oil shale, accounting for 32 % of gross electricity consumption. Continuing this trend, in 2024, Estonia produced 3.4 GWh of renewable electricity, which comprised 63 % of total Estonian electricity production. Biomass remains the dominant renewable source of electricity, generating a total of 1.2 TWh. Onshore wind, and solar generated 0.7 TWh, and 0.69 TWh respectively. Moving forward with renewable goals, Estonia further added capacity (solar from 120 MW to 1.1 GW, wind from 330 MW to 700 MW) and increased total generation of both energy sources to beyond 1 TWh for each, with wind topping out at 1.2 TWh. [52] On the other hand, hydro remains negligible, standing at 0.025 TWh. This has meaningfully reduced Estonia's carbon intensity but has simultaneously increased its dependence on weather patterns similar to those affecting Lithuania.

In addition, gas-fired capacity has declined sharply, from 80–130 MW historically to about 10 MW in 2024, further limiting dispatchable backup. Estonia aims to add 2 GW of onshore and offshore wind by 2030[53], and is preparing a hybrid 1000 MW EST-LV HVDC link (Gulf of Riga hybrid interconnector) to accommodate future offshore capacity.[54] Offshore zones are under planning (Saaremaa, Gulf of Riga), but no installations have begun.

Finland, although integrated into the same Nordic–Baltic electricity market and connected to Estonia via two HVDC interconnectors (EstLink 1 & 2), remains part of the Nordic synchronous area rather than the Continental European system to which the Baltic States synchronised in 2025, occupies a structurally different position. Its generation portfolio is dominated by onshore wind which makes up the largest share in the generation capacity (8.2 GW), and hydropower (3.2 GW). These renewables

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48 International Energy Agency (2023). *Estonia 2023: Energy Policy Review.* https://iea.blob.core.windows.net/assets/8b462840-c9a6-4f71-81eb-d5acd1213e68/Estonia2023.pdf

49 Government of Estonia (2025). *Estonia's National Energy and Climate Plan (NECP) to the year 2030 Update*. Tallinn. https://kliimaministeerium.ee/en/national-energy-and-climate-plan

50 Elering (2024). *Eesti Elektrivarustuskindluse Aruanne.*

51 Estonian Competition Authority (2024). *Electricity and gas market summary. https://aastaraamat.konkurentsiamet.ee/en/aastaraamat-2024-trends-and-overviews/2024-electricity-and-gas-market-summary*

52 Tullenergia (2025). *Estonia: Solar, wind energy production exceeds 1 TWh in 2024.* https://tuuleenergia.ee/estonia-solar-wind-energy-production-exceeds-1-twh-in-2024/?lang=en

53 Marko Tooming (2025). *Wind farm developers consider Estonia's 2030 targets overly optimistic.* ERR News. https://news.err.ee/1609589606/wind-farm-developers-consider-estonia-s-2030-targets-overly-optimistic

54 ERR (2020). *New Baltic power connection could happen through Liivi offshore wind farm. ERR News.* https://news.err.ee/1036972/new-baltic-power-connection-could-happen-through-liivi-offshore-wind-farm

are reinforced by a large and stable nuclear generation (4.4 GW), which improved with the commissioning of the 1.6 GW Olkiluoto-3 reactor in April of 2023.[55]

A pivot towards low-carbon energy sources after the Russian invasion of Ukraine is especially evident in 2021, fossil fuels covered 36% of Finland's total energy supply, the second-lowest share among IEA countries and much lower than the IEA average of 70%. In 2024 energy production by fossil free, that is nuclear, wind, solar, and other renewable fuels, energy sources rose to 95 %.[56] In similar manner, net imports fell from 20.0 TWh in 2019 to 3.6 TWh in 2024 due to rising wind generation and restored nuclear availability.

Although Finland's generation structure is anchored in nuclear, onshore wind and hydropower, the country is simultaneously emerging as a future offshore wind hub in the northern Baltic Sea. Maritime spatial planning documents identify several large-scale offshore development zones, and current estimates foresee 6–8 GW of offshore wind potential by the late 2030s, with some analyses placing the technical potential closer to 10 GW in Finnish Baltic waters. Permitting and seabed leasing procedures are significantly more advanced than in the Baltic States, positioning Finland as the most mature offshore wind market in the subregion and a likely exporter of both electricity and power-to-X commodities in the long term.[57] It is clear only that Finland acts as a stabilising anchor: its system provides inertia, flexible hydro, and winter adequacy that partially buffers Baltic market volatility.

Across these four systems, several overarching trends emerge. The region is moving away from fossil baseload toward variable and climate-dependent renewables, but the degree and pace of this shift vary sharply. Lithuania and Estonia lead in RES growth but carry increasing variability risks; Latvia provides hydrological flexibility but faces climate sensitivity; Finland anchors regional adequacy but introduces its own structural asymmetries. The overall effect is a collectively interdependent generation ecosystem, where each country's resource profile shapes the operational stability, price formation and security outlook of the others. As synchronisation and market integration deepen, these interdependencies will become more consequential, requiring coordinated planning and shared responsibility for balancing, reserves and adequacy.

5.1.1.2. Electricity Consumption

Electricity consumption patterns across the Baltic states and Finland reveal significant structural differences, with Finland clearly standing out due to exceptionally high per-capita demand, while Lithuania and Latvia show similar and moderate consumption levels, and Estonia sits in between, historically higher than its Baltic peers but now declining (Fig. 5.3.). While the Baltics exhibit strong long-term electrification growth since 2000, their recent per-capita consumption (2021–2024) has remained relatively stable at around 4–7 MWh per person. Finland's consumption per capita reaches

[55] Teollisuuden Voima Oyj (2023). *The Olkiluoto 3 (OL3) plant unit is the third most powerful nuclear power unit in the world.*, OL3. https://www.tvo.fi/en/index/production/plantunits/ol3.html
[56] Statistics Finland. (2024). *Altogether 95 per cent of Finland's electricity production was based on fossil-free energy in 2024.* https://stat.fi/en/publication/cm1kktw8ualm207vwnzpsmpc8?
[57] Castren & Snellman (2021). *The Time for Offshore Wind Farms Approaching in Finland – Hundreds of Turbines in Development.* https://www.castren.fi/the-time-for-offshore-wind-farms-approaching-in-finland-hundreds-of-turbines-in-development/

14–16 MWh annually, reflecting a colder climate[58], electricity-intensive industries[59], and a higher degree of electrified heating[60].

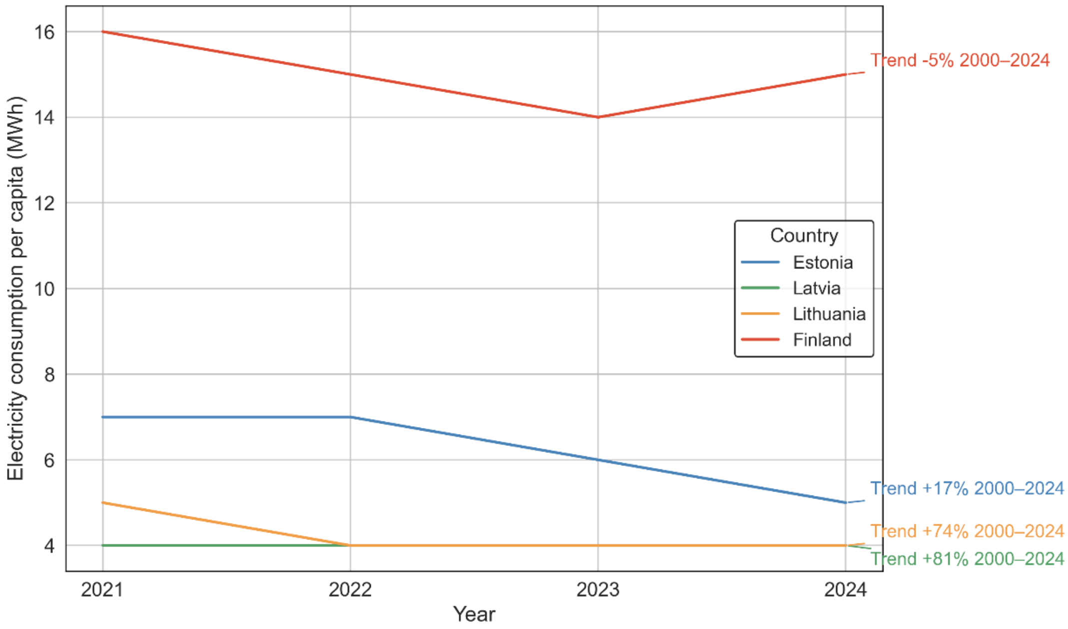

Figure 5.3. Electricity consumption per capita in the Baltic States and Finland (2021–2024, IEA data)

In the Baltic region, Lithuania and Latvia show broadly similar electricity consumption per capita in 2021–2023 (approximately 3.7–4.2 MWh per person annually), consistent with comparable socio-economic structures and moderate electrification levels. Both countries also record strong long-term growth in per-capita electricity consumption since 2000 (+74% in Lithuania and +81% in Latvia), consistent with sustained economic expansion and gradual electrification across end-use sectors (Fig. 5.3).

Estonia's consumption remained at 7 MWh per capita in 2021–2022, but declined to 5 MWh by 2024, despite a much weaker long-term growth trend (+17% since 2000) (Fig. 5.3). This recent contraction signals industrial restructuring[61], improved building energy efficiency[62], and demand-side sensitivity[63] to high electricity prices during 2022–2023, which encouraged both behavioural conservation[64] and system-level efficiency investments. The 2023 contraction coincided with a sharp reduction in oil shale-based electricity production: Estonia's power plants generated 37% less electricity than in 2022, mainly due to lower oil shale use, and major oil shale units reduced output

[58] Eurostat (2025). *Cooling and heating degree days by country - annual data.* https://ec.europa.eu/eurostat/databrowser/view/nrg_chdd_a/default/table
[59] Motiva (2025). *Energy use in Finland. Final consumption of energy.* Industry. https://www.motiva.fi/en/solutions/energy_use_in_finland/final_consumption_of_energy
[60] EPHA (2023). *In Finland heat pumps sales increased 50% in 2022*. https://ehpa.org/news-and-resources/news/in-finland-heat-pumps-sales-increased-50-in-2021/
[61] ERR (2024). *Statistics: Industrial production volume fell by 10.5 percent in 2023*. ERR News. https://news.err.ee/1609244436/statistics-industrial-production-volume-fell-by-10-5-percent-in-2023
[62] European Commission (2019). *Opening the door to energy efficient apartments in Estonia.* https://ec.europa.eu/regional_policy/en/projects/estonia/opening-the-door-to-energy-efficient-apartments-in-estonia
[63] Konkurentsiamet (2023). *2022 Electricity and Gas Market Summary: A Year of Price Shocks.* *https://www.konkurentsiamet.ee/en/news/2022-electricity-and-gas-market-summary-year-price-shocks*
[64] European Environment Agency (2025). Final energy consumption.

substantially. While a decline in generation does not mechanically imply a decline in domestic consumption, the oil-shale pullback marks a clear shift in the system's operating regime and competitiveness, which is consistent with price-driven demand adjustment and broader economic contraction signals observed over 2022–2023[65].

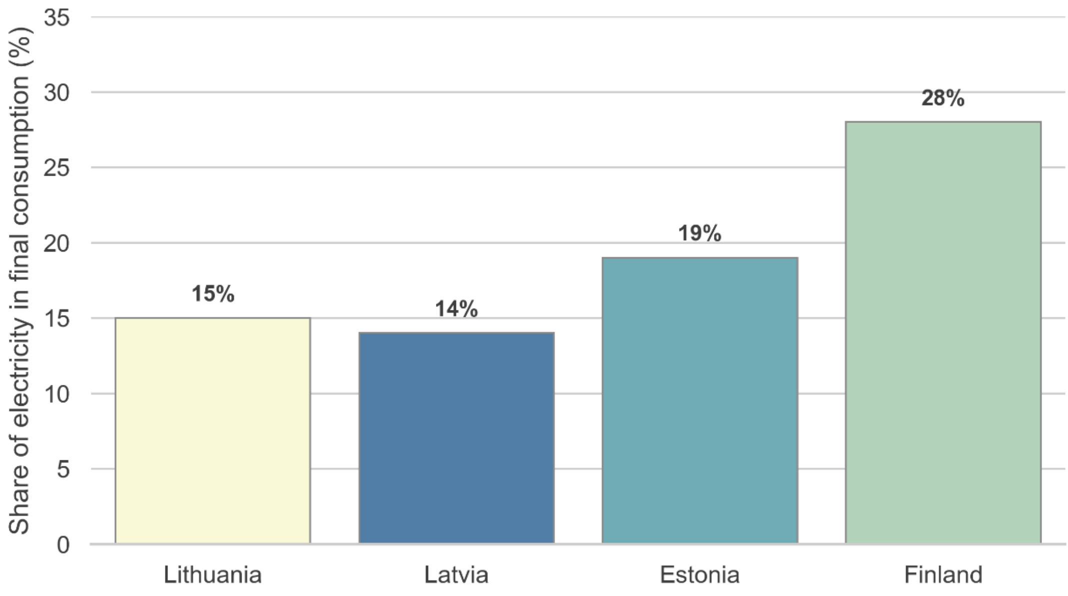

Figure 5.4. Share of electricity in final energy consumption by country (2023, IEA data)

Finland remains the most distinct case: electricity consumption per capita fluctuated between 14 and 16 MWh from 2021–2024, reflecting one of the highest levels of electrification in Europe-comparable markets. Unlike the Baltics, Finland's long-term trend is slightly negative (–5% since 2000, Fig. 5.3), demonstrating that demand growth has been more than offset by major efficiency gains[66], industrial restructuring, and saturation of electricity use in heating through heat pumps and smart-load balancing[67]. The rebound from 14 MWh (2023) to 15 MWh (2024) is consistent with cold winter[68] heating variability, rather than a structural reversal.

The share of electricity in final energy consumption highlights very different levels of electrification maturity. Lithuania's electricity share in 2023 (15%) is lower than Estonia (19%) and substantially lower than Finland (28%) (Fig. 5.4). This is typical for countries where biomass, district heating, and transport fuels still play a dominant role in final energy use. Latvia's electricity share in 2023 (14%) is comparable to Lithuania's, reflecting similar end-use patterns and limited electrification in transport and heating. Estonia's higher share is partly explained by greater reliance on electric heating in multi-

[65] Statistics Estonia (2024). *Oil shale electricity production decreased last year.* https://stat.ee/en/news/oil-shale-electricity-production-decreased-last-year
[66] Odyssee-Mure publications. Country profile: Finland.
[67] European Commission (2024). *Finland: Status of the heat pump* market. https://publications.jrc.ec.europa.eu/repository/handle/JRC137131
[68] Finnish Meteorological Institute (2024). *Winter was colder than usual*. https://en.ilmatieteenlaitos.fi/press-release/5kbPVjfwcHYFUjGa0FbZpn

apartment buildings[69] and digital service infrastructure[70], while Finland's 28% share signals advanced electrification of both heating (widespread heat pumps) and industry, especially pulp and paper, metals, chemicals, and large data facilities.

A comparison of electricity consumption across countries shows clear structural differences in sectoral demand, with significant variation in industrial, residential, and commercial consumption patterns (Fig. 5.5). In Lithuania, the largest electricity-consuming sectors in 2023 were industry (12,168 TJ), commercial and public services (12,221 TJ), and residential consumption (11,330 TJ). Transport electricity use remains marginal (377 TJ), signalling that EV penetration is still low and rail electrification impact limited, while fishing and other sectors report no electricity demand, which is normal for Lithuania's sectoral energy-accounting structure. Lithuania's commercial and public services consuming more electricity than residential demand reflects a strong service-sector footprint, public-sector building stock, retail, and administrative load, consistent with your professional focus in the public sector.

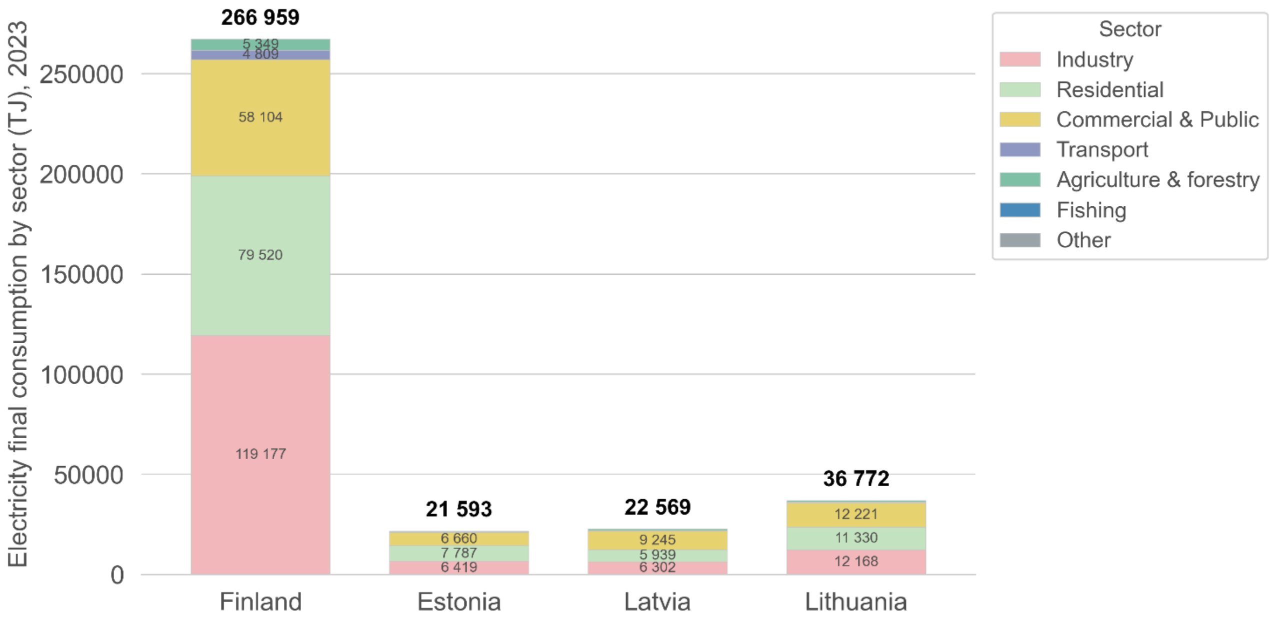

Figure 5.5. Sectoral composition of electricity final consumption in the Baltic States and Finland (2023, IEA data)

In Latvia, residential electricity consumption (5,939 TJ) is lower than Lithuania's, but transport electricity demand is slightly higher (386 TJ) and fishing consumes 44 TJ, reflecting coastal economy activity and port-adjacent electrified operations. Latvia's commercial services demand (9,245 TJ) remains the largest sector overall.

Estonia's 2023 consumption structure is notable for its high residential electricity use (7,787 TJ), exceeding both Latvia and Lithuania, which aligns with Estonia's building-heating mix and urban

[69] Elering (2023). *Sensitivity analysis to Estonian electricity demand scenarios*. https://elering.ee/sites/default/files/2024-01/Sensitivity%20analysis%20to%20Estonian%20electricity%20demand%20scenarios%20-%20ARUANNE.pdf
[70] Invest Estonia (2023). Estonia has the most advanced data center in the region. https://investinestonia.com/estonia-has-the-most-advanced-data-center-in-the-region/

density, while commercial electricity demand fell sharply to 6,660 TJ by 2023, down from 11,721 TJ in 2021, a clear signal of energy-efficiency retrofits, reduced heating load, and strong conservation behaviour during price volatility.

Finland's electricity demand scale dwarfs the region, with industry alone consuming around 119,117 TJ, nearly ten times more than the entire electricity demand of any single Baltic country. Residential electricity demand is also very high (79,520 TJ in 2023), which is consistent with Finland's cold-climate heating needs and a high degree of electrified heating technologies (notably heat pumps). Transport electricity consumption is also material (4,809 TJ), reflecting advanced rail electrification[71] and EV uptake, unlike in the Baltic countries.

Lithuania's profile is characterised by an industry-led adjustment rather than a broad-based contraction in service-sector electricity use (Fig. 5.6 and 5.7). Industrial electricity final consumption fell from 14,140 TJ in 2021 to 12,168 TJ in 2023, while commercial and public services remained comparatively stable (above 12,000 TJ by 2023). This split is consistent with the 2022–2023 energy-price shock affecting energy-intensive production more abruptly than the service sector: Lithuania's official energy balance notes that national electricity demand declined in 2022 versus 2021 (–5.5% to 13.4 TWh), reflecting broad demand-side tightening during the crisis[72].Within industry, short-term curtailments at major energy-intensive sites are a plausible mechanism, most notably Achema, the country's largest industrial gas consumer and a flagship fertiliser/ammonia producer. The extremely high gas prices in late summer 2022 made ammonia production uneconomic and led Achema to reduce or substantially scale back operations, which would be expected to depress both fuel use and associated industrial activity during the shock period[73,74].

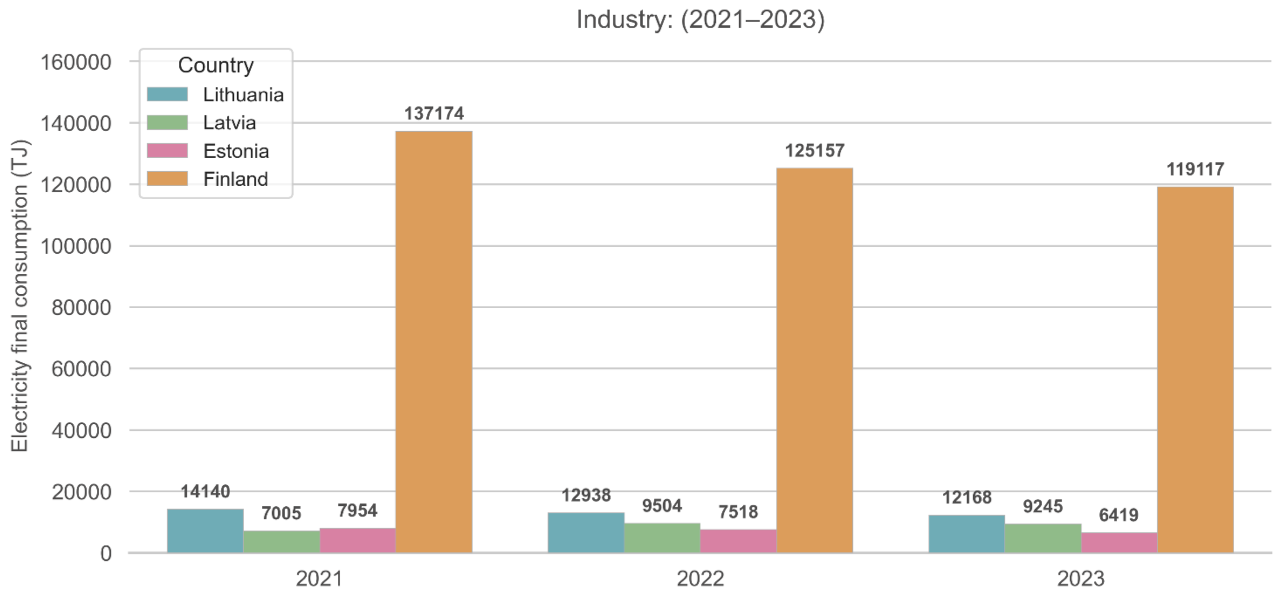

Figure 5.6. Electricity final consumption in industry by country (2021–2023, IEA data)

[71] European Commission. (n.d.) *European Alternative Fuels Observatory. Transport modes. Rail.* https://alternative-fuels-observatory.ec.europa.eu/transport-mode/rail
[72] Official Statistics Portal (2023). *Environment, Agriculture and Energy in Lithuania (edition 2023).* https://osp.stat.gov.lt/en/lietuvos-aplinka-zemes-ukis-ir-energetika-2023/apie-leidini
[73] Argus Media (2023). *Lithuania drives September gas consumption in Baltics.* https://www.argusmedia.com/en/news-and-insights/latest-market-news/2498272-lithuania-drives-september-gas-consumption-in-baltics
[74] European Commission (2023) Country Report. Lithuania 2023. https://economy-finance.ec.europa.eu/publications/2023-country-report-lithuania_en

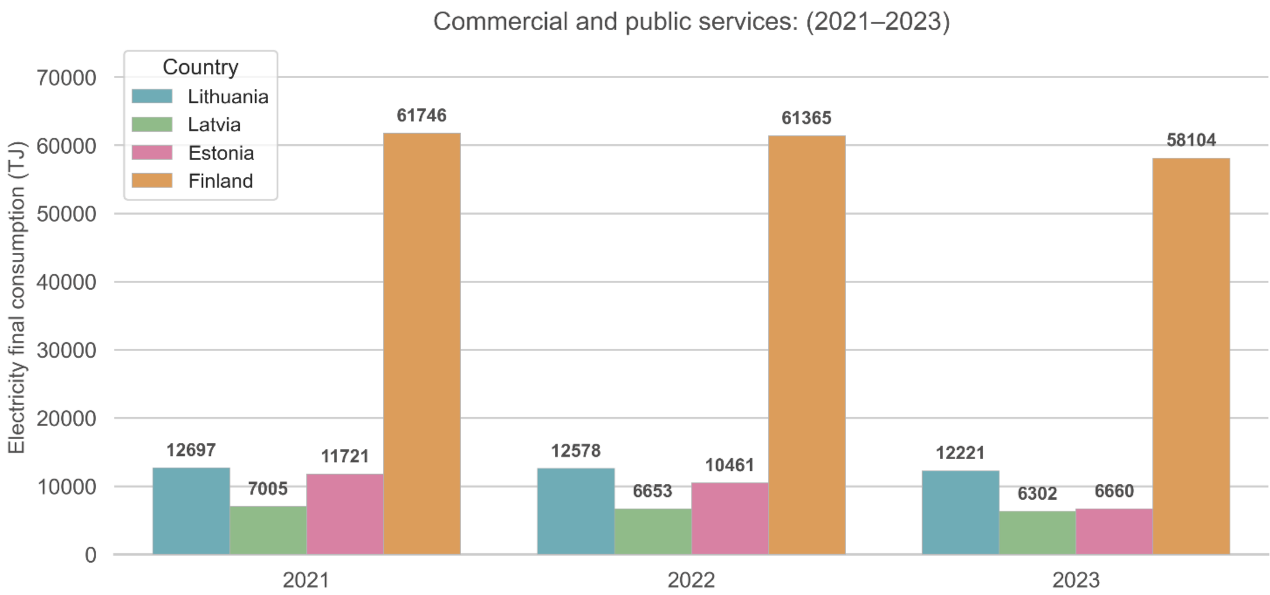

Figure 5.7. Electricity final consumption in commercial and public services by country (2021–2023, IEA data)

Taken together, the data support an interpretation in which Lithuania's industrial electricity decline primarily reflects price-driven production adjustments and operational optimisation in energy-intensive manufacturing, whereas the service-sector electricity profile appears more resilient, suggesting that the main demand contraction in 2022–2023 was concentrated in industry rather than driven by a structural collapse in commercial electricity use.

Unlike the other Baltic States and Finland, Latvia recorded a temporary increase in industrial electricity consumption in 2022 (9,504 TJ), up from 7,005 TJ in 2021, despite the severe electricity price shock and extreme fuel-price volatility[75]. At the system level, however, Latvia's overall electricity consumption decreased in 2022 (reported at –3.75%), implying that the industrial increase is likely sector-specific and may reflect shifts in industrial output structure[76]. This sectoral concentration implies that changes in production volumes and operating regimes in a small number of energy-intensive industries can materially affect aggregate industrial electricity demand. In 2022, the share of natural gas in the transformation sector declined sharply to 36.6%, while wood chips increased to 52.8%, surpassing gas for the first time[77]. This rapid reconfiguration of the fuel mix reflects a response to extreme gas price increases and altered operating conditions in combined heat and power and district-heating systems, with potential spillover effects on electricity generation patterns and industrial electricity offtake. Latvia's commercial and public-services electricity demand declined from 7,005 TJ (2021) to 6,302 TJ (2023). This downward trend is consistent with demand-side adjustment during the 2022–2023 energy-price shock, including government-led public-sector

[75] European Commission (2023). *Country Report. Latvia 2023*.https://economy-finance.ec.europa.eu/publications/2023-country-report-latvia_en
[76] LSM (2023). SPRK: Pērn Latvijā elektroenerģijas patēriņš saruka par 3,75%. https://www.lsm.lv/raksts/zinas/ekonomika/sprk-pern-latvija-elektroenergijas-paterins-saruka-par-375.a499650/
[77] Official statistics portal (2023). *Energy consumption reduced by 2.8 % in 2022*.https://stat.gov.lv/en/statistics-themes/business-sectors/energy/press-releases/12336-energy-consumption-2022

energy-saving measures[78], and it may also reflect gradual efficiency improvements supported by building renovation and energy-efficiency programmes (Fig. 5.6 and 5.7).

Estonia experienced the most dramatic industrial reduction (from 7,954 TJ in 2021 to 6,419 TJ in 2023) and an even steeper drop in commercial-services electricity use (from 11,721 TJ in 2021 to 6,660 TJ in 2023, returning to approximately the 2004 level) (Fig. 5.6 and 5.7). This pattern is consistent with a demand-side response during the 2022–2023 price shock, as Estonia's system operator and market reporting document that electricity consumption fell during the energy-crisis period (e.g., –7.8% in 2022 vs 2021 in both transmission volumes and consumption statistics)[79,80]. The continued weakness into 2023 is also plausible given that Estonia's average day-ahead exchange price remained elevated in 2023 (reported at 90.78 €/MWh), sustaining incentives for conservation and operational optimisation beyond the initial 2022 peak[81]. The decline may additionally reflect lower heating-related loads in a milder year, and the gradual impact of energy-efficiency investments supported by EU and national co-financed building renovation/retrofit schemes[82]. However, the main reason was a combination of sustained price-driven demand reduction (with conservation measures and operational tightening carrying into 2023), structural changes in building operation and occupancy. Efficiency investments and retrofits can contribute but would typically explain only part of a drop of this magnitude over such a short period.

Finland's industrial electricity consumption fell from 137,174 TJ in 2021 to 119,117 TJ in 2023 (from 38.1 TWh to 33.1 TWh), and this direction is consistent with crisis period demand adjustment rather than a purely structural shift (Fig. 5.6). Finnish system and market reporting describes a clear consumption pullback during the energy crisis, driven by high prices and security-of-supply concerns. Fingrid explicitly notes that electricity consumption in Finland decreased (around 6%) due to very high prices and concern over adequacy of supply after the disruption of traditional supply chains following Russia's invasion of Ukraine[83]. In 2023, Finland's Energy Authority reports that total electricity consumption decreased to around 80 TWh (–2%), with the decline concentrated in winter and parts of spring–summer, which is consistent with both price-sensitive load reduction and operational optimisation in industry[84,85]. Reporting on the same period also highlights that the year-on-year decrease was driven particularly by industry, reinforcing the interpretation that industry was

[78] Ministry of Economics Republic of Latvia (2022). *Public authorities are ordered to introduce an energy management system and reduce consumption of heating, electricity, petroleum products and natural gas.* https://www.em.gov.lv/en/article/public-authorities-are-ordered-introduce-energy-management-system-and-reduce-consumption-heating-electricity-petroleum-products-and-natural-gas
[79] Elering (2022). *2022 Annual Report.* https://elering.ee/sites/default/files/2023-03/Annual%20Report%202022.pdf
[80] Konkurentsiament (2023). *Electricity and gas markets in Estonia report 2022*. https://www.ceer.eu/wp-content/uploads/2024/04/C23_Estiona_EN.pdf
[81] Estonian Competition Authority (2023). *Annual Report 2023*. https://aastaraamat.konkurentsiamet.ee/en/annual-report-2023
[82] EIS. *Reconstruction grant 2022-2027*. https://eis.ee/en/services/kodudkorda/
[83] Fingrid (2023). Finland's Transmission System Operator. https://www.fingrid.fi/en/
[84] Energy authority (2023). *National Report on the state electricity and gas markets in Finland to the European Union Agency for the Cooperation of Energy Regulators and to the European Commission. 2023.* Finland.https://energiavirasto.fi/documents/11120570/13026619/National+Report+on+electrcity+and+gas+markets+in+2023+in+Finland.pdf/64cf6db3-0995-bdd1-21d6-795daf7df53e/National+Report+on+electrcity+and+gas+markets+in+2023+in+Finland.pdf?t=1720680024410
[85] Fingrid (2024). *Fingrid's Financial Statements Bulletin January–December 2023: Clean and high-quality electricity system and largest ever grid investments created conditions for electricity consumption growth.* https://www.fingrid.fi/en/news/news/2024/fingrids-financial-statements-bulletin-januarydecember-2023-clean-and-high-quality-electricity-system-and-largest-ever-grid-investments-created-conditions-for-electricity-consumption-growth/

the main balancing segment during the shock[86]. Finland's industry is highly electricity-intensive and dominated by pulp and paper, chemicals, and basic metals. Motiva reports[87] that in 2023 industrial electricity consumption was about 36 TWh, and that pulp & paper alone represents the largest share of industrial final energy use. In parallel, industrial output conditions weakened in the crisis period: UNECE[88] notes that pulp production decreased by 15% in 2022 vs 2021 in Finland, which is consistent with reduced operating hours and lower electricity use in the largest electricity-consuming industrial segment. In other words, the 2021–2023 decline can be credibly framed as the combined effect of high-price demand curtailment/demand response and lower capacity utilisation in electricity-intensive manufacturing, with efficiency improvements and process optimisation acting as reinforcing contributors. Finland's commercial and public-services electricity use also decreased from 61,746 TJ in 2021 to 58,104 TJ in 2023 (from 17.2 TWh to 16.1 TWh) (Fig. 5.7), aligning with the same macro pattern of energy savings under elevated prices. The Energy Authority notes that Finland's 2023 consumption reduction was concentrated in specific months (notably winter and parts of spring–summer), consistent with building-operation adjustments (HVAC setpoints, ventilation schedules, lighting and operating hours) that are typical levers in the service and public sector when prices remain high[89].

5.1.1.3. Storage and Flexibility

Energy storage is increasingly recognized as an important component of system flexibility across the Baltic–Nordic region as more renewable energy is added. While the four countries differ significantly in their resource bases and system architectures, all four countries are expanding (to different degrees) their flexibility portfolios, including large-scale batteries and, where applicable, pumped hydro and other long-duration storage options. The pace and scale of developments, however, vary widely, reflecting distinct national priorities and current levels of system vulnerability.

Lithuania currently has the largest operational utility-scale battery energy storage system (BESS) capacity among the Baltic States. The national "Energy Cells" program delivered four 50 MW/50 MWh battery parks (Vilnius, Alytus, Utena, Šiauliai), totaling 200 MW/200 MWh, which now provide very fast-acting reserves and instantaneous response services (e.g., automatic response within 1 second)[90]. Beyond these already commissioned assets, Lithuania's national plans envisage more than 2,500 MW of storage capacity by 2030, combining battery systems and modernized pumped hydro[91]. The 900 MW Kruonis pumped storage plant remains the region's largest dispatchable long-duration flexibility asset in the Baltic States, further strengthened by the addition of battery-based fast reserves[92]. Among Baltic States, Lithuania has developed the most advanced regulatory framework for storage participation in balancing and ancillary services markets, positioning itself as an early regional hub for modern flexibility solutions (Fig. 5.8).

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[86] YLE news (2024). *Electricity consumption in Finland down 2% year-on-year*. https://yle.fi/a/74-20068915
[87] Motiva report (2023). *Energy use in Finland. Industry.* https://www.motiva.fi/en/solutions/energy_use_in_finland?i=21
[88] Natural Resources Institute Finland (2023). *Forest Sector Market Statement for Finland 2023.* https://unece.org/sites/default/files/2023-11/Market%20statement%20Finland%202023.pdf
[89] Fingrid (2023). *Finland's Transmission System Operator*. https://www.fingrid.fi/en/
[90] Lietuvos Respublikos Energetikos Ministerija (2023). *Pradėjo veikti „Energy cells" Šiaulių ir Alytaus baterijų parkai.* https://enmin.lrv.lt/lt/naujienos/pradejo-veikti-energy-cells-siauliu-ir-alytaus-bateriju-parkai/
[91] Ministry of Energy of the Republic of Lithuania. (2024). *National Energy Independence Strategy of the Republic of Lithuania*. https://enmin.lrv.lt/public/canonical/1742986630/6022/NENS%202024-2.12_EN%20(1).pdf
[92] Ignitis. Kruonis Pumped Storage Hydroelectric Power Plant (KPSHP). https://ignitisgamyba.lt/en/our-activities/electricity-generation/kruonis-pumped-storage-hydroelectric-power-plant-kpshp/4188

Estonia is rapidly scaling its storage capacity as part of its transition away from oil-shale-based generation. Two major projects developed by Baltic Storage Platform OÜ will add 200 MW/400 MWh across the Kiisa and Aruküla sites, forming Estonia's first large grid-scale battery portfolio[93]. In addition, Eesti Energia has commissioned a 26.5 MW/53.1 MWh BESS at Auvere[94], while long-term planning includes the 500 MW/6 GWh Paldiski pumped hydro project as a potential backbone of long-duration flexibility[95]. These developments signal a decisive move toward inverter-based reserves capable of stabilising a system increasingly dependent on variable wind and solar generation.

Latvia is following a hybrid development model, combining storage with co-located renewable generation. The state utility Latvenergo plans 250 MW/500 MWh of battery capacity by 2030, supported by a pipeline of hybrid installations[96]. Early projects include a 65 MW solar and 92 MWh BESS plant in Saldus municipality[97] and a 10 MW/20 MWh system paired with the 58.8 MW Targale wind farm[98]. While Latvia benefits from significant hydropower reserves, increasing climate-driven hydrological variability has prompted the state to accelerate development of battery-based reserves to ensure year-round flexibility.

Finland's battery energy storage sector is expanding gradually, driven by rapid wind power growth, rising electricity price volatility, and regulatory adaptation. While the country's strong nuclear and hydropower base reduces short-term dependence on batteries, market signals have intensified: hours with zero or negative electricity prices reached around 900 in 2024. As of mid-2025, roughly 250 MW of BESS capacity is operational, including the 30 MW/41 MWh Ainola system co-located with a wind farm and the 5 MW/10 MWh Rando Grid facility. The development pipeline is accelerating, with major projects such as the 70 MW/140 MWh Nivala BESS, the 55 MW/110 MWh Uusnivala project, and several 50 MW scale systems expected to enter operation by 2025–2026. Within the next two years, Finland's operational BESS capacity is projected to more than double[99]. Together, these deployments indicate a shift toward batteries as a complementary flexibility resource in a power system increasingly shaped by variable wind generation.

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[93] Nordic Investment Bank (2025). *NIB finances two large-scale battery energy storage parks in Estonia*.https://www.nib.int/news/nib-finances-two-large-scale-battery-energy-storage-parks-in-estonia

[94] M. Maisch (2025). *Estonia inagurates its largest battery energy storage project*. ESS News. https://www.ess-news.com/2025/03/27/estonia-inagurates-its-largest-battery-storage-project/

[95] Energy Storage Europe (2025). *Estonian Government approves Long-Term Energy Development Plan, including support for Long-Duration Energy Storage.https://energystorageeurope.eu/news/estonian-government-approves-long-term-energy-development-plan-supporting-long-duration-energy-storage/*

[96] Latvenergo (2025). *Latvenergo invests heavily in battery systems, plans to become the Baltic market leader in BESS.* https://latvenergo.lv/en/pazinojumi/zina/latvenergo-invests-heavily-battery-systems-plans-become-baltic-market-leader-bess

[97] European Energy (2025). E*uropean Energy secures financing for hybrid solar and storage project in Latvia*. https://europeanenergy.com/2025/11/10/european-energy-secures-financing-for-hybrid-solar-and-storage-project-in-latvia/

[98] A. Colthorpe (2024). *Latvia's first utility-scale battery storage project inaugurated ahead of Russian grid uncoupling.* Energy Storage News. Latvia: first BESS opens ahead of Russia grid uncoupling - Energy-Storage.News

[99] T. Rayner (2025). *Spotlight on Finland: Energy storage sector set to double. ESS News*. https://www.ess-news.com/2025/07/29/spotlight-on-finland-energy-storage-sector-set-to-double/

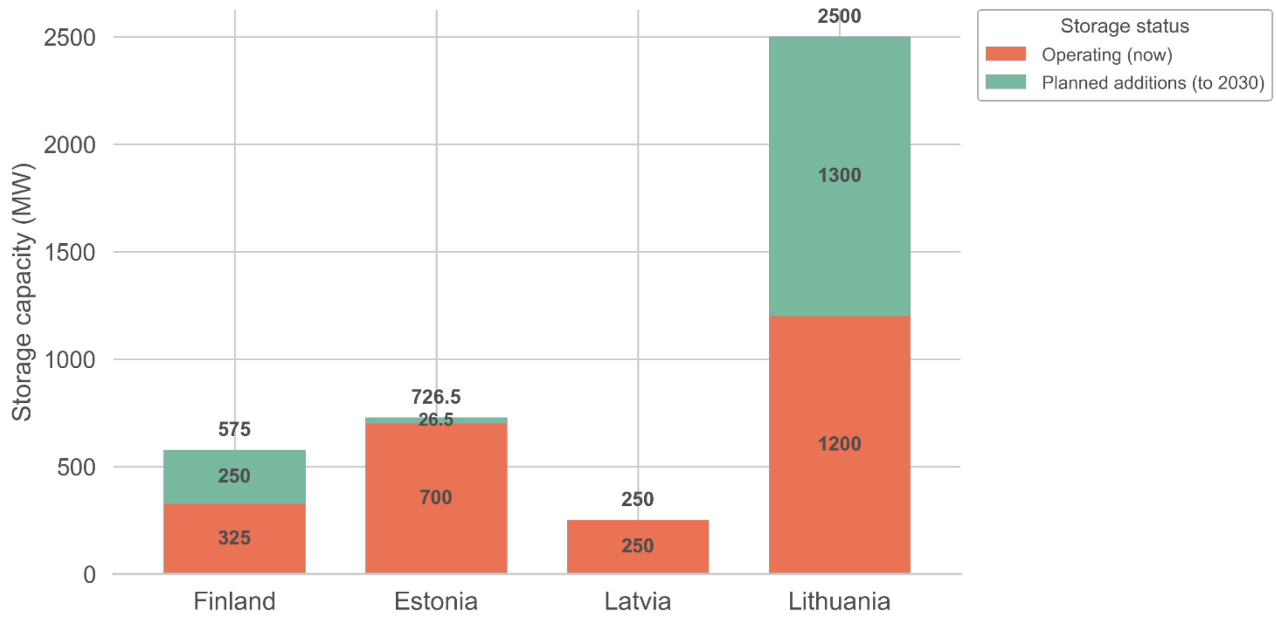

Figure 5.8. Baltic–Nordic renewable energy storage: 2030 plans vs current (2025) deployment

Taken collectively, these developments indicate that the Baltic States are transitioning at different speeds toward storage-enabled renewable systems. Lithuania currently possesses the region's most advanced operational portfolio, Estonia is rapidly catching up with large-scale BESS and pumped hydro plans, Latvia is integrating storage through hybrid RES architectures and Finland remains anchored in hydro and nuclear but is gradually moving toward more diversified flexibility resources. Across the region, storage is emerging not merely as an ancillary service, but as a foundational element of adequacy, balancing capability, and system stability in a future defined by high renewable variability and deep regional interdependence.

5.1.1.4.System Adequacy

Across these four systems, several overarching trends emerge. The region is moving away from fossil baseload toward variable and climate-dependent renewables, but the degree and pace of this shift vary sharply. Lithuania and Estonia lead in RES growth but carry increasing variability risks; Latvia provides hydrological flexibility but faces climate sensitivity; Finland anchors regional adequacy but introduces its own structural asymmetries. The overall effect is a collectively interdependent generation ecosystem, where each country's resource profile shapes the operational stability and security outlook of the others. As synchronization and market integration deepen, these interdependencies will become more consequential, requiring coordinated planning for balancing, reserves, and adequacy. In terms of consumption, it continues to grow due to industrial electrification, heat pump uptake and transport electrification. Peak demand is expected to grow, while dispatchable capacity is not increasing at the same pace. This widens the adequacy gap during low-wind winters, especially as Estonia accelerates the retirement of fossil-based generation.

The Baltic adequacy margin is strongly shaped by cross-zonal capacity:

- Lithuania relies on NordBalt for winter imports from Sweden, especially during cold, low-wind conditions.
- Latvia depends on exchanges with Estonia when northern wind output is high and on Lithuania during broader regional shortfalls.

- Estonia relies heavily on imports from Finland via the EstLink corridor to cover part of its consumption in tight winter situations.
- Poland, connected through LitPol Link, has become an increasingly important partner for managing scarcity periods, particularly as regional synchronisation and cross-border trade deepen

The adequacy model is therefore hybrid – combining domestic generation, Latvian hydropower flexibility, cross-border interconnectors and still-limited storage. This makes the system particularly vulnerable during "compound events", when weak wind, low hydro, high demand and interconnector constraints occur at the same time. The major key adequacy events that we identified:

1. The most critical adequacy scenario involves extended periods of low wind during sub-zero temperatures. Given that only Lithuania and Estonia now have a combined about 2,5 GW installed wind capacity[100] simultaneous low-wind events can result in multi-GW generation deficits. During winter cold spells, low temperatures often coincide with weak wind and limited solar output, causing renewable generation to fall and imports from Finland, Sweden and Poland to run close to their limits. If such conditions occur together with reduced EstLink, NordBalt availability or congestion towards Poland, adequacy risks in the Baltic system become significantly more severe.

2. Hydropower is Latvia's adequacy cornerstone. In a dry year, Latvian hydro output can decline by 1–2 TWh[101], equivalent to more than 15% of Latvias annual electricity consumption.[102] Such deficits force Latvia to import from Estonia and Lithuania, countries which themselves rely on imports during winter.

3. The 2024 EstLink 2 outage (Jan–Sep) illustrates how a single HVDC failure can sharply reduce adequacy margins. During the outage, Estonia's ability to import from Finland was reduced, and day-ahead prices were around 10% higher, with consumers paying roughly €18/MWh more than they would have without the outage.[103] NordBalt outages similarly affect Lithuania. During the planned annual NordBalt outage on 21–27 October 2024, when the cable was fully unavailable due to maintenance, wholesale electricity prices in Lithuania rose by 109%, from about 58 €/MWh to 120 €/MWh.[104]

4. Finnish and Swedish hydrology strongly affects Baltic adequacy. During low-hydro years, Swedish SE3 and SE4 prices rise, reducing available cheap imports and pushing Baltic prices higher.

5. Post-2025, Baltic frequency stability depends on:

- domestic FCR/FFR procurement,
- frequency support via LitPol Link,

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[100] Elering (2025). *Both solar and win energy production exceeded one terawatt-hours last year*. https://elering.ee/en/article/both-solar-and-wind-energy-production-exceeded-one-terawatt-hours-last-year
[101] AST (2025). *Latvian electricity market overview.* https://ast.lv/en/electricity-market-review?year=2024&month=13
[102] KPMG (2024). *Study on electricity consumption trends in the Baltics and Nordics*. https://www.ast.lv/sites/default/files/editor/Consumption_forecast_Final_Executive_Summary.pdf
[103] ERR (2024). *Estonian-Finnish undersea power link Estlink 2 down again due to fault.* https://news.err.ee/1609560328/estonian-finnish-undersea-power-link-estlink-2-down-again-due-to-fault
[104] Lithuanian Energy Agency (2024). *Didmeninės elektros kainos padidėjo dėl vykusių „NordBalt" remonto darbų bei veikusių šiluminių elektrinių. https://www.ena.lt/Naujiena/seda-20241028/*

- inertia contributions from Kruonis HAE,
- fast battery response in Lithuania.

When low inertia, limited interconnector capacity and weak wind happen at the same time, the power system faces its toughest operating conditions.

Baltic TSOs outline several strategies to counter adequacy risks:

1. As part of the Baltic synchronisation with Continental Europe, all three countries are fundamentally strengthening their 330 kV backbone.
2. Lithuania plans two offshore wind farms with a combined capacity of 1.4 GW (2 × 700 MW), while Estonia and Latvia are jointly developing the cross-border ELWIND project, backed by 15 GW technical potential[105]; in parallel, Finland is preparing multi-GW offshore auctions and zoning.[106] By 2030, Baltic wind capacity may exceed 5–7 GW, with Estonia and Lithuania becoming wind-dominant systems.
3. Lithuania has already installed a 200 MW battery system (four 50 MW units) to provide fast reserves and support isolated operation, and further storage projects are being prepared in the region.
4. Lithuania, Latvia and Germany have agreed on a concept for a 2 GW, ~600 km hybrid offshore interconnector that would connect Baltic offshore wind to the German market and add a new corridor for regional adequacy.[107]
5. Estonia is advancing SMR plans, having selected GE–Hitachi's BWRX-300 as its preferred design[108], while Lithuania is preparing an SMR feasibility study as a longer-term adequacy option. The SMR generation capacity should reach around 1.5 GW by 2040.[109] Finland's nuclear fleet will continue to anchor regional stability, providing predictable baseload through OL3 and potential lifetime extensions for existing reactors.
6. As fossil baseload retires further, particularly oil-shale in Estonia, the entire Baltic adequacy position will hinge increasingly on:

    - winter wind availability,
    - Swedish and Finnish hydro,
    - interconnector reliability,
    - growth of storage resources,
    - market-wide demand flexibility

The Baltic–Nordic electricity system is entering a period of profound transformation. As renewable deployment accelerates, fossil baseload retires, and interconnector patterns evolve under new geopolitical and market realities, the region faces both unprecedented opportunities and heightened risks. The 2030–2040 horizon is defined by a structural shift toward an increasingly electrified,

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[105] Elwind (2024). *Elwind.* Online: https://elwindoffshore.eu/elwind/
[106] BlueCluster (2024). *Offshore wind in Finland: ambitions, opportunities and challenges.* https://www.bluecluster.be/news/offshore-wind-in-finland-ambitions-opportunities-and-challenges
[107] Offshore Energy (2025). *2 GW hybrid offshore interconnector in the plans to hook up Lithuania, Latvia and Germany*. https://www.offshore-energy.biz/2-gw-hybrid-offshore-interconnector-in-the-plans-to-hook-up-lithuania-latvia-and-germany
[108] Fermi Energia (2024). *Fermi Energia has selected GE Hitachi Nuclear Energy's BWRX-300 small modular reactor for deployment in Estonia by the early 2030s.* https://fermi.ee/en/bwrx-300/
[109] LRT (2024). *Lithuania will need 5 small nuclear reactors – minister. https://www.lrt.lt/en/news-in-english/19/2424310/lithuania-will-need-5-small-nuclear-reactors-minister*

interconnected, and weather-dependent power system, one where security of supply will depend on coordinated regional governance rather than national strategies alone.

5.1.2. Nuclear sector

Availability of nuclear energy in the Baltic-Finnic region is limited. The only nation with an active nuclear energy generation is Finland with it's Latvia and Estonia have never had a nuclear power plant, however in Lithuania once played a dominant role in Lithuania's energy sector for several decades, producing up to 70–80% of national electricity output at its peak. Even after the closure of Unit 1 at the end of 2004, Ignalina continued to dominate the electricity market, accounting for nearly 70.7% of gross electricity generation in 2009.[110] Consequently, the most significant structural transformation in Lithuania's energy system occurred with the final shutdown of Unit 2 in 2009, a condition of Lithuania's accession to the European Union due to safety concerns related to the plant's Soviet-designed RBMK reactors. Following the closure of INPP, Lithuania experienced a sharp reduction in domestic electricity generation capacity, increasing reliance on imports and exposing the country to external energy dependencies. However, with the rise of variable renewable generation, Lithuania has started looking into GEN IV SMRs as a potential option for baseline generation and balancing.[111] Lithuania's interest in SMRs is further underpinned by projections indicating a sixfold increase in electricity demand by the mid-century, driven by electrification, industrial transformation, and climate neutrality objectives. Importantly, Lithuania retains institutional advantages stemming from its historical nuclear experience, including a well-established regulatory authority, experience in radioactive waste management, and public familiarity with nuclear energy as described in the National Energy Independence Strategy.[112]

Estonia has also decided to move on SMRs as potential technology to help along energy transition away from the dominant oil–shale generation which has conflicted with country's climate commitments and EU environmental regulations.[113] Current planning envisions the construction of Estonia's first nuclear power plant – most likely SMR-based – with operations potentially commencing around 2035.[114] This timeline reflects the long-term, multi-stage nature of nuclear deployment, requiring early political commitment, regulatory capacity building, and sustained institutional coordination. From an energy security perspective, nuclear power is increasingly framed as a replacement for oil shale, reducing emissions while strengthening system resilience.[115]

Latvia, on the other hand, is undecided. Latvian government has contemplated either starting their own SMR project or joining Estonian one, however no concrete decision has been made. The reasoning is the same – to cover the variability of increasing renewable generation.

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[110] World Nuclear Association (2024). *Nuclear Power in Lithuania.* https://world-nuclear.org/information-library/country-profiles/countries-g-n/lithuania

[111] World Nuclear News (2025). *Lithuania to look into nuclear energy option*. https://www.world-nuclear-news.org/articles/lithuania-to-look-into-nuclear-energy-options

[112] Ministry of Energy of the Republic of Lithuania (2024). *Nacionalinė energetinės nepriklausomybės strategija (NENS)*, https://enmin.lrv.lt/public/canonical/1761819548/6664/NENS%202024-2.12.pdf.

[113] European Parlament (2025). *Estonia's climate action strategy.* *https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2025)772911*

[114] Nucnet (2024). *Fermi Energia Moves Back Timeline For First Operational SMR To 2035.* https://www.nucnet.org/news/fermi-energia-moves-back-timeline-for-first-operational-smr-to-2035-2-3-2024

[115] The Northern Voices (2025). *Baltic States Embrace Nuclear Power for Energy Security and Climate Goals.* https://www.thenorthernvoices.com/post/baltic-states-embrace-nuclear-power-for-energy-security-and-climate-goals?

The one clear leader in terms of availability of nuclear energy is certainly Finland. Finns have long been proponents of nuclear energy, viewing it as a cornerstone of its strategy to achieve energy security and meet climate neutrality targets by 2035. The geopolitical shifts of 2022-2024, and the Russian invasion of Ukraine, has reframed the role of nuclear power in Finland. It is not only a tool to reach decarbonization goals, but also a critical instrument of national security of energy supply. Nuclear power provides stable, predictable, and domestically controlled electricity production that is foundational to this security.

Finland's commitment to nuclear power is also a function of its high energy demand, driven by an energy-intensive industrial base and a cold climate, resulting of energy consumption 14,000 kWh/yr per capita in 2023.[116] The same year 42.3 % of all electricity in Finland was generated by nuclear means, making it the single largest component of the national energy mix. The technological and economic framework of nuclear energy is built upon a foundation of high societal trust. This has allowed for the stable, long-term planning necessary for complex project needed for nuclear power, which is a sharp contrast to the politically contentious environment for nuclear energy in many other European nations.[117]

As of January 2025, the country operates five nuclear reactors across two power plants – Olkiluoto and Loviisa – situated along the Baltic Sea. The combined net capacity of these reactors stands at 4,394 MW and represents one of the most modern and efficient nuclear fleets in Europe.

Current nuclear infrastructure:

- Olkiluoto Nuclear Power Plant: located close to Eurajoki, southwestern Finland, the Olkiluoto facility houses three reactors. The first two, Olkiluoto 1 and 2, are 890 MWe boiling water reactors that have been operational since the late 1970s and early 1980s, respectively. They have undergone significant upgrades throughout their operational life.[118] The third unit, Olkiluoto 3, is a European Pressurized Reactor (EPR) with a capacity of 1,600 MW. That is the most significant nuclear development in the entire Baltic Sea region's energy landscape during the 2022-2024 period. After a protracted construction period marked by delays and cost overruns, Olkiluoto 3 commenced regular electricity production in April 2023, becoming Europe's most powerful nuclear reactor[119]. Its launch was a transformative event, substantially increasing Finland's electricity self-sufficiency and reducing its dependence on electricity imports.

[116] Penttinen, S.-L. (2025). *Nuclear Energy in Finland*. Journal of Agricultural and Environmental Law. https://doi.org/10.21029/JAEL.2025.38.91
[117] Vehmas, J., Rentto, A., Luukkanen, J., Auffermann, B., & Kaivo-oja, J. (2022). *The Finnish Solution to Final Disposal of Spent Nuclear Fuel*. https://doi.org/10.1007/978-3-658-40496-3_11#DOI
[118] Penttinen, S.-L. (2025). *Nuclear Energy in Finland*. Journal of Agricultural and Environmental Law. https://doi.org/10.21029/JAEL.2025.38.91
[119] Tanner J., *Europe's most powerful nuclear reactor kicks off in Finland* , AP News, Online: https://apnews.com/article/finland-energy-nuclear-power-reactor-741341cfdf79e655a2a680e1b1130917

Figure. 5.9. Olkiluoto 3 reactor. Source: Yle[120].

- Loviisa Nuclear Power Plant: Situated on the island of Hästholmen in Loviisa, southeastern Finland, this plant comprises two soviet-designed VVER-440 pressurized water reactors, Loviisa 1 and 2, which began operations in the late 1970s and early 1980s. A unique feature of these reactors is that, despite being of a Soviet design, they were extensively modified at the owner's request during construction to comply with Western safety standards and incorporate Western control systems. Both Loviisa units have been granted lifetime extensions, allowing them to continue operation until 2050, ensuring a predictable and secure supply of low-carbon power for decades to come[121]

5.1.3. Natural gas sector

The availability of natural gas in the Baltic–Nordic region has undergone a total structural transformation. Between 2022 and 2024, the region transitioned from a linear, pipeline-based import regime dependent on the Russian Federation to a diversified, triangular architecture defined by Liquefied Natural Gas (LNG) inflows, underground storage buffering, and cross-border redistribution. In terms of physical security, the "availability gap" created by the cessation of Russian imports has been closed; however, this equilibrium has been achieved not through new supplies, but through a historic contraction in consumption.

5.1.3.1. Natural gas Production, Supply and Trade Flows

Within less than two years, Lithuania, Latvia, Estonia and Finland replaced a deeply entrenched, pipeline-based import regime with an LNG-centred, interconnector-driven and storage-dependent supply architecture. This transformation has fundamentally altered not only national supply structures but also the regional logic of gas distribution, decoupling national consumption from national import volumes.

[120] Yle (2018). *Long-delayed Olkiluoto 3 nuclear reactor to go online in January 2020*. https://yle.fi/a/3-10532547
[121] Penttinen, S.-L. (2025). *Nuclear Energy in Finland*. Journal of Agricultural and Environmental Law. https://doi.org/10.21029/JAEL.2025.38.91

Across the region, natural gas has simultaneously lost quantitative importance in the energy balance and gained qualitative importance in security-of-supply terms. By 2024, the share of gas in total energy supply had declined to 20.1% in Lithuania, 17% in Latvia, 7.4% in Estonia and 4.4% in Finland, reflecting long-term structural decline trends ranging from −27% in Lithuania to −60% in Finland since 2000. Despite this contraction, gas remains almost entirely import-dependent, with net imports exceeding 99% of total supply in all four countries, underscoring the continued exposure to external supply conditions[122].

In Lithuania, the post-crisis supply transformation is particularly pronounced. In 2024, total natural gas supply amounted to 63.4 PJ, covering 20.1% of total energy supply, while net gas imports accounted for 99.3% of domestic supply. Although total gas supply declined by 27% compared to 2000 levels, the share of gas in total energy imports remained substantial at 18%, highlighting its continued relevance in external energy dependency.

Since April 2022, Lithuania has fully terminated Russian gas imports and relies exclusively on LNG and European market connectivity[123]. The Klaipėda LNG terminal has become the dominant physical entry point of gas not only for Lithuania but for the entire Baltic gas system. Its regasification capacity significantly exceeds Lithuania's reduced post-crisis consumption, resulting in a structural surplus available for regional redistribution. As early as 2023–2024, this surplus translated into sustained export flows toward Latvia, primarily for seasonal storage in Inčukalns, and toward Poland via the Gas Interconnection Poland–Lithuania (GIPL).

This configuration confirms Lithuania's structural transition from a terminal importer into a regional supply and transit hub embedded within the broader EU gas market. Import volumes increasingly reflect regional balancing needs rather than domestic demand, marking a fundamental break with the pre-2022 supply logic.

Latvia's gas supply structure is dominated by the Inčukalns Underground Gas Storage Facility, which functions as the principal seasonal balancing mechanism for the Baltic–Nordic gas system[124]. In 2024, Latvia's total gas supply amounted to 30.1 PJ, representing 17% of total energy supply and reflecting a 34% decline since 2000. Net gas imports exceeded 100% of domestic supply, a technical outcome of storage injections and withdrawals rather than direct consumption[125].

Import volumes declined structurally from over 46 PJ in 2019 to approximately 30 PJ in 2024, consistent with the observed contraction in regional gas demand. Nevertheless, gas retained a notable weight in Latvia's energy import structure, accounting for 19% of total energy imports in 2024[126]. Unlike Lithuania and Finland, Latvia does not function as a primary LNG entry point; instead, its strategic importance derives from its storage function rather than import diversification. Latvia's gas security is thus less a function of national supply autonomy and more a function of regional system coordination and storage availability.

[122] International Energy Agency (2025). *Finland/Lithuania/Latvia/Estonia – Countries and Regions.* Natural Gas data.
[123] Ministry of Energy of the Republic of Lithuania.2022. Lithuania completely abandons Russian gas imports. https://enmin.lrv.lt/en/news/lithuania-completely-abandons-russian-gas-imports/
[124] Conexus. Information about the storage. https://www.conexus.lv/information-about-storage
[125] International Energy Agency (2025). *Latvia – Countries and Regions*. https://www.iea.org/countries/latvia/natural-gas
[126] International Energy Agency (2025). *Latvia – Countries and Regions*. https://www.iea.org/countries/latvia/natural-gas

Estonia's gas supply position is structurally shaped by the absence of domestic production and underground storage, combined with its role as a transit corridor linking Latvia and Finland. In 2024, Estonia's total gas supply amounted to 11.5 PJ, representing just 7.4% of total energy supply and a 59% decline relative to 2000. Net imports exceeded domestic supply at 106%, reflecting transit flows and system balancing rather than internal demand growth[127].

The share of gas in Estonia's total energy imports fell to 12% in 2024, underscoring its marginal role in the national energy balance. Physical supply security is achieved almost entirely through regional integration, with dependence on cross-border inflows, access to LNG via neighbouring systems and seasonal balancing through Inčukalns storage. The acquisition of state control over Paldiski LNG infrastructure in 2023[128] added a strategic insurance layer but did not fundamentally alter Estonia's reliance on regional rather than national supply assets.

Finland's supply reconfiguration following the cessation of Russian pipeline deliveries in 2022 was both rapid and structural. By 2024, total gas supply stood at 57.7 PJ, representing just 4.4% of total energy supply and a 60% decline compared to 2000. Net imports exceeded 104% of domestic supply, reflecting LNG inflows exceeding reduced national consumption[129].

The commissioning of the Inkoo FSRU[130] provided Finland with regasification capacity well above its post-crisis demand, ensuring physical supply adequacy under normal conditions. Notably, Finland transitioned from a purely importing system to an exporting one: gas exports reached 5.9 PJ in 2023 and increased to 18.1 PJ in 2024, primarily via Balticconnector toward Estonia. This marks a structural shift in Finland's role from a terminal consumer to an active participant in regional gas redistribution.

From a regional perspective, the Baltic–Nordic gas system has transitioned from a linear east–west pipeline regime into a triangular LNG–storage–interconnector architecture. LNG now enters primarily through Klaipėda and Inkoo, is seasonally stored in Inčukalns, and redistributed through GIPL and Balticconnector according to market and system conditions. This configuration has dramatically increased geopolitical resilience by eliminating single-supplier dominance.

However, the new system introduces novel vulnerabilities. Supply security is increasingly contingent on LNG market liquidity, terminal operability, maritime routes in the Baltic Sea and the physical integrity of cross-border interconnectors. The Balticconnector rupture in October 2023[131] demonstrated how a single infrastructure failure can temporarily compress regional flexibility, even in the absence of aggregate supply shortages.

At the same time, declining gas demand has reduced infrastructure utilisation rates, raising unit costs and weakening long-term investment incentives. Gas infrastructure in the region increasingly serves

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[127] International Energy Agency (2025). *Estonia – Countries and Regions*. https://www.iea.org/countries/estonia/natural-gas

[128] Estonian Stockpiling Agency.2023. State acquires Paldiski LNG jetty with port property from private companies. https://varudekeskus.ee/en/news/state-acquires-paldiski-lng-jetty-port-property-private-companies

[129] International Energy Agency (2025). *Finalnd – Countries and Regions*. https://www.iea.org/countries/finland/natural-gas

[130] GasGrid (2023) Gasgrid's Inkoo LNG-terminal was supplemented with LNG. https://gasgrid.fi/en/2023/04/04/gasgrids-inkoo-lng-terminal-was-supplemented-with-lng/

[131] Reuters (2023). Finland says 'outside activity' likely damaged gas pipeline, telecoms cable. https://www.reuters.com/markets/commodities/finnish-government-hold-news-conference-suspected-pipeline-leak-media-2023-10-10/

collective security functions rather than national consumption needs, creating a structural tension between high strategic value and declining economic centrality.

5.1.3.2. Natural gas Demand and Consumption

In the period between 2019 and 2021, natural gas demand across Lithuania, Estonia and Finland exhibited a relatively stable pre-crisis baseline, reflecting structural patterns of industrial production, district heating and CHP generation. Despite differences in national energy mixes, gas played a predictable and largely normalised role within electricity generation, heat supply and industrial processes. This equilibrium was abruptly and irreversibly disrupted in 2022, when the effects of the geopolitical supply shock, unprecedented price escalation and emergency fuel substitution triggered a region-wide contraction of gas demand of historic magnitude. Across the region, natural gas has lost its former role as a baseload input and is being repositioned as a residual or conditional fuel, retained only where substitution is technically constrained, economically prohibitive, or strategically necessary for system flexibility.

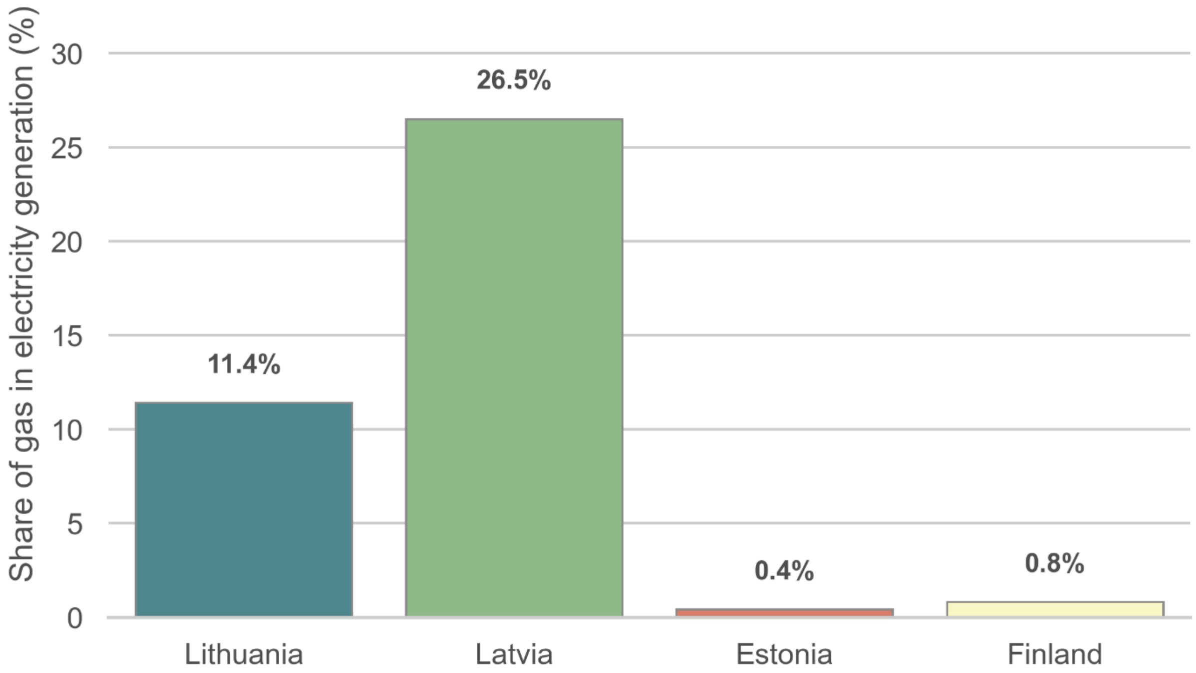

Figure 5.10. Share of natural gas in electricity generation, 2024 (IEA data)

Prior to the crisis, Lithuanian gas demand remained tightly clustered around 23–24 TWh per year in 2019–2021, reflecting the dominant weight of non-energy industrial consumption. In 2023, around 84% of Lithuania's natural gas supply was consumed directly by final users,[132] underlining the exceptional concentration of demand. This apparent stability, however, masked a critical structural vulnerability: more than half of national gas consumption was linked to ammonia production at AB Achema. When gas prices surged in 2022 and fertilizer production was suspended in September of

[132] International Energy Agency (2025). *Lithuania – Countries and Regions*. https://www.iea.org/countries/lithuania/natural-gas

that year,[133] Lithuania experienced an immediate structural collapse on the demand side. By 2023, total gas consumption had fallen to 15 TWh, implying a contraction of approximately 9 TWh, over one-third of national demand, within two years. In 2023, natural gas consumption in Lithuania was dominated by non-energy use, which accounted for 45.2% of total demand, reflecting the role of gas as an industrial feedstock. Industry represented a further 23.9%, while residential consumption remained significant at 17.4%, indicating continued reliance on gas for heating. Commercial and public services contributed 8.8%, with transport and agriculture together accounting for only marginal shares. (Fig. 5.11(b). The reduction was overwhelmingly concentrated in non-energy industry, where consumption declined from 44.6 PJ (12.4 TWh) in 2019 to 22.0 PJ (6.1 TWh) in 2023. In contrast, residential, commercial and district heating demand proved comparatively inelastic. The partial recovery observed in 2024, when gas supply increased to 63.4 PJ (16.9 TWh), reflects a price-dependent restart of fertilizer production. Gas has shifted from a industrial input to a strategic and contingent production factor. Despite this demand collapse, gas still accounted for 11.4% of Lithuania's electricity generation in 2024 (921 GWh) (Fig. 5.10) and 17% of CO_2 emissions from fuel combustion in 2023,[134] highlighting a persistent security-relevant role in both power system balancing and emissions exposure.

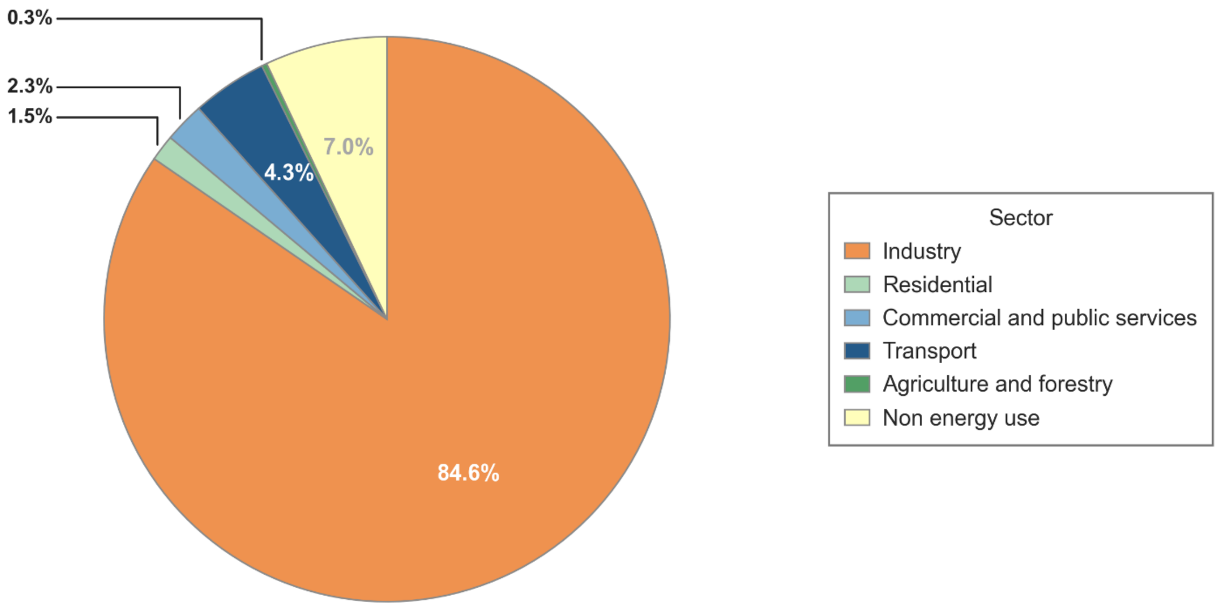

Figure 5.11(a). Natural gas consumption structure by sectors in Finland, 2023 (IEA data)

[133] LRT (2022). *Lithuania's biggest fertiliser maker suspends production over soaring gas prices.* https://www.lrt.lt/en/news-in-english/19/1765607/lithuania-s-biggest-fertiliser-maker-suspends-production-over-soaring-gas-prices

[134] International Energy Agency (2025). *Lithuania – Countries and Regions*. https://www.iea.org/countries/lithuania/natural-gas

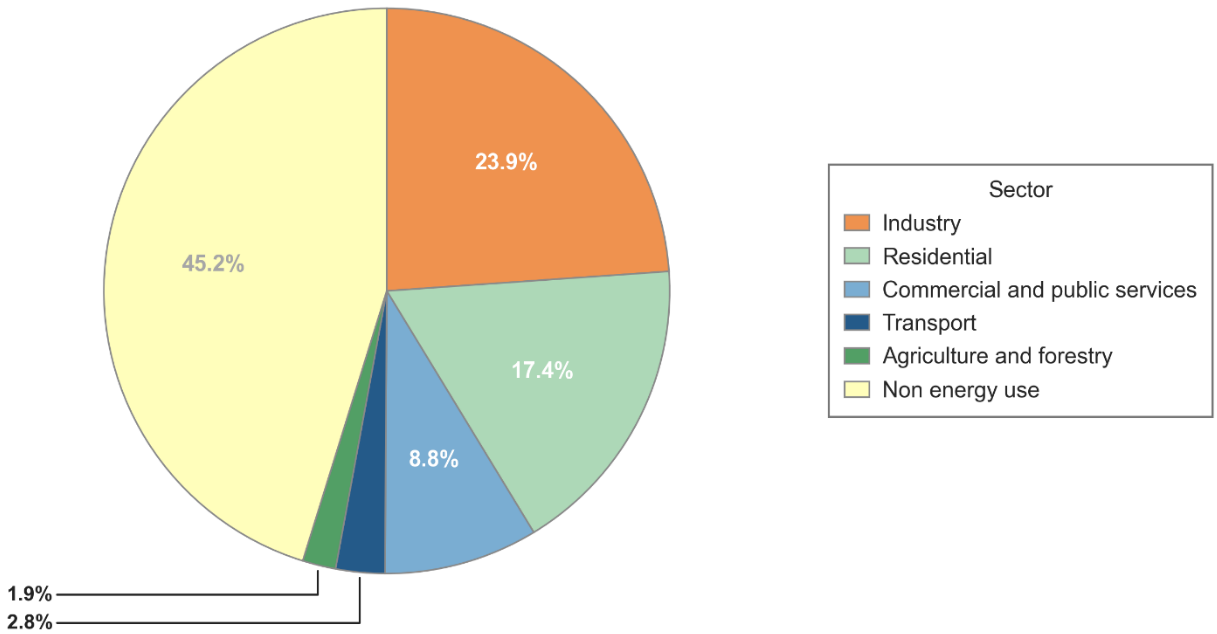

Figure 5.11(b). Natural gas consumption structure by sectors in Lithuania, 2023 (IEA data)

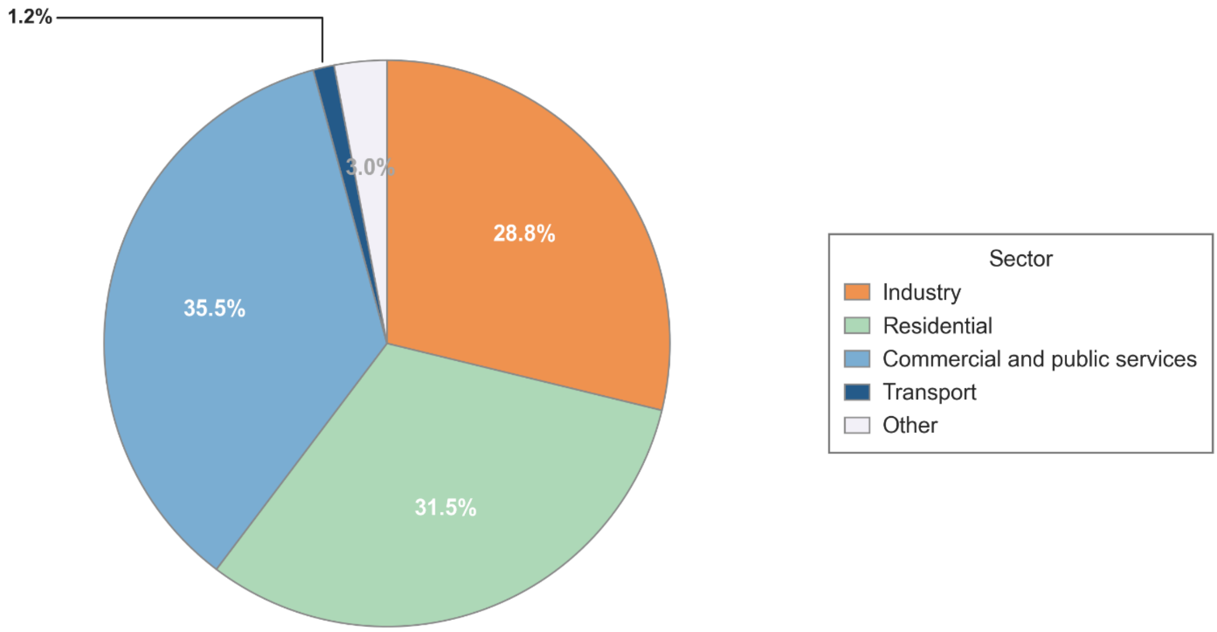

Figure 5.11(c). Natural gas consumption structure by sectors in Latvia, 2024 (IEA data)

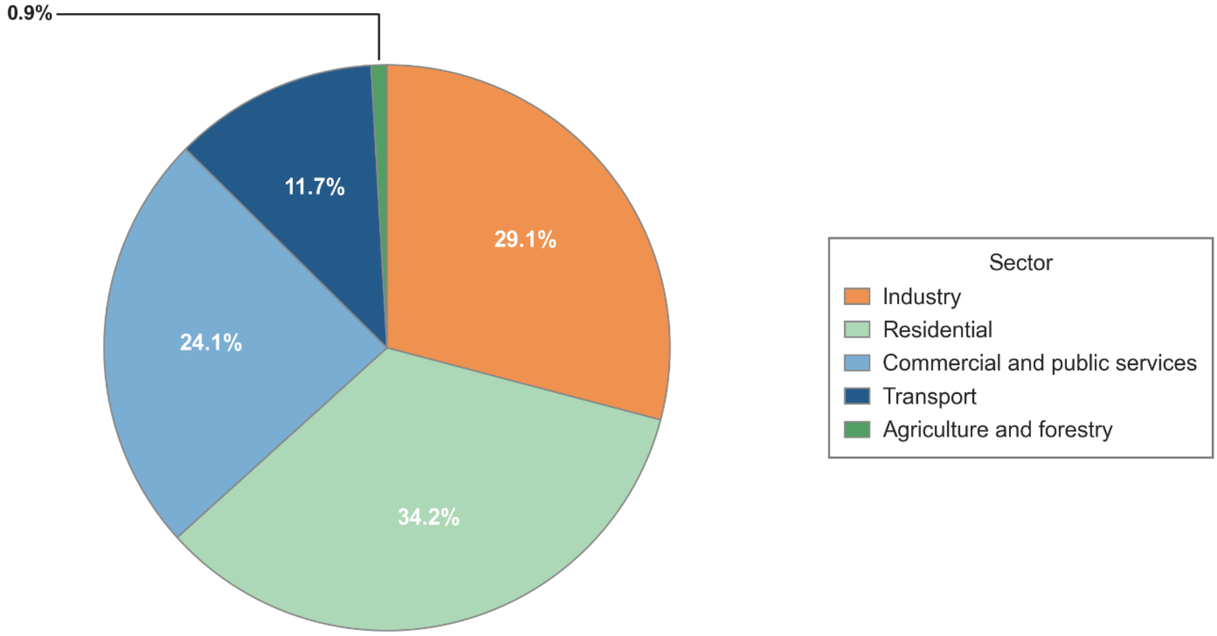

Figure 5.11(d). Natural gas consumption structure by sectors in Estonia, 2023 (IEA data)

Estonia's gas demand trajectory followed a fundamentally different logic. Gas consumption declined sharply after 2021, driven not by industrial shutdowns but by systematic fuel substitution in the heating sector, which historically accounted for approximately two-thirds of national gas demand. Rising gas prices and explicit government policy accelerated the transition toward biomass-based district heating and alternative heating technologies. Between 2019 and 2023, gas consumption declined across all major sectors, with particularly steep reductions in commercial and public services (from 3.4 PJ (0.94 TWh) to 1.8 PJ (0.50 TWh)) and industry (from 4.6 PJ (1.28 TWh) to 2.2 PJ (0.61 TWh)). Based on the Fig.11(d), natural gas consumption in Estonia is dominated by residential and industrial users. The residential sector accounts for the largest share (34.2%), reflecting the continued role of natural gas in space heating, while industry represents a substantial 29.1%. Commercial and public services also play a significant role (24.1%), whereas transport contributes a more limited share (11.7%). Natural gas use in agriculture and forestry is marginal, at below 1%, underscoring its negligible role in this sector. By 2024, gas accounted for only 0.4% of electricity generation (23 GWh) and 9% of CO_2 emissions from fuel combustion (Fig. 5.10).[135] Estonia's post-2022 demand contraction thus reflects a structural phase-out dynamic rather than a cyclical shock. Gas is increasingly confined to residual, non-substitutable applications and short-term backup functions.

In Finland, the demand collapse in 2022 was both sudden and systemically deep. Prior to the crisis, Finnish gas consumption remained stable at approximately 25 TWh per year, serving CHP generation, refining-related hydrogen production and heavy industry. Following the suspension of Russian pipeline deliveries in May 2022, gas demand contracted to 10.7 TWh, nearly a 50% reduction in a single year. This contraction was enabled by rapid emergency fuel switching toward biomass and

[135] International Energy Agency (2025). *Estonia – Countries and Regions*. https://www.iea.org/countries/estonia/natural-gas

alternative fuels in both district heating and industry. Based on the Fig. 5.11(a), natural gas consumption in Finland is overwhelmingly concentrated in the industrial sector, which accounts for 84.6% of total use. This reflects the dominant role of gas in industrial heat and process applications, while household consumption is comparatively limited (1.5%), indicating a much smaller reliance on gas for residential heating. Commercial and public services (2.3%) and transport (4.3%) play minor roles, and non-energy use represents a modest share (7.0%), likely linked to feedstock applications. Gas use in agriculture and forestry is negligible, at around 0.3%. By 2024, gas accounted for just 0.8% of electricity generation (675 GWh) (Fig. 5.10) and 8% of CO_2 emissions.[136] Industry now dominates gas demand, accounting for nearly 85% of final consumption, while residential and service-sector use has been largely marginalised. Finland has thus entered a structurally lower gas-intensity equilibrium, with gas retained primarily as a strategic flexibility fuel rather than a baseload energy carrier.

Latvia represents a structurally distinct gas demand regime within the Baltic–Nordic region. In 2024, natural gas accounted for 27% of total electricity generation (1,7 GWh), the highest share among the analysed countries (Fig. 5.10), and 26% of CO_2 emissions from fuel combustion in 2023. Unlike Estonia and Finland, where gas has been largely marginalised in the power sector, Latvia continues to rely on gas-fired generation as a core system-balancing and flexibility resource. On the demand side, Latvian gas consumption is predominantly anchored in socially and service-oriented sectors (Fig 5.11(c). In 2024, residential consumption accounted for 31.5% of final gas demand, while commercial and public services represented 35.5%. Industry constituted a comparatively smaller share (28.8%), indicating a demand structure fundamentally different from Lithuania's industrially concentrated profile. The 2022 energy crisis triggered a significant but non-destructive contraction in gas demand across all major sectors. Industrial consumption declined sharply from 5.1 PJ (≈ 1.4 TWh) in 2021 to 3.6 PJ (≈1.0 TWh) in 2022 (−30%), followed by a partial recovery to 4.0 PJ (≈1.1 TWh) in 2024. Residential demand fell by approximately 26% between 2021 and 2023, reflecting price sensitivity and efficiency adjustments rather than structural fuel substitution.[137] Consumption in commercial and public services exhibited a more gradual decline, underscoring the limited short-term substitutability of gas in socially critical applications. These dynamics suggest that Latvia's post-crisis gas demand adjustment differs fundamentally from both Lithuania's price-elastic industrial collapse and Estonia's policy-driven phase-out. Instead, Latvia exhibits a socially anchored and power-sector-driven gas demand regime, where consumption persistence is shaped by household heating needs, public services and electricity system balancing requirements. As a result, while absolute demand has declined, gas retains a structurally significant role in Latvia's energy system, with direct implications for energy security, emissions exposure and infrastructure planning.

From a regional perspective, the post-2022 reconfiguration reveals three distinct adjustment mechanisms. Lithuania exhibits a highly price-elastic industrial demand regime, Estonia follows a policy-driven structural phase-out pathway, and Finland represents a rapid emergency-substitution model with strategic gas retention. Latvia remains under-specified on the demand side despite its infrastructural importance.

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[136] International Energy Agency (2025). *Finland – Countries and Regions*. https://www.iea.org/countries/finland/natural-gas

[137] International Energy Agency (2025). *Latvia – Countries and Regions*. https://www.iea.org/countries/latvia/natural-gas

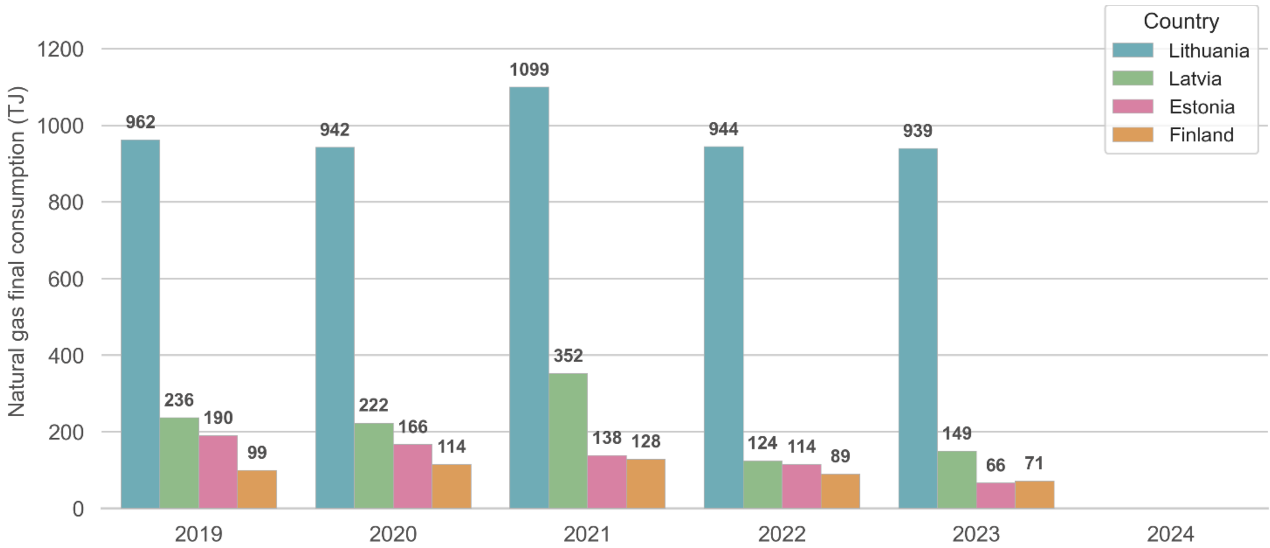

Figure 5.12(a). Natural gas consumption in agriculture and forestry sector, 2019–2024 (TJ, country comparison)

Across all sectors, natural gas consumption patterns differ markedly among Lithuania, Latvia, Estonia and Finland, reflecting structural differences in energy use and sectoral dependence (Fig. 5.12(a-e). In agriculture and forestry, gas use remains negligible in all four countries and does not materially affect overall demand. In commercial and public services, Lithuania consistently records the highest consumption levels, while Latvia and Estonia show a pronounced decline after 2021 and Finland maintains comparatively low and gradually decreasing use. Industrial consumption dominates gas demand in Lithuania and Finland, although both experience a significant contraction after 2021, with the decline being particularly sharp in Estonia, whereas Latvia's industrial gas use remains lower but relatively more stable. In the transport sector, gas consumption increases in Lithuania and Finland through 2021–2023, reflecting the uptake of CNG and LNG, while Estonia shows more volatile trends and Latvia remains marginal. In the residential sector, Lithuania stands out as the largest gas consumer, despite a clear post-2021 reduction, while Latvia and Estonia experience substantial demand contraction following the energy crisis, and Finland continues to display very limited and declining household gas use, consistent with the predominance of alternative heating technologies.

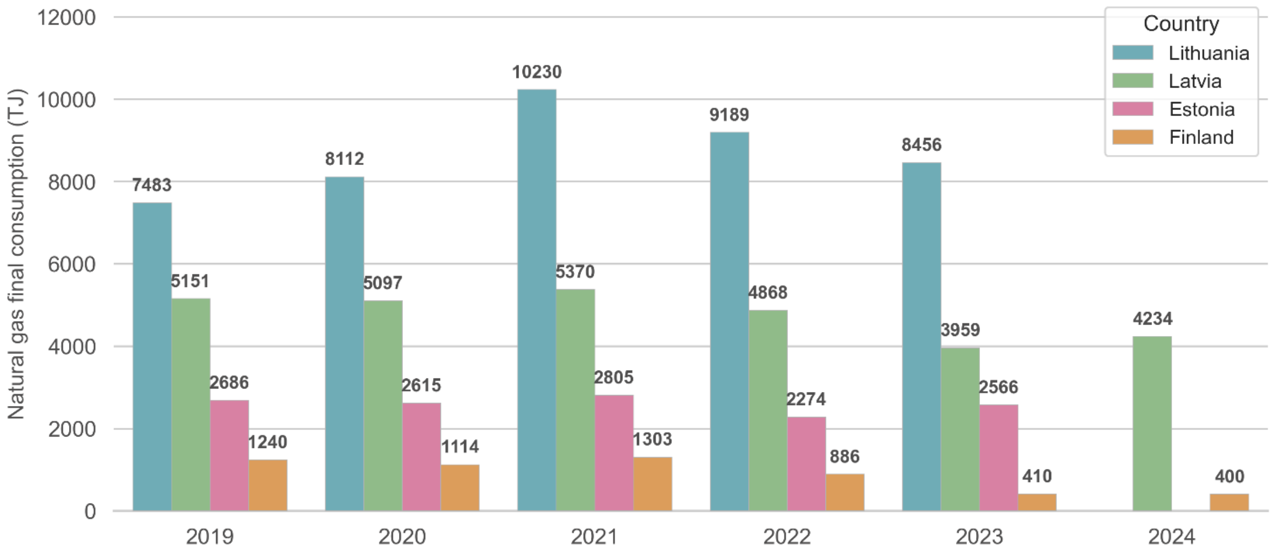

Figure 5.12(b). Natural gas consumption in residential sector, 2019–2024 (TJ, country comparison)

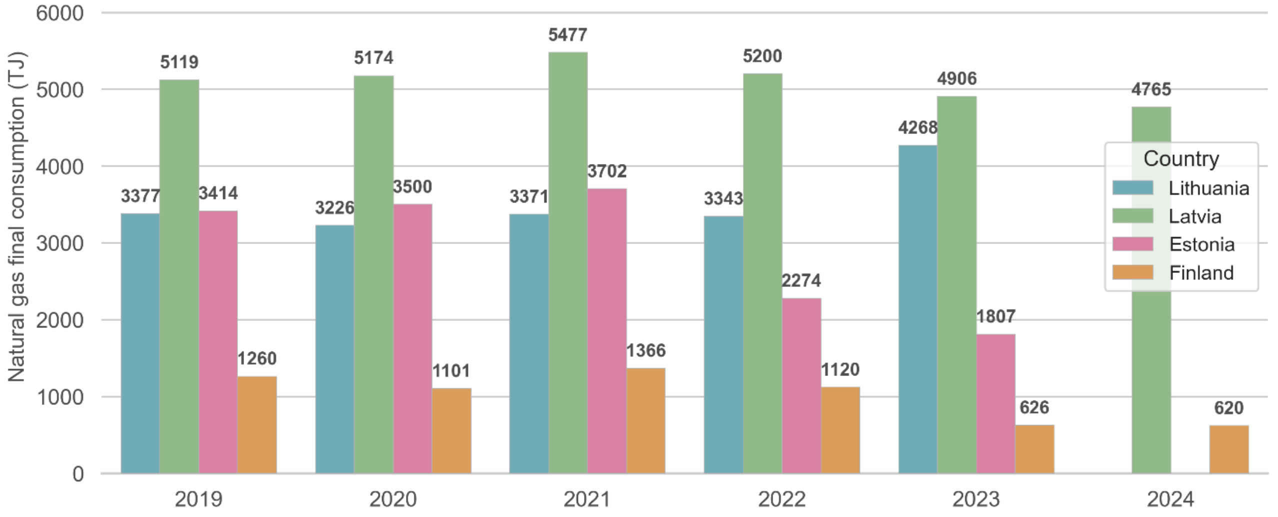

Figure 5.12(c). Natural gas consumption in commercial and public service sector, 2019–2024 (TJ, country comparison)

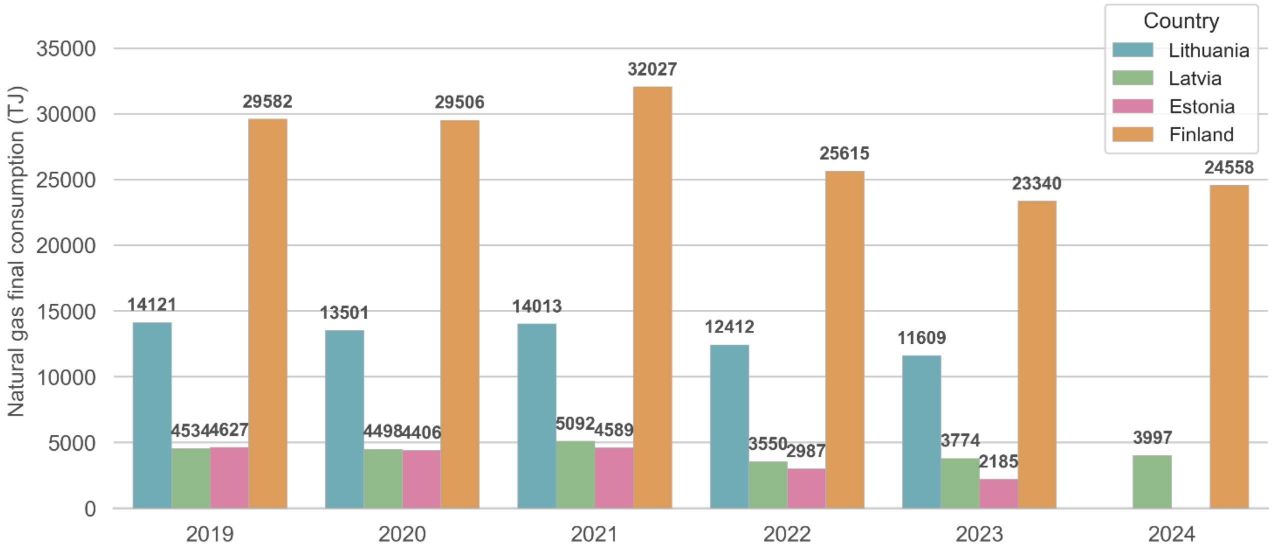

Figure 5.12(d). Natural gas consumption in industrial sector, 2019–2024 (TJ, country comparison)

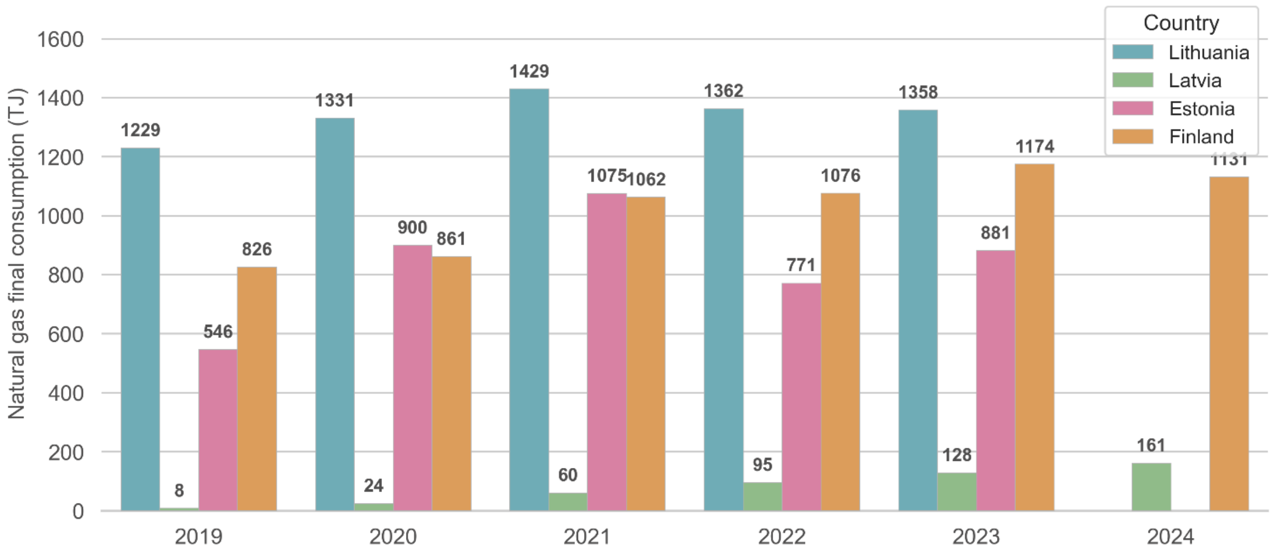

Figure 5.12(e). Natural gas consumption in transport sector, 2019–2024 (TJ, country comparison)

Crucially, these demand reductions cannot be interpreted as temporary demand destruction. In all observed cases, gas has lost its former structural centrality. Even where partial rebounds have occurred, demand no longer follows the pre-crisis trajectory. This transformation carries paradoxical energy security implications: lower absolute consumption reduces exposure to import dependency and price shocks, yet shrinking systems face declining infrastructure utilisation, fragile cost recovery and heightened risks of under-investment in critical assets. The region thus enters a security zone in which geopolitical resilience improves while economic sustainability of gas infrastructure weakens.

5.1.3.3. Current State of Physical Availability

The gas sector has entered a "structurally paradoxical" phase. Physical supply security has been radically strengthened through LNG diversification and redundant capacity, yet the utilization of this infrastructure is falling due to the shrinking demand base.

The combined regasification capacity of Klaipėda and Inkoo, alongside the GIPL connection, provides an import potential that vastly outstrips the region's reduced consumption profile. Availability is now contingent on the integrity of specific cross-border assets. For Finland, which lacks domestic underground storage, the availability of winter reserves depends on the Balticconnector pipeline linking it to Latvia. The rupture of this line in 2023 demonstrated that while LNG terminals can cover daily demand, the *availability of flexibility* relies on cross-border integration. Despite volume declines, gas remains a critical stabilization layer. In Lithuania and Latvia, it remains essential for peak power balancing and specific industrial processes. The region has moved from a model of "gas for growth" to "gas for security," where availability is maintained not for baseload expansion, but for system resilience.

In summary, the Baltic–Nordic region has successfully filled the availability vacuum left by Russia. It has done so by establishing a surplus of import capacity relative to a permanently reduced demand, securing physical flows through a triangular lattice of LNG terminals and underground storage.

5.1.4. Oil sector

In the context of the Baltic–Nordic oil sector, "Availability" refers to the physical capacity to secure sufficient volumes of crude oil and refined petroleum products to maintain essential economic mobility and industrial function. Unlike the natural gas sector, where the post-2022 crisis triggered massive demand destruction, oil demand has remained structurally robust, particularly in the transport sector. Consequently, the region has not solved its availability challenge through reduced consumption, but through a radical substitution of supply sources.

The period between 2022 and 2024 marked the definitive end of the "eastern availability" model, where Russian crude and products provided the baseload supply. It has been replaced by a "maritime availability" model, where physical security is determined by access to global seaborne markets. While this has eliminated geopolitical supplier coercion, it has revealed a deep structural hierarchy within the region: Lithuania and Finland act as the guarantors of physical availability through their domestic refining capabilities, while Latvia and Estonia function as downstream dependencies relying on cross-border redistribution.

5.1.4.1. Structural Role of Oil

Across Lithuania, Latvia, Estonia and Finland, oil retains a critical systemic function, particularly in transport, freight and certain industrial processes. Despite steady progress in electrification and fuel substitution, petroleum products continue to underpin day-to-day economic activity and remain central to short-term energy security. The core pattern is similar: oil is progressively marginalised in electricity generation, yet remains deeply embedded in transport systems, freight logistics and certain industrial value chains. This structural asymmetry creates a shared energy security vulnerability, where the most rapidly transforming sector (electricity) is no longer the main source of risk, while the hardest-to-transition sector (transport) remains highly exposed to external supply shocks.

While all four countries are formally aligned with EU decarbonisation objectives, their oil dependency profiles reveal different levels of systemic rigidity and resilience. Lithuania exhibits the highest structural reliance, followed by Latvia and Estonia, whereas Finland demonstrates the most advanced diversification – yet even there, oil remains firmly anchored in mobility systems.

Lithuania stands out as the most oil-intensive system, with oil accounting for approximately 41% of total primary energy supply in 2024. This level clearly exceeds Latvia (32.7%), Estonia (around 37% of final consumption) and Finland (20.5%)[138]. However, the nature of this dependency differs: Lithuania's structure is shaped not only by consumption but also by its role as a refining hub, as it hosts the only refinery in the Baltic States – ORLEN Lietuva[139].

Latvia and Estonia occupy an intermediate position. Both show similar shares of oil products in total final energy consumption (around 37%)[140], yet Latvia's system is more strongly characterised by pure import dependence, lacking both domestic production and refining capacity. Estonia has reduced conventional oil use in electricity generation to marginal levels, with remaining oil dependency concentrated in transport, while oil shale is treated as a separate category.

Finland, by contrast, demonstrates a distinctly lower structural reliance. Oil accounts for just over one-fifth of total energy supply[141], reflecting its strong nuclear base and advanced renewable deployment. Still, oil remains significant in the transport and freight sector, underlining that even highly diversified systems retain strategic exposure through mobility.

Across all four countries, transport emerges as the primary channel of oil dependency and the key stress point from an energy security perspective. In Lithuania, transport consumes approximately 83% of all oil products, making it the single most critical vulnerability node. Freight activity constitutes a substantial share of road transport, reinforcing demand for diesel. Latvia follows a similar pattern, with transport accounting for 69% of oil product consumption, and gas/diesel forming approximately 75% of the total oil product mix. Consumption levels have remained remarkably stable in recent years, indicating slow structural change. Estonia shows even stronger concentration in transport, where 78% of oil products are used, with gas/diesel comprising 68% of the mix. Finland presents a more balanced picture: transport accounts for 52% of oil product use, reflecting greater diversification in other sectors, yet even here mobility remains the main contributor to oil dependency[142]. This

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[138] International Energy Agency (2025). *Finland/Lithuania/Latvia/Estonia – Countries and Regions*. Oil data.

[139] International Energy Agency (2025). *Lithuania 2025. Energy Policy Review.* *https://iea.blob.core.windows.net/assets/0f37fbed-856d-4fde-8f2b-4db10d9bfd2a/Lithuania2025.pdf*

[140] International Energy Agency (2025). *Latvia/Estonia – Countries and Regions*. Oil data.

[141] International Energy Agency (2025). *Finland – Countries and Regions*. https://www.iea.org/countries/finland/oil

[142] International Energy Agency (2025). *Finland/Lithuania/Latvia/Estonia – Countries and Regions*. Oil data.

comparative pattern indicates that energy security risks in the region are no longer dominated by power generation, but by the slow transformation of transport infrastructure, vehicle fleets and logistics chains.

A key structural differentiator among the four countries is the presence (or absence) of domestic refining and production infrastructure.

Lithuania's ORLEN Lietuva refinery processes approximately 9.8 million tonnes of crude oil annually, operating close to maximum capacity[143]. Lithuania produces significantly more refined oil products than it consumes domestically, resulting in a sustained net export position. Most output is supplied to neighbouring markets, notably Estonia, Latvia, Poland and Ukraine[144]. This positions Lithuania as both a consumer and a strategic supplier but also increases systemic exposure to crude import disruptions and refinery operational risks. Finland also operates substantial refining capacity (approximately 12 million tons annually)[145] yet remains fully dependent on imported crude oil. This creates a similar exposure pattern to Lithuania but within a more diversified overall energy mix. Latvia is structurally dependent on imported refined products, while Estonia, although possessing domestic oil shale–based production, still relies on imports for refined transport fuels in the absence of conventional refining capacity. While this reduces vulnerability to refinery disruption within national borders, it heightens exposure to regional competition and international supply scarcity during crisis periods. From an energy security perspective, Lithuania and Finland face higher infrastructure-linked risk concentration, whereas Latvia and Estonia face higher logistical vulnerability in supply continuity.

While transport dominates oil consumption volumes, industry and non-energy use form a critical, often under-analysed layer of structural dependence with direct implications for energy security, competitiveness and crisis resilience. In contrast to transport, where substitution pathways are increasingly visible (EVs, modal shift, rail electrification), industrial oil use is more deeply embedded in process-level technologies and supply chains, making it more resistant to rapid transformation.

Across the four countries, oil plays three main industrial roles: 1) process fuel for heat and machinery, 2) feedstock and material use in petrochemical/materials value chains, and 3) operational backup in sectors requiring high reliability.

Beyond refining itself, oil products support chemical manufacturing, construction materials and heavy logistics hubs. Although direct industrial consumption of oil products represents only around 2% of final use, non-energy use adds a further 8%, indicating a sizeable material-use component alongside fuel demand in Lithuania. [146] The indirect role is significantly larger when refinery-linked value chains are considered. This creates a structural dependency not only in energy terms, but also in industrial employment and export capacity – meaning that abrupt oil phase-out would pose systemic socio-economic risks. In Latvia, oil use in industry remains comparatively limited (around 5%), while non-energy use is also material at ~8%[147]. The absence of domestic refining means industrial sectors depend on uninterrupted access to imported refined products, reinforcing exposure to supply chain disruption. In crisis conditions, this could directly affect production continuity in food

[143] ORLEN. ORLEN Lietuva. https://www.orlenlietuva.lt/EN/Company/OL/Pages/default.aspx
[144] International Energy Agency (2025). *Lithuania 2025. Energy Policy Review.* *https://iea.blob.core.windows.net/assets/0f37fbed-856d-4fde-8f2b-4db10d9bfd2a/Lithuania2025.pdf*
[145] Neste. Porvoo refinery. https://www.neste.com/about-neste/how-we-operate/production/porvoo-refinery
[146] International Energy Agency (2025). *Lithuania – Countries and Regions*. https://www.iea.org/countries/lithuania/oil
[147] International Energy Agency (2025). *Latvia – Countries and Regions*. https://www.iea.org/countries/latvia/oil

processing, wood products and lightweight manufacturing. Estonia shows a broadly comparable industry and non-energy use structure to Lithuania and Latvia. Around 5% of oil products are used directly in industry, supplemented by 7% in non-energy use[148]. This implies that Estonia's oil dependency is less about large-scale industrial fuel demand and more about a combination of residual process use and material applications captured under non-energy use. Compared to transport, these uses tend to be more structurally embedded and therefore adjust more slowly, reinforcing the importance of gradual, sector-specific transition pathways rather than rapid substitution. Finland represents the most advanced case of industrial oil decoupling. While oil historically played a major role in process heat and industrial machinery, sustained decarbonisation policies have significantly reduced its importance. Currently, around 15% of oil products are used in industry and 16% in non-energy applications[149]. Remaining oil use is concentrated in high-temperature processes, heavy machinery and chemical manufacturing, where substitution typically requires capital-intensive technological change. Finland's experience demonstrates that targeted industrial and energy policy can progressively reduce oil dependence without eroding competitiveness, albeit over extended time horizons.

Figure. 5.13. ORLEN Lietuva oil refinery in Mažeikia. Source: LRT

From an energy security perspective, industrial oil use represents a double-edged risk: it not only ties manufacturing output to volatile global oil markets but also links industrial continuity to import infrastructure stability. Countries with strong industrial diversification (Finland) or refining-linked ecosystems (Lithuania) face different but equally significant transformation challenges.

Electricity sector: declining strategic relevance of oil. Oil has been effectively marginalised in electricity generation across the region:

1. Lithuania: 2.2% of electricity generation in 2024[150].
2. Estonia: 0.3% in 2024 (17 GWh) (excluding oil shale)[151].
3. Latvia: 0% in 2024[152].

[148] International Energy Agency (2025). *Estonia – Countries and Regions*. https://www.iea.org/countries/estonia/oil
[149] International Energy Agency (2025). *Finalnd – Countries and Regions*. https://www.iea.org/countries/finland/oil
[150] International Energy Agency (2025). *Lithuania – Countries and Regions*. https://www.iea.org/countries/lithuania/oil
[151] International Energy Agency (2025). *Estonia – Countries and Regions*. https://www.iea.org/countries/estonia/oil
[152] International Energy Agency (2025). *Latvia – Countries and Regions*. https://www.iea.org/countries/latvia/oil

4. Finland: 0.3% in 2024 (229 GWh)[153].

At first glance, Estonia looks fully aligned with the regional picture, IEA data shows only 0.3% electricity generation from oil in 2024. This is technically correct, but incomplete: Estonia's system has relied not on petroleum-based oil, but on oil shale, which is accounted for separately in standard statistical breakdowns. In practice, oil shale generation still covered a sizeable slice of demand in the recent period: from July 1, 2022 to November 30, 2024, Estonia consumed ~19.2 TWh of electricity, while the Eesti and Balti plants produced ~4.7 TWh from oil shale, i.e., ~24.5% of consumption[154].

This confirms that oil no longer plays a substantive strategic role in power system resilience. Therefore, substituting oil in electricity generation yields relatively limited security benefits compared to targeted interventions in transport. A critical shared insight emerges progress in renewable electricity generation does not automatically translate into reduced oil-related security risks. Without systemic transformation of the transport sector – electrification of freight, modal shift, rail optimisation and accelerated EV adoption – oil will remain the dominant strategic vulnerability in all four systems.

5.1.4.2. Oil Supply Structure and Import Dependency

There is a clear hierarchy of dependency models that can be spotted: ranging from near-total import reliance to partial domestic buffering. While all four countries depend on maritime crude inflows in varying degrees, the structural risks differ fundamentally: Lithuania and Finland operate refinery-centred systems, Latvia functions as a pure downstream consumer market, and Estonia maintains a hybrid model built around domestic oil shale extraction. From an energy security standpoint, this creates four distinct vulnerability profiles, shaped not by consumption alone, but by the concentration of physical infrastructure, diversification of supply sources and degree of domestic production replacement potential.

[153] International Energy Agency (2025). *Finland – Countries and Regions*. https://www.iea.org/countries/finland/oil
[154] ERR news. *Analysis: Estonia's oil shale plants kept price of electricity 17% lower in 2024.* https://news.err.ee/1609638418/analysis-estonia-s-oil-shale-plants-kept-price-of-electricity-17-lower-in-2024

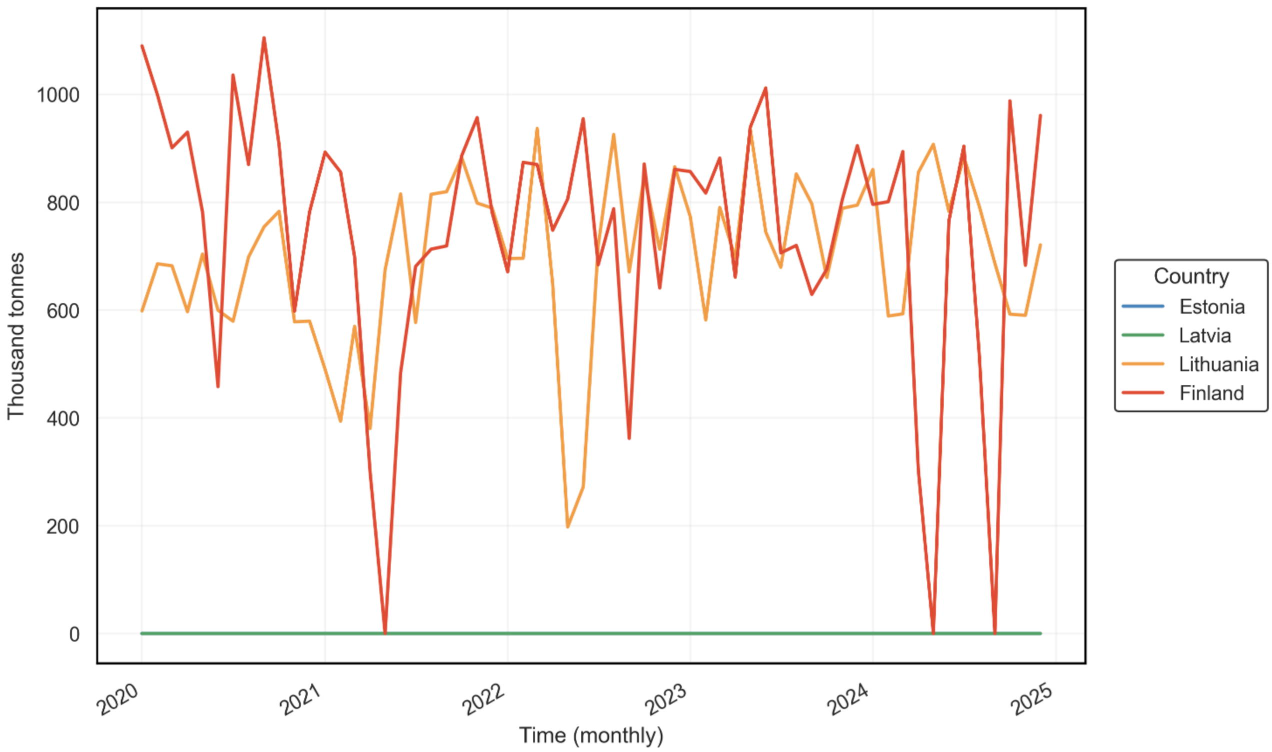

Figure 5.14. Monthly crude oil imports in the Baltic States and Finland, 2020–2024 (Eurostat data)

Lithuania remains almost entirely dependent on imported crude oil (Fig. 5.14): net crude imports accounted for 99.7% of total crude supply in 2024[155]. Following the cessation of Russian crude supply via the Druzhba pipeline in 2006[156] and the full termination of any remaining imports from Russia in 2022[157], Lithuania has transitioned to a fully maritime-based crude oil import model. The Būtingė offshore terminal now functions as the single critical entry point for crude, enabling supply from global markets and effectively replacing pipeline vulnerability with maritime exposure.
Crude oil imports[158]:

- 2022: 357,626 TJ (8.54 million tonnes)
- 2023: 389,601 TJ (9.30 million tonnes)
- 2024: 383,616 TJ (9.15 million tonnes)

When converted into proportional structure (Fig. 5.15), the origin profile of crude oil imports (2023) was as follows[159]:

- Saudi Arabia: **39%**
- Norway: **27%**
- United States: **23%**
- United Kingdom: **8%**
- Algeria: **2%**

[155] International Energy Agency (2025). *Lithuania – Countries and Regions*. https://www.iea.org/countries/lithuania/oil
[156] Jamestown (2006). *Russian oil supplies to lithuania cut off.* https://jamestown.org/russian-oil-supplies-to-lithuania-cut-off/
[157] Ministry of Energy of the Republic of Lithuania (2022) No more Russian oil, gas and electricity imports in Lithuania from Sunday
[158] International Energy Agency (2025). *Lithuania – Countries and Regions*. https://www.iea.org/countries/lithuania/oil
[159] Lithuanian Energy Agency (2024). Lietuvos energetikos sektoriaus duomenų apžvalga 2024. https://www.ena.lt/uploads/2024-metines-EDA-apz/2024_metine-EDA.pdf

- Other countries: **<1%**

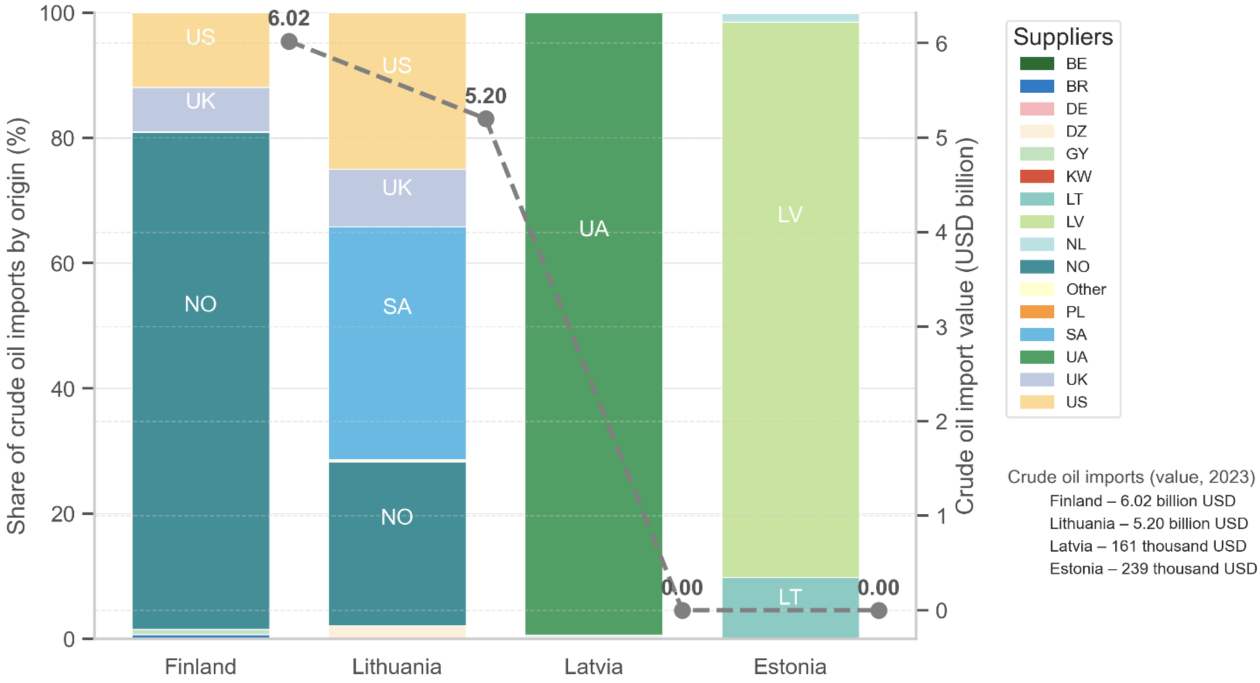

Figure 5.15. Crude oil import diversification and total spending, 2023 (OEC data)

This distribution indicates one of the most diversified crude supply portfolios in the Baltic Sea region. No single supplier exceeds a 40% dominance threshold, and the top three suppliers jointly account for around 89% of flows. From a geopolitical standpoint, this significantly reduces direct leverage by any single exporting state, particularly in comparison with Latvia and Estonia whose supply is structurally anchored in a narrow regional refinery space.

However, this diversification must be interpreted in conjunction with the physical supply architecture. Regardless of origin, nearly all crude enters Lithuania through a single maritime node, the Būtingė offshore terminal, establishing a critical infrastructural concentration point. Therefore, Lithuania combines geopolitical diversification with infrastructural fragility, a configuration that shifts the primary risk from supplier manipulation to logistical chokepoint disruption.

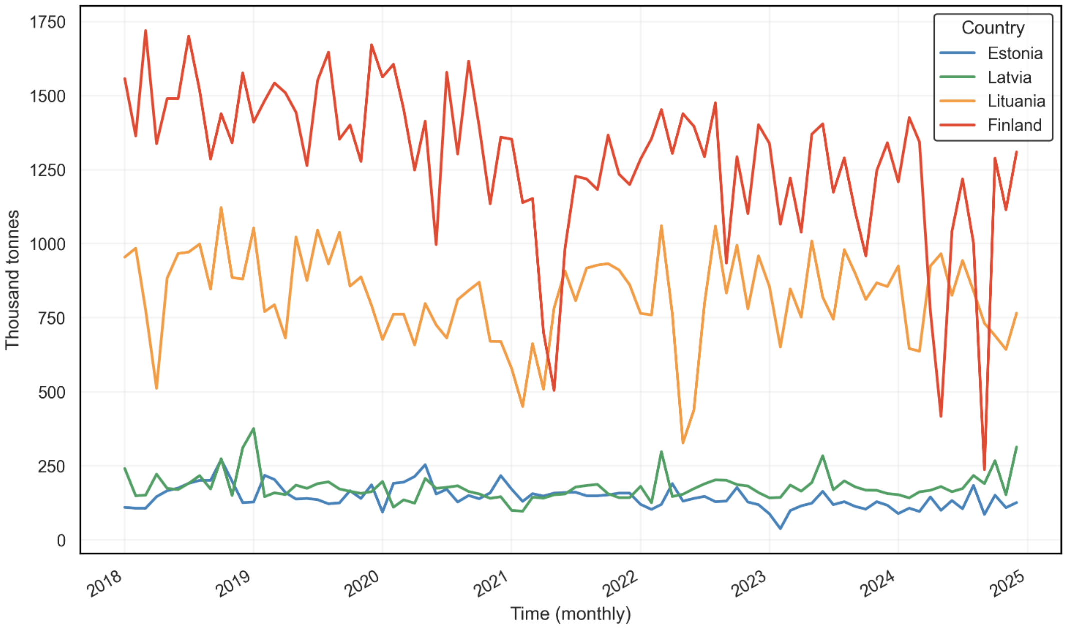

Figure 5.16. Imports of oil and petroleum products by country - monthly data (Eurostat data)

ORLEN Lietuva processed approximately 9.1 million tonnes of crude in 2024[160]. This positions Lithuania as a regional refining hub, with 64% of total oil products production exported (by volume share, not value). Net crude imports amounted to approximately 383,616 TJ in 2024, equivalent to ~9.2 million tonnes[161]. Lithuania's strength lies in supplier diversification, but its main structural risk is the physical concentration of imports through a single offshore terminal, making logistics continuity the dominant risk factor.

While Lithuania is structurally positioned as a major exporter of refined petroleum products, it simultaneously remains a notable importer of specific refined fuel categories (Fig. 5.16). This creates a dual-flow configuration in which the country both supplies the region and depends on external inflows for certain product types, qualities or balancing requirements. In 2023, Lithuania imported refined petroleum products worth approximately USD 737 million. When recalculated into proportional structure (Fig. 5.17), the origin profile appears as follows[162]:

- Finland: **26%**
- Netherlands: **12%**
- United States: **9%**
- Belgium: **8%**
- Latvia: **7%**
- Other countries: **38 %**

This structure reveals a more diversified import landscape than in Latvia or Estonia, reflecting Lithuania's need for product-specific balancing rather than volumetric dependency. Imports from Finland dominate, indicating a functional interdependency between the two largest refining systems

[160] ORLEN (2024). Akcinės bendrovės „Orlen Lietuva" finansinių ataskaitų rinkinys už 2024 m. gruodžio 31 d. pasibaigusius metus. https://www.orlenlietuva.lt/LT/Company/Reports/Documents/ORLEN%20Lietuva%202024%20stand%20alone_LT.pdf

[161] International Energy Agency (2025). *Lithuania – Countries and Regions*. https://www.iea.org/countries/lithuania/oil

[162] OEC. Refined Petroleum in Lithuania. Trade balance data. https://oec.world/en/profile/bilateral-product/refined-petroleum/reporter/ltu?redirect=true

in the region, Mažeikiai and Porvoo, particularly in relation to specialised fuel blends, seasonal adjustments and strategic stock rotations. The fastest growing sources of refined product imports between 2022 and 2023 (the United States, United Arab Emirates)[163] further indicate that Lithuania's import stream is increasingly oriented toward supply optimisation rather than structural dependency. This suggests a strategic logic focused on flexibility, market arbitrage and compliance with evolving fuel specification standards, rather than systemic reliance.

Lithuania therefore exhibits a complex but comparatively resilient oil supply architecture:

- It is almost fully dependent on imported crude oil, yet from highly diversified sources.
- It exports most of its refined production, anchoring regional fuel stability.
- Simultaneously, it imports targeted volumes of refined products to maintain system flexibility, product standardisation and supply continuity.

From a political strategic perspective, this dual role transforms Lithuania from a simple import-dependent actor into a balancing node within the Baltic fuel ecosystem. However, this balancing function increases operational sensitivity: disruption of its refining or maritime import infrastructure would not only create national shortages, but also destabilise regional fuel markets reliant on Lithuanian output.

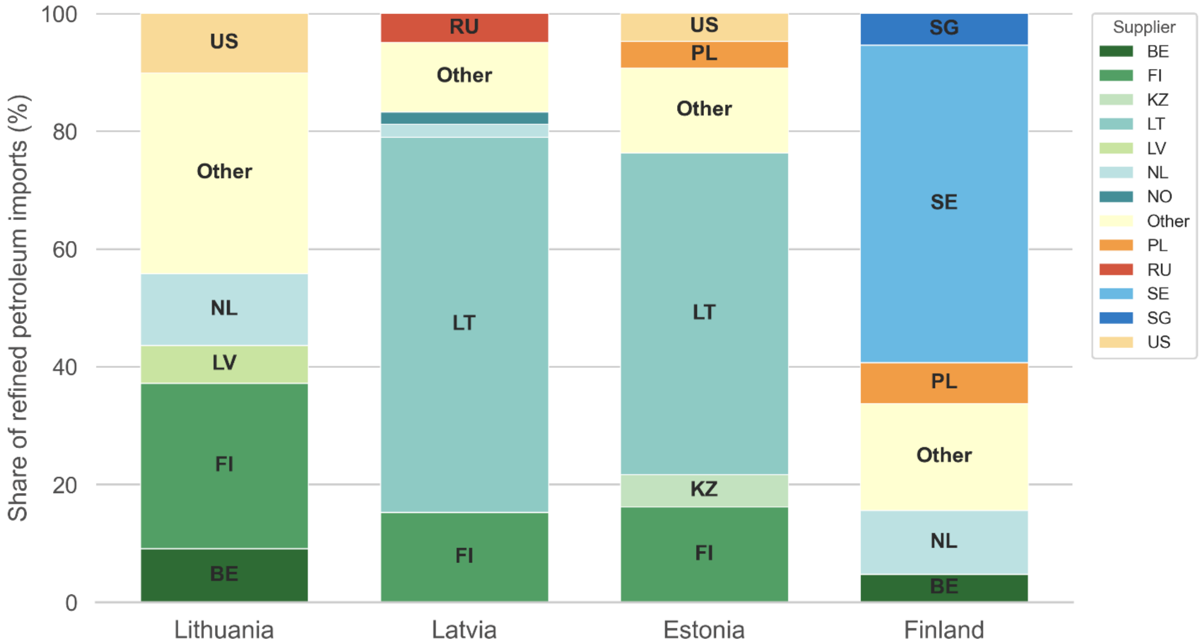

Figure 5.17. Supplier structure of refined petroleum imports (2023) (OEC data)

Strategically, Lithuania's oil system plays a dual role: it is both a consumer and a stabilising component of the regional energy security system.

Latvia's oil system operates as a purely downstream market with no domestic crude oil production and no refining capacity. Consequently, its strategic exposure is defined almost exclusively by the concentration of imported refined petroleum products (Fig. 5.16). In 2023, Latvia imported refined

[163] OEC. Refined Petroleum in Lithuania. Trade balance data. https://oec.world/en/profile/bilateral-product/refined-petroleum/reporter/ltu?redirect=true

petroleum products worth approximately USD 1.32 billion. Recalculated into percentage structure (Fig. 5.17), the origin of this supply was as follows[164]:

- Lithuania: **63%**
- Finland: **15%**
- Russia: **5%**
- Netherlands: **2%**
- Norway: **2%**
- Other countries: **13%**.

This distribution demonstrates an extreme level of regional concentration: nearly 78% of Latvia's liquid fuel supply depended on just two neighbouring refineries – Mažeikiai and Porvoo. From an energy security perspective, Latvia's vulnerability is therefore not global but regional and infrastructural. Any prolonged disruption to Lithuanian or Finnish refining capacity would translate into immediate internal fuel stress with limited alternative short-term substitution capacity. Crude oil imports into Latvia are very limited, indicating that Latvia operates mainly as a consumption endpoint within the Baltic oil system rather than as an integrated participant in the crude oil value chain. Oil products constitute 63% of total energy imports (2024), underlining structural exposure to external supply continuity. In absolute terms, oil product import volumes remained broadly stable between 2022 and 2024, at around 2.2–2.4 million tonnes per year.

Oil product imports[165]:

- 2022: 94,349 TJ (2.25 million tonnes)
- 2023: 92,832 TJ (2.22 million tonnes)
- 2024: 98,643 TJ (2.36 million tonnes)

Estonia's hybrid model combines domestic shale oil production with external refined product imports, partially masks its import dependency, but does not eliminate it. In 2023, Estonia imported refined petroleum products worth approximately USD 1,15 billion (Fig. 5.16). The recalculated structural breakdown is as follows[166]:

- Lithuania: **49%**
- Finland: **18%**
- Kazakhstan: **10%**
- Sweeden: **4%**
- United States: **4%**
- Poland: **4%**
- Other countries: **11%**

Despite its shale oil industry, approx. 70% of Estonia's refined fuel imports are sourced from Lithuania and Finland (Fig. 5.17), demonstrating a dependency architecture strikingly similar to Latvia's, with a somewhat more diversified structure. The presence of Kazakhstan and the United

[164] OEC. Refined Petroleum in Latvia. Trade balance data. https://oec.world/en/profile/bilateral-product/refined-petroleum/reporter/lva?selector1654id=percentage&selector1147id=tradeOption&selector1151id=2023
[165] International Energy Agency (2025). *Latvia – Countries and Regions*. https://www.iea.org/countries/latvia/oil
[166] OEC. Refined Petroleum in Estonia. Trade balance data. https://oec.world/en/profile/bilateral-product/refined-petroleum/reporter/est?selector1654id=percentage&selector1147id=tradeOption&selector1151id=2023

States reflects attempts at wider diversification, yet the gravitational core of the system remains the Baltic refining axis. Oil products constitute 65% of total energy imports (2024), underlining structural exposure to external supply continuity.

Oil product imports[167]:

- 2022: 70,872 TJ (1.69 million tonnes)
- 2023: 58,391 TJ (1.39 million tonnes)
- 2024: 64,090 TJ (1.53 million tonnes)

Oil shale extraction fell to 8.5 million tonnes in 2024, down from over 10 million tonnes in previous years, signalling structural contraction due to EU climate regulation and Emissions Trading System pressure[168]. While Estonia occasionally exports more liquid fuels than it imports (in crude-equivalent terms)[169], this autonomy is carbon intensive and increasingly incompatible with long-term EU frameworks.

Estonia benefits from short-term supply independence, but this advantage is limited and difficult to sustain under current policies. Its resilience to geopolitical shocks is higher than Latvia's, but its long-term stability is lower due to regulatory phase-out pressure.

Finland's refined petroleum imports in 2023 amounted to approximately USD 3.25 billion (Fig. 5.16). When recalculated into structural percentages, the import origin profile appears as follows[170]:

- Sweden: **56%**
- Netherlands: **11%**
- Poland: **6%**
- Singapore: **5%**
- Qatar: **4%**
- Belgium: **4%**
- Other countries: **18.2%**

This distribution highlights a dual reality: Finland's refined petroleum import structure is relatively diversified beyond its dominant supplier, yet remains structurally anchored in Sweden, which accounts for 56% of imports (Fig. 5.17). However, the strategic difference lies in Finland's own refining capacity and technological sophistication, which provide domestic buffering and operational flexibility absent in Latvia and Estonia. As a result, Finland's vulnerability is less related to immediate fuel availability and more to exposure along maritime supply routes and global crude and freight markets, risks that become particularly relevant under scenarios of Baltic Sea militarisation, shipping disruption, or insurance withdrawal. Finland operates one of Northern Europe's most advanced refineries (Porvoo), granting high system flexibility. However, the refinery remains fully dependent on imported crude oil (Fig. 5.14).

[167] International Energy Agency (2025). *Estonia – Countries and Regions*. https://www.iea.org/countries/estonia/oil
[168] ERR news.2025. Oil shale mining in Estonia fell to record low in 2024. https://news.err.ee/1609676333/oil-shale-mining-in-estonia-fell-to-record-low-in-2024
[169] Estonian Stockpiling Agency (2025). Estonian exports of liquid fuels exceed imports for the second year in a row.https://varudekeskus.ee/en/news/estonian-exports-liquid-fuels-exceed-imports-second-year-row
[170] OEC. Refined Petroleum in Finland. Trade balance data. https://oec.world/en/profile/bilateral-product/refined-petroleum/reporter/fin?selector1654id=percentage&selector1147id=tradeOption&selector1151id=2023

Crude oil imports[171]:

- 2022: 421,750 TJ ≈ 10.1 million tonnes
- 2023: 444,415 TJ ≈ 10.6 million tonnes
- 2024: 392,489 TJ ≈ 9.4 million tonnes

From an energy security perspective, Finland's crude oil import profile exhibits partial diversification combined with a clear structural anchor. While imports are sourced from multiple countries (Fig. 5.15), including Norway, the United Kingdom and the United States, the supply mix remains heavily concentrated, with Norway accounting for the dominant share. This configuration provides short-term reliability through politically stable and geographically proximate suppliers, reducing exposure to high-risk regions. However, the reliance on a limited set of North Sea–linked maritime routes also introduces vulnerability to shipping disruptions, port access constraints and broader Baltic Sea security risks. As a result, Finland's energy security challenge is less about supplier diversity in nominal terms and more about the resilience of maritime logistics and refining system continuity under conditions of regional instability.

When viewed systemically, the Baltic–Finnish oil space does not function as four separate national systems, but as a single interdependent fuel ecosystem anchored around two main refinery poles (Lithuania and Finland).

- Latvia and Estonia are structurally subordinated to this ecosystem as net receivers of refined products.
- Lithuania is the primary stabiliser – and simultaneously the most critical single point of systemic failure.
- Finland occupies a semi-autonomous position, combining external exposure with strong internal resilience.

This architecture creates a paradoxical security environment: while formal diversification has improved post-Russia, the operational system has become more concentrated and therefore structurally more sensitive to highly localised disruption scenarios.

The dominant risk in Baltic-Finnish oil security no longer lies in supplier nationality, but in the configuration of physical infrastructure and the hierarchy of dependence within the regional refinery network. In crisis conditions, the most vulnerable actors will be those positioned furthest downstream (Latvia, Estonia), while regional stability will increasingly depend on the uninterrupted functionality of Lithuanian and Finnish refining systems.

This structural reality suggests that future energy security policy should shift focus from simple supplier diversification toward resilience of regional logistics nodes, shared emergency planning and coordinated reserve strategies across the Baltic Sea basin.

The oil supply architecture of Lithuania, Latvia, Estonia and Finland reveals a clear hierarchy of dependency models, ranging from near-total import reliance to partial domestic buffering. While all four countries depend on maritime crude inflows in varying degrees, the structural risks differ fundamentally: Lithuania and Finland operate refinery-centred systems, Latvia functions as a pure

[171] International Energy Agency (2025). *Finland – Countries and Regions*. https://www.iea.org/countries/finland/oil

downstream consumer market, and Estonia maintains a hybrid model built around domestic oil shale extraction.

From an energy security standpoint, this creates four distinct vulnerability profiles, shaped not by consumption alone, but by the concentration of physical infrastructure, diversification of supply sources and degree of domestic production replacement potential.

Table 1. Comparative assessment of oil supply vulnerabilities and system resilience

Country	**Structural model**	**Core vulnerability**	**Relative resilience**
Lithuania	Refinery + single maritime terminal	Infrastructure concentration	Medium
Latvia	Pure import-dependent consumer	External refinery reliance	Low
Estonia	Domestic shale oil hybrid	Policy & climate constraint	Medium
Finland	Integrated refinery + diverse supply	Maritime chokepoints & price volatility	High

The oil security landscape of the Baltic–Finnish region demonstrates a transition from geopolitical to infrastructural risk. While supply source diversification has improved, the central challenge now lies in the physical concentration of entry points and limited domestic substitution capacity. Lithuania and Finland represent refining-centric systems with different resilience levels, Latvia is structurally exposed as a downstream market, and Estonia operates a temporally autonomous but strategically constrained hybrid model. Together, they illustrate that oil dependency in Northern Europe is no longer defined solely by origin, but increasingly by infrastructure, policy compatibility and crisis response capability.

The comparative analysis of Lithuania, Latvia, Estonia and Finland reveals that oil's strategic significance has shifted from power generation to transport. While Finland has made the most progress in diversifying its energy base, no country has fully resolved the transport dependency dilemma. Lithuania remains the most structurally constrained due to its dual role as a major consumer and refiner, whereas Latvia and Estonia display import-driven vulnerability patterns.

From a systemic energy security perspective, the decisive transition frontier is not electricity but mobility. Without targeted intervention in transport systems, oil will continue to function as a latent security risk and a structural anchor of fossil dependency throughout the coming decades.

When assessed using the Herfindahl–Hirschman Index (HHI) for refined petroleum imports, all four countries exhibit structurally concentrated supply patterns. Latvia and Estonia record particularly high concentration scores (HHI ≈ 4,500 and 3,500 respectively), reflecting their heavy reliance on a narrow set of regional suppliers – primarily Lithuanian and Finnish refineries. Finland also falls into the highly concentrated category (HHI ≈ 3,450), with over half of its refined product imports originating from Sweden. Lithuania, by contrast, shows a moderately concentrated profile (HHI ≈ 2,330), indicating a more diversified import structure for refined products and suggesting that its import flows primarily serve as a flexibility and balancing instrument rather than a core dependency channel.

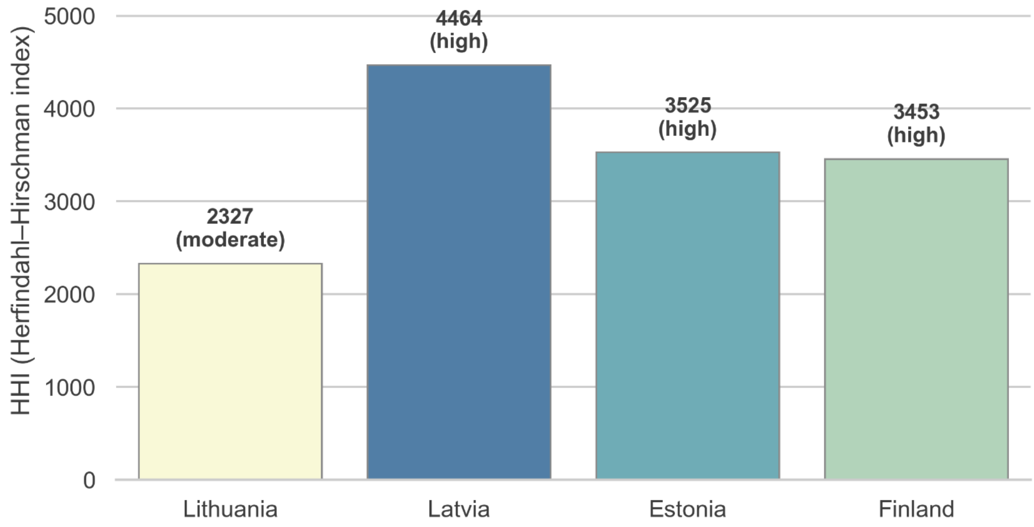

Figure 5.18. Supplier concentration (HHI) of refined petroleum imports (2023)

From a security perspective, these HHI scores confirm that Latvia and Estonia are structurally positioned at the most vulnerable end of the regional refined products chain, with limited room for rapid supplier substitution. Finland combines high concentration with strong internal refining capacity, which partially mitigates the risk associated with import-side dependence. Lithuania's lower HHI score reflects a more balanced import structure that complements, rather than replaces, its own refining output, reinforcing its role as a regional balancing node rather than a structurally dependent end-consumer.

5.1.4.3. Security of Supply and Risk Scenarios

The security of oil supply in Lithuania, Latvia, Estonia and Finland has become one of the most sensitive dimensions of the region's overall energy security architecture. While the four countries differ in their structural roles within the oil value chain, they share a common post-2022 reality: the complete severance of oil imports from Russia[172],[173],[174] and a transition toward a more diversified, globally exposed, and market-dependent supply system. This shift has enhanced geopolitical autonomy but simultaneously increased exposure to global price volatility, maritime logistics risks and infrastructure concentration effects.

Across the region, oil no longer functions as a domestically anchored commodity but rather as a globally traded strategic resource whose availability depends on uninterrupted shipping routes, port operations, refinery integrity and coordinated emergency stock management. As a result, oil supply security must be assessed not only through the lens of supplier diversification, but also through structural resilience, system redundancy and crisis preparedness.

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[172] Ministry of Energy of the Republic of Lithuania (2022). No more Russian oil, gas and electricity imports in Lithuania from Sunday

[173] Euronews (2025). Ending Russian energy ties is a political choice, says Latvia's President Rinkēvičs.https://www.euronews.com/my-europe/2025/09/24/ending-russian-energy-ties-is-a-political-choice-says-lavtian-president-rinkevics

[174] Estonian Tax and Customs Board (2022). Additional prohibitions on fuel from 5.12.2022.https://www.emta.ee/en/news/additional-prohibitions-fuel-5122022

In the European Union, "strategic petroleum reserves" constitute a mandatory regulatory mechanism designed to safeguard member states against supply disruptions of geopolitical, market or operational origin. Under Council Directive 2009/119/EC (14 September 2009) [175], all EU countries are required to maintain minimum stocks of crude oil and/or petroleum products, ensuring that reserves correspond to at least 90 days of net imports or 61 days of average domestic consumption, whichever is higher. These stocks may be organised either by the state or by designated Central Stockholding Entities (CSEs) and can be stored in tank farms, terminals or other certified facilities. The directive allows flexibility in the composition of reserves: member states may hold crude oil, refined products, or a strategic combination tailored to national system needs. This framework forms a core pillar of the EU's collective security-of-supply architecture, providing a uniform and enforceable baseline for crisis preparedness across the Union.

Lithuania occupies a structurally central position within the regional oil system due to the presence of the Mažeikiai refinery operated by ORLEN Lietuva[176] and the Būtingė offshore terminal[177], which together form the core of national and regional crude oil processing and import infrastructure. Since the permanent cessation of Russian oil deliveries via the Druzhba pipeline, Lithuania has fully reoriented toward seaborne crude imports sourced from Saudi Arabia, Norway, the United States and other global suppliers[178]. This diversification substantially strengthens geopolitical resilience; however, it also consolidates systemic risk around a single refining site. The Mažeikiai complex therefore represents a critical single point of failure: any prolonged technical disruption, supply-chain interruption or targeted attack would have immediate cross-border consequences for fuel supply in Lithuania and neighbouring markets.

Lithuania's strategic oil reserves, maintained in compliance with EU requirements[179], provide an important buffer against short-term supply shocks and allow the government to respond to emergency situations through controlled stock release mechanisms. Nevertheless, the structural concentration of refining capacity and the heavy reliance on maritime logistics underscore a persistent vulnerability to port disruption, shipping constraints in the Baltic Sea, or extreme weather events affecting offshore terminal operations. In parallel, the gradual tightening of EU climate policy presents a longer-term structural risk for the economic viability of large-scale refining assets, creating a dual challenge of maintaining short-term supply security while navigating an inevitable transition away from oil-intensive systems.

Latvia represents the most structurally exposed profile in the region. The country has no domestic crude production or refining capacity and is fully reliant on imported petroleum products[180]. While supplier diversification mitigates direct geopolitical risk, Latvia's oil security is highly sensitive to external logistics performance and the availability of neighbouring infrastructure. In the absence of domestic refining, Latvia depends on sustained access to imported fuels via ports and overland routes, which creates heightened vulnerability during large-scale regional disruptions or prolonged logistical

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[175] Council of the European Union. *Directive 2009/119/EC of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products*. https://eur-lex.europa.eu/eli/dir/2009/119/oj/eng

[176] ORLEN. Refinery.https://www.orlenlietuva.lt/EN/Company/OL/Pages/Refinery.aspx

[177] ORLEN. Terminal and Pipelines. https://www.orlenlietuva.lt/EN/Company/OL/Pages/Terminal-and-Pipelines.aspx

[178] Lithuanian Energy Agency (2024). Lietuvos energetikos sektoriaus duomenų apžvalga 2024. https://www.ena.lt/uploads/2024-metines-EDA-apz/2024_metine-EDA.pdf

[179] Lithuanian Energy Agency (2024). Lietuvos energetikos sektoriaus duomenų apžvalga 2024. https://www.ena.lt/uploads/2024-metines-EDA-apz/2024_metine-EDA.pdf

[180] International Energy Agency (2024). *Latvia 2024.Energy Policy Review*. https://www.iea.org/reports/latvia-2024

bottlenecks. Although Latvia maintains strategic oil reserves[181] in line with EU requirements, the absence of vertically integrated infrastructure limits its ability to independently stabilise supply chains during systemic crises.

Estonia presents a structurally distinct configuration due to its domestic shale oil industry[182]. The production of shale-derived oil reduces crude import dependency and provides a degree of internal security of supply, particularly for certain segments of the domestic fuel market. However, this apparent strategic advantage is counterbalanced by significant exposure to regulatory, environmental and transition-related risks. The shale oil sector remains one of the most carbon-intensive energy systems in the European Union[183], rendering it progressively incompatible with long-term climate policy trajectories. As a result, Estonia faces a complex trade-off: domestic oil production enhances short-term resilience but deepens long-term structural vulnerability in the context of accelerating decarbonisation imperatives and tightening emissions constraints.

Finland, while less directly dependent on the Baltic States for oil supply, occupies a crucial stabilising role within the regional framework. Its advanced strategic petroleum stockpiling system[184] and diversified import portfolio contribute to a comparatively robust security posture. Nevertheless, Finland's reliance on maritime supply routes through the Baltic Sea exposes it to similar shipping risks, extreme weather disruptions and potential chokepoint vulnerabilities as its southern neighbours. The geographic scale of Finland, combined with a highly energy-intensive transport and industrial sector, further amplifies the strategic necessity of maintaining uninterrupted oil supply chains during crises.

At the regional level, several overarching risk categories define the contemporary oil security landscape. First, infrastructure concentration risk remains pronounced, particularly in Lithuania, where refining and import infrastructure are geographically concentrated. Second, logistics vulnerability persists across all countries due to heavy reliance on maritime transport in a semi-enclosed and geopolitically sensitive sea basin. Third, exposure to volatile global oil markets introduces fiscal and macroeconomic instability risks, especially for smaller economies with limited price-buffering capacity. Finally, climate transition pressure introduces structural uncertainty: while reducing long-term oil dependency is strategically desirable, rapid policy-induced contraction may destabilise existing systems before alternative infrastructures are fully operational.

In this context, the oil sector's security profile is no longer defined solely by physical supply availability but by the resilience of systemic architecture, strategic governance mechanisms and the capacity to absorb both geopolitical and structural transition shocks. The four-country cluster thus faces an increasingly complex balancing act: safeguarding short-term fuel availability for critical sectors while progressively reducing structural dependence on oil to align with long-term climate and security objectives.

Future risk scenarios for the region include: a prolonged disruption of Baltic Sea shipping lanes; a major technical failure at the Mažeikiai refinery; global oil market shocks triggered by instability in

[181] The Baltic Times (2024). *First ship carrying Latvia's strategic oil reserves arrives at Riga Port.*https://www.baltictimes.com/first_ship_carrying_latvia_s_strategic_oil_reserves_arrives_at_riga_port/
[182] International Energy Agency (2023). *Estonia 2023: Energy Policy Review.* https://iea.blob.core.windows.net/assets/8b462840-c9a6-4f71-81eb-d5acd1213e68/Estonia2023.pdf
[183] International Energy Agency (2023). *Estonia 2023: Energy Policy Review.* https://iea.blob.core.windows.net/assets/8b462840-c9a6-4f71-81eb-d5acd1213e68/Estonia2023.pdf
[184] International Energy Agency (2020). *Finland's legislation on oil security*. Finland's legislation on oil security – Analysis - IEA

major export regions; and accelerated EU climate policy interventions rendering parts of existing oil infrastructure economically non-viable. The adequacy of strategic reserves, diversification of supply routes, and cross-border coordination mechanisms will therefore remain decisive determinants of resilience in this evolving security environment.

5.1.5. Hydrogen sector

Hydrogen availability for the region remains contingent rather than assured. Existing physical volumes are concentrated in Finnish and Lithuanian industry, while Estonia and Latvia still remain mostly in the pilot-scale. Future availability is projected to grow rapidly on paper, but it is bounded by three hard constraints: surplus of electricity (renewable + nuclear for clean hydrogen), the build-out of electroliers, and the timely delivery of transport and storage infrastructure.

5.1.5.1. Hydrogen Production and Use

Across Finland, Lithuania, Estonia and Latvia, the historical experience with hydrogen production and use differs markedly, both in scale and in functional role within national energy systems. Existing hydrogen production ranges from long-established, industrial-scale applications in Finland and Lithuania to very limited or pilot-level use in Estonia and Latvia. This diversity reflects differences in industrial structure, legacy infrastructure and market development, but also indicates varying starting points for future hydrogen deployment. While some countries possess operational experience, technological capability and partial infrastructure that can support a transition toward low-emission hydrogen, others have the opportunity to build new hydrogen markets by drawing on regional practices and emerging cross-border value chains. Understanding these contrasting baselines is essential for assessing realistic pathways for hydrogen development and its potential contribution to energy security and system resilience in the region.

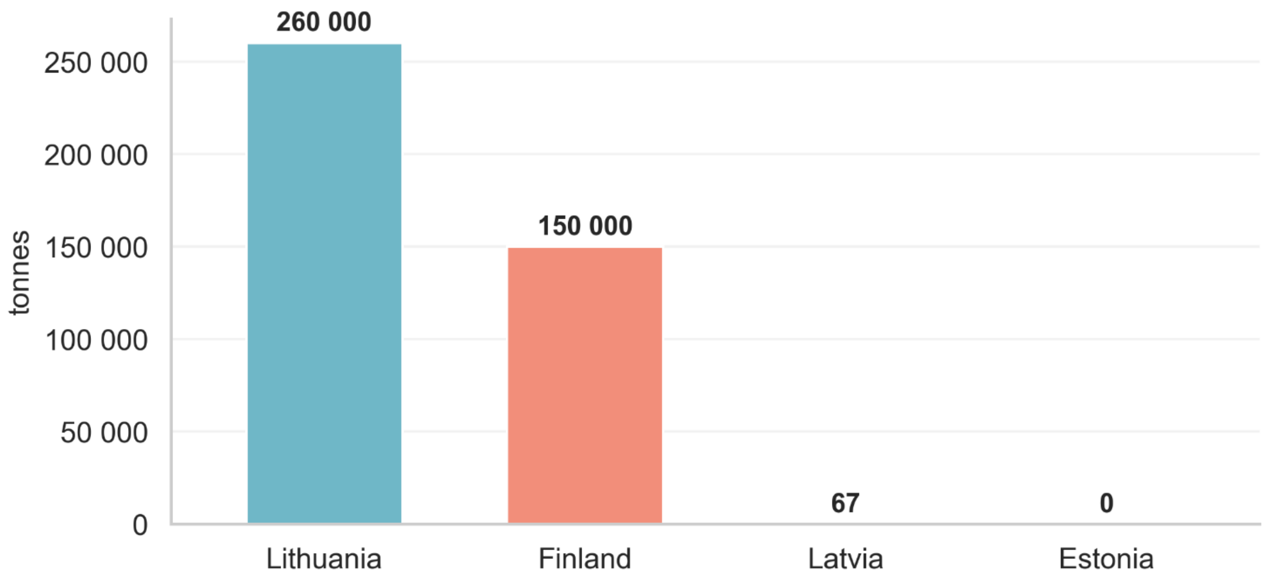

Figure 5.19. Hydrogen consumption by country in the early 2020s.

Finland has an established history of industrial hydrogen use. Current domestic hydrogen production for industrial applications is estimated at approximately 5 TWh per year (2020), with the majority produced via steam methane reforming. Hydrogen is primarily consumed in oil refining and biofuel production, as well as in the chemical industry, mining, and ore processing. Finland has consumed around 150 000 tonnes of hydrogen (Fig. 5.19). In addition to this dedicated production, around 800 GWh per year of by-product hydrogen is generated within industrial processes and subsequently utilised for industrial boilers, district heating, and as process gas, contributing to on-site energy and material efficiency[185].

In the early 2020s, Lithuania's hydrogen production was predominantly fossil-based (Fig. 5.19), primarily supporting ammonia manufacturing and oil refining, with estimated annual volumes of approximately 260,000–320,000 tonnes[186], placing the country among the top ten hydrogen consumers in Europe at that time. This level of hydrogen use reflects the existence of mature industrial know-how, established technologies, and partial infrastructure, as well as a workforce experienced in large-scale hydrogen handling and integration into industrial value chains. Following 2022, Lithuania's hydrogen production and consumption declined significantly, by roughly half, driven mainly by natural gas price shocks, market volatility, and strategic shifts away from conventional natural gas–based reforming pathways. While this contraction reduced short-term hydrogen volumes, it also accelerated structural change, strengthening incentives to diversify feedstocks, improve efficiency, and explore clean hydrogen and alternative reforming routes. As a result, Lithuania retains a strong industrial and infrastructural foundation that can support a transition toward low-emission hydrogen production, positioning the country favourably for future scale-up once market and policy conditions stabilize.

Estonia and Latvia have historically had only limited hydrogen production and use, with no large-scale captive industrial hydrogen systems comparable to those found in countries with ammonia or refinery-based hydrogen demand (Fig. 5.19). In Estonia, there are currently no companies producing or consuming hydrogen at a significant scale. The nitrogen fertiliser producer *AS Nitrofert*, which once represented a potential hydrogen-intensive industrial user, has experienced a long-term decline since the dissolution of the Soviet Union and has suspended operations in recent years due to high natural gas prices, with the possibility of permanent closure. In Latvia, hydrogen use has so far remained largely confined to demonstration-scale transport applications. The most prominent example is the Riga hydrogen trolleybus project, under which ten trolleybuses are equipped with hydrogen-powered range extenders. To support this initiative, the public transport operator *Rigas satiksme* has deployed a hydrogen refuelling station (HRS), the first of its kind in the Baltic States. The station has a production capacity of approximately 300 kg of hydrogen per day, produced via steam methane reforming, and is strategically located in Riga, a key node on the core and comprehensive TEN-T corridors linking road, airport, and seaport infrastructure. While current hydrogen consumption in Latvia remains very small in absolute terms, estimated at around 67 tonnes per year, mainly in transport and other minor applications, the project has established initial technical capabilities and regional infrastructure that could support future cross-border hydrogen mobility developments involving Latvia, Estonia, and Lithuania[187].

Across the four countries examined, hydrogen use and prospective deployment remain highly uneven and closely linked to existing industrial structures rather than to a broadly diversified energy function. In Finland and Lithuania, hydrogen has historically played a role in specific industrial value chains, refining, ammonia, and biofuel production, where technological capability, operational experience

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[185] BergMann (2023). *The Finnish Hydrogen Sector.* https://www.bergmann.fi/e/article/the_finnish_hydrogen_sector

[186] Lithuanian Innovation Agency (2022). Vandenilio iš atsinaujinančiųjų išteklių energijos gamybos ir naudojimo pramonėje Lietuvoje galimybių studija https://inovacijuagentura.lt/site/binaries/content/assets/analitika/apzvalgos/2023/vandenilio-galimybiu-studija.pdf

[187] Netherlands Enterprise Agency (2024). *Hydrogen in the Baltic States.* https://www.rvo.nl/files/file/2023-07/2023-Opportunities-for-Dutch-companies-in-the-Baltic-Hydrogen-economy.pdf

and partial infrastructure already exist. In contrast, Estonia and Latvia have had only marginal hydrogen use, largely limited to legacy industrial decline in Estonia and small-scale transport demonstrations in Latvia. As a result, the region currently lacks a balanced hydrogen ecosystem in which production, demand and infrastructure evolve in a coordinated manner.

From an energy security perspective, this implies that hydrogen's present contribution is structurally narrow rather than system wide. Where hydrogen is used, it tends to be concentrated in sectors with limited short-term fuel-switching flexibility, while in most other parts of the energy system it remains absent or experimental. At the same time, current hydrogen production, whether fossil based or emerging low emission hydrogen, remains strongly dependent on external inputs, notably natural gas prices, electricity market conditions, imported technologies, and supply chains. This limits hydrogen's ability to function as an autonomous stabilising or system balancing element during periods of system stress.

However, the region holds exceptionally large renewable energy potential, supported by sufficient land and sea availability for new wind, solar, and hybrid energy projects. This creates the structural precondition for scaling domestic renewable hydrogen production beyond niche applications. Unlocking this potential, though, requires a robust enabling framework. Critical elements include a clear and harmonised EU level definition of renewable (green) hydrogen, an aligned national legal basis, predictable state support mechanisms, and long-term regulatory certainty that renewable hydrogen targets for transport and industry will remain stable over time. Equally important are transparent procurement models, long term offtake contracts, and investment certainty for producers and consumers.

Policy instruments could materially accelerate adoption. Expanded use of carbon pricing measures, including higher carbon taxes or a broader application of Carbon Contracts for Difference (CCfDs), would improve the competitiveness of green hydrogen relative to fossil alternatives. Likewise, wider implementation of "Contracts for Carbon Difference" type mechanisms could reduce market risk and mobilise industrial demand at scale. Finally, export viability depends on cross border hydrogen infrastructure, port and terminal capacity, and pipeline or shipping connections that allow renewable hydrogen and its derivatives to reach foreign markets reliably, enabling integration into emerging European and global hydrogen trade corridors.

5.1.6. Indicators: Availability

System Resilience and Supply Security

The Availability dimension measures the physical presence of energy and the system's resilience against supply shocks. The results reveal a distinct divergence between the Baltic States' strategies and Finland's established stability.

Table 2. Availability indicators and LEA EnSec scores

Indicator	Finland (FI)	Estonia (EE)	Latvia (LV)	Lithuania (LT)
Energy Import Dependency[188]	**4** (30%)	**5** (4%)	**4** (34%)	**2** (71%)

[188] World-Bank.org (n.d.). *Energy imports, net (% of energy use) - Latvia, Lithuania, Finland, Estonia, European Union*. https://data.worldbank.org/indicator/EG.IMP.CONS.ZS?locations=LV-LT-FI-EE-EU

Low Carbon Generation (nuclear + RES)[189]	**5** (92.3%)	**3** (52.8%)	**4** (72.9%)	**4** (67.4%)
Supply Diversification (HHI: gas, oil, electricity)[190]	**2** (2721)	**1** (8481)	**1** (7387)	**3** (2084)
Average Score	**3.7**	**3.0**	**3.0**	**3.0**

Finland achieves the highest average score (3.7) in this dimension, driven by a robust domestic generation mix. With 92.3% of its electricity generated from low-carbon sources (primarily nuclear and renewables), Finland demonstrates high supply-side security.

In contrast, the Baltic States face structural trade-offs. Estonia scores a perfect 5 for import dependency due to its domestic oil shale industry, which renders it nearly self-sufficient (only 4% dependency). However, this comes at the cost of lower supply diversification. Both Estonia and Latvia score a critical 1 on the Herfindahl-Hirschman Index (HHI), indicating an extreme post-2022 concentration of suppliers, as they rely overwhelmingly on a single neighbouring country for gas and electricity imports, Finland and Lithuania, respectively.

Lithuania presents the inverse profile: it has the highest import dependency (71%, Score 2), making it the most exposed to global market volatility. However, it manages this risk through superior diversification (Score 3), leveraging the Klaipėda LNG terminal and oil refinery to access global markets, resulting in the healthiest HHI score of the Baltic group.

5.2. Accessibility

While Availability focuses on the physical presence of energy resources, Accessibility aims at the nation's capacity to transport them. In the APERC framework, accessibility is traditionally defined by the physical and geopolitical barriers that stand between the consumer and the energy source. However, for Finland, Estonia, Latvia and Lithuania, the period of 2022–2024 has redefined this concept. Accessibility is an exclusively technical issue no more as it has been realigned with the concepts of sovereignty and national security.

Although politically and economically these four nations were integrated into the Western Europe, physically, however, their energy systems remained physically tied to infrastructure inherited from the former Soviet and Russian energy system. The natural gas pipelines have exclusively flowed from East to West, creating a physical "lock-in" mechanism which dictated market terms. Even though Latvia and Estonia were completely dependent on Russian gas for years, the launch of Lithuanian FSRU "Independence" in 2015[191] has provided some alternative to the regional gas supply. Inkoo LNG in 2023 has allowed to further decrease dependency. Even more critically, the electrical grids of the Baltic States operated within the IPS/UPS system (the BRELL ring), meaning that the frequency stability of Vilnius, Riga, and Tallinn was technically managed from Moscow. While market coupling via NordPool created commercial bridges to the Nordic countries, the underlying physics remained dependent on the Russian Federation.

[189] Eurostat (2025). *Energy Database.* https://ec.europa.eu/eurostat/web/energy/database
[190] Statistic departments: https://stat.gov.lv/en; https://osp.stat.gov.lt/en; https://www.stat.ee/en; https://stat.fi/en
[191] DELFI EN (2015). *Baltic leaders welcome Lithuania's "Independence" as energy security guarantee for all region,* LRT.https://www.lrt.lt/en/news-in-english/19/74087/baltic-leaders-welcome-lithuania-s-independence-as-energy-security-guarantee-for-all-region?srsltid=AfmBOoq19LdO1zptKe6NIu58hQ1iAAi2QjDm6SCdzKOrgJGxT9Z_EeLV

The Russian invasion of Ukraine has shattered the assumption that commercial accessibility is driven more by economics than geopolitics. As the danger of dependency on Russia has became clearer than ever, the region was forced to find alternative routes of energy supply. Accessibility was securitizied. As noted in the study's methodology, energy infrastructure has moved from the realm of normal politics to security politics. The objective is no longer just to connect, but to control.

Accessibility in this region is no longer defined by the capacity of existing pipelines, but by the ability to bypass them. The collapse of the "Eastern vector" necessitated the immediate activation of a "Western/Maritime vector." The region shifted from a model of linear dependency (pipelines from the East) to a model of distributed redundancy (LNG terminals in Inkoo and Klaipėda, and bidirectional interconnectors like the Balticconnector and GIPL).

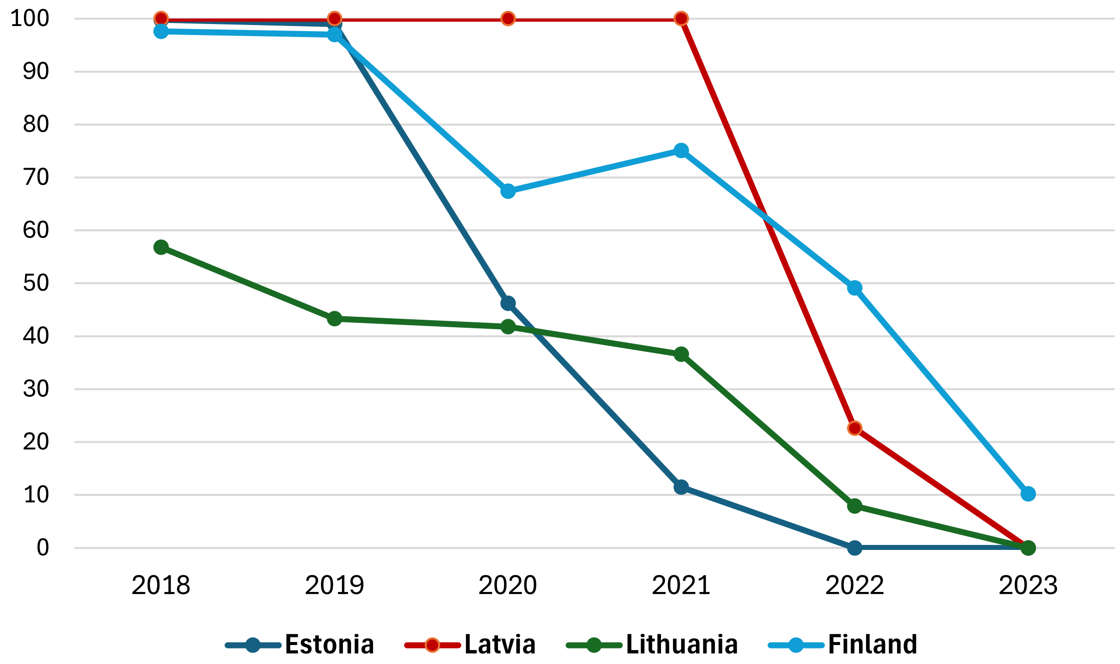

Figure 5.20. Share of Russian gas in total gas imports (2018–2023)

Post-2022, accessibility is governed by the principles of securitization and redundancy. The analysis in this chapter explores how the region is moving away from a centralized hub-and-spoke model toward a mesh-like network of interconnectors. This shift is driven by two distinct imperatives:

1. The geopolitical break that led to physical disconnection from Russian energy grids is not just about stopping trade; it is about eliminating the technical leverage an adversary holds over the system. This is most evident in the electricity sector, where the "synchronization" project aims to connect the Baltic grids to the Continental European Network via Poland, permanently detaching them from the Russian-controlled IPS/UPS system.
2. Resilience to hybrid threats encapsulated by the sabotage of the Nord Stream pipelines and the damage to the Balticconnector in 2023 demonstrated that maritime accessibility is fragile. "Access" is not guaranteed simply because a pipe exists; the physical protection of subsea assets has become a prerequisite for energy security.

Consequently, this chapter evaluates Accessibility not just as a measure of how well these nations are connected to the EU, but how resilient those connections are to disruption.

5.2.1. Electricity sector

In the Baltic–Nordic electricity sector, Accessibility has been transformed from a static condition of grid connection into a dynamic issue of grid synchronization, congestion management, and resilience. The period 2022–2025 marked the most significant shift in the region's infrastructural history: the physical decoupling from the Russian-controlled IPS/UPS system (BRELL) and the successful synchronization with the Continental European Network (CEN) on February 9, 2025. Accessibility is no longer defined by the legacy ties to the East, but by the robustness of the "Western" and "Northern" corridors that now anchor the Baltic States to the European market.

5.2.1.1. Cross-Border Electricity

Cross-border electricity flows are a defining feature of the Baltic–Nordic power system, shaping both operational security and price dynamics. Following the suspension of Russian electricity trading in the Baltics in May 2022, commercial balancing increasingly shifted to Nordic and Continental European interconnections, while synchronous operation with the Russian and Belarusian system continued until the Baltic States' full disconnection and synchronisation with Continental Europe in February 2025. These developments highlight uneven dependencies: Nordic market conditions often influence Baltic prices when interconnector capacity is available, whereas the Baltic States remain more exposed to volatility, with their import–export balance varying with weather-driven renewable output, domestic generation availability, and seasonal tightness. Looking ahead, security of supply is expected to strengthen as the Baltic States consolidate operation within the Continental Europe Synchronous Area and advance priority interconnection projects alongside intra-Baltic grid reinforcements. However, until new capacity is commissioned, the region remains sensitive to the availability and reliability of a limited number of critical cross-border corridors (Fig. 5.21).

Lithuania remains the most structurally import-dependent system in the region, though the scale of dependency has decreased markedly as domestic renewable generation expanded. In 2024, Lithuania generated 7.66 TWh, while total electricity demand was 13.2 TWh, implying a net import dependence of roughly 5.5 TWh[192]. This represents about a 22% reduction in net import dependence compared with 2023, when net imports were approximately 6.9 TWh[193]. Lithuania's electricity import structure shifted notably between 2022 and 2025. In 2022, total imports reached 11.22 TWh, with the largest share coming from Sweden (5.03 TWh via NordBalt), followed by Latvia (4.08 TWh) and smaller volumes from Poland (1.10 TWh). In 2025, however, imports from Sweden declined significantly, falling to 2.91 TWh, about 42% lower than 2022 levels, primarily due to increased domestic renewable generation[194].

Latvia's import-export position is more cyclical, shaped primarily by hydrological variability. In 2024, Latvia generated 5.91 TWh of electricity, covering 84.6% of domestic electricity consumption (6.98 TWh) and resulting in a net import deficit of 1.07 TWh[195]. In years with lower domestic generation, Latvia's net import deficit can exceed 2 TWh. Cross-border balances are most often

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[192] Vert (2025). *Annual Report on Electricity and Natural Gas Markets of the Republic of Lithuania to the European Commission*. https://vert.lt/en/Documents/VERT%20Metine%20ataskaita%20EK%202024%20EN%20sk.pdf
[193] Vert (2025). *Annual report on the electricity and natural gas markets of the Republic of Lithuania to the European Commission*. https://www.ceer.eu/wp-content/uploads/2024/10/C24_Lithuania-EN.pdf
[194] Litgrid (n.d.). *National electricity demand and generation*. https://www.litgrid.eu/index.php/power-system/power-system-information/national-electricity-demand-and-generation/3523
[195] AST (2024). *Latvian electricity market overview.* https://www.ast.lv/en/electricity-market-review?month=13&year=2024

shaped by north–south flows (Estonia → Latvia) and by Latvia's exchanges with Lithuania, while reverse flows from Lithuania to Latvia occur but are typically smaller on an annual basis. Export flows vary substantially. In 2023, electricity exports from the Latvian grid totalled 3.27 TWh. Latvia's hydro-dominated system makes it an important source of flexibility in wet/high-inflow years, while in lower-inflow years the regional system relies more on imports to cover the deficit (e.g., in 2024 as hydropower output fell).

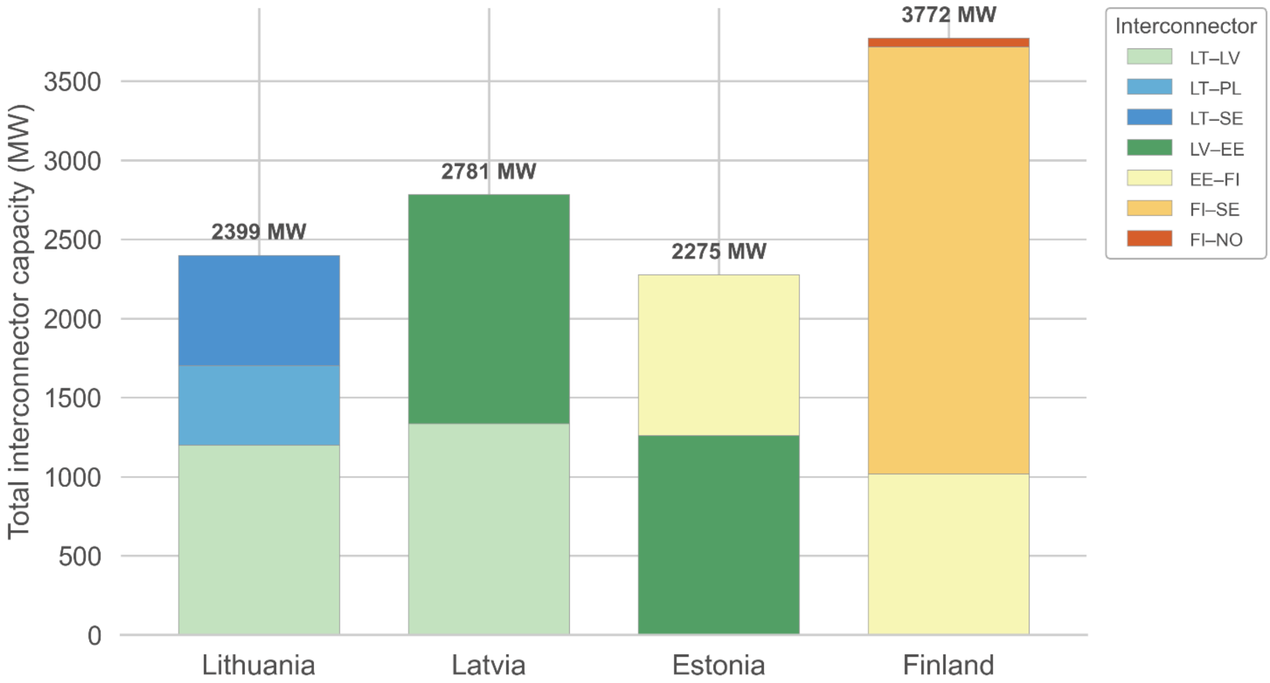

Figure 5.21. Interconnector capacity by country (based on NTC, 2024; ENTSO-E)[196]

Estonia's cross-border position has reversed sharply over the last decade. Once a consistent net exporter supported by oil-shale generation, Estonia has become a net importer as oil-shale output and dispatchable fossil capacity declined in 2019. In 2024, domestic electricity production was about 3.8 TWh while net dispatchable capacity was around 1.2 GW[197]. In 2024, Estonia imported more electricity than it exported, with imports exceeding exports by a significant margin and contributing to its status as the Baltic country with the highest share of imported electricity relative to domestic consumption. Estonia's net imports accounted for around 37 % of consumption that year, reflecting the country's continued dependence on cross-border electricity to balance lower oil-shale generation and fluctuating renewable output[198]. Estonia's cross-border balance is often shaped by exchanges with Finland via EstLink 1 and EstLink 2, for example, in 2024 EstLink 2 transmitted about 1.7 TWh from Finland to Estonia, while flows in the opposite direction were minimal. Import reliance tends to increase during high-demand periods, but the seasonal pattern depends on market prices,

[196] ENTSO-E (2024). *Maximum NTC.* https://www.nordpoolgroup.com/globalassets/download-center/tso/max-ntc.pdf
[197] Eesti energia (2024). *Unaudited Annual Report 2024*. https://public-docs.enefit.ee/ettevottest/investorile/2024/2024-aastaaruanne-ENG.pdf
[198] Estonian Competition Authority (2024). *2024 electricity and gas market summary.* https://aastaraamat.konkurentsiamet.ee/en/aastaraamat-2024-trends-and-overviews/2024-electricity-and-gas-market-summary

interconnector availability and renewable output. For example, in December 2024, wind energy covered 28.4% of the electricity demand due to good wind conditions (7.5% in 2023), while shale covered 21.2% (33% in 2023)[199]. The EstLink 2 outage from late January to early September 2024 reduced the available Finland–Estonia transfer capacity and, according to market participants' estimates, contributed to higher electricity prices in Estonia during the repair period[200]. This episode highlights the Baltic region's sensitivity to outages in a limited number of cross-border HVDC corridors. While Estonia can export within the Baltics during high-wind hours, annual balances indicate substantial reliance on imports, making the system particularly sensitive to interconnector availability when supply is tight and price differentials are large.

Finland, in contrast, has shifted from being a net importer to near self-sufficiency: net imports declined from around 20 TWh in 2019[201] to about 3.2 TWh in 2024[202], following the commissioning of the 1.6 GW Olkiluoto-3 reactor and the rapid expansion of onshore wind generation. In 2024, electricity net imports were about 3.2 TWh, equivalent to roughly 4% of Finland's total electricity consumption. Import sources also changed structurally: electricity imports from Russia, covering roughly around 10% of Finland's consumption in recent years, were suspended in mid-May 2022 when cross-border trading was halted, and have not resumed since[203]. Most remaining imports come from Sweden (via connections to SE1 and SE3; 5.3 TWh in 2024), while imports from Norway are marginal (0.2 TWh) and imports from Estonia via EstLink are negligible on an annual basis, occurring only in limited hours under specific market conditions[204]. Norway remains an important Nordic flexibility provider through its hydro reservoirs, which can influence regional price dynamics, although Finland's direct electricity imports from Norway are small compared with imports from Sweden.

The 2025 synchronisation of the Baltic States with the Continental Europe Synchronous Area reshaped cross-border operation. After 9 February 2025, LitPol Link has been operated in AC mode and the capacity made available to the market has been assessed with frequency-stability needs in mind, implying constrained and variable commercial transfer capacities rather than a uniform utilisation increase[205]. Poland provides the Baltics with an additional westward interconnection via LitPol Link, which can support imports during regional supply tightness and enable exports when surplus is available. However, since synchronisation in February 2025, the commercial capacity offered to the market on LitPol Link has been constrained (reported around ~150–170 MW on average), limiting the scale of this flexibility compared with Nordic interconnections. However, the current 150 MW commercial limit on LitPol Link is a transitional constraint linked to synchronisation

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[199] Enefit (2025). *Overview of the energy market: Estonia's wind energy production set a record for the third consecutive month and brought consumers cheaper electricity prices*. https://www.enefit.ee/en/-/uudised/energiaturu-ulevaade-eesti-tuuleenergia-toodang-pustitas-kolmandat-kuud-jarjest-rekordi-ning-toi-tarbijale-soodsama-elektrihinna

[200] Tooming M (2024). *Estlink 2 repairs increasingly impacting electricity prices each month. ERR News* https://news.err.ee/1609423753/estlink-2-repairs-increasingly-impacting-electricity-prices-each-month

[201] Statistics Finland (2019). *More district heat was produced with renewable fuels than with fossil fuels for the first time in 2019*. https://stat.fi/til/salatuo/2019/salatuo_2019_2020-11-03_tie_001_en.html

[202] Fibgrid (2025). https://www.fingrid.fi/contentassets/c29ab4fa69644ccd95e639c96adcc961/fingrid-corporate-presentation-2025.pdf

[203] Fingrid (2022). *Electricity trading with Russia will suspend – no threat to the sufficiency of electricity in Finland.* https://www.fingrid.fi/en/news/news/2022/electricity-trading-with-russia-will-suspend--no-threat-to-the-sufficiency-of-electricity-in-finland/

[204] Fingrid (2024). *Annual review and financial statements. 2024.* https://www.fingrid.fi/globalassets/dokumentit/fi/tiedotteet/ajankohtaista/toimintakertomus-ja-tilinpaatos-2024-en-julkaisuversio.pdf

[205] Litgrid (2025). *Litgrid first half results: strategic energy independence projects continue to be successfully implemented*. https://www.litgrid.eu/index.php/news-events-/news/litgrid-first-half-results-strategic-energy-independence-projects-continue-to-be-successfully-implemented/36229

needs; Litgrid is evaluating and consulting on steps to increase market capacity in 2026 and beyond[206].

Figure 5.22. Baltic synchronisation. ENTSO-E, 2025

The post-synchronisation period is accompanied by a pipeline of new and reinforced interconnections that aim to diversify supply routes, reduce single-corridor vulnerability and improve adequacy under stress conditions. Lithuania's planned Harmony Link with Poland is already in the design phase and is widely communicated as targeting commissioning around 2030, strengthening the Baltic States' western interface beyond the existing LitPol Link[207]. In the north, Estonia and Finland are advancing EstLink 3 as a new HVDC link (subsea cable plus converter stations), with Elering indicating an investment decision around 2028 and construction envisaged for 2035–2038; the project is also listed on the EU's PCI/PMI Union list, underscoring its strategic relevance for cross-border capacity development[208]. Finland and Sweden, in parallel, have initiated planning for Fenno-Skan 3 (estimated ~800 MW, completion targeted around 2038) and are pursuing the next step in FI–SE transfer expansion via Aurora Line 2 (also recognised in the EU PCI/PMI list and Nordic grid planning work), which together would increase Nordic system flexibility and resilience–an important buffer for the

[206] Lithgrid (2025). *Litgrid to increase electricity transmission capacity with Poland, invites market participants for consultation.* https://www.litgrid.eu/index.php/news-events-/news/litgrid-to-increase-electricity-transmission-capacity-with-poland-invites-market-participants-for-consultation/36290
[207] Baltic wind (2025). *Litgrid commences design work for the Harmony Link overland interconnector.* https://balticwind.eu/litgrid-commences-design-work-for-the-harmony-link-overland-interconnector
[208] Elering (n.d.). EstLink 3. https://elering.ee/en/estlink-3

wider Baltic-Nordic market during scarcity events[209]. Within the Baltics, security of supply benefits also depend on internal and cross-border reinforcements: Latvia's internal 330 kV upgrades have been supported explicitly to ensure reliable operation of the Estonia–Latvia third interconnection during maintenance and emergency modes[210], and the EU PCI/PMI list additionally names the Latvia–Lithuania cross-border strengthening project, both of which improve the region's ability to route power when individual elements are constrained[211]. Finally, an additional western interconnection is under evaluation through a around 2 GW and 600 km hybrid offshore interconnector concept linking Lithuania/Latvia with Germany, with the Lithuanian Ministry of Energy and partners indicating a possible 2035–2037 completion range, potentially adding a major additional corridor for contingency support and renewable integration, albeit still at a study/concept stage[212].

5.2.1.2. Network Infrastructure and System Operations

Electricity network infrastructure in the Baltic–Nordic region has undergone its most significant transformation since the early 1990s. The combination of new HVDC interconnections, the 2025 synchronisation with Continental Europe, and a growing share of weather-dependent generation has reshaped system operations fundamentally. Although the region's meshed network improves resilience, its asymmetrical structure-dominated by north-south HVDC corridors and limited east-west redundancy continues to shape supply security and price formation.

The 9 February 2025 synchronisation with the Continental European Network marked a historic shift for Lithuania, Latvia and Estonia, ending their dependence on IPS/UPS technical arrangements. The connection to the Continental synchronous area is enabled through the Lithuania–Poland interconnector (LitPol Link), and initial monitoring confirmed stable synchronous operation.

Before the synchronization, the Baltic operators carried out a full isolated-operation (island mode) test, during which all cross-border links with Russia and Belarus were disconnected and the Baltic grid had to maintain its own 50 Hz frequency without external support. The test demonstrated that system operators could balance generation and demand internally, manage voltage control and withstand typical disturbances, though it also revealed the need for fast-acting reserves and improved coordination among the three TSOs. The successful island-mode operation confirmed that the Baltic grid was technically ready for autonomous functioning and paved the way for a secure transition to CEN synchronization[213]. Since synchronization, the role of LitPol Link has expanded, with higher utilization reflecting both enhanced commercial exchange opportunities and its growing importance for system services, including stability support, balancing, and reserves. However, the Baltic system

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[209] Statnett (2025). *Nordic Grid Development Perspective 2025*. https://www.statnett.no/globalassets/for-aktorer-i-kraftsystemet/planer-og-analyser/nordic-grid-development-perspective-2025.pdf
[210] European Commission (2020). *CEF Energy: Reinforcing the internal grid infrastructure of Latvia.* https://cinea.ec.europa.eu/news-events/news/cef-energy-reinforcing-internal-grid-infrastructure-latvia-2020-11-06_en
[211] European Commission (n.d.). *ANNEXES to the COMMISSION DELEGATED REGULATION (EU) …/... amending Regulation (EU) 2022/869 of the European Parliament and of the Council as regards the Union list of projects of common interest and projects of mutual interest*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=intcom:C%282025%298144
[212] Lithuanian Ministry of Energy (2025). *Lithuania, Latvia and Germany plan an offshore electricity interconnector*. https://enmin.lrv.lt/en/news/lithuania-latvia-and-germany-plan-an-offshore-electricity-interconnector
[213] EPSO-G (2025). Baltijos šalių elektros sistemos sėkmingai atjungtos nuo Rusijos elektros tinklų. https://www.epsog.lt/lt/naujienos/baltijos-saliu-elektros-sistemos-sekmingai-atjungtos-nuo-rusijos-elektros-tinklu

remains constrained by limited internal transmission capacities, particularly in the LT–LV–EE north–south spine[214].

The regional grid is underpinned by several strategic transmission assets, each with distinct operational roles:

- **NordBalt (700 MW)** – historically Lithuania's main import link from Sweden. Annual utilization remained high, slipping only slightly from 79% in 2022 to 77% in 2023 (SE4→LT), and in 2024 NordBalt was among the most utilised HVDC links at ~83%[215].
- **EstLink 1 (350 MW) and EstLink 2 (650 MW) –** connecting Estonia and Finland. These links supply Estonia with Finnish surplus during low wind hours, but can reverse during Finnish scarcity periods. The 2024 outages of EstLink 2 (Jan 2024–Sep 2024 and Dec 2024–Jun 2025)[216] caused price spikes and exposed the vulnerability of relying on two parallel DC links with no synchronous backup.
- **LitPol Link (500 MW) –** after synchronisation, its role expanded from commercial trade to system security. Its growing two-way utilisation reflects a more flexible corridor, used both to export Baltic surplus and to import support when regional supply tightens.
- **Norway–Sweden–Finland HVDC corridors** (Fenno-Skan 1/2 and the new Aurora Line): while not directly linked to the Baltics, they shape Nordic price formation and congestion patterns, which can in turn affect price spreads between the Baltics and Sweden (SE4).

Despite this network, east–west redundancy remains limited. The Baltics rely on a single major western synchronous corridor, constraining flexibility during low-wind/high-load events and increasing dependence on DC links whose availability is finite and non-synchronous.

Lithuania increasingly faces transmission constraints in Western/Northwestern Lithuania during high wind output periods, which can necessitate renewable generation curtailment. Litgrid's grid development priorities include reinforcing the Northwest corridor, including projects such as the Darbėnai–Bitėnai 330 kV line and related network expansion measures[217]. In parallel, Lithuania is increasingly exploiting the complementary profiles of wind and solar by developing hybrid parks connected at a single grid access point[218], while the TSO deploys dynamic line rating to squeeze more transfer capability out of existing corridors[219]. Moreover, the 200 MW *Energy Cells* battery system[220] and a new wave of BESS projects are being integrated as part of the transmission system, providing

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[214] ENTSO-E (2025). *Regional Investment Plan 2024: Baltic Sea.* https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2024/forapproval/l_250317_entso-e_RIPs_2024_BS_07.pdf

[215] ENTSO-E (2025). *ENTSO-E HVDC utilisation and availability statistics 2024*. https://eepublicdownloads.entsoe.eu/clean-documents/SOC%20documents/Nordic/2024/HVDC_Utilisation_and_Availability_Statistics_2024.pdf

[216] Fingrid. (2024). *The EstLink 2 electricity interconnector between Finland and Estonia returns to commercial operation*.. https://www.fingrid.fi/en/news/news/2024/the-estlink-2-electricity-interconnector-between-finland-and-estonia-returns-to-commercial-operation/

[217] Litgrid (n.d.). *330 kV linijos Darbėnai–Bitėnai statyba.* https://www.litgrid.eu/index.php/sinchronizacija/sinchronizacijos-projektai/330-kv-linijos-darbenaibitenai-statyba/31591

[218] Ignitis Renewables (2024). *Ignitis Renewables has completed its first hybrid solar and wind project.* https://ignitisrenewables.com/ignitis-renewables-has-completed-its-first-hybrid-solar-and-wind-project/

[219] EPSO-G (2023). *Annual Report. 2023.* https://www.epsog.lt/uploads/documents/files/finansine-informacija/2023_Annual_Report.pdf

[220] BNS (2023). *Keturi „Energy cells" baterijų parkai pradeda veikti visa 200 MW galia.* VZ.lt. https://www.vz.lt/pramone/energetika/2023/10/18/keturi-energy-cells-bateriju-parkai-pradeda-veikti-visa-200-mw-galia

frequency control, congestion management and additional effective hosting capacity for a wind-and-solar portfolio now exceeding 5 GW[221].

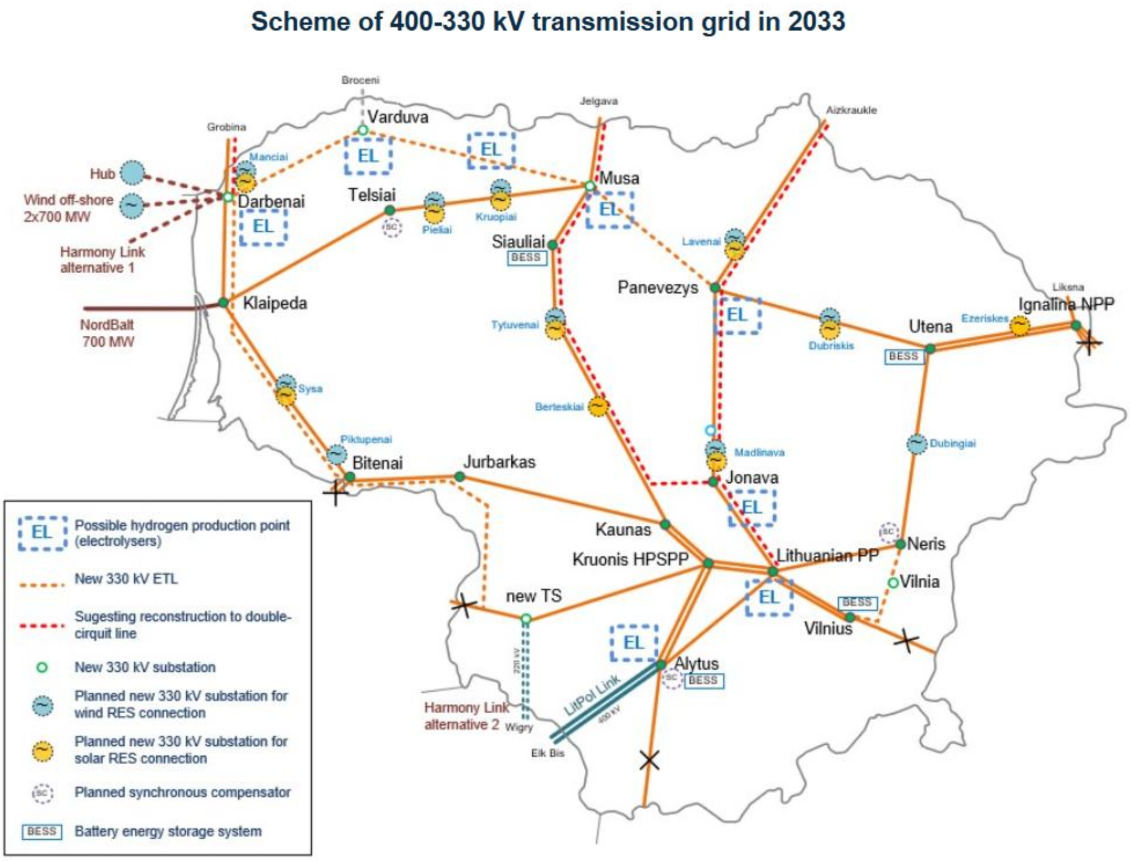

Figure 5.23. Scheme of 400-330 kV transmission grid in 2033. Source: Litgrid

Latvia has constraints around the Kurzeme Ring and Riga node, especially when Pļaviņas operates at high discharge. This affects north–south flows and forces redispatch in certain hydro-dominant conditions[222]. Latvia is combining "hard" grid reinforcement with "smart" system measures: completion of the Kurzeme Ring, new 330 kV corridors and the strengthening of the Riga node provide the backbone to absorb growing wind and solar output, while AST's 2025–2034 development plan introduces the concept of disconnectable generation and foresees innovative tools such as dynamic line throughput monitoring, battery energy storage systems and temporary producer restrictions so that a much larger, highly variable RES portfolio can be connected to the 110 kV and 330 kV networks without proportionate increases in traditional network investment[223].

Estonia faces grid reinforcement needs in Western Estonia as wind and solar connect increasingly in areas where the transmission network has historically been weaker. Elering's development plan highlights bottlenecks and outlines investments to increase 110–330 kV transfer capability and improve reliability. In addition, Elering's connection concept allows earlier commissioning of generation, but may require temporary production limitation if the grid becomes overloaded before

[221] Lithuanian Ministry of Energy (2025). *Prie Lietuvos elektros tinklo prijungtas didžiausias vėjo parkas, saulės ir vėjo elektrinių galia viršija 5 GW.* https://enmin.lrv.lt/lt/naujienos/prie-lietuvos-elektros-tinklo-prijungtas-didziausias-vejo-parkas-saules-ir-vejo-elektriniu-galia-virsija-5-gw-yrKy/
[222] AST (n.d.). The Kurzeme Ring. https://ast.lv/en/transmission-network-projects/kurzeme-ring
[223] AST (2024). *Power Transmission System Development Plan.* https://www.ast.lv/en/content/power-transmission-system-development-plan

all reinforcements are completed[224]. The main RES integration challenges are geographic and technical: transmission capacity is limited in Western Estonia and on the islands, where most large onshore and future offshore wind projects are located. Network investment programme to increase distributed and renewable electricity volumes in Western Estonia and islands foresees investments in 110 and 330 kV electricity grids[225]. At the same time, Elering's 2030 strategy stresses that dispersed, fluctuating generation will require fast, time-shiftable flexibility and new stability tools, which is why Estonia is investing in synchronous condensers[226], grid digitalisation and, where necessary, the legal option to curtail or redispatch generation to safeguard voltage and frequency stability.

These constraints underscore the need for accelerated grid reinforcement to align with RES growth trajectories. The region is preparing a new wave of strategic infrastructure that will reshape system operations:

- EstLink 3 (planned capacity is 700 MW): will help harmonise electricity prices and enable more affordable Nordic renewable energy to reach Estonia. It will also strengthen energy security by allowing larger cross-border power flows in line with EU and Estonian green goals[227].
- Gulf of Riga hybrid interconnector (Estonia–Latvia offshore link): a proposed 1 000 MW hybrid HVDC link enabling both interconnection and future offshore wind integration[228].
- Harmony Link (planned capacity is 700 MW) is planned between Lithuania and Poland to support cross-border trade between Continental Europe and the Baltic States and improve security of supply[229].
- Baltic–Nordic offshore grid vision: The Baltic states have significant offshore wind energy potential, estimated at around 14,5 GW in Latvia, 4.5 GW in Lithuania, and 7 GW in Estonia[230].
- Finland is planning a rapid expansion of offshore wind, with industry targets of around 1 GW of offshore capacity by 2030, 16 GW by 2040, and up to 24 GW by 2045[231]. To keep the system stable, Fingrid plans to limit how much capacity can be concentrated in one node (about 1.3 GW per connection point) and is also studying hybrid HVDC links[232].

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224 Elering (2024). *Eesti Elektriülekandevõrgu Arengukava 2024-2033.* https://elering.ee/sites/default/files/public/elekter/elektris%C3%BCsteem/Eesti%20elektri%C3%BClekandev%C3%B5rgu%20arengukava%202024-2033.pdf

225 European Comission (2025). Estonia - Final updated NECP 2021-2030. https://commission.europa.eu/publications/estonia-final-updated-necp-2021-2030-submitted-2025_en

226 Siemens Energy (2025). Ensuring voltage and frequency stability in Estonia's grid. https://www.siemens-energy.com/global/en/home/stories/synchronous-condensers-in-estonia.html

227 Elering (n.d.). *EstLink 3.* https://elering.ee/en/estlink-3

228 Melisa Cavcic (2023). *Hybrid interconnector projects in North Sea and Baltic Sea beef up Europe's green energy ties.* Offshore-Energy.biz. https://www.offshore-energy.biz/hybrid-interconnector-projects-in-north-sea-and-baltic-sea-beef-up-europes-green-energy-ties/

229 Litgrid (n.d.). *Construction of Harmony Link interconnector.* https://www.litgrid.eu/index.php/synchronisation/synchronisation-projects/construction-of-harmony-link-interconnector/31599

230 Baltic Wind (2021). *The Baltic Sea offshore wind potential reaches 93 GW.* https://balticwind.eu/the-baltic-sea-offshore-wind-potential-reaches-93-gw/

231 Renewables Finland (2025). *Ambitious offshore wind targets set by Renewables Finland.* https://suomenuusiutuvat.fi/en/ambitious-offshore-wind-targets-set-by-renewables-finland/

232 Fingrid (2024). *Fingrid explored preliminary possibilities to connect offshore wind power to main grid.* https://www.fingrid.fi/en/news/news/2024/fingrid-explored-preliminary-possibilities-to-connect-offshore-wind-power-to-main-grid/

- Baltic States-Germany interconnector (planned capacity is 2 GW): key step to deepen market integration, enhance security of supply and unlock new offshore and onshore renewable energy projects in Lithuania, Latvia and Germany[233].

The shift to a system dominated by HVDC links and inverter-based renewables reduces natural inertia. Following synchronisation, Baltic TSOs are required to maintain higher levels of frequency containment reserve (FCR) and fast frequency reserve (FFR). Lithuania's Kruonis pumped storage plant remains the largest inertia-providing asset in the Baltics, while Estonia and Latvia increasingly rely on FRR provision from CEN markets via Poland[234].

Reserve activation patterns also shifted:

- Latvia's hydro fleet acts as the region's primary fast upward reserve during high inflow periods,
- Estonia increasingly imports balancing energy from Finland during low wind,
- Lithuania activates domestic battery storage for fast frequency response (FFR), marking one of the first large-scale BESS integrations in the CEN synchronous area.

These dynamics illustrate a region in transition from fossil-dominated, inertia-rich systems to a hybrid network of hydro, wind, solar, batteries and HVDC interconnectors, requiring increasingly sophisticated operational strategies.

5.2.2. Nuclear sector

In the Baltic-Finnish region nuclear Accessibility in 2022-2024 was redefined in a similar manner as electricity sector. However, for nuclear, the difference lays in the fact that accessibility to nuclear is more so driven by technological bottlenecks, and access to nuclear fuel and its storage sites. No Baltic States have access to nuclear energy as of writing this study, however, Lithuania still has multiple active nuclear facilities. Currently in the process of decommissioning is the Ignalina NPP, but more importantly, Lithuania still has active spent fuel and radioactive waste facilities. Lithuania does not reprocess spent nuclear fuel, but discharges it in the cooling pods, and transfers to dry-type spent fuel locations (SFSF-1 and SFSF-2). To note, in March 2022, Lithuanian nuclear energy regulator VATESI has further issued 2 permits to industrial waste–management companies to process radioactive waste.[235]

Long-lived waste is planned to be stored for ~50 years in a dedicated facility with a planned capacity of ~2,000 m³ (extendable up to ~8,000 m³ via additional modules), before final disposal. Finally, Lithuania's "access" to a complete nuclear lifecycle is explicitly planned through a deep geological repository: VATESI describes a government-approved schedule targeting site investigation completion by 2047, construction 2058–2067, operation 2068–2074, and closure 2075–2079, with Ignalina NPP responsible for implementation alongside the Ministry of Energy.[236]

[233] Lithuanian Ministry of Energy (2025). *Lithuania, Latvia and Germany plan an offshore electricity interconnector.*
[234] *Reserve provision changes post-synchronisation.* https://enmin.lrv.lt/en/news/lithuania-latvia-and-germany-plan-an-offshore-electricity-interconnector/
[235] State Nuclear Power Safety Inspectorate (n.d.). *Nuclear facilities in Lithuania.* https://vatesi.lrv.lt/en/nuclear-facilities/nuclear-facilities-in-lithuania/
[236] [236] State Nuclear Power Safety Inspectorate (n.d.). *Spent nuclear fuel and long-lived radioactive waste treatment facilities.* https://vatesi.lrv.lt/en/nuclear-facilities/radioactive-waste-management-facilities/spent-nuclear-fuel-and-long-lived-radioactive-waste-treatment-facilities/

For the nuclear champion of the selected countries, Finnish nuclear has seen landscape 2 major strategic actions taken: diversification of nuclear fuel away from Russia, and final implementation phase of its permanent nuclear waste repository.

First of all, the nuclear supply origin into Finland has been a critical vulnerability in Finnish energy sector. In response to Russia's war against Ukraine, Finland strategically reduced dependence on Russian nuclear fuel, and its supplier TVEL. Finnish utility Fortum partnered with the American company Westinghouse Electric to develop, license, and supply a new non-Russian fuel type for its VVER-440 reactors. The first batch was successfully loaded during the plant's annual maintenance in August 2024. While Fortum will honor its existing contracts with Russia's TVEL until their expiration in 2027 and 2030, this diversification marks a significant step towards enhancing Finland's energy security.[237]

Second, Finland has its status as the undisputed global leader in nuclear waste management. It's the first country in the world to move to the implementation phase of a deep geological repository for spent nuclear fuel.[238] The Onkalo repository, located on Olkiluoto Island, is designed to securely store spent nuclear fuel for up to 100,000 years. The facility, situated approximately 430 meters underground, has entered its final testing phase, with disposal activities scheduled to commence in 2025, with the capacity to hold 6,500 tonnes of spent nuclear fuel.[239] This project exemplifies Finland's proactive approach to addressing the long-term challenges associated with nuclear waste.[240]

5.2.3. Natural gas sector

In the Baltic–Nordic region, the concept of gas accessibility has shifted from a commercial logic of capacity allocation to a strategic logic of sovereign control and physical redundancy. The period of 2022–2024 marked the definitive end of the "Eastern vector", the Soviet-legacy pipeline architecture that tethered the region to Russian supply, and the accelerated operationalization of a "Western/Maritime vector." Accessibility is now defined by the region's ability to bypass historical geographic bottlenecks through a securitized mesh of Liquefied Natural Gas (LNG) terminals and cross-border interconnectors.

5.2.3.1. Natural gas Infrastructure and Critical Nodes of Systemic Vulnerability

The post-2022 gas security architecture of the Baltic–Nordic region is structurally defined not by national self-sufficiency, but by a small number of critical, highly loaded cross-border assets whose operational integrity determines the stability of the entire regional system. While diversification away from Russian pipeline gas has significantly reduced geopolitical supplier risk, it has simultaneously

[237] E. Luoma and A. Kauranen (2024). *Finland's Fortum uses US nuclear fuel to cut Russia dependence*. Reuters. https://www.reuters.com/business/energy/finlands-fortum-starts-using-us-nuclear-fuel-bid-reduce-russian-dependence-2024-09-02/
[238] Vehmas, J., Rentto, A., Luukkanen, J., Auffermann, B., & Kaivo-oja, J. (2022). *The Finnish Solution to Final Disposal of Spent Nuclear Fuel*. https://doi.org/10.1007/978-3-658-40496-3_11#DOI
[239] Penttinen, S.-L. (2025). *Nuclear Energy in Finland*. Journal of Agricultural and Environmental Law. https://doi.org/10.21029/JAEL.2025.38.91
[240] S. El-Showk (2022) *FINAL RESTING PLACE: Finland is set to open the world's first permanent repository for high-level nuclear waste. How did it succeed when other countries stumbled*?, SCIENCE, https://www.science.org/content/article/finland-built-tomb-store-nuclear-waste-can-it-survive-100000-years

reconcentrated physical security around LNG terminals, interconnectors and the Inčukalns underground storage facility, thereby transforming the nature of systemic vulnerability.

In Lithuania, the Klaipėda LNG terminal constitutes the single most important physical entry point for natural gas into the Baltic region[241]. Following the termination of Russian imports in 2022, Klaipėda became the dominant source of gas not only for Lithuania, but also for Latvia and, indirectly, for Estonia and Poland. Lithuania's 2022 decision to acquire the FSRU *Independence*–with the ownership transfer formally completed in December 2024, transformed the Klaipėda LNG terminal from a leased commercial asset into a strategic national security infrastructure object, anchoring long-term regional supply resilience[242]. At the same time, this centrality creates a structural single-point-of-failure risk: any prolonged disruption of Klaipėda's operations, whether technical, maritime or hybrid in nature, would immediately propagate across the entire Baltic supply system.

The Gas Interconnection Poland–Lithuania (GIPL) constitutes the second critical pillar of regional infrastructure. Beyond its immediate commercial function, GIPL has a profound geopolitical significance: it permanently embedded the Baltic gas system into the continental European grid and eliminated the historical isolation of the region[243]. From an energy security perspective, GIPL functions as both a redundancy corridor and a pressure relief valve, enabling surplus LNG-based gas from Lithuania to flow southward and, under crisis conditions, allowing gas to be drawn northward from Central European storage systems. However, GIPL's security role also implies strategic exposure: as the only direct high-capacity physical connection between the Baltic and continental systems, its operational continuity is now of systemic importance for the entire region.

In Finland, the Inkoo FSRU and the Balticconnector pipeline jointly define the country's new gas security architecture. Inkoo provides Finland with autonomous LNG access and sufficient regasification capacity under normal conditions[244], while Balticconnector links the Finnish system to Estonia and, via Inčukalns, to the wider Baltic storage network[245]. The absence of domestic underground storage fundamentally elevates the strategic role of Balticconnector: any long-term interruption of this link would compress Finland's security envelope to the operational reliability of LNG terminals alone. While this configuration has proven sufficient under post-2022 conditions, it remains structurally exposed to maritime disruption, technical faults and hybrid interference in the Gulf of Finland.

In Estonia, the gas infrastructure system is structurally defined by its transit function and lack of autonomous storage. The Estonian transmission grid binds together Latvian storage, Finnish LNG access and residual technical links with Russia. While Russian flows have been suspended, the physical topology of the network remains unchanged, creating a layered exposure to both legacy and newly emerging security risks. The establishment of state control over the Paldiski LNG infrastructure

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[241] Amber Grid (2022). *Natural gas transmission System operator's ten year Network development plan 2022-2031.* https://ambergrid.lt/uploads/documents/Amber%20Grid_TYNDP_2022.pdf

[242] Ministry of Energy of the Republic of Lithuania (2024). *Lithuania takes ownership of FSRU Independence – national flag raised aboard.* https://enmin.lrv.lt/en/news/lithuania-takes-ownership-of-fsru-independence-national-flag-raised-aboard/

[243] European Commission (2022). *Inauguration of gas interconnection between Poland and Lithuania.* https://commission.europa.eu/news-and-media/news/inauguration-gas-interconnection-between-poland-and-lithuania-2022-05-05_en

[244] Excelerate Energy (2022*). Excelerate Energy Delivers FSRU Exemplar to Finland with Commissioning Cargo.* https://excelerateenergy.com/news/excelerate-energy-delivers-fsru-exemplar-to-finland-with-commissioning-cargo/

[245] European Commission (n.d.). *Balticconnector.* https://cinea.ec.europa.eu/featured-projects/balticconnector_en

in 2023[246] added an important crisis insurance layer, but did not fundamentally alter Estonia's dependency on regional infrastructure rather than national assets. Estonia's security position thus remains structurally derivative: its resilience is anchored less in domestic infrastructure than in the stable functioning of Latvian, Lithuanian and Finnish nodes.

Latvia occupies a structurally singular position through the Inčukalns Underground Gas Storage Facility, which functions as the core temporal balancing mechanism of the entire Baltic–Nordic gas system. With its large working gas volume, Inčukalns enables the seasonal decoupling of LNG import schedules and winter consumption across Lithuania, Estonia and Finland. In operational terms, Inčukalns transforms a volatile spot-based LNG supply chain into a quasi-baseload regional supply system. This function cannot be substituted by any other asset currently operating in the region. As a result, Inčukalns represents not merely a national strategic asset, but a regional cornerstone of gas security. From an infrastructure-resilience perspective, Latvia reports a very strong N-1 infrastructure standard (220.67%) and has formal obligations to maintain sufficient working gas in Inčukalns to ensure daily withdrawal capacity under crisis conditions[247]. Inčukalns has significant redundancy and can sustain partial operation even after an attack or industrial accident[248]. Yet, despite this centrality, the present material does not provide sufficient transparency regarding Latvia's internal transmission constraints, compressor station redundancy, or emergency operating regimes under complex failure scenarios.

The Balticconnector rupture in October 2023[249] marked the first real-world stress test of the post-2022 gas infrastructure architecture. The physical disconnection of Finland from the Baltic grid compressed regional supply flexibility and temporarily eliminated Finland's access to Inčukalns storage. Although supply adequacy was preserved through LNG at Inkoo and alternative routing, the incident revealed the non-linear propagation of infrastructure failures in an interdependent system. A single rupture did not only affect bilateral flows, but temporarily restructured the entire multilateral gas network in the Baltic Sea region. Subsequent incidents reported in late 2024, involving damage to multiple undersea telecommunications cables[250] and a major cross-border power interconnector in the Baltic Sea[251], triggered criminal investigations and prompted NATO to strengthen its maritime presence, reinforcing the assessment that hybrid and physical threats to subsea energy infrastructure now represent a persistent systemic risk rather than an exceptional contingency. Subsequent incidents reported in late 2024 further reinforced the assessment that hybrid and physical threats to undersea energy infrastructure now constitute a persistent systemic risk factor rather than an exceptional contingency.

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[246] Estonian Stockpiling Agency (2023). *State acquires Paldiski LNG jetty with port property from private companies.* https://varudekeskus.ee/en/news/state-acquires-paldiski-lng-jetty-port-property-private-companies

[247] Sabiedrisko pakalpojumu regulešanas komisija (2024). *2024 Annual Report of the Public Utilities Commission of the Republic of Latvia on the National Energy Sector, Prepared for the European Commission.* https://www.sprk.gov.lv/sites/default/files/editor/ED/Elektroenergija/2025/2024%20Annual%20Report%20of%20the%20PUC%20Latvia%20on%20the%20National%20Energy%20Sector.pdf

[248] IEA (2024). *Latvia: Energy Policy Review..*

[249] Reuters (2023). *Finland says 'outside activity' likely damaged gas pipeline, telecoms cable.* https://www.reuters.com/markets/commodities/finnish-government-hold-news-conference-suspected-pipeline-leak-media-2023-10-10/

[250] Reuters (2024). *European nations denounce Russian hybrid attacks, cable cut probes launched.* https://www.reuters.com/business/media-telecom/lithuania-steps-up-surveillance-sea-following-damage-undersea-cable-2024-11-19/

[251] Reuters (2024). *NATO to boost Baltic Sea presence after cables broken.* https://www.reuters.com/world/europe/estonias-navy-protect-baltic-sea-power-cable-2024-12-27/

From a comparative energy security perspective, the Baltic–Nordic gas infrastructure system now exhibits a dual vulnerability structure. On the one hand, the removal of Russian pipeline dependence has fundamentally improved geopolitical robustness and eliminated coercive supplier leverage. On the other hand, the region's security is now concentrated around a narrow set of high-value physical nodes–Klaipėda LNG, Inkoo FSRU, GIPL, Balticconnector and Inčukalns–whose uninterrupted operation is indispensable for system continuity. These nodes are simultaneously economic infrastructure, strategic security assets and potential geopolitical targets.

A further structural tension emerges from the interaction between declining gas demand and rising infrastructure criticality. As absolute consumption volumes shrink in Lithuania, Estonia and Finland, the commercial utilisation rate of LNG terminals, pipelines and storage declines. Yet their strategic value under crisis conditions increases rather than diminishes. This creates a growing security–economics divergence, where assets of diminishing market relevance retain–or even amplify–their systemic security importance. Managing this divergence will require sustained regulatory support, targeted capacity remuneration mechanisms and coordinated cross-border security investment, lest critical infrastructure be allowed to degrade under purely commercial logic.

In sum, the post-2022 Baltic–Nordic gas infrastructure system is best characterised as geopolitically resilient yet physically concentrated. It no longer depends on a single external supplier, but it does depend on the flawless operation of a small number of critical cross-border assets. The region's future gas security will therefore not be primarily determined by market access to LNG, but by the protection, redundancy and coordinated governance of these infrastructural choke points.

5.2.3.2.Security of Supply, Crisis Management and Risk Scenarios

The gas supply accessibility of the Baltic–Nordic region has shifted from a regime of contractual and supplier-based dependence to a regime dominated by physical infrastructure resilience, crisis coordination and system flexibility. The 2022 gas shock and the subsequent 2023–2024 infrastructure disruptions revealed that security of supply is no longer primarily determined by long-term contracts, but by the real-time operability of LNG terminals, cross-border interconnectors, storage withdrawal capacity and emergency demand management.

The 2022 supply rupture represented the most profound stress test of the regional gas system. For Finland, the immediate halt of Russian pipeline deliveries in May 2022 constituted a full physical supply shock rather than a market-driven price shock. Security of supply was preserved not through alternative pipeline imports, but through rapid LNG deployment, access to sea markets and emergency fuel substitution, primarily toward coal, biomass and alternative fuels in district heating and industry[252]. The Finnish system stabilised within months, but at the cost of a permanent structural contraction of gas demand. This episode demonstrated that Finland's post-2022 gas security is founded not on storage depth, but on exceptional short-term fuel-switching capacity and LNG responsiveness.

In Lithuania, the crisis unfolded primarily as a price-driven industrial shock rather than a physical shortage. The existence of Klaipėda LNG ensured uninterrupted supply in volumetric terms, yet the price environment rendered large-scale industrial consumption economically unviable. The

[252] IEA (2023). *Finland: Energy Policy Review.*

suspension of ammonia production at AB Achema in September 2022[253] illustrates that, under extreme market conditions, formal supply security does not guarantee demand security. Lithuania thus entered a crisis regime in which the physical availability of gas coexisted with de facto demand destruction, reshaping the national security calculus from one of volume adequacy toward one of economic affordability and industrial competitiveness.

In Estonia, gas security is primarily ensured through fuel switching in district heating, cross-border flows with Latvia and Finland, and access to the Inčukalns storage facility. Estonia's comparatively low structural gas dependency limited the macroeconomic impact of the shock, but at the same time exposed the heating sector to accelerated substitution pressure. The Estonian case thus illustrates a security model based more on structural exit from gas than on long-term reinforcement of gas supply resilience.

Latvia's crisis experience was shaped less by an immediate physical shortage than by the need to manage winter adequacy through its storage-centred system. In practice, the security response relies on maintaining sufficient working gas in Inčukalns and, if needed, prioritising protected customers while curtailing non-essential demand, alongside fuel switching in heat and CHP that helped compress gas consumption after 2022. In parallel, Latvia's lack of a domestic large-scale LNG terminal meant that diversification in the post-2022 environment depended primarily on regional connectivity and access to LNG supplies routed through neighbouring infrastructure rather than national self-sufficiency.

A second, fundamentally different class of security risks materialised in October 2023, when the Balticconnector pipeline between Finland and Estonia was physically ruptured[254]. Unlike the 2022 shock, which was driven by geopolitical supply withdrawal, the Balticconnector incident constituted a direct infrastructure failure with immediate system-wide consequences. Although physical gas supply to Finland was preserved through LNG at Inkoo, the outage severed Finland's access to Inčukalns storage for several months. This temporarily converted Finland from a fully interconnected system into a territorially isolated LNG-dependent subsystem. The episode demonstrated with clarity that, in the new LNG–interconnector regime, single-infrastructure outages can instantaneously restructure the entire regional security geometry.

The Balticconnector rupture also revealed important systemic nonlinearities. The loss of a single pipeline link did not affect only bilateral trade between two countries; it reshaped price formation, storage utilisation strategies and intra-regional balancing across the entire Baltic–Nordic gas system. Even though aggregate LNG capacity remained sufficient, the distribution of flexibility within the system was abruptly compressed, exposing the region to heightened short-term volatility and operational risk. The reported incidents affecting undersea infrastructure again in late 2024 reinforce the assessment that hybrid and physical threats to subsea energy assets are no longer low-probability contingencies but part of the structural security environment.

From a risk-scenario perspective, three dominant classes of gas security threats now coexist in the Baltic–Nordic region. The first is market-driven shock, exemplified by the 2022 price explosion,

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[253] LRT.lt (2022). *Lithuania's biggest fertiliser maker suspends production over soaring gas prices.* https://www.lrt.lt/en/news-in-english/19/1765607/lithuania-s-biggest-fertiliser-maker-suspends-production-over-soaring-gas-prices?srsltid=AfmBOoolTTPHhZgxDCPCu72ZYvZBWeqQW7o8wb0RQoqVwL6ezkgo-FZJ
[254] Reuters (2023). *Finland says 'outside activity' likely damaged gas pipeline, telecoms cable.* https://www.reuters.com/markets/commodities/finnish-government-hold-news-conference-suspected-pipeline-leak-media-2023-10-10/

which preserves physical supply but destroys demand through affordability constraints. The second is geopolitical supply interruption, which has been largely neutralised with respect to Russian gas but remains relevant in a global LNG market exposed to geopolitical fragmentation. The third is physical infrastructure failure, affecting subsea pipelines, LNG terminals or critical compressor stations, with the Balticconnector incident serving as a real-world illustration of such risk propagation.

A defining feature of the post-2022 security regime is that no single country can now fully secure its gas system independently. Lithuania's LNG-based supply dominance, Latvia's storage centrality, Estonia's transit positioning and Finland's LNG dependence now form an explicitly interdependent security web. This interdependence enhances collective resilience against supplier coercion, but simultaneously amplifies exposure to common-mode infrastructure failures and coordinated hybrid actions.

An additional structural challenge emerges from the interaction between declining gas demand and crisis-readiness requirements. As gas consumption contracts structurally in Lithuania, Estonia and Finland, maintaining high-cost emergency capacities–LNG terminals, underground storage, compressor redundancy and security reinforcements–becomes increasingly difficult to justify on a purely commercial basis. Yet the strategic need for these assets remains undiminished. This creates a growing reliance on explicit state intervention and cross-border coordination to sustain security-critical infrastructure under conditions of falling market utilisation.

The evolution of accessibility and crisis management in the Baltic–Nordic gas system marks a transition from a supplier-risk-dominated regime to an infrastructure- and coordination-risk-dominated regime. While geopolitical leverage associated with Russian pipeline imports has been effectively eliminated, it has been replaced by a security environment where the integrity of a limited number of physical and organisational nodes determines the stability of the entire regional system. The strategic challenge for the coming decade will be to ensure that this new infrastructure-centred security architecture remains operational, financially sustainable and politically coordinated under conditions of accelerating gas demand decline.

5.2.3.3. Infrastructure Utilization and Strategic Value

A final paradox of the new accessibility regime is the divergence between economic utilization and security value. As gas demand structurally declines across the region (due to decarbonization and high prices), the commercial utilization of pipelines and terminals is falling. However, their importance for accessibility has increased. These assets are no longer just commercial conduits; they are strategic reserves essential for crisis resilience. Maintaining the accessibility of the gas system now requires treating infrastructure as a public good for national security, ensuring that capacity remains available even as market throughput decreases.

In summary, accessibility in the Baltic–Nordic gas sector is no longer defined by the capacity of Soviet-era pipelines, but by the resilience of a new, securitized maritime and continental network. The region has successfully built the physical capacity to transport gas independently of Russia, but this independence relies on the continuous integrity of subsea assets and the maintenance of a highly interdependent cross-border grid.

5.2.4. Oil sector

In the Baltic–Nordic oil sector, Accessibility has fundamentally shifted from a model of land-based pipeline connectivity to one of maritime logistics and infrastructural sovereignty. Historically, the region's accessibility was dictated by the Soviet-legacy Druzhba pipeline system, which created a physical "lock-in" to Russian supply. Following the total cessation of Russian imports in 2022, accessibility is no longer governed by the capacity of existing pipelines, but by the ability to bypass them. The region has transitioned from a linear "Eastern vector" to a "Western/Maritime vector," where security is defined by the resilience of ports, the capacity of offshore terminals, and the integrity of regional refining nodes. This shift has introduced a new strategic vulnerability: while geopolitical risk has been reduced, physical risk has been reconcentrated into a small number of critical maritime gateways.

5.2.4.1. Oil Terminals

The spatial distribution and functional configuration of oil terminals across Lithuania, Latvia, Estonia and Finland constitute a critical layer of the regional oil security architecture. These terminals perform not only routine commercial functions but also act as strategic nodes enabling supply continuity, buffering capacity and route flexibility under disrupted conditions. As illustrated in Figure 5.24, the oil terminal network in the selected countries reveals pronounced asymmetries in capacity concentration, logistical orientation and systemic importance.

From an energy security perspective, the terminal system exhibits a clear hierarchy. Lithuania functions as the primary crude oil entry and redistribution point for the Baltic States, while Latvia and Estonia operate predominantly as downstream transit and consumption nodes with comparatively limited strategic autonomy. Finland, in contrast, represents a structurally more resilient subsystem with diversified terminal infrastructure directly linked to large-scale refining operations.

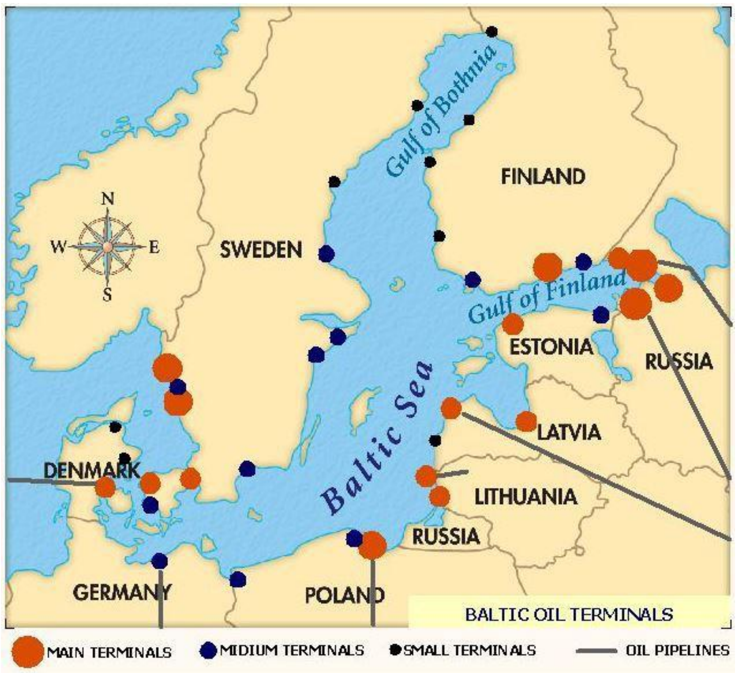

Figure 5.24. Oil terminals in Baltic Sea Region[255]

Lithuania hosts two critical oil terminals that jointly underpin the operational continuity of its refining system and regional oil supply. The Klaipėda Oil Terminal, operated by KN Energies, provides handling services for both crude oil and petroleum products, enabling discharge from and loading onto tankers. The terminal's total throughput capacity reaches approximately 8 million tonnes per year, positioning it as a key logistics node for product flows supporting domestic consumption and regional redistribution[256]. The Būtingė Offshore Terminal, owned by ORLEN Lietuva, represents the strategic lifeline of Lithuania's crude oil system. Located in an ice-free zone of the Baltic Sea, it operates year-round and serves as the exclusive maritime entry point for crude oil destined for the Mažeikiai refinery. In operational terms, the Būtingė Offshore Terminal receives on average about 95 crude oil tankers per year, with annual crude oil imports amounting to approximately 9.5 million tonnes, underscoring its central role in supplying the Mažeikiai refinery via global maritime oil routes[257]. This configuration establishes Lithuania as the principal crude oil gateway for the Baltic States, a systemic single-point-of-entry for national refining operations and a node of high strategic value but equally high vulnerability concentration.

Latvia's oil terminal infrastructure is concentrated in three ports: Ventspils, Riga and Liepāja, reflecting a classic downstream logistics orientation rather than a system anchored in domestic processing. As of 2024, liquid bulk operations at the Port of Riga are concentrated in ten dedicated terminals with an aggregate capacity of approximately 14 million tonnes per year, focused mainly on refined oil products, including fuel oil, gas oil, gasoline, jet fuel and kerosene[258]. The Ventspils Nafta Terminals (now operating as Vitol Terminal Latvia) in the Port of Ventspils constitute one of the largest oil product transhipment complexes in the Baltic States, with an estimated handling capacity on the order of several million tonnes per year[259]. Historically linked to Russian transit flows, Ventspils remains a major logistical asset but one whose strategic relevance increasingly depends on shifting supply patterns and diversification efforts. In the Port of Liepāja, the DG Terminal – an independent liquid bulk tank terminal established in 2000 and operating within the Liepāja Special Economic Zone – provides transshipment services for crude oil, petroleum products and other liquid cargos, operating year-round in the ice-free port and supported by licensed EU customs facilities[260]. While smaller in scale, it contributes to Latvia's overall distribution redundancy. Structurally, Latvia's terminal system is characterised by high total throughput capacity, strong transshipment orientation and limited strategic buffering or supply sovereignty.

In Estonia, oil terminal infrastructure is closely linked to both import needs and the export of domestically produced shale oil. The primary maritime gateway for Estonia is the Port of Tallinn, which comprises several harbours, including Muuga and Paldiski South, capable of handling crude oil, petroleum products and other liquid bulk cargoes. These harbours host multiple specialised terminals supported by extensive tank storage facilities, enabling significant imports and

[255] Drzarga M.et. al. (2016). *Oil pipeline critical infrastructure network. Journal of Polish Safety and Reliability Association Summer Safety and Reliability Seminars*. Volume 7, Number 2.
[256] KN Energies (n.d.). *Klaipėda liquid energy products terminal*. https://knenergies.lt/en/terminal/klaipeda-liquid-energy-products-terminal/
[257] ORLEN (n.d.). *Terminal and Pipelines*. https://www.orlenlietuva.lt/EN/Company/OL/Pages/Terminal-and-Pipelines.aspx
[258] Freeport of Riga (n.d.).*Port performance.* https://rop.lv/en/port-performance
[259] VTL (n.d.). *About VTL*. https://www.vtl.lv/en/
[260] DG Terminals (n.d.).. *DG Termināls Overview.* https://dgterminals.lv/

transshipment of refined fuels and other liquid bulk commodities in the northern Baltic region[261]. A distinct feature of Estonia's oil logistics system is the Port of Sillamäe, the easternmost deep-water port in the European Union, which operates year-round. The Sillamäe terminal performs a dual role by facilitating the transit of imported petroleum products while also supporting the export of domestically produced shale oil[262]. Through its dedicated liquid bulk infrastructure, the port provides substantial handling capacity, reinforcing Estonia's hybrid supply model that combines imported fuels with domestic unconventional oil production. Overall, Estonia's terminal infrastructure supports partial supply autonomy, export capability for shale oil, but limited classical crude oil system flexibility.

Finland maintains the most diversified and structurally resilient oil terminal system among the four countries. Three principal oil port terminals form the backbone of this infrastructure: Sköldvik (Porvoo), Naantali and Hamina-Kotka. Additionally, multiple smaller oil import terminals contribute to national supply flexibility. Crude oil is primarily imported through the Porvoo and Naantali terminals, both owned by Neste[263]. These terminals are directly integrated with Finland's refining system and provide substantial crude oil handling capacity. Collectively, the Porvoo and Naantali harbours handle around 24 million tonnes per year of crude oil, renewable and chemically recycled feedstocks, as well as fossil, renewable and circular products and other end products[264]. This configuration enables Finland to sustain high operational continuity, rapid supply reconfiguration and strong buffering capacity in crisis scenarios.

The distribution of oil terminals across the Baltic Sea region reveals a structurally imbalanced resilience pattern:

- Lithuania functions as the regional refining gatekeeper, combining high systemic importance with high infrastructure concentration risk.
- Latvia operates as a logistics-oriented transit corridor, with high handling capacity but structurally limited strategic autonomy.
- Estonia demonstrates a hybrid security model, blending terminal-based imports with domestic shale production, though increasingly constrained by environmental pressures.
- Finland serves as an external stabiliser, embedding high redundancy and integrated capacity within its terminal-refinery system.

This spatial configuration underscores the strategic necessity for regional coordination in infrastructure protection, emergency stock routing and crisis response planning, particularly given the dependency of Latvia and Estonia on Lithuanian and Finnish terminal-reliant systems.

5.2.4.2. Security of Accessibility

Lithuania operates one refinery at Mažeikiai. This plant is the only refinery in the three Baltic States and is tightly coupled with the Būtingė offshore terminal and Klaipėda product infrastructure[265]. In normal times this configuration is efficient: the refinery can draw on global seaborne crude, optimise its product slate between gasoline, diesel, jet and heavy fractions, and export a substantial share of

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[261] Port of Tallinn (n.d.). *Liquid Bulk is handled in 2 different harbours: Muuga Harbour and Paldiski South Harbour.* https://www.ts.ee/en/liquid-bulk/
[262] SILPORT (n.d.). *SILPORT*. https://www.silport.ee/eng/index.html
[263] IEA (2023). *Finland: Energy Policy Review.*
[264] NESTE (n.d.). *Porvoo refinery*. https://www.neste.com/about-neste/how-we-operate/production/porvoo-refinery
[265] ORLEN (n.d.). *Orlen Lietuva*.https://www.orlenlietuva.lt/EN/Company/OL/Pages/default.aspx

output to neighbouring markets. From a security-of-supply perspective, however, the system is highly concentrated. A single prolonged outage at Mažeikiai would instantly transform Lithuania, Latvia and Estonia from a largely balanced sub-region into pure product importers competing for supply from Finland, Poland and north-west European hubs. In other words, the refinery is simultaneously an economic asset and a systemic single point of failure.

Finland's oil system is structurally more resilient than that of the Baltic States due to the scale and integration of the Porvoo refining and terminal complex. Following the decommissioning of the Naantali refinery in 2021[266], Finland's crude oil refining capacity is concentrated at a single large, highly integrated site that is embedded in a broader value chain including crude and product trading, petrochemicals, marine bunkering and regional export flows. This integration supports the economic viability of refining operations in a declining European oil market and allows supply adjustments through multiple ports and product import routes, limiting exposure to domestic single-asset risk compared with Lithuania.

Latvia and Estonia occupy a different position altogether. Neither country operates a crude refinery, both rely on imported refined products and, in Estonia's case, on the export of domestically produced shale oil[267]. Their security of supply model is thus built around ports, storage and inland distribution rather than around processing. Latvia's large terminals in Riga and Ventspils, and Estonia's facilities in Tallinn and Sillamäe, can each handle many millions of tonnes per year of oil products. This gives both countries substantial logistical capacity and the ability to switch between suppliers and routes when markets are liquid. At the same time, the absence of any local refining means that, in a severe disruption of regional product flows, there is no fall-back option to convert crude into fuels domestically. The only realistic buffers are strategic stocks, commercial inventories and access to foreign refining centres.

Geography and infrastructure patterns amplify these differences. Western and central Europe benefit from dense product pipeline networks and, in a few corridors, navigable inland waterways that connect ports, refineries and inland demand centres[268]. Around the Baltic Sea the picture is very different. Population density is low, demand centres are scattered, and there is little or no economic case for long-distance product pipelines or large-scale barge transport. Road, rail and short-sea shipping remain the dominant modes. For Lithuania, Latvia and Estonia this means that almost all refined products must pass through a limited number of ports and storage clusters; for Finland, it reinforces the importance of its own refinery–terminal complexes. Transport disruptions, port blockages or damage to a handful of key terminals would therefore have outsized effects compared with more interconnected regions. From a strategic perspective several conclusions follow:

1. First, Lithuanian refining capacity is not a dispensable legacy asset; it is a critical pillar of Baltic oil security. As the only refinery in the three Baltic States, Mažeikiai provides domestic optionality and regional stabilisation.
2. Second, Finland's refinery system functions as a northern balancing hub. It offers redundancy for Finnish consumers and, if needed, can help cover part of Baltic product demand in stress scenarios. Maintaining this capacity in line with climate policy, through efficiency upgrades, fuel switching, low-sulphur products and, over time, bio- and e-fuel integration, is a genuine security investment, not just an industrial one.

[266] NESTE. *NESTE annual report 2024.* https://mb.cision.com/Main/16699/4112211/3291298.pdf
[267] IEA. (2023). *Estonia Energy Policy Review.*
[268] NATO (2021). *Central Europe Pipeline System (ceps).* https://www.nato.int/en/what-we-do/deterrence-and-defence/central-europe-pipeline-system-ceps

3. Third, Latvia and Estonia must compensate for the absence of refineries by over-performing on downstream resilience. That implies adequate strategic stocks, diversified long-term contracts with multiple suppliers, high-reliability port and terminal infrastructure, and formalised co-operation arrangements with Lithuania and Finland for emergency resupply. In effect, they trade industrial optionality for a “logistics-plus-stocks” security model.
4. Finally, at regional level, the combination of refineries in Lithuania and Finland and none in Latvia or Estonia creates a dependency triangle: Lithuania as the processing core for the southern Baltic, Finland as the northern hub, Latvia and Estonia as consumption and transit nodes in between. As oil demand gradually declines in line with decarbonisation pathways, European refineries are increasingly expected to evolve rather than disappear. In the Baltic–Nordic region, existing refining assets are more likely to undergo progressive transformation towards sustainable fuel production – including advanced biofuels, synthetic fuels and low-carbon blends – while continuing to serve as essential security infrastructure for the foreseeable future. This transition still requires careful strategic oversight. If the pace of technological conversion, ownership change or regulatory adjustment outstrips the region’s ability to maintain reliable fuel supply, security of supply could be weakened before alternative technologies and infrastructure fully mature. Therefore, the challenge is not to prevent refinery decline, but to ensure that their functional repurposing occurs in a controlled, security-conscious manner that preserves resilience throughout the transition period.

This logic suggests that refining policy, infrastructure protection and regional emergency planning should be treated as integral parts of Baltic energy security strategy, not as narrow industrial policy issues.

5.2.4.3. Oil Pipelines

Strategic assessment of the Lithuania–Latvia crude oil pipeline from an energy security perspective. The crude oil pipeline connection between Lithuania and Latvia – linking the Mažeikiai refinery with Latvia’s oil transport network – should be understood primarily as legacy and contingency infrastructure rather than as an active supply corridor. ORLEN Lietuva owns a crude oil pipeline leading to Ventspils, as well as a separate products pipeline supplying diesel fuel to Ventspils[269], reflecting historical cross-border integration of the Baltic oil system. Lithuania’s crude oil system is overwhelmingly oriented toward seaborne imports via the Būtingė Offshore Terminal, which serves as the exclusive maritime entry point for crude oil supplied to the Mažeikiai refinery. As a result, the Lithuania–Latvia pipeline does not materially reduce Lithuania’s exposure to maritime logistics or tanker-based supply risks.

From an energy security perspective, the pipeline retains relevance as a contingency asset. Its physical existence provides limited but non-negligible optionality for cross-border re-routing or balancing of crude flows under exceptional conditions, such as prolonged disruption of port infrastructure or severe regional supply stress. For Latvia, which lacks domestic refining capacity, the pipeline does not constitute a primary crude supply route but rather reflects structural integration with Lithuania’s refining system. While this strengthens regional connectivity, it simultaneously reinforces dependency on a single refining hub, concentrating risk around the Mažeikiai complex.

[269] ORLEN (n.d.). *Terminal and Pipelines*. https://www.orlenlietuva.lt/EN/Company/OL/Pages/Terminal-and-Pipelines.aspx

In geopolitical and security terms, the pipeline thus exhibits a dual character: it contributes to infrastructural cohesion and regional connectivity, while also reinforcing concentration risks around the Lithuanian refining hub. Against the backdrop of hybrid threats, sabotage risks and increasing sensitivity of critical energy infrastructure in Europe, the Lithuania–Latvia crude pipeline should therefore be treated as a strategic reserve capability rather than a primary supply solution, valuable primarily for emergency routing and systemic elasticity under exceptional stress scenarios, provided it is preserved, monitored and incorporated into contingency planning frameworks.

In the longer-term transition context, as refineries progressively shift towards sustainable fuel production, such cross-border crude infrastructure may further evolve into a contingency-oriented asset, supporting controlled system reconfiguration and preventing abrupt security gaps during transitional phases. Estonia's fuel security architecture is fundamentally different from that of its Baltic neighbours. Instead of relying on crude-oil refining, Estonia has built a distinctive infrastructure around its domestic oil shale industry, which remains one of the most advanced and large-scale shale operations globally[270]. The strategic backbone of this system consists of four major components:

- Oil shale mining sites supplying the domestic resource base,
- Shale-oil processing plants operated primarily by Eesti Energia, KKT and VKG[271],
- Integrated storage and industrial facilities linked to mining and upgrading complexes,
- Import terminals for refined petroleum products, which complement domestic production but do not replace it.

This configuration creates a hybrid security model partial supply autonomy through domestic shale-oil production, and structural limitations stemming from the absence of classical crude-oil refining flexibility. Estonia has historically been one of the world's leading oil-shale regions. Prior to the latest EU decarbonisation constraints, annual extraction reached around 16 million tonnes, enabling Estonia to cover a substantial share of its own fuel and power demand. Highly developed processing infrastructure, particularly Enefit's 280-series plants using circulating fluidised-bed (CFB) technology, allows the conversion of oil shale into liquid fuels, electricity, and value-added chemical products[272]. This industrial ecosystem provides Estonia with a degree of primary-fuel autonomy that neither Latvia nor Lithuania possesses, as both rely entirely on imported crude or refined petroleum for their feedstock. However, Lithuania maintains a major refining complex at Mažeikiai, which ensures substantial domestic production of transport fuels even though all crude inputs are imported. In contrast, Latvia lacks both domestic resources and refining capacity.

The commercial value of shale-oil production lies primarily in the generation of intermediate shale-oil products and heavy fuel fractions suitable for industrial use, heating, and further upgrading, rather than in the large-scale domestic production of fully refined transport fuels. In certain periods, over 70% of mined oil shale in Estonia has been utilised for fuel conversion and power generation[273]. The relatively high calorific quality of shale oil and its suitability for downstream refining give Estonia a degree of security and market relevance uncommon for a state without conventional crude reserves.

[270] IEA. (2023). *Estonia Energy Policy Review.*
[271] Republic of Estonia Environment Agency (2024). Estonian Informative Inventory Report 1990-2022. https://keskkonnaportaal.ee/sites/default/files/Estonian%20Informative%20Inventory%20Report%202024_v1.pdf
[272] Skyquestt (2025). *Oil Shale Market Size, Share, and Growth Analysis*. https://www.skyquestt.com/report/oil-shale-market
[273] Skyquestt (2025). *Oil Shale Market Size, Share, and Growth Analysis*. https://www.skyquestt.com/report/oil-shale-market

Despite its strategic importance, the shale-oil model faces mounting transition pressures. EU Green Deal rules, ETS cost escalation, and climate-policy trajectories require Estonia to phase out oil-shale-based electricity by 2035 and progressively reduce industrial emissions. The volume of oil shale mined in Estonia in 2024 fell to a record low, at a little over 8.5 million tons[274]. Estonian oil shale producers have responded by investing in advanced upgrading technologies to reduce emissions intensity and maintain operational viability during the transition[275]. However, from an energy-security perspective, this introduces a structural dilemma:

- The sector remains critical for short-term resilience, providing domestic fuel production in an otherwise import-dependent region.
- Yet long-term regulatory pressure steadily erodes its economic viability, raising the risk of premature capacity decline before alternative low-carbon fuels and flexibility solutions are fully deployed.

Estonia's shale-oil infrastructure gives the state a unique buffer within the Baltic region: limited but meaningful domestic fuel autonomy, industrial conversion capacity, and export potential that can offset regional supply tensions. However, this comes with systemic vulnerabilities:

- A high concentration of assets in a geographically compact industrial zone
- Rising operational costs driven by EU climate policy
- Limited substitutability with conventional refining pathways
- Dependence on import terminals for part of the transport-fuel portfolio

As the EU energy transition accelerates, Estonia must balance two imperatives simultaneously preserving the security benefits of domestic fuel production, and managing a controlled structural shift toward cleaner technologies without creating supply-security gaps. In this regard, the Estonia shale-oil system is best understood not as a declining legacy industry, but as a strategic transitional asset, providing resilience under today's security environment while progressively adapting to a decarbonised future.

5.2.5. Hydrogen sector

In the emerging Baltic–Nordic hydrogen sector, Accessibility is currently defined by a transition from isolated, "captive" industrial islands to a projected transnational network. Unlike the oil and gas sectors, where accessibility focuses on rerouting existing flows away from Russian infrastructure, hydrogen accessibility is fundamentally about the creation of entirely new physical connectivity where none currently exists. At present, the region lacks a dedicated hydrogen transport grid, meaning accessibility is strictly limited to on-site production and consumption clusters. The strategic objective is to overcome this fragmentation through the development of cross-border corridors and localized "hydrogen valleys," transforming hydrogen from a site-specific chemical input into a tradable regional energy carrier.

5.2.5.1. Infrastructure

Hydrogen infrastructure constitutes one of the most critical and constraining elements in determining whether hydrogen can evolve from a strategic concept into a functional contributor to national and

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[274] Rane Kundla (2025). *Oil shale mining in Estonia fell to record low in 2024.* ERR.ee https://news.err.ee/1609676333/oil-shale-mining-in-estonia-fell-to-record-low-in-2024
[275] IEA. (2023). *Estonia Energy Policy Review.*

regional energy security. Across Estonia, Latvia, Lithuania and Finland, hydrogen infrastructure development remains uneven, reflecting differences in policy ambition, existing gas and port assets, industrial demand concentration and geological conditions.

Finland and the Baltic States (Estonia, Latvia, Lithuania), recognising that hydrogen transport infrastructure is a prerequisite for scaling clean hydrogen markets, not just announcing projects, have joined forces with Poland and Germany to advance the Nordic-Baltic Hydrogen Corridor (NBHC). The project foresees a new onshore hydrogen transmission corridor to move green hydrogen from Finland through Estonia, Latvia, Lithuania and Poland to Germany, explicitly aligning with the EU's hydrogen strategy and the REPowerEU agenda by supporting decarbonisation, market integration and supply diversification[276].

Institutionally, NBHC is promoted by a consortium of gas TSOs (Gasgrid Finland, Elering, Conexus Baltic Grid, Amber Grid, GAZ-SYSTEM and ONTRAS) reflecting a "system operator-led" approach to cross-border planning and implementation. In policy terms, this matters because TSOs are positioned to translate strategic targets into pipeline routing, technical standards, permitting pathways, and interoperability with the emerging European hydrogen network, reducing the risk that hydrogen remains fragmented into isolated national pilots.

From a project maturity perspective, NBHC has moved beyond concept stage into structured development. It completed a pre-feasibility study in 2024, which framed key conditions for implementation and quantified both supply potential and corridor scale. The corridor is currently described as roughly 2,500 km (main pipeline) with an indicative 48-inch (1,200 mm) diameter, and a stated ambition to transport around 2.7 Mt H_2/year by 2040 (often referenced as around 91 TWh) with further upside discussed toward 2050[277,278].

The same pre-feasibility work highlights the broader opportunity: the Nordic-Baltic region's renewable hydrogen production potential is estimated at about 27.1 Mt by 2040, supporting a narrative of meaningful export capability alongside domestic demand growth[279].

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[276] NBHC (n.d.). *Nordic-Baltic Hydrogen Corridor.* https://www.nordicbaltichydrogencorridor.com
[277] Gaz-System (2022). *Nordic-Baltic hydrogen corridor*. https://www.gaz-system.pl/en/hydrogen-market/projects/nordic-baltic-hydrogen-corridor.html
[278] Elering (2025). *Nordic-Baltic Hydrogen Corridor.* https://elering.ee/en/nordic-baltic-hydrogen-corridor
[279] James Burgess (2024). *Nordic-Baltic Hydrogen Corridor completes pre-feasibility study.* S&P Global. https://www.spglobal.com/energy/en/news-research/latest-news/energy-transition/090924-nordic-baltic-hydrogen-corridor-completes-pre-feasibility-study

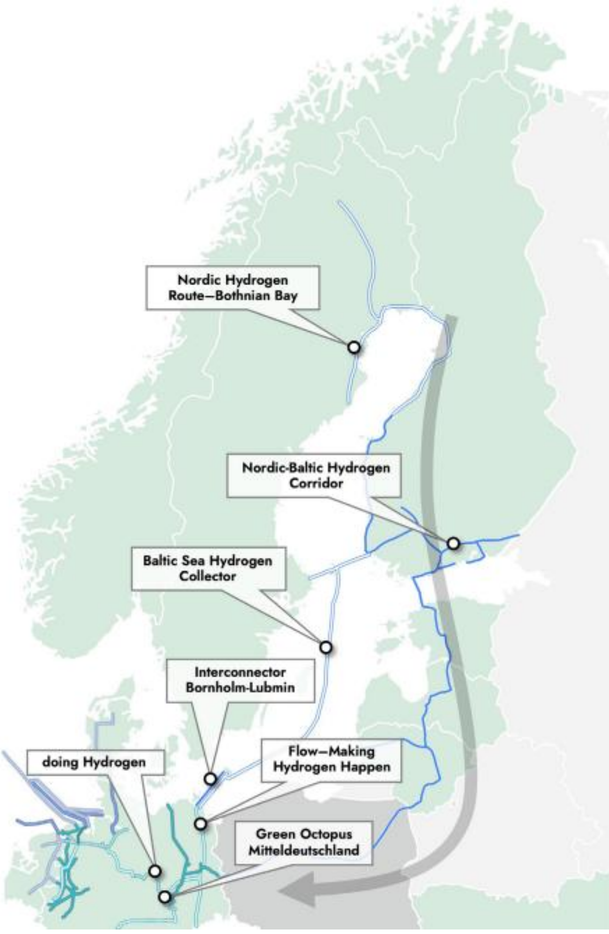

Figure 5.25. Transnational Hydrogen infrastructure. Source: European Hydrogen Backbone, 2023

Crucially for EU policy alignment, NBHC obtained Project of Common Interest (PCI) recognition in April 2024 under the BEMIP Hydrogen framework, which is intended to enable advantages such as streamlined permitting and eligibility for EU support mechanisms[280]. Following pre-feasibility, project partners entered the feasibility phase (announced late 2024/early 2025 in different partner communications) and secured Connecting Europe Facility (CEF) support: a maximum €6.8 million grant earmarked for in-depth feasibility studies covering technical, economic, regulatory and environmental dimensions of a large-scale cross-border hydrogen pipeline network[281].

In terms of expected benefits, NBHC is framed as a market-making corridor: (i) connecting competitive clean hydrogen supply from the Baltic Sea region to industrial clusters and consumption centres along the route and in Central Europe; (ii) enabling regional cooperation and deeper EU market integration through shared infrastructure; and (iii) strengthening energy security by reducing reliance on imported fossil fuels and improving resilience to geopolitical shocks and price volatility. Beyond transport, the corridor narrative increasingly emphasises system value, hydrogen balancing and flexibility services, and links to storage/renewables build-out where most economical,

[280] European Comission (n.d.). *Baltic Energy Market Interconnection Plan.* https://energy.ec.europa.eu/topics/infrastructure/high-level-groups/baltic-energy-market-interconnection-plan_en
[281] https://www.ontras.com/en/aktuelles/newsroom/wasserstoff-importkorridor-nbhc-erhaelt-cef-foerderung

positioning NBHC not only as an import/export line but also as a backbone for hydrogen value chains around the Baltic Sea[282,283].

Looking ahead, NBHC's publicly communicated timeline points to feasibility work culminating in the mid-to-late 2020s and an early 2030s commissioning ambition. If realised on this schedule, NBHC would likely rank among the earlier operational cross-border hydrogen pipelines in Europe, an outcome with outsized signalling value for investment decisions in electrolysers, industrial offtake, ports/logistics, and cross-sector integration in the Nordic-Baltic region.

5.2.5.2. Interim Access

Given the long lead times associated with large-scale pipelines, hydrogen accessibility in the near term is being operationalized through localized "hydrogen valley" models. These valleys integrate renewable electricity generation, electrolysis, storage, and end-use demand within confined geographic areas, creating self-contained access systems. The BalticSeaH2 initiative is the most advanced example in the region, linking Southern Finland and Estonia across the Gulf of Finland.[284]

Supported by EU funding, the project aggregates more than 25 demonstration and investment cases, aiming to establish a localized hydrogen market that connects offshore wind, industrial users, and transport applications. In Estonia in particular, national policy documents emphasize hydrogen valleys as the primary near-term mechanism for accessibility, explicitly acknowledging that nationwide pipeline networks are not expected in the short term. This shows that hydrogen access will initially be nodal rather than systemic, emerging through clusters before being integrated into broader corridors.

Ports play a central role in this nodal accessibility model, especially given the region's ambition to become a net exporter of green hydrogen and hydrogen-derived fuels. As a result, maritime infrastructure is increasingly framed as an export gateway rather than a domestic distribution hub.

- In Latvia, the Port of Liepāja has reserved land for a Power-to-X terminal, including plans for up to 1 GW of electrolysis capacity, targeting approximately 150,000 tonnes of hydrogen-equivalent output annually. Project descriptions emphasize export orientation toward European markets rather than domestic consumption.[285]
- In Finland, ports such as Oulu are emerging as northern hydrogen hubs, with plans for e-fuels and hydrogen derivatives production. Finland's national hydrogen strategy explicitly links hydrogen development to the export of high-value industrial commodities, including ammonia and synthetic fuels. [286]

[282] Gaz-System (2022). *Nordic-Baltic hydrogen corridor*.
[283] Nordic-Baltic Hydrogen Corrdor (2025). https://www.nordicbaltichydrogencorridor.com
[284] BalticSeaH2 (2025). *Creating Europe's First Large-Scale Cross-Border Hydrogen Valley*. https://balticseah2valley.eu/
[285] LSM.lv (2024). *Liepāja plans first hydrogen production plant in Latvia.* https://eng.lsm.lv/article/economy/business/10.04.2024-liepaja-plans-first-hydrogen-production-plant-in-latvia.a549823/#:~:text=The%20EU%20climate%2Dneutral%20scenario,Seen%20a%20mistake
[286] HydrogenInsight (2025). Hy2gen unveils 200MW green hydrogen/e-fuels project in central Finland https://www.hydrogeninsight.com/transport/hy2gen-unveils-200mw-green-hydrogen-e-fuels-project-in-central-finland/2-1-1906954 HydrogenInsight (2025). *Hy2gen unveils 200MW green hydrogen/e-fuels project in central Finland.* https://www.hydrogeninsight.com/transport/hy2gen-unveils-200mw-green-hydrogen-e-fuels-project-in-central-finland/2-1-1906954

- In Lithuania, the Port of Klaipėda is developing a multi-megawatt electrolyzer to supply green hydrogen for maritime vessels and heavy road transport, creating a multi-modal access node linking shipping and land-based logistics. Accessibility for the transport sector remains the least developed dimension. [287]

Latvia has established the Baltic region's first operational hydrogen refuelling node in Riga, supplying hydrogen-powered trolleybuses and serving as an initial access point along TEN-T corridors. Lithuania's hydrogen strategy sets a target of at least 10 hydrogen refuelling stations by 2030, primarily to support heavy-duty and freight transport. However, across the wider region, hydrogen mobility remains constrained by the absence of a continuous, cross-border refuelling network, limiting interoperability and market uptake. Structural barriers continue to restrict hydrogen accessibility. The Baltic–Nordic region lacks geological hydrogen storage options, such as salt caverns, which complicates seasonal balancing and reduces supply reliability during periods of low renewable generation. While blending hydrogen into existing natural gas grids is frequently discussed as an interim solution, national strategies–particularly in Lithuania–treat blending above 5–10% as experimental, citing technical, regulatory, and safety constraints. Consequently, true, system-wide hydrogen accessibility remains contingent on the future construction of dedicated transmission infrastructure, especially the NBHC pipeline.

5.1.5. Indicators: Accessibility

Market Integration and Infrastructure Connectivity

Accessibility assesses the ability of nations to trade energy and the reliability of the delivery infrastructure. This is the strongest performing dimension for the region overall, reflecting massive investments in cross-border connectivity.

Table 3. Accessibility indicators and LEA EnSec scores

Indicator	Finland (FI)	Estonia (EE)	Latvia (LV)	Lithuania (LT)
Electricity Interconnection[288]	**4** (47.3%)	**5** (221.9%)	**5** (291.6%)	**5** (193.9%)
Gas N-1 Compliance	**5** (162.3%)	**3** (105%)	**5** (220.7%)	**3** (111%)
Grid Reliability (SAIDI)	**5** (12 min)	**3** (142 min)	**2** (215 min)	**1** (399 min)
Average Score	**4.7**	**3.7**	**4.0**	**3.0**

The Baltic States achieve perfect scores (5) for electricity interconnection. Driven by the synchronization project with Continental Europe, Latvia, Estonia, and Lithuania have developed transmission capacities that vastly exceed their domestic peak demand (ratios >190%). This ensures exceptional import/export flexibility.

However, a significant disparity exists in domestic grid reliability (SAIDI). Finland achieves a world-class score (5) with only 12 minutes of average annual outage time per customer, reflecting long-term

[287] Port of Klaipėda (2025). *Green Port: hydrogen production and refuelling stations.* https://portofklaipeda.lt/en/port-authority/projects/green-port-hydrogen-production-and-refuelling-stations/

[288] Ember Energy (2025). *Interconnection capacity*. https://ember-energy.org/data/europe-electricity-interconnection-data-tool/

investment in "weatherproof" underground cabling. Conversely, Lithuania (399 minutes) and Latvia (215 minutes) struggle with aging infrastructure and overhead lines susceptible to weather events, resulting in low scores (1 and 2, respectively). Lithuania especially was hit by a severe storm in the summer of 2024, which has impacted the score considerably. However, as Lithuanian DSO ("Energijos Skirstymo Operatorius") did not consider it a *force majeure,* we have kept this data point as valid.

In terms of gas infrastructure redundancy (N-1 Rule), Latvia and Finland lead (Score 5). Latvia benefits from the massive Inčukalns underground gas storage, while Finland's Inkoo LNG terminal provides a significant surplus buffer. Lithuania and Estonia meet the EU compliance standard (>100%) but possess smaller safety margins.

5.3. Affordability

Affordability is the dimension where "security" collides with reality, tangible for the household budgets and the corporate costs. It is the purely economic dimension of the energy security. While Availability and Accessibility determine if energy is present and whether it can be effectively supplied, Affordability determines the cost of energy consumption on society. It is directly connect to the economic activity as energy is the bedrock of growth. Strojny et. al. (2023) defines this dimension as not merely low prices, but as the relative cost burden placed on consumers and the ability of the national economy to maintain competitiveness while securing essential supplies.[289]

For the Baltic-Finnic region, the 3-year period between 2022 to 2024 redefined the financial logic of energy. Although Baltic States did not necessarily benefit from the cheaper Russian hydrocarbons. For example, Lithuanians paid more than Germany per cubic meter as Russian Gazprom held monopoly of gas imports. Russia has been weaponizing energy resources, especially fossil fuels, before 2022 attack against Ukraine. However, Russian resources including fossil fuels and electricity have provided an economic advantage by their ease-of-access through various connections, pipelines, and presence of Russian hydrocarbon giants like Gazprom and Lukoil in Baltic and Finnish markets.

The core contrast explored is between Finland's structural resilience–bolstered by nuclear baseload– against the Baltic States' "double exposure" to gas volatility and inflationary pressure. When it comes to affordability, a key divergence can be spotted: while the Baltics resorted to market interventions to shield consumers, Finland maintained market-conforming mechanisms to preserve price signals. Ultimately, the region is transitioning from an era defined by OPEX volatility to one of CAPEX intensity. The future affordability will be determined not by the daily price of imported fuel, but by the efficient management of the high fixed costs required to build a decarbonized, interconnected energy system.

This chapter argues that the crisis of 2022 was not solely a supply shock, but a structural price shock that exposed the diverging economic resilience of Finland compared to Estonia, Latvia, and Lithuania. The central aspect analysed is the trade-off between immediate social protection–shielding citizens from volatility–and long-term market efficiency. As supply lines were reconfigured from East to West, the cost of energy became a premium paid for national sovereignty.

[289] Strojny et. al (2023)

5.3.1. Electricity sector

In the Baltic–Nordic electricity sector, Affordability is the dimension where the structural shift from dispatchable fossil generation to weather-dependent renewables impacts the consumer wallet. The period 2019–2024 revealed that the region has transitioned from a stable, if import-dependent, pricing regime to one characterized by extreme volatility. Affordability is no longer determined by the cost of fuel inputs (like gas or oil shale) alone, but by the interplay of weather conditions, interconnector availability, and the pricing dynamics of the Nord Pool market. While the region successfully decoupled from Russian energy, the cost of this energy security was a shock to households and industries, exposing the varying resilience of national markets.

5.3.1.1. Market Dynamics and Price Formation

Electricity price formation in the Baltic–Nordic region is characterised by profound structural asymmetries that reflect generation portfolios, transmission constraints, hydrological conditions, and the increasing dominance of weather-dependent renewables. Although the Baltics and Finland belong to the same Nord Pool bidding zone architecture, their exposure to price shocks differs sharply. The period 2019–2024 highlights a system transitioning from fossil-based, supply-driven pricing to a volatility-prone, weather-driven market highly sensitive to wind, hydro, and interconnector availability.

Nordic prices historically acted as a stabilising anchor for the Baltics, but the region has experienced growing price divergence since 2021. The Baltic price area (LT–LV–EE) often decouples from Finland (FI) due to north–south transmission congestion and limited capacity on EstLink during high-price periods. From 2022 to 2024, Baltic day-ahead prices often exceeded Finnish prices during peak hours, particularly during EstLink 2 limitations and low Latvian hydro conditions. Conversely, during strong wind conditions in Lithuania, electricity prices occasionally fell below Finnish levels, although such periods remain relatively infrequent (based on hourly price data from Nord Pool).

Price formation is highly sensitive to Swedish conditions. On 12 December 2024, hourly Nord Pool prices in the Swedish bidding zone SE4 reached around 309 €/MWh, coinciding with a Lithuanian zone price of approximately 234 €/MWh, illustrating direct price transmission under stressed conditions. These episodes reflect that during high demand and low wind output, price formation in the Baltic market can be strongly influenced by conditions in neighbouring Nordic zones when cross-border capacity via NordBalt is not constrained.

Interconnector availability materially affects Baltic price dynamics. EstLink 2 was out of service from 26 January to 4 September 2024 and again from 25 December 2024 until 25 June 2025, reducing transfer capacity between Finland and Estonia. Following the December 2024 outage, Baltic day-ahead prices increased markedly compared with the preceding days, illustrating how reduced Nordic import capability can tighten the market in Estonia and Latvia. In Latvia the day-ahead price rose from €33 /MWh to €142 /MWh (December 26–27), roughly four times higher, illustrating this impact.[290]

[290] Latvian Public Media (2024). *Electricity stock prices high in Latvia Friday due to EstLink 2 damage.* https://eng.lsm.lv/article/economy/economy/27.12.2024-electricity-stock-prices-high-in-latvia-friday-due-to-estlink-2-damage.a581605

Similarly, NordBalt constraints, arising from SE4 congestion, offshore cable maintenance, or low Swedish production, reduced Lithuanian access to Nordic surplus and contributed to higher price spreads. During the planned annual NordBalt outage on 21–27 October 2024, when the cable was fully unavailable due to maintenance, wholesale electricity prices in Lithuania surged by 109% to around 120 EUR/MWh[291].

The rapid expansion of wind and solar capacity in the Baltic States has increased intra-day price volatility. In 2024, wind generation in Lithuania reached 3.49 TWh and solar generation 1.27 TWh, contributing to numerous low-price hours, particularly in summer, when prices in the Lithuanian bidding zone occasionally fell to zero or temporarily below 0 €/MWh[292]. Recent market analyses show that in Estonia, electricity prices increasingly depend on wind generation, especially in autumn and winter when solar output declines[293]. Hours with strong wind (often together with solar) are associated with very low or even negative prices, whereas periods of low wind, particularly during colder spells, coincide with marked price increases[294]. In 2023, significantly higher water inflows boosted electricity production at Latvia's Daugava hydropower plants, which collectively generated 3.7 TWh, the second-highest annual output in the past 25 years[295]. This underscores Latvia's price sensitivity to hydrology: spring floods on the Daugava can lead to unusually high hydropower output, during which Latvia often fully covers its own demand, becomes a net exporter, and sees electricity prices decline[296].

In Finland, the rapid build-out of wind power and the commissioning of the OL3 nuclear unit have transformed price formation, but not by reducing volatility. While average day-ahead prices in the Finnish bidding zone fell sharply between 2022 and 2024, the Energy Authority's volatility indicator for hourly prices rose from 86% (2022) to 100% (2023) and 163% (2024), alongside an increase in negative-price hours from 467 in 2023 to 725 in 2024 (around 10% of all hours)[297,298].

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[291] Lithuanian Energy Agency. (2024). *Didmeninės elektros kainos padidėjo dėl vykusių „NordBalt" remonto darbų bei veikusių šiluminių elektrinių*. https://www.ena.lt/Naujiena/seda-20241028/

[292] Lithuanian Energy Agency (2024). *Lietuvos energetikos sektoriaus duomenų apžvalga.* https://www.ena.lt/eda-metu-apzvalgos/

[293] M. Tooming (2024). *Volatile wind behind Estonia's fluctuating electricity prices.* ERR.ee. Volatile wind behind Estonia's fluctuating electricity prices | News | ERR

[294] Enefit (2025). *Energy market overview: Electricity price is increasingly dependent on wind energy and less on solar energy.* https://www.enefit.ee/en/-/uudised/elektrihind-soltub-uha-enam-tuuleenergiast-ja-vahem-paikeseenergiast

[295] Latvenergo (n.d.). *Generation. Daugava hydropower plants.* https://latvenergo.lv/en/par-mums/razosan

[296] D. Zalamane (2023). *Electricity prices in Latvia steadily dropping.* LSM.lv. https://eng.lsm.lv/article/economy/economy/28.04.2023-electricity-prices-in-latvia-steadily-dropping.a506680/

[297] Energy authority (2023). *National Report on the state electricity and gas markets in Finland to the European Union Agency for the Cooperation of Energy Regulators and to the European Commission.*

[298] Energy authority (2024). *National Report on the State of Electricity and Gas Markets in Finland.*

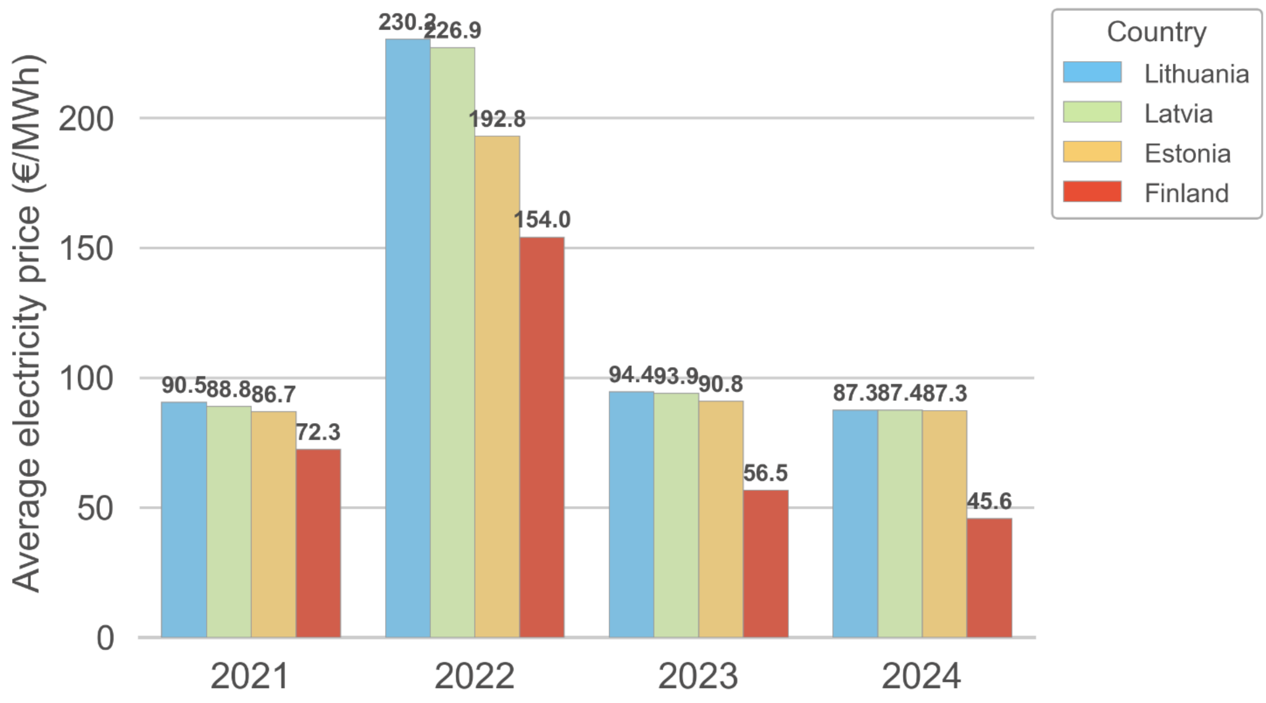

Figure 5.26. Yearly aggregated Nord Pool electricity price averages across Baltic–Nordic countries (2021–2024)

Between 2021 and 2024, Nord Pool electricity price averages show (Fig. 5.26) a shared regional trend but diverging national profiles. Prices surged dramatically in 2022 across all four markets, reflecting an exceptional regional price shock. In the subsequent years, prices moderated, though the decline has been uneven: Finland exhibits the strongest downward trend, followed by Lithuania, Estonia, and Latvia, whose averages remain closely aligned. Baltic price convergence after 2022 signals increasing market interdependence, while Finland's sharper decrease reflects its larger share of stable, low-cost generation and a higher frequency of very low-price hours. Overall, the data illustrates both the scale of the 2022 shock and the gradual return toward more differentiated, but increasingly coupled Nordic and Baltic pricing dynamics.

Several structural forces contribute to the region's increased price volatility:

1. Growing shares of wind, solar and hydro increase the sensitivity of Baltic–Nordic prices to weather variability, particularly wind conditions and hydrological inflows.
2. Remaining north–south transmission bottlenecks inside and between the Baltic countries mean that, when flows are high (e.g. during strong wind output), cross-zonal capacity is quickly saturated, and local scarcity prices are amplified.
3. In Estonia, the gradual reduction of oil-shale generation, combined with limited additions of new dispatchable capacity, can tighten medium-term adequacy margins.
4. After synchronisation with Continental Europe, Poland becomes the Baltic system's main western synchronous corridor. However, internal congestion and allocation constraints in Poland can limit the capacity made available on LitPol Link, so its role as a source of flexibility for the Baltics is often constrained in practice.
5. Because Baltic bidding zones are strongly interconnected with Sweden via NordBalt and Finland via EstLink, Baltic wholesale prices are often strongly influenced by SE3/SE4

conditions (hydro balance, wind output) and Nordic–Continental interconnector dynamics, not only by local Baltic supply–demand fundamentals.

Together, these factors generate a system where price outcomes reflect not only local production but also Finnish nuclear output, Swedish hydrology, EstLink availability, and even Central European load cycles transmitted via Poland. Looking ahead, several tendencies will shape long-term price trajectories:

- Baltic and Nordic prices may increasingly diverge, driven by persistent congestion, tighter Estonian capacity and stronger seasonal swings.
- Lithuanian and Estonian price swings may intensify**,** driven by large wind build-outs that create long stretches of very low prices but deeper scarcity when wind drops.
- Latvia will remain the key balancing state, controlling price stabilisation through hydropower availability.
- Finland will increasingly become the region's price anchor, especially as offshore wind and additional nuclear upgrades progress.
- Link to Germany may create a new westward corridor for Baltic offshore wind, ease north–south congestion, and diversify price formation beyond Nordic/Polish conditions.

The interplay between Nordic nuclear and hydro on the one hand, and weather-driven Baltic generation on the other, is likely to keep driving volatility unless significant new storage, demand flexibility, or grid reinforcements materialise. In practical terms, this means that more batteries, flexible industrial demand, smarter use of CHP plants and stronger cross-border links would be needed to absorb surplus wind and hydro and to soften price spikes when wind and inflows are low. If these investments and market changes move slowly, the region is likely to face more pronounced cycles of very low prices followed by sharp spikes: very low or even negative prices in windy, wet periods and sharp jumps when local generation and imports are constrained. Over the next decade, the key issue is whether growing weather-dependence can be managed, or whether it will continue to drive persistent price gaps and uncertainty.

5.3.1.2. Market Adequacy

As renewables grow, price volatility will increase during both surplus and scarcity periods. Frequent price collapses during high wind and price spikes during low-wind winter evenings may undermine investment certainty unless markets evolve, as illustrated by Lithuania, which in 2025 already recorded more than 100 hours with day-ahead prices at or below 0 EUR/MWh during periods of very strong wind and solar generation.

By 2030–2040, Baltic TSOs and regulators may need:

- capacity mechanisms or reliability options (particularly in Estonia and Lithuania),
- enhanced ancillary-service markets,
- new congestion-management tools,
- real-time price signals for industrial demand response,
- and harmonised rules for Baltic-wide flexibility participation.

Failure to adapt market design may accelerate adequacy deficits even in systems with rapidly expanding renewables. In particular, reliance on short-term energy-only pricing without complementary flexibility mechanisms may discourage investment in firm and dispatchable capacity, as prolonged periods of low or negative prices erode revenue streams for assets that are critical during scarcity events. The absence or delayed introduction of capacity markets, scarcity pricing reforms, and flexibility remuneration schemes (such as availability payments, fast-response reserve markets or long-duration storage incentives) risks creating a structural mismatch between installed renewable capacity and the system's ability to guarantee supply during low-wind, low-solar conditions. In such a setting, investors prioritise volume over reliability, leading to a paradox where total installed capacity grows while effective system resilience deteriorates. In this context, hydrogen production through large-scale electrolysis can emerge as a structural balancing instrument, providing price-responsive demand during renewable surplus periods while simultaneously supporting long-term decarbonisation of industry. However, without dedicated market frameworks, predictable price signals or targeted support schemes, hydrogen risks evolving as an opportunistic rather than systemic stabilising component of the power system.

5.3.2. Nuclear sector

In nuclear sector, affordability is a key issue. Post–2022 security turn sharpens the nuclear edge as it is exactly what states seeking energy independence and sovereignty need: stable base generation. But that stability is purchased through a very high upfront CAPEX, long lead times, and financing risk. Affordability in this case is decided less by the uranium price than by interest rates, construction discipline, and how liabilities (waste + decommissioning) are funded. As stated in Estonian nuclear feasibility study – most life-cycle cost is incurred before the first MWh is produced, and nuclear LCOE is unusually sensitive to the cost of capital—precisely the variable that worsened across Europe in 2022–2024.[299]

On the other hand, Finland demonstrates the upside of already paid for baseload generation. When Nordic power prices averaged €135.86/MWh in 2022, then fell to €56.44/MWh in 2023 and €42.01/MWh in 2024**,** the system moved from scarcity pricing to surplus conditions—yet nuclear's value was that its production economics stayed comparatively stable while gas-linked volatility whipsawed the market.[300] Under TVO's Mankala cost-price model, the rolling average three year cost of Olkiluoto generation was €21.96/MWh. Such low and stable prices not only are a great indicator of energy security, but also provide a safety net for energy intensive industry.[301] However, Finland demonstrates a CAPEX risk as well. Olkiluoto 3's decade-long delay and overruns pushed the project's total reported cost to roughly €11 billion, even though the plant began regular production in April 2023.[302] In the nuclear context, affordability also includes end-of-life costs: Finnish National Nuclear Waste Management Fund reported €3.1 billion in assets at end-2024, stated to cover

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[299] Ministry of Climate of Estonia. (2024). *Final Report: Possibilities for the Implementation of Nuclear Energy in Estonia*. https://kliimaministeerium.ee/sites/default/files/documents/2024-02/Final%20Report%20-%20Possibilities%20for%20the%20Implementation%20of%20Nuclear%20Energy%20in%20Estonia.pdf

[300] Anne Kauranen (2024). Finland's Fortum says new nuclear not feasible at current prices. Reuters.com https://www.reuters.com/business/energy/finlands-fortum-says-new-nuclear-not-feasible-current-prices-2024-08-15

[301] Teollisuuden Voima Oyj. (2023). *Teollisuuden Voima's Annual and Sustainability Report 2023*. https://www.tvo.fi/material/sites/tvo/pdft/d2mapqetq/TVO_Annual_Sustainability_Report_2023_final.pdf

[302] Teollisuuden Voima Oyj. (2023). *Regular electricity production has started at Olkiluoto 3 EPR* (Press release, 16 April 2023. https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2023/regularelectricityproductionhasstartedatolkiluoto3epr.html

remaining waste management costs including dismantling of existing nuclear facilities.[303] In addition, an accessibility/affordability concern is nuclear fuel. In the case of Finland, the major costs were incurred during Loviisa plant's transition to Westinghouse fuel following an agreement in November 2022. It stands as an example where "non-Russian" supply chain resilience can carry transitional costs but is treated as a premium for sovereignty.

For the Baltic States, this affordability conversation is contradictory. The region is looking at new nuclear options (mostly Small Modular Reactors), but Lithuania is still paying the steep price for its old Ignalina plant. A 2021 audit pegged Ignalina's decommissioning cost at €3.3 billion, noting that the EU has historically covered about 85% of the bill.[304] Beyond simply dismantling the plant, the real long-term cost is waste management. Regulators note that dry fuel storage and a planned deep geological repository (scheduled for 2068) involve decades of construction and operation—meaning costs continue to pile up long after the electricity stops flowing. This expensive history makes the region cautious about new spending.

Estonia is the only Baltic state to offer a concrete public cost model between 2022 and 2024. The government's 2024 nuclear feasibility report outlines specific figures based on developer estimates: €1.55 billion to build the first reactor and €1.35 billion for the second. It creates a model where operating costs—which cover everything from fuel to waste and decommissioning fees—sit at roughly €20/MWh. Even though nuclear saves money on imported fossil fuels in the long run, but demands massive upfront capital. Because of this heavy initial investment, the report emphasizes that even tiny shifts in financing terms can drastically alter the final price of electricity. (Ministry of Climate of Estonia, 2024).[305] Consequently, affordability for Estonia doesn't depend on the price of uranium, but on the cost of money. The real challenge is whether the state can reduce risk enough—through long-term contracts or guarantees—to keep interest rates (WACC) down. That challenge became much harder after rates rose in 2022, even as the security situation made nuclear power more attractive.

5.3.3. Natural gas sector

In the Baltic–Finnic region, the period between 2022 and 2024 redefined the financial logic of natural gas. Affordability is the dimension where security strategy collides with economic reality, tangible for household budgets and corporate balance sheets. While the shift from Russian pipelines to global LNG secured physical Availability and maritime Accessibility, it fundamentally altered the Affordability equation. The region transitioned from an era defined by monopolistic pricing constraints to one that is captured by global market volatility. The current gas system of the Baltic States and Finland is based on "sovereignty premium"–the inherent cost of independence.

This section argues that the gas crisis of 2022 was not a supply shock, but rather a structural price shock that exposed the diverging economic resilience of the four nations. The analysis explores how the cost of energy became a mechanism of demand destruction and how the region is moving toward

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[303] Ministry of Economic Affairs and Employment of Finland. (2025). *Financial statement for 2024 of National Nuclear Waste Management Fund has been adopted*. https://tem.fi/en/-/financial-statement-for-2024-of-national-nuclear-waste-management-fund-has-been-adopted
[304] National Audit Office of Lithuania (2021). *Decommissioning process of the Ignalina Nuclear Power Plant*. https://www.valstybeskontrole.lt/EN/Product/Download/4097
[305] Ministry of Climate of Estonia. (2024). *Final Report: Possibilities for the Implementation of Nuclear Energy in Estonia*. https://kliimaministeerium.ee/sites/default/files/documents/2024-02/Final%20Report%20-%20Possibilities%20for%20the%20Implementation%20of%20Nuclear%20Energy%20in%20Estonia.pdf

a future where affordability is determined not just by fuel prices, but by the management of high fixed infrastructure costs in a shrinking market.

5.3.3.1. Market Dynamics and Price Formation

The transformation of the Baltic–Nordic gas market after 2022 fundamentally altered not only physical supply patterns, but also the mechanisms of price formation, risk transmission and market behaviour. Whereas the pre-crisis gas market was largely anchored to long-term pipeline-based contracts and relatively stable hub-linked pricing, the post-crisis system is now structurally embedded in the global LNG spot market, with substantially higher short-term volatility, stronger exposure to geopolitical events and significantly elevated price transmission into domestic economies[306].

Prior to 2022, regional gas pricing for Lithuania, Latvia and Estonia was closely aligned with a combination of long-term Russian pipeline contracts and regional trading through GET Baltic, while Finland operated under a derogation-based, quasi-monopolistic import regime[307]. In this configuration, price volatility was moderate, and industrial, district heating and household consumers were largely shielded from abrupt market shocks through contract averaging and regulatory buffers.

This regime collapsed in 2022. The rapid pivot toward LNG-based procurement immediately exposed all four countries to TTF-driven and global LNG price dynamics (see **Table 4**), in which European prices were increasingly shaped by competition with Asian demand, shipping constraints and geopolitical risk premium[308]. Under these conditions, gas prices no longer functioned as a marginal production input, but as a system-wide macroeconomic shock variable, affecting inflation, industrial competitiveness and household affordability simultaneously.

Table 4. TTF front-month natural gas price dynamics, 2021–2024 (Data source: Trading Economics[309])

Period	*Average TTF price (EUR/MWh)*	*Maximum monthly average (EUR/MWh)*	*Minimum monthly average (EUR/MWh)*	*Price range (max-min) (EUR/MWh)*	*Key market context*
2021	45	102 (Dec)	16 (Mar)	86	Pre-crisis tightening, recovery-driven demand
2022	**135**	**221 (Sep)**	**80 (Feb)**	**141**	**Russian supply cut, LNG scramble, geopolitical shock**
2023	42	69 (Jan)	29 (Jun)	40	Demand destruction, mild winter, LNG oversupply
2024	35	46 (Dec)	28 (Apr)	27	Structural decoupling from pipeline gas, stabilisation

306 IEA (2022).*Gas Market Report, Q4-2022.*
307 ACER (2022) *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2021.*
308 IEA (2022). *Gas Market Report, Q4-2023.*
309 Trading Economics (n.d.). *Natural Gas*. https://tradingeconomics.com/commodity/natural-gas

In Lithuania, the price shock was transmitted most violently into the industrial sector. While physical supply via Klaipėda LNG remained uninterrupted, wholesale prices surged to levels that rendered ammonia production at AB Achema economically unsustainable. The suspension of production in September 2022[310] demonstrates the core characteristic of the new price regime: market clearing occurred through demand destruction rather than through supply rationing. Gas was available, but at prices incompatible with energy-intensive export production. Although price levels moderated in 2023–2024, Lithuanian industrial gas demand remains structurally conditioned by expectations of renewed price spikes rather than by pre-crisis stability assumptions.

At the retail level, Lithuanian household gas consumers were partially insulated through regulatory price controls and delayed tariff adjustment, which postponed full price pass-through by roughly one year[311]. This regulated buffering softened the socio-political impact of the shock in the short term, but also created a temporal dislocation between wholesale market reality and retail consumer signals, delaying behavioural adjustment and energy efficiency incentives.

In Finland, the price channel interacted with a fundamentally different institutional structure. The abrupt loss of Russian supply coincided with extreme spot market prices, but Finland's emergency response relied far less on price mediation and far more on direct fuel substitution in CHP generation and industry[312]. Gas prices therefore functioned less as a consumer signal and more as a systemic trigger for immediate cross-fuel switching. As a result, Finland's gas demand collapsed independently of retail price formation mechanisms, driven primarily by the operational logic of energy utilities and large industrial users.

In Estonia, the gas price shock accelerated an already ongoing heating-sector transition. Rising prices reinforced the economic rationale for biomass-based district heating and alternative heating technologies[313]. In this context, gas prices acted not merely as short-term market signals, but as structural exit incentives, speeding up the displacement of gas from the heating segment. Estonia's experience illustrates how price dynamics can function as a transition accelerator rather than only as a volatility risk.

In Latvia, rising prices did not primarily trigger abrupt industrial shutdowns, but instead reinforced an already advanced shift away from gas in district heating and CHP, where biomass rapidly displaced natural gas after 2022[314]. In this context, gas prices functioned less as a marginal consumer signal and more as a structural pressure accelerating fuel substitution in heat supply, while overall system adequacy was preserved through withdrawals from Inčukalns storage and regional LNG access. Latvia's experience thus illustrates a price-driven transition pathway in which gas demand adjustment occurred mainly through fuel switching and demand compression in heating, rather than through market exit by large industrial consumers.

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[310] Achema (2022). *Nevaldomai brangstant gamtinėms dujoms, bendrovė „Achema" laikinai stabdo gamyklos veiklą.* https://www.achema.lt/en/naujienos/nevaldomai-brangstant-gamtinems-dujoms-bendrove-achema-laikinai-stabdo-gamyklos-veikla/

[311] European Commission (2023). *Lithuana, 2023 Country report.*

[312] IEA (2023). *Finland: Energy Policy Review.*

[313] IEA. (2023). *Estonia Energy Policy Review.*

[314] IEA (2024). *Latvia: Energy Policy Review.*

At the regional market level, the establishment of the FinEstLat market zone[315] created an integrated trading space for Finland, Estonia and Latvia with harmonised balancing rules and tariff structures. In principle, this integration should enhance price convergence, liquidity and cross-border arbitrage. However, the events of 2022–2023 demonstrated that market integration under extreme stress amplifies rather than dampens volatility, as price shocks propagate instantly across interconnected systems. Under LNG-dominated supply conditions, regional prices no longer reflect local marginal costs, but rather the opportunity cost of cargoes in a globally contested LNG market.

An important post-crisis characteristic of the gas market is the emergence of a dual price logic. For industrial users and CHP producers, prices now reflect real-time international LNG and hub dynamics. For households and protected consumers, prices remain partially mediated through regulatory intervention, price caps or delayed tariff indexation. This duality generates asymmetric behavioural responses: while industry reacts through immediate curtailment or fuel switching (See Table 5), households adjust more gradually, often with significant policy lag (See Table 6)[316].

Table 5. Non-household natural gas prices in the Baltic States, H1 2021–H2 2024 (EUR/kWh) (Data source: Eurostat[317])

Country	2021-H1	2021-H2	2022-H1	2022-H2	2023-H1	2023-H2	2024-H1	2024-H2
Estonia	0.0382	0.0789	0.1246	**0.1768**	0.1045	0.0731	0.0651	0.0740
Latvia	0.0316	0.0646	0.0946	**0.1786**	0.1269	0.0822	0.0670	0.0717
Lithuania	0.0341	0.0936	0.1223	**0.1380**	0.0938	0.0699	0.0526	0.0560

Note: Prices refer to average non-household gas prices across all consumption bands, including taxes and levies. Comparable household gas price data for Finland are not available.

Table 6. Household natural gas prices in the Baltic States, H1 2021–H2 2024 (EUR/kWh) (Data source: Eurostat[318])

Country	2021-H1	2021-H2	2022-H1	2022-H2	2023-H1	2023-H2	2024-H1	2024-H2
Estonia	0.045	0.069	0.105	0.104	**0.112**	0.080	0.068	0.080
Latvia	0.048	0.079	0.088	0.158	**0.160**	0.130	0.144	0.141
Lithuania	0.037	0.049	0.062	0.134	**0.195**	0.155	0.082	0.069

Note: Prices refer to average household gas prices across all consumption bands, including taxes and levies. Comparable household gas price data for Finland are not available.

The interaction between declining demand and persistent price volatility creates a second-order market distortion. As absolute gas consumption shrinks, fixed infrastructure costs are recovered over a smaller sales base, exerting upward pressure on network tariffs even as commodity prices normalise.

[315] VERT (2020). *Baltijos šalių energetikos reguliuotojų susitikime – dėmesys elektros ir gamtinių dujų rinkoms.* https://vert.lt/Puslapiai/naujienos/2020-metai/2020-rugsejis/reguliuotoju-susitikime-demesys-elektros-ir-duju-rinkoms.aspx
[316] European Commission (2024). *Study on energy prices and costs - evaluating impacts on households and industry's costs – 2024 edition.*
[317] Eurostat (n.d.) *Natural gas price statistics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Natural_gas_price_statistics
[318] Eurostat (n.d.) *Natural gas price statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Natural_gas_price_statistics*

This mechanism risks transforming gas from a volatile energy carrier into a structurally high-cost residual fuel, further reinforcing long-term demand erosion.

From a systemic perspective, the Baltic–Nordic gas market has thus entered a regime in which price formation is no longer primarily a regional equilibrium mechanism, but a transmission channel for global geopolitical risk into domestic energy systems. The decoupling of regional prices from local supply–demand fundamentals undermines the traditional role of price as a stabilising signal and replaces it with a risk-driven volatility regime.

In sum, post-2022 gas price dynamics in Lithuania, Estonia and Finland display three defining features:
(i) direct exposure to global LNG volatility,
(ii) asymmetric transmission across industrial and household consumers, and
(iii) a reinforcing interaction between high prices and structural demand decline. Latvia's position within this new regime remains insufficiently documented in the available material.

5.3.4. Oil sector

In the Baltic–Nordic oil sector, Affordability is the dimension where security strategy collides with economic reality. It is the tangible cost of sovereignty. The period between 2022 and 2024 redefined the financial logic of energy, transitioning the region from a pricing environment influenced by stable, long-term supply arrangements to one governed by the volatility of global spot markets. While the pivot to diversified maritime imports secured physical availability, it fundamentally altered the affordability equation. The region has traded the political risks of Russian monopoly for the economic risks of global market exposure, resulting in a system where fuel is secure but structurally more sensitive to external price shocks.

5.3.4.1. Market Dynamics and Price Formation

The oil markets of Lithuania, Latvia, Estonia and Finland operate within an increasingly globalised and highly volatile pricing environment, where national fuel prices are shaped less by domestic production structures and more by international crude benchmarks, refined product spreads, regulatory frameworks and logistical costs. Since the termination of Russian oil imports[319],[320],[321],[322] the Baltic–Nordic region has fully integrated into global oil price dynamics, exposing national economies to external shocks originating far beyond the immediate geographical neighbourhood.

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[319] Ministry of Energy of the Republic of Lithuania (2022). https://enmin.lrv.lt/en/news/no-more-russian-oil-gas-and-electricity-imports-in-lithuania-from-sunday/
[320] IEA. (2023). *Estonia Energy Policy Review*
[321] Bank Of Finland (2024). *The collapse of trade with Russia has had a limited effect on Finnish manufacturing*. https://www.bofbulletin.fi/en/2024/3/the-collapse-of-trade-with-russia-has-had-a-limited-effect-on-finnish-manufacturing/
[322] EuroNews (2025). *Ending Russian energy ties is a political choice, says Latvia's President Rinkēvičs*.https://www.euronews.com/my-europe/2025/09/24/ending-russian-energy-ties-is-a-political-choice-says-lavtian-president-rinkevics

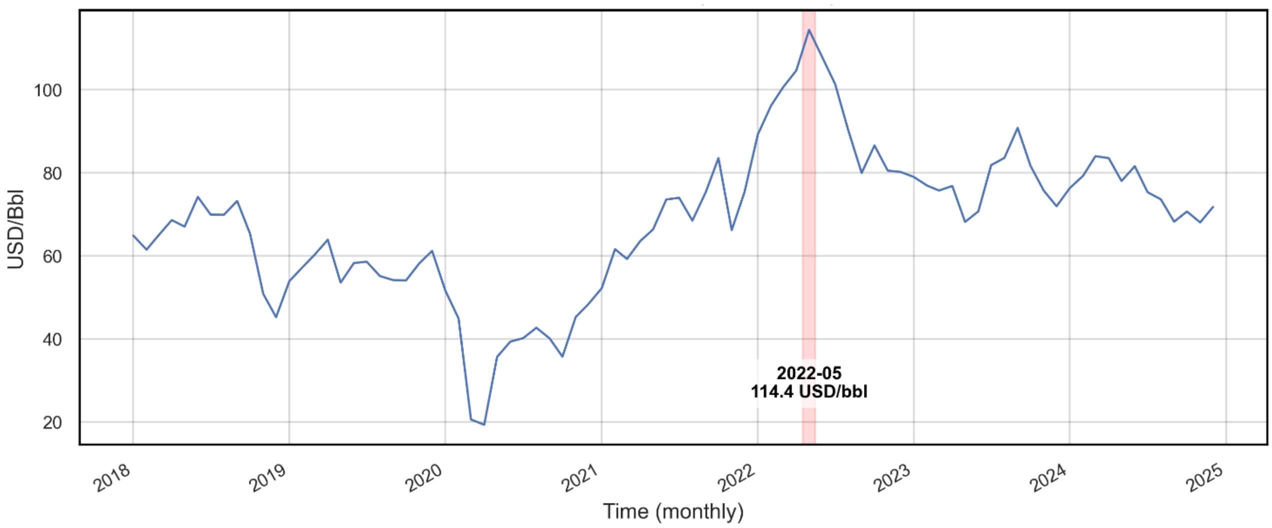

Figure 5.27. Brent crude oil price (adjusted for inflation), 2018-2025[323]

Across all four countries, the retail prices of oil products: diesel, gasoline and heating oil, are predominantly driven by international crude reference prices (Brent), refined product market dynamics in North-West Europe, and regional supply-demand balances. This integration has diminished the insulation effect previously provided by long-term stable supply arrangements, replacing it with a more market-responsive but also more volatile pricing regime.

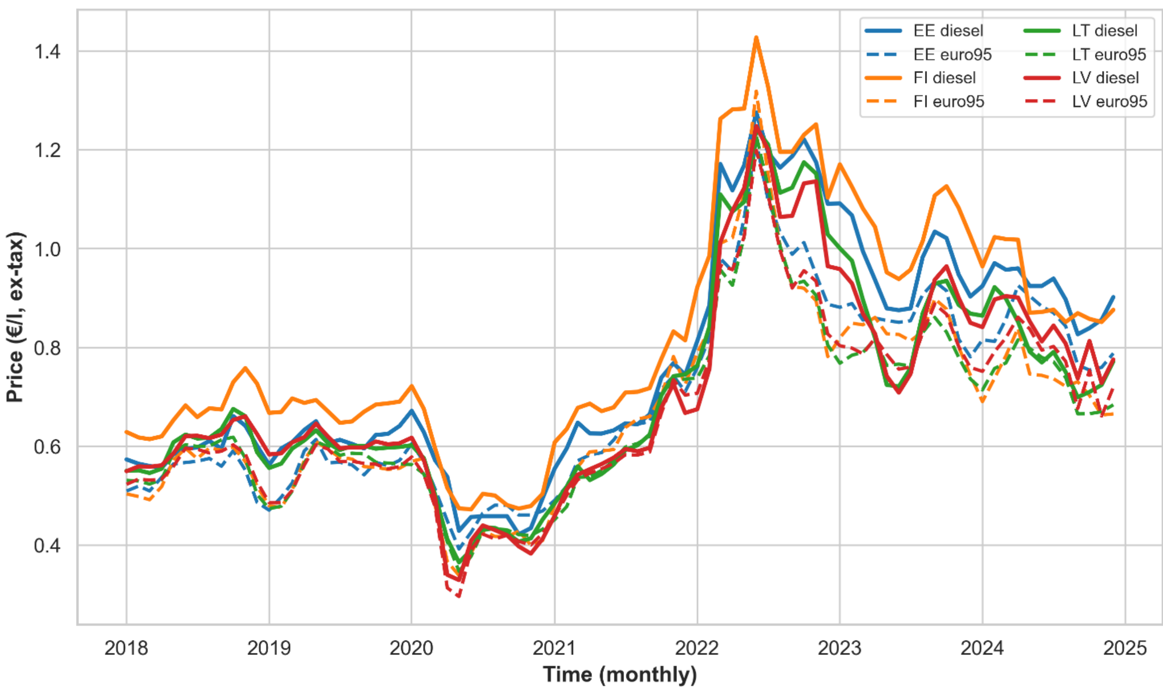

Figure 5.28. Wholesale diesel and petrol (Euro95) prices excluding taxes, 2018–2024[324]

Lithuania exhibits a unique dual exposure. While domestic refining at Mažeikiai creates some degree of supply stability, it does not shield the country from global price movements. The refinery operates

[323] Macrotrends (n.d.). *Crude oil prices data*. https://www.macrotrends.net/1369/crude-oil-price-history-chart
[324] European Commission (n.d.). *Weekly Oil Bulletin*. https://energy.ec.europa.eu/data-and-analysis/weekly-oil-bulletin_en

under international market conditions, with crude procurement and product sales priced against global benchmarks. As a result, Lithuanian fuel prices remain closely correlated with international market trends, with additional sensitivity stemming from refinery operational margins, maintenance cycles and logistical constraints at the Būtingė terminal.

Latvia and Estonia, as net importers of refined petroleum products, display a more direct pass-through of international price fluctuations to end consumers. The absence of domestic refining amplifies their exposure to refined product price volatility, particularly during periods of market tightness or regional supply disruptions. In such circumstances, fuel price formation is influenced by availability constraints, transport costs and temporary market imbalances, rather than solely by crude price movements. Estonia's shale oil production slightly moderates its exposure to imported crude dependency, but this effect is limited. Shale-derived fuels are not structurally decoupled from global pricing trends, as production costs are high and final product prices remain benchmarked to international markets. Consequently, the protective effect of domestic shale oil is primarily strategic in supply availability terms, rather than price stabilisation.

Finland demonstrates a comparatively more complex pricing structure. While still subject to the same global forces shaping fuel price formation, Finland's more mature energy market and broader infrastructural capacity allow for somewhat smoother price transmission dynamics. However, even within Finland, fuel prices remain highly responsive to international market volatility, especially during periods of global geopolitical instability or supply chain disruption.

Across the region, regulatory mechanisms such as excise duties, carbon pricing and fuel taxation play a significant role in shaping end-user prices. These policy instruments increasingly constitute a material share of final retail fuel prices and serve as both fiscal tools and behavioural levers within broader decarbonisation strategies. The proportion of tax components in fuel pricing therefore introduces an additional layer of political sensitivity, particularly during periods of rapid price escalation.

The oil price shock of 2022[325] demonstrated the systemic vulnerability of the region to global energy crises. Rapid price escalation translated into immediate inflationary pressure, disproportionately affecting transport-intensive sectors, household expenditure and logistics chains. Although price levels subsequently stabilised, the episode revealed that the region remains structurally exposed to external price volatility, with limited domestic mechanisms for price buffering.

The relationship between crude oil benchmarks and wholesale fuel prices in the Baltic–Nordic region further reinforces this vulnerability. Regression analysis indicates a strong and consistent pass-through from Brent prices to wholesale diesel costs, with a clearer correlation once a one-month lag is introduced, reflecting the operational realities of refinery cycles, shipping times and inventory turnover. Although the magnitude of the pass-through varies slightly across countries, the overall pattern shows that global crude price movements remain the dominant driver of underlying fuel costs, while national taxation layers modulate the retail outcome. In practical terms, this means that a 10 USD/bbl increase in Brent typically translates into approximately €0.10–0.12/l in wholesale diesel price growth across the region, underscoring that the countries differ more in tax policy than in underlying market behaviour.

[325] IEA (2022). *World Energy Outlook 2022.* https://www.iea.org/reports/world-energy-outlook-2022

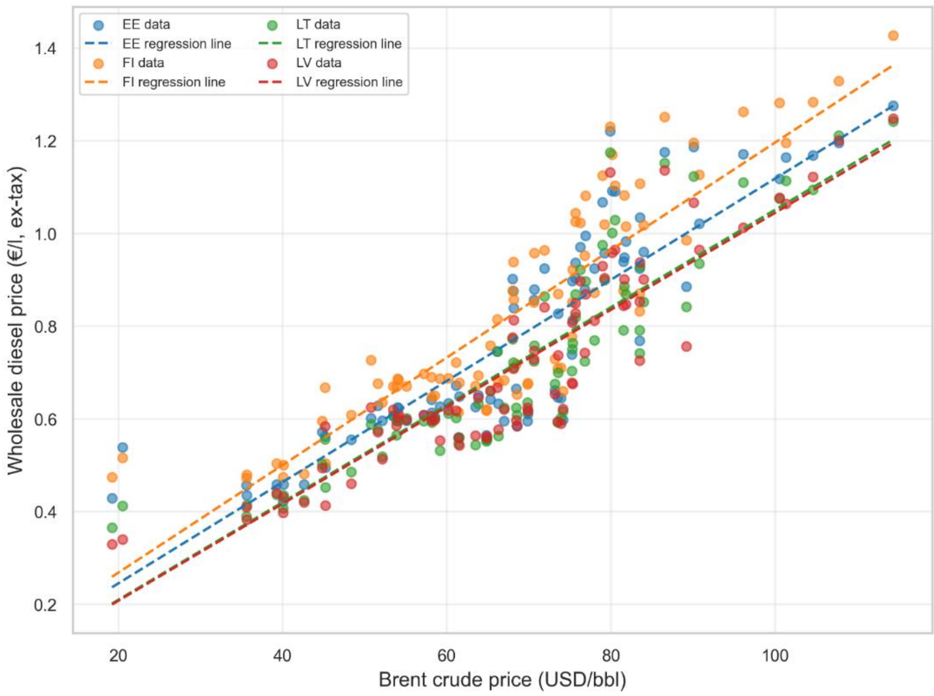

Figure 5.29. Brent crude oil price vs wholesale diesel price in Baltic–Nordic countries, 2018-2025 (based on EC weekly oil bulletin and historical data of Brent (Europe) crude oil prices)

Market dynamics in the Baltic–Nordic oil system must therefore be understood as a complex interaction between global benchmark dependency, regional logistics performance and national regulatory frameworks. Price formation no longer reflects local production cost structures but rather a layered system of international pricing signals, policy-driven mark-ups and infrastructure-based constraints.

5.3.5. Hydrogen sector

In the Baltic–Nordic hydrogen sector, Affordability is currently the primary barrier to market formation. Unlike established energy commodities where affordability focuses on consumer price stability, hydrogen affordability focuses on the "green premium"–the stark cost difference between renewable hydrogen and incumbent fossil alternatives. Currently, the sector operates under a significant cost disadvantage: while fossil-based (grey) hydrogen trades at approximately €1/kg, green hydrogen production costs range between €4 and €8/kg. This gap renders green hydrogen economically unviable for most industrial applications without substantial public subsidy. Consequently, affordability is not defined by market equilibrium but by the efficiency of state support mechanisms and the levelized cost of renewable electricity input.

5.3.5.1. Market and Prices

Active identification and mitigation of bottlenecks across the hydrogen value chain is essential to enable the sector's growth and to create conditions for competitive hydrogen pricing. Permitting delays, regulatory uncertainty, and insufficient clarity around investment frameworks have been noted as barriers in several Nordic and Baltic contexts; addressing these through streamlined procedures and predictable investment environments can improve investor confidence and reduce effective cost of capital. Competitive electricity prices and abundant renewable energy potential are fundamental drivers of hydrogen cost competitiveness, as electricity typically accounts for 60–70 % of electrolytic hydrogen production costs. In the Nordic-Baltic region, historically low power purchase agreement (PPA) prices for onshore wind and solar, such as observed in Finland (e.g., ~36 €/MWh for wind and ~47 €/MWh for solar), support lower hydrogen production costs compared to many other EU markets, and this relative advantage is likely to persist even in the face of rising interest rates and energy market volatility that have slowed new renewable investment decisions in recent years.

The ability to align electrolyser operations with periods of high renewable generation and low electricity prices offers significant potential to reduce hydrogen production costs, however, hydrogen demand in industrial applications will likely remain comparatively stable relative to variable renewable supply. This decoupling highlights the critical role of hydrogen storage, both within transmission pipeline infrastructure and in purpose-built facilities, to balance production and consumption profiles, enable flexible electricity demand response, and absorb seasonal variability, particularly where access to geological storage (e.g., salt caverns in Central Europe) is limited. Large-scale storage capacity will therefore become increasingly valuable as renewable penetration increases and as electrolytic capacity scales up to support decarbonisation objectives[326].

Hydrogen's full potential can be unlocked in energy systems that generate substantial, low-cost renewable power surpluses, where electricity prices are consistently very low. Today, fossil-based hydrogen wholesale prices average around €1/kg, largely determined by the cost of the input energy carrier (typically natural gas or other hydrocarbons). By comparison, hydrogen produced using carbon capture and storage (CCS) pathways remains significantly more expensive at €5–8/kg, while current green hydrogen production costs range between €4–8/kg, depending primarily on renewable electricity prices, electrolyser utilisation, and financing conditions[327]. However, it is believed, that major investments in clean hydrogen production infrastructure are projected to unlock substantial economic value: estimates suggest competitive clean hydrogen pricing could reach around €2.5/kg by 2030 and ~€2.0/kg by 2040[328], levels at which annual hydrogen production in regions with strong renewable resources could be valued at billions of euros per year, with additional downstream value from hydrogen derivatives such as e-fuels. These price benchmarks provide useful reference points for assessing future hydrogen market viability in the Nordic-Baltic region, which will need to incorporate electricity price trajectories, investment cost evolution, infrastructure availability, storage economics, and policy frameworks to assess how hydrogen prices may evolve under different decarbonisation pathways.

[326] Fingrid, Gasgrid Finland (2023). *Energy transmission infrastructures as enablers of the hydrogen economy and clean energy system.* https://www.fingrid.fi/globalassets/dokumentit/en/news/energy-transmission-infrastructures-as-enablers-of-the-hydrogen-economy-and-clean-energy-system---final-report.pdf
[327] IEA (2022). *Global Hydrogen Review* 2022. https://www.iea.org/reports/global-hydrogen-review-2022/executive-summary
[328] EHB (2022). *Five hydrogen supply corridors for Europe in 2030.* https://ehb.eu/files/downloads/1653999355_EHB-Supply-corridors-presentation-Full-compressed-1.pdf

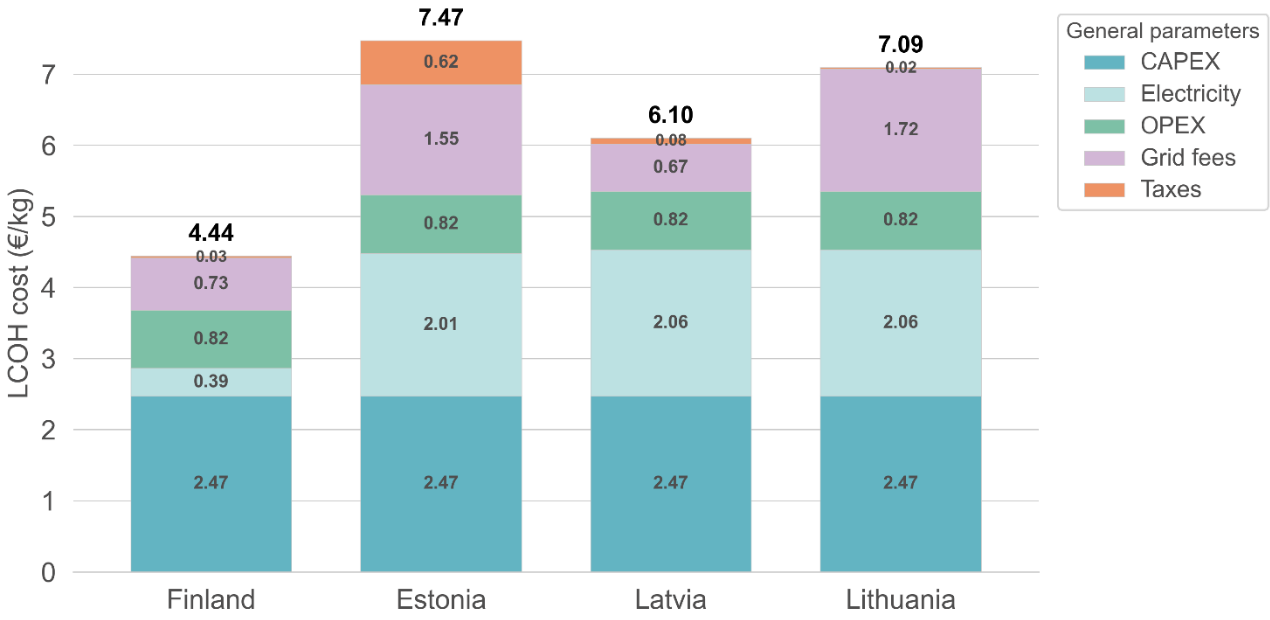

Figure 5.30. Levelized Cost of Hydrogen (LCOH) components in four countries using wholesale electricity and alkaline electrolysis (2024 as the reference year based on European Hydrogen Observatory data)

Integrating these factors into policy and system modelling enables more nuanced projections of hydrogen cost curves and the potential timing and scale of industrial uptake, while also illuminating where targeted interventions, such as support for storage infrastructure or regulatory certainty, can most effectively reduce hydrogen production costs and enhance market development[329]. It was estimated that the development of the hydrogen economy could bring 16–34 billion euros in 2035 and 41–69 billion euros in 2045 into the Finnish economy[330].

To date, the lowest estimated production cost of green hydrogen in Estonia is associated with utility scale solar parks, where levelized hydrogen production costs are assessed at approximately €4.5–5.2/kg under favourable electricity market conditions. Forward looking estimates indicate that by 2030, Estonia's most competitive green hydrogen cost levels could fall to €3.4–4.2/kg, primarily driven by declining electrolyser CAPEX, increasing utilisation rates, and lower-cost renewable electricity supply[331]. Analysis for Lithuania[332] further confirms that green hydrogen cost spans a wide range: from €2.8/kg up to €8/kg, depending on key system and market variables, including renewable wholesale electricity prices, grid charges and taxes, network tariffs, availability of storage, and hydrogen transport or infrastructure access options. These findings underline that hydrogen price competitiveness in the Nordic-Baltic region will depend less on electrolyser scale alone and more on temporal electricity price alignment, system flexibility, and the maturity of enabling infrastructure such as pipelines and large-scale storage.

[329] Fingrid, Gasgrid Finland (2023). *Energy transmission infrastructures as enablers of the hydrogen economy and clean energy system*
[330] Guidehouse, (2023). *Clean hydrogen economy strategy for Finland supporting analysis report*. Unpublished.
[331] Viks–Binsol P. et. al. (2021). *EESTI VESINIKURESSURSSIDE KASUTUSELEVÕTU ANALÜÜS.* https://www.sei.org/wp-content/uploads/2021/07/lopparuanne-vesinikuressursside-kasutamise-analuus.pdf
[332] Lithuanian Energy Agency (2024). *"LT 100" Projekto rezultatai.* https://www.ena.lt/lt100-projekto-rezultatai/

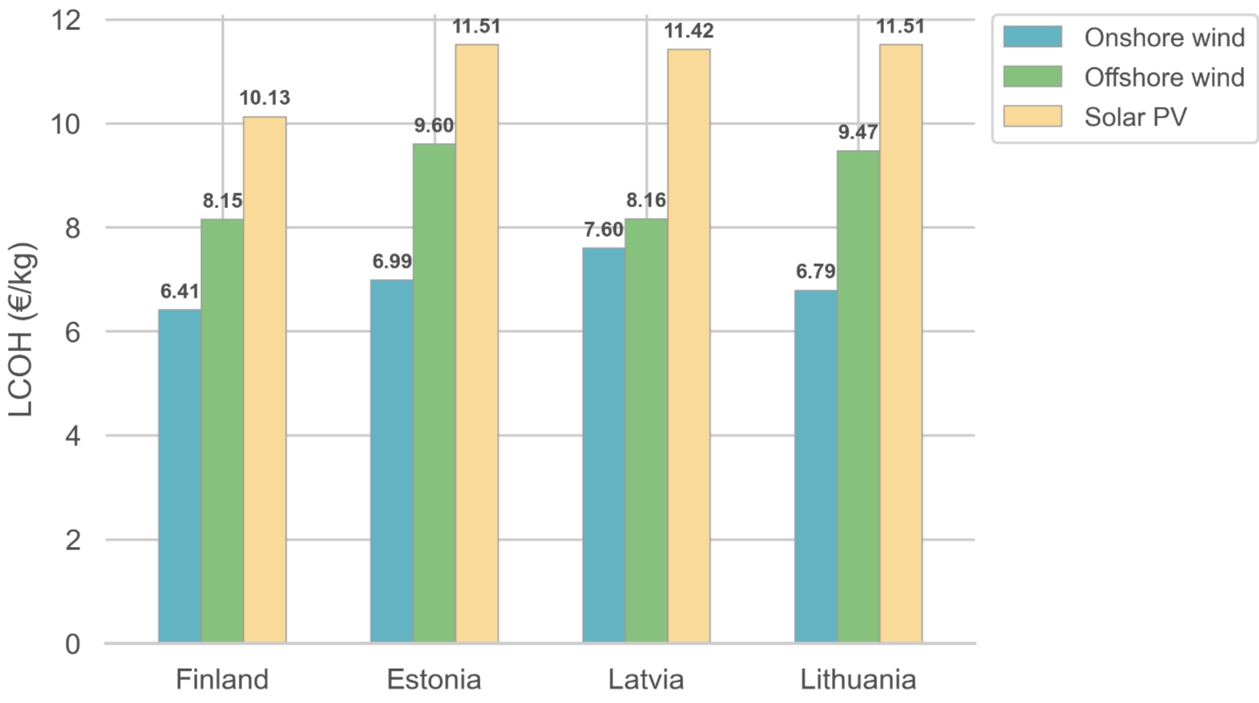

Figure 5.31. Hydrogen LCOH across countries by electricity source (2024 as the reference year based on European Hydrogen Observatory data)

Based on the European Hydrogen Observatory's LCOH calculator[333], which enables the comparison of hydrogen production costs via low-temperature water electrolysis (Alkaline or PEM) across all EU27 countries using 2024 as the reference year for electrolyser CAPEX values and electricity source data, it is possible to benchmark the Levelized Cost of Hydrogen (LCOH) for Finland and the Baltic states on a consistent methodological basis. The stacked LCOH breakdown for the wholesale electricity and alkaline electrolysis scenario (Fig. 5.30) reveals that Finland achieves the lowest cost structure (€4.44/kg), driven by exceptionally low electricity procurement costs and minimal taxes, despite similar electrolyser CAPEX assumptions (€2.47/kW across all countries). In contrast, the Baltic states show significantly higher electricity-driven LCOH outcomes, particularly Estonia (€7.47/kg) and Lithuania (€7.09/kg), where grid fees and electricity costs dominate the total cost stack. The second chart (Fig. 5.31), showing LCOH sensitivity to dedicated renewable electricity sources, demonstrates that hydrogen production in all four countries is most cost-efficient under onshore wind, while Solar PV leads to the highest LCOH values in every case. Estonia and Lithuania experience the steepest cost increase under offshore wind and Solar PV, compared to Finland and Latvia.

Key cross-country insights indicate that:

1. Electricity price and network-related charges are the main differentiators of LCOH, exceeding the influence of electrolyser CAPEX in all Baltic cases;
2. Onshore wind provides the strongest competitive advantage for hydrogen cost reduction across the region, especially for Finland and Lithuania.
3. Offshore wind does not guarantee lower LCOH unless accompanied by very low grid fees.

[333] European Hydrogen Observartory (n.d.). *Levelised Cost of Hydrogen Calculator*. https://observatory.clean-hydrogen.europa.eu/tools-reports/levelised-cost-hydrogen-calculator

4. Solar PV remains structurally expensive for hydrogen production in Northern and Baltic energy systems (>€10/kg in all countries), implying that PV-based hydrogen competitiveness by 2030 will depend heavily on surplus generation periods, storage coupling, and reduced network charges.

Additionally, Finland's uniquely low electricity cost share in the wholesale scenario highlights the importance of market access, interconnections, and flexible system balancing, while Estonia's high taxes and Lithuania's high grid fees emphasize that regulatory cost components remain a critical bottleneck for green hydrogen scaling in the Baltic region unless reformed.

5.3.6. Indicators: Affordability

Economic Burden on Consumers

Affordability measures the cost competitiveness of energy. The data reveals a clear divide between the northern and southern nations in the study group.

Table 7. Affordability indicators and LEA EnSec scores

Indicator	Finland (FI)	Estonia (EE)	Latvia (LV)	Lithuania (LT)
Household Electricity Price	**5** (€0.170)	**5** (€0.173)	**3** (€0.206)	**4** (€0.184)
Household Gas Price	**4** (€0.091)	**5** (€0.074)	**2** (€0.142)	**5** (€0.075)
Transport Fuel Affordability	**3** (Low burden)	**2** (Med burden)	**1** (High burden)	**2** (Med burden)
Average Score	**4.0**	**4.0**	**2.0**	**3.7**

Finland and Estonia share the top position (Average Score 4.0). Both countries benefit from deep integration into the Nord Pool spot market, securing the lowest electricity prices in the region. Furthermore, Estonia and Lithuania offer the most competitive gas prices (Score 5), successfully passing on the benefits of global LNG access to consumers.

Latvia acts as a regional outlier with the lowest score (2.0). It faces the highest electricity prices and a natural gas price (€0.142/kWh) that is nearly double that of its neighbors. Additionally, when adjusted for income levels, Latvia ranks lowest for transport fuel affordability (Score 1), indicating a significant cost-of-living burden on its population relative to the other studied nations.

5.4. Acceptability

Traditionally **Acceptability** is viewed as the environmental conscience of energy policy. It has been a measure of how well energy system aligns with ecological limits and societal values of a nation (Strojny et. al., 2023). Usually, the focus is directed at "social license to operate", meaning everything from greenhouse has (GHG) emissions, land-use disputes to the public's willingness to host infrastructure. However, for the Baltic-Finnish regionin the wake of 2022, the concept of Acceptability has underwent a considerable change from environmentally conscious "saving the planet" to securitized "saving the state".

As in other regions, prior to the Russian invasion of Ukraine, the debate over the energy transition in this region was characterized by a tension between the costs of decarbonization and the comfort of the status quo. The events of 2022 have resolved the tension considerably as renewable energy goals tie in well with energy independence and sovereignty. The change of direction away from Russia was framed not strictly as an environmental imperative, but more so as a patriotic duty. Energy independence became the central organizing principle, strengthening social license for rapid deployment of renewable technologies.

We explore a critical "carbon dilemma" where the LULUCF sectors in both Finland and Estonia flipped from carbon sinks to net sources of emissions[334], significantly complicating the path to climate neutrality. This degradation of natural sinks exacerbates the friction caused by the security-driven retention of carbon-intensive assets, such as Estonia's oil shale industry–which maintains one of the highest carbon intensities of energy supply among IEA members,[335] and Finland's peat reserves. Furthermore, the "social license" for transition varies significantly by national context: it manifests as an urgent economic "Just Transition" in Estonia's Ida-Viru county[336], high public support for nuclear power in Finland,[337] and a participatory "prosumer" revolution in Lithuania, where regulatory frameworks have successfully engaged the population in solar generation.[338]

This chapter analyzes how these four nations are navigating the complex trade-offs between environmental sustainability and urgent security needs. We argue that while geopolitical crisis accelerated the deployment of clean energy, it also forced difficult, temporary compromises – such as the reactivation of oil shale and peat capacities. We also explore differing narratives on energy security, independence and various accepted routes of transition in the region.

5.4.1. Electricity sector

In the Baltic–Nordic electricity sector, Acceptability has evolved from a largely passive "social license to operate" into an active, securitized mandate. Historically, the acceptability of energy projects was debated through the lens of environmental impact (e.g., opposition to new pylons or wind farms). However, the 2022 invasion of Ukraine fundamentally reframed the narrative: renewable energy infrastructure is no longer just "green"; it is "sovereign." The transition away from fossil fuels and Russian dependence has been embraced as a patriotic duty, creating an exceptionally permissive environment for infrastructure development that would have been politically difficult a decade ago. As such, policy environment has been considerably restructured to fall in line with the occurring changes.

5.4.1.1. The Securitization of the Electricity Sector

Although it falls out of the scope of the study, the clearest electricity sector experession of the new securitized environment has been the disconnection away from the Russia/Belarus–controlled

[334] International Energy Agency (2023). *Estonia 2023: Energy Policy Review.* https://iea.blob.core.windows.net/assets/8b462840-c9a6-4f71-81eb-d5acd1213e68/Estonia2023.pdf
[335] International Energy Agency (2023). *Estonia 2023: Energy Policy Review.* https://iea.blob.core.windows.net/assets/8b462840-c9a6-4f71-81eb-d5acd1213e68/Estonia2023.pdf
[336] International Energy Agency (2023). *Estonia 2023: Energy Policy Review.* https://iea.blob.core.windows.net/assets/8b462840-c9a6-4f71-81eb-d5acd1213e68/Estonia2023.pdf
[337] International Energy Agency (2023). *Finland 2023: Energy policy review*. https://www.iea.org/reports/finland-2023
[338] International Energy Agency. (2025). *Energy Policy Review: Lithuania 2025.* https://www.iea.org/reports/lithuania-2025

IPS/UPS system. Estonia, Latvia, and Lithuania did so on the 8th of February, 2025.[339] The official narrative coming out of all 3 Baltic States in regards to this multi-year project has been that of sovereignty and independence.[340] However, Russian websites and propaganda pundits have been active to delegitimize this move. At the beginning of 2025 alone, Russian portals recorded a total of 61,390 news items about Lithuania, Latvia, or Estonia, 12.6% of which were related to the energy sector.[341] The main goal of attacks through information field is to sow panic and mistrust among the populations i.e. lower the acceptability of similar actions seeking energy independence.

However, securitized acceptability indeed collides with a tightening carbon constraint: alignment with EU climate goals and climate neutrality. Finland's environment ministry reports that the LULUCF sector has been a net emissions source from 2018 onward, weakening the ability to offset electricity- and economy-wide emissions through land sinks.[342] However, Estonia's official UNFCCC reporting shows a noticeable reduction in the LULUCF sector which had net emission of 339.29 kt CO_2 in 2022. That was 58.2 % lower than in 2021.[343] It is important to note that Estonia holds other difficulties in regard to oil shale generation which still retains legitimacy as a valid back–up generation source. As such, during the 2022 crisis oil shale plants were restarted to secure supply while reducing energy ties to Russia.[344]

In terms of opinion on RES, citizens of all nations look favourably at further development of wind and solar especially. Finnish public opinion stands at 94 % of citizens support solar, and 88 % of citizens support wind energy.[345] In Latvia, numbers are similar: 78 % of Latvian society support expansion of wind.[346]

Finally, the region's "social license" for electricity transition is not uniform. It is indeed mediated through distinct participation models. Lithuania stands out for acceptability–through–participation model: the DSO ("ESO") reports over 124 000 prosumers which indicated mass engagement in solar generation rather than passive consent.[347] In addition, 88% of Lithuanians view solar energy very positively or positively, 77% view wind energy positively when produced in offshore wind farms, and 75% view wind energy positively when produced in onshore wind farms.[348]

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339 Lithuanian Ministry of Energy (2025). *Baltic States' Energy Independence Day: Lithuania, Latvia, and Estonia Synchronize with Continental European Networks.* https://enmin.lrv.lt/en/news/baltic-states-energy-independence-day-lithuania-latvia-and-estonia-synchronize-with-continental-european-networks/

340 Lithuanian Ministry of Foreign Affairs (2025). *Minister Budrys in Latvia: Baltic States are an Example of Energy Independence for Europe.* https://www.urm.lt/en/news/928/minister-budrys-in-latvia-baltic-states-are-an-example-of-energy-independence-for-europe:43481

341 Raminta Majauskaitė (2025). *Atsijungimas nuo BRELL tapo Maskvos propagandos taikiniu: siekė sukelti paniką. LRT.lt.* https://www.lrt.lt/naujienos/verslas/4/2482104/atsijungimas-nuo-brell-tapo-maskvos-propagandos-taikiniu-sieke-sukelti-panika

342 Finnish Ministry of Enviroment (2024). *Annual Climate Report 2024.* https://ym.fi/en/annual-climate-report-2024

343 Estonian Ministry of Climate (2024). *Estonia's Fist Biennial Transperency Report.* https://unfccc.int/sites/default/files/resource/EST_BTR%20I_2024.pdf

344 Janis Laizans (2022). *Estonia turns back to shale oil as it cuts off Russian power.* Reuters.com. https://www.reuters.com/business/energy/estonia-turns-back-shale-oil-it-cuts-off-russian-power-2022-10-19

345 BotH2nia (2025). *Solar and wind power remain Finland's most popular forms of energy production.* https://www.both2nia.com/en/news/solar-and-wind-power-remain-finlands-most-popular-forms-energy-production

346 Latvian Wind Energy Association (2024). *Survey: the security and stability of electricity supply is becoming increasingly important for the Latvian society; young people consistently support renewables.* https://wea.lv/en/skds-survey-2024/

347 ESO (2025). *Atsinaujinančios energetikos naujienos: gaminančių vartotojų skaičius per 2024 m. išaugo 40 procentų.* https://www.eso.lt/naujienos/atsinaujinancios-energetikos-naujienos-gaminanciu-vartotoju-skaicius-per-2024-m.-isaugo-40-procentu/4462

348 KurkLietuva (2025). *Challenges of developing green technologies and strengthening community support in Lithuania.* https://kurklietuvai.lt/projektai/challenges-of-developing-green-technologies-and-strengthening-community-support-in-lithuania

5.4.1.2. Policy Environment and Future

The profound restructuring of the Baltic–Nordic electricity system, driven by synchronization, renewable expansion, retiring fossil capacities and growing interconnector dependence, creates both strategic opportunities and new vulnerabilities. Policymaking in this environment must reconcile ambitious decarbonization with a tightening adequacy margin, growing weather-dependence and increasing exposure to external market conditions. The evidence presented across previous sections reveals several critical implications for regional governance, market design and infrastructure planning.

Strengthening regional adequacy requires coordinated investment and policy alignment. The Baltics face structurally declining dispatchable capacity, particularly in Estonia, where oil-shale retirements have outpaced the development of new firm resources. Lithuania's and Estonia's wind expansion trajectories, while necessary for the 2030 and 2050 climate goals, deepen exposure to low-wind winter periods. Latvia's hydropower stabilizes the region but cannot offset Baltic-wide scarcity during dry years. As Finland is not synchronously connected and Sweden increasingly experiences hydrology-driven volatility, the Baltics must not assume continuous availability of foreign supply. Strategic implication: adequacy must be treated as a collective Baltic challenge rather than a national issue. Joint adequacy planning, common reserve procurement and shared reliability standards will be likely essential to mitigate adequacy gaps.

Interconnector policy must evolve from trade facilitation to security-of-supply assurance. Historically, interconnectors were assessed primarily on their economic value for market integration. The new system reality with high RES penetration, volatile hydro, nuclear seasonality means interconnectors increasingly function as security assets. Outages on NordBalt or EstLink 2 immediately raise price spreads and reduce adequacy margins, while LitPol Link has become a critical westward buffer after synchronisation. Strategic implication: future interconnector development should prioritize redundancy, resilience and flexibility, not only congestion relief. This includes hybrid offshore hubs, EstLink 3, LitPol Link corridor reinforcement, and the Gulf of Riga HVDC corridor. The proposed Baltic–German offshore connection should be seen first as a tool to strengthen reliability and security of supply, and only second as a market-integration project.

The Baltics are at the edge of Europe's power system, so they have fewer alternatives when a link is constrained or out. They rely on one main western synchronous corridor, while Nordic links are HVDC cables with limited availability. This increases vulnerability to outages and Nordic hydropower swings, so more redundancy and multi-purpose interconnectors are needed. Grid reinforcement must keep pace with renewable expansion. Internal congestion in all three Baltic States limits the full utilization of existing interconnectors and renewable generation. Lithuania's north–west bottlenecks, Latvia's Kurzeme Ring constraints, and Estonia's west coast and Tartu node limitations increasingly require redispatch and curtailment. Strategic implication: transmission expansion must be synchronized with renewable deployment trajectories. This includes transparent capacity allocation for offshore wind, grid-friendly RES siting rules, and accelerated permitting reforms for 220–330 kV reinforcements.

Flexibility markets and storage must become central pillars of Baltic system development. Lithuania's adoption of utility-scale battery storage (200 MW / 200 MWh installed and >4 000 MWh planned by 2050) demonstrates the transformative potential of fast-response resources in low-inertia systems.

Estonia and Latvia remain early in storage deployment, yet the need is growing rapidly as RES penetration rises. Strategic implication: Baltic-wide flexibility markets must be developed, allowing storage, demand response and industrial flexibility to participate in balancing, congestion management and adequacy support. Regulatory frameworks must ensure predictable revenue models for batteries, particularly under the CEN synchronous regime.

Offshore wind governance must be coordinated regionally. Offshore wind ambitions differ across the region: Lithuania targets 1.4 by 2030, Latvia–Estonia are advancing ELWIND (1–2 GW after 2033), and Finland is moving towards large-scale leasing and tenders (3 GW by 2030). These projects will reshape regional flows, requiring offshore grid planning, hybrid interconnectors and fair cost allocation. Strategic implication: a Baltic–Nordic Offshore Coordination Platform should be established to align plans, share permitting practices, coordinate seabed surveys and avoid duplicated infrastructure.

Market design reforms needed to manage growing volatility. Baltic price volatility results from weather-dependence, Nordic congestion, interconnector outages and declining thermal capacity, which together weaken long-term investment signals remain uncertain under frequent price spikes and collapses. Strategic implication: capacity mechanisms, reliability options or strategic reserves may be required, especially in Estonia and Lithuania, to ensure sufficient firm capacity. Market rules must also incentivise demand-side participation and flexible industrial load.

Long-term security of supply requires diversified technology pathways. While wind and solar dominate current policy trajectories, security of supply requires diversified portfolios. Estonia's SMR assessments, Lithuania's hydrogen pilot integration plans and Finland's long-term nuclear strategy illustrates differing approaches. Strategic implication: Baltic States should jointly assess long-term decarbonised firm capacity options, including SMRs, long-duration storage, green hydrogen-to-power and cross-border balancing partnerships.

Security cooperation must deepen post-synchronisation. Following synchronisation, the Baltics rely on CEN's reserve-sharing framework, Polish system support and domestic resources. Operational complexity has increased due to low inertia, larger balancing needs and the shift in price-setting dynamics. Strategic implication: a Baltic System Security Protocol is needed, covering coordinated outage planning, reserve sharing, low-frequency event response and joint black-start preparedness.

Across all dimensions: adequacy, market stability, infrastructure resilience and decarbonisation, the region is entering a high-volatility decade. Policy must be proactive rather than reactive, recognising that traditional security-of-supply assumptions no longer hold. A coordinated Baltic strategy, supported by Nordic and Continental European partnerships, will be essential to ensure that decarbonisation does not come at the expense of reliability.

5.4.2. Nuclear sector

In the Baltic-Finnish region, the post-2022 Acceptability of nuclear energy stopped being primarily about climate goals and emissions targets. Russia's invasion of Ukraine has caused energy insecurity in the dependent nations of Europe. Nuclear projects that were entangled with Russia lost political viability, while Western nuclear cooperation increase as part of strategic resilience. Finland illustrates this well: public approval of nuclear remained overall high (61% in favour; 9% against in spring 2024, per Finnish Energy/Verian),[349] but Russia-dependent Hanhikivi/Fennovoima project was terminated in May 2022 as Russia would build it and supply it with their nuclear fuel.[350]

Finland's acceptance of nuclear power is built on results and good management: nuclear energy became directly linked to stable prices and reliable supply just as security concerns grew. The start of regular generation at Olkiluoto 3 on 16 April 2023 was presented as a major win for clean domestic energy; TVO noted that after OL3 came online, the plant produced roughly 30% of Finland's electricity, reinforcing the view that nuclear is not just low-carbon, but essential for the nation.[351] At the same time, the government extended the Loviisa plant's operating license to 2050 in a decision announced in February 2023. This signaled that extending the life of existing plants is seen as a safe, less controversial path than building massive new projects from scratch. Finland also moved to modernize its rules for the future: STUK launched a project in 2022 to renew nuclear safety regulations, supporting the Ministry's reform of the Nuclear Energy Act—a key step in clearing the legal path for SMRs and new technologies.[352]

Estonia represents the region's clearest example of introducing nuclear power as a security necessity. Public opinion data from 2022–2024 shows steady majority support, justified by the need for energy security and long-term affordability. A Kantar Emor survey reported by Fermi Energia in February 2023 found that 61% of people favored considering SMRs for Estonia's energy security. Critically for local planning, the survey noted that "most" supporters would be willing to allow a plant near their own residence, suggesting this acceptance is practical, not just theoretical.[353] Institutionally, Estonia moved from discussion to action. The Nuclear Energy Working Group produced a government-commissioned final report in 2024, followed by parliamentary approval: the Riigikogu debated nuclear energy as "a matter of significant national importance" in April 2024 and passed a Resolution supporting its adoption in June 2024. These steps marked a shift from debate to a firm mandate, embedding nuclear power into state planning rather than leaving it as a project-by-project negotiation.[354]

Latvia's approach during 2022–2024 is more hesitant, best understood as institutional exploration without a political promise to build. Latvia joined the U.S. FIRST program in April 2022 to build capacity for responsible SMR infrastructure—a move designed to build competence and safety culture while keeping options open.[355] However, Latvia's broader politics still lean toward renewables. In March 2024, Latvia signed an EU statement prioritizing renewables and grids rather than the pro-nuclear declaration, indicating that nuclear is not yet mainstreamed in Latvian politics

349 Finnish Energy (2024). *Popularity of nuclear power continues strong in Finland.* https://energia.fi/en/press-releases/popularity-of-nuclear-power-continues-strong-in-finland/

350 World-Nuclear News (2022). *Fennovoima cancels Hanhikivi 1 contract with Russia.* https://www.world-nuclear-news.org/Articles/Fennovoima-cancels-Hanhikivi-1-contract-with-Russi

351 TVO (2023). *Regular electricity production has started at Olkiluoto 3 EPR.* https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2023/regularelectricityproductionhasstartedatolkiluoto3epr.html

352 STUK (n.d.). *Renewal of the nuclear safety regulation.* https://stuk.fi/en/renewal-of-the-nuclear-safety-regulation

353 Fermi Enerrgia (2023). *61% supports considering a small nuclear power plant in Estonia, most of them would allow it close to their homes*. https://fermi.ee/en/61-toetab-eestisse-vaikese-tuumajaama-kaalumist-enamik-neist-lubaks-selle-ka-oma-elukoha-lahedale

354 Riigikogu (2024). *The Riigikogu passed a Resolution on supporting the adoption of nuclear energy in Estonia*. https://www.riigikogu.ee/en/press-releases/plenary-assembly/the-riigikogu-passed-a-resolution-on-supporting-the-adoption-of-nuclear-energy-in-estonia

355 Latvian Ministry of Economics (2022). *Latvia joins the nuclear safety and clean energy development promotion programme established by the United States.* em.gov.lv/en/article/latvia-joins-nuclear-safety-and-clean-energy-development-promotion-programme-established-united-states

the way it is in Finland or Estonia. At the societal level, a February 2024 survey reported by the Latvian Wind Energy Association noted that support for nuclear had actually dropped compared to the previous year. The survey found that electricity cost was the most important factor for the public, suggesting that Latvia's "social license" for nuclear is fragile and highly dependent on whether it can compete with the cheaper narrative of renewables.[356]

Lithuania's public acceptance is uniquely shaped by its history and local concerns. The country is still managing the difficult decommissioning the old Ignalina plant, and how well it governs this process determines public trust. A June 2023 survey published by the Lithuanian Wind Energy Association showed that only 23% favored nuclear power as a development priority, and it was rated one of the most "uncomfortable" technologies to have near one's home (only 14% were comfortable with it within 3 km).[357] Yet, the post-2022 security reality has reopened the door at the strategic level. Lithuania's updated National Energy Independence Strategy, approved in 2024, explicitly keeps a pathway open for new nuclear and SMRs. Furthermore, 2024 moves to join the European SMR Industrial Alliance and sign a U.S.–Lithuania civil nuclear cooperation agreement show a deliberate government effort to rebuild legitimacy for nuclear power through Western partnerships and new technology.[358]

5.4.3. Natural gas sector

In the wake of 2022, the concept of Acceptability in the Baltic–Finnish gas sector underwent a fundamental transformation. Historically viewed through the lens of environmental impact and the "social license to operate," the acceptability of natural gas was redefined by the imperative of national survival. The debate shifted from "saving the planet" (decarbonization) to "saving the state" (sovereignty).

Prior to the Russian invasion of Ukraine, natural gas held a tenuous position as a "bridge fuel"–a cleaner alternative to Estonian oil shale or peat, facilitating the transition to renewables. The events of 2022 collapsed this narrative. The social license for natural gas is no longer derived from its utility as a transition fuel, but strictly from its origin: "non-Russian" gas is accepted as a patriotic necessity, while Russian gas is rejected as a geopolitical threat. This chapter analyzes how Lithuania, Latvia, Estonia, and Finland have navigated the trade-offs between environmental sustainability and urgent security needs, accepting higher costs and even temporary carbon-intensive substitutions to secure independence.

5.4.3.1. Policy Enviroment

The post-2022 reconfiguration of the Baltic–Nordic gas system fundamentally alters the logic of gas-sector governance in Lithuania, Latvia, Estonia and Finland. Natural gas has transitioned from a backbone fuel embedded in long-term contractual supply chains into a risk-sensitive, infrastructure-

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[356] Latvian Wind Energy Association (2024). *Survey: the security and stability of electricity supply is becoming increasingly important for the Latvian society; young people consistently support renewables.* https://wea.lv/en/skds-survey-2024

[357] LVEA (2023). *Survey: people in Lithuania are most supportive of renewable energy.* https://lvea.lt/en/apklausa-lietuvos-gyventojai-labiausiai-palaiko-atsinaujinancia-energetika

[358] Lithuanian Energy Institute (2024). *LEI joins the European Small Modular Reactor Industry Alliance.* https://www.lei.lt/en/lei-joins-the-european-small-modular-reactor-industry-alliance

dependent and economically volatile transition carrier[359]. Under these conditions, traditional energy policy instruments – focused on supply diversification and market liberalisation – are no longer sufficient to guarantee security of supply, economic stability and coherence with long-term decarbonisation objectives. Gas policy must now be governed as a controlled risk-management problem under structural decline, rather than as a standard energy market segment.

A central implication of the post-crisis regime is the shift of security risk from external suppliers to internal infrastructure integrity and coordination capacity. The elimination of Russian pipeline dependence has removed the dominant geopolitical leverage mechanism over the region's gas systems. However, this achievement has been replaced by a new class of vulnerabilities concentrated in a small number of high-value physical assets – Klaipėda LNG, Inkoo FSRU, Balticconnector, GIPL and the Inčukalns underground storage facility. Policy frameworks must therefore move beyond supplier diversification and explicitly prioritise the protection, redundancy and coordinated governance of these cross-border choke points. This requires a transition from nationally bounded gas security strategies toward a formally institutionalised Baltic–Nordic gas security governance architecture, in which the failure of any single asset is treated as a regional emergency rather than a bilateral commercial incident.

The 2022–2024 crisis cycle also revealed a fundamental asymmetry between formal supply security and effective demand security. Lithuania's experience demonstrates that uninterrupted physical supply does not guarantee industrial operability under extreme price conditions[360]. Meanwhile, Finland's emergency fuel switching[361] shows that supply security can be preserved even with massive demand destruction. These contrasting responses underscore that gas policy can no longer be oriented solely around volumetric adequacy. It must explicitly integrate price-risk management, industrial competitiveness thresholds and substitution feasibility into national security planning. Without such integration, large segments of the industrial base remain exposed to abrupt shutdowns under future price spikes, even in the presence of fully diversified LNG supply.

The structural divergence among the four countries further complicates policy coordination. Lithuania's gas system remains highly sensitive to a small number of energy-intensive industrial processes; Estonia's system is structurally oriented toward exit through heating-sector substitution; Finland's system depends on LNG-based flexibility and rapid fuel-switching capacity; and Latvia's system functions as the temporal balancing and storage core of the entire region. This heterogeneity makes the application of uniform gas policy instruments across the region structurally inappropriate. Regional governance must therefore operate through functionally differentiated roles, rather than through symmetry-based coordination. Lithuania requires industrial risk-mitigation instruments; Estonia requires heating-sector transition management; Finland requires LNG and CHP flexibility optimisation; Latvia requires storage-centric security regulation and investment support.

Another defining policy challenge arises from the security–economics divergence of gas infrastructure. As absolute gas demand contracts across the region, the commercial utilisation rates of LNG terminals, pipelines and storage facilities decline[362]. At the same time, their strategic value

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[359] IEA (2023). *Medium-Term Gas Report 2023.* https://www.iea.org/reports/medium-term-gas-report-2023
[360] Achema (2022). Nevaldomai brangstant gamtinėms dujoms, bendrovė „Achema“ laikinai stabdo gamyklos veiklą. https://www.achema.lt/en/naujienos/nevaldomai-brangstant-gamtinems-dujoms-bendrove-achema-laikinai-stabdo-gamyklos-veikla/
[361] IEA (2023). *Medium-Term Gas Report 2023*
[362] IEEFA (2025). Europe's LNG imports decline 19% with gas demand at 11-year low. Europe's LNG imports decline 19% with gas demand at 11-year low | IEEFA

for crisis preparedness and seasonal balancing increases. If left to purely market-based logic, this divergence would lead to underinvestment, accelerated asset degradation and rising systemic risk. Maintaining security-critical gas infrastructure under conditions of shrinking demand therefore requires explicit regulatory and fiscal intervention, including capacity remuneration mechanisms, strategic reserve mandates and cross-border cost-sharing arrangements. Without such instruments, the region risks entering a phase of infrastructure hollowing-out, where assets remain formally available but operationally fragile.

The decarbonisation–security interaction also demands a recalibration of policy sequencing. Estonia's accelerated phase-out of gas in the heating sector illustrates how climate policy can structurally reduce exposure to gas price volatility and import dependency. At the same time, Lithuania's and Finland's experience demonstrates that premature displacement of gas without fully deployable alternatives can expose critical industrial and CHP systems to instability. Gas policy must therefore be embedded within a dual-system transition framework, in which declining fossil gas is synchronised with the scalable availability of electricity, biomass, renewable gases and synthetic fuels. Policy failure in this synchronisation would either lock in unnecessary fossil dependence or generate transitional security gaps.

At the regional level, the gas system has now become an explicitly collective security asset. LNG inflows through Klaipėda and Inkoo, seasonal buffering through Inčukalns, and redistribution via GIPL and Balticconnector create a deeply interdependent architecture. This interdependence reduces exposure to individual supplier coercion, but simultaneously amplifies exposure to common-mode failures and coordinated hybrid threats. Effective policy must therefore move from cooperation as a political aspiration to cooperation as a legally and operationally binding security protocol. Joint infrastructure stress-testing, shared emergency dispatch rules, synchronised storage drawdown strategies and unified cyber–physical protection standards become indispensable policy instruments in this new environment.

Finally, the gas market's integration into the global LNG pricing regime introduces a permanent layer of external volatility that cannot be neutralised through domestic regulation alone. Under such conditions, gas can no longer function as a stable price anchor for industry, heating or power generation[363]. Policy responses must therefore prioritise the reduction of structural gas exposure, rather than persistent attempts to dampen its price fluctuations. Electrification, biomass, hydrogen and synthetic fuels thus become not only decarbonisation vectors, but core instruments of macro-energy security policy.

In sum, the strategic task for the gas sector in Lithuania, Latvia, Estonia and Finland is no longer to optimise a growing market, but to govern a shrinking but critical system under conditions of heightened geopolitical, infrastructural and price risk. Securing physical flows, sustaining infrastructure under declining utilisation, managing asymmetric national vulnerabilities and synchronising decarbonisation with security are now inseparable components of a single policy problem. The success of the regional energy transition will depend not on how rapidly gas disappears from energy balances, but on how coherently and safely its role is reconfigured within an increasingly electrified and high-volatility global energy system.

[363] IEEFA (2024). Conflict exposes natural gas to price volatility. Conflict exposes natural gas to price volatility | IEEFA

5.4.4. Oil sector

In the Baltic–Nordic oil sector, acceptability constitutes the most friction-laden dimension of energy security, defined by a structural conflict between the immediate necessity of mobility and the long-term imperatives of climate policy. Unlike natural gas, where the primary acceptability crisis was geopolitical (Russian origin), the oil sector faces a dual legitimacy crisis: a geopolitical rejection of Russian crude and a broader, policy-driven rejection of fossil fuels in general. Consequently, the social license for oil has bifurcated. While the consumption of non-Russian oil remains socially accepted as a prerequisite for economic stability and national defence in the short term, the infrastructure and long-term usage of petroleum products are increasingly viewed as liabilities to be managed and phased out rather than assets to be developed.

5.4.4.1. Security versus Decarbonization

Across the Baltic States and Finland, oil occupies a structurally contradictory position. On the one hand, it remains indispensable to the transport sector, which continues to rely overwhelmingly on oil products. In Lithuania, approximately 83% of final oil consumption is absorbed by transport,[364] while in Estonia the figure stands at around 78%,[365] reflecting a similar structural dependence on road-based mobility and freight. Diesel alone accounts for more than 60% of final road transport energy use at the EU level, with national shares even higher in the Baltics due to logistics intensity and limited modal alternatives.

On the other hand, the long-term political acceptability of oil has been undermined by the European Union's decarbonization framework. The "Fit for 55" package, designed to deliver a minimum 55% reduction in net greenhouse gas emissions by 2030, explicitly targets the transport sector as a core source of emissions reductions. Central to this shift is Regulation (EU) 2023/851, which sets binding CO_2 standards for new passenger cars and vans consistent with a de facto phase-out of internal combustion engine vehicle sales by 2035, even if the precise implementation pathway remains under political debate.[366] This combination has effectively withdrawn the long-term political license for oil, without eliminating short- and medium-term reliance. The resulting policy stance does not frame oil as a growth sector, but as a temporary stabilizer. Energy security discourse has therefore shifted: instead of prioritizing the expansion of oil supply, governments increasingly focus on ensuring an orderly and secure decline of oil dependence. In this transitional landscape, the retention of refineries, terminals, and storage facilities is justified less by their economic return than by the security risks associated with dismantling them before alternative energy carriers–electricity, hydrogen, or advanced biofuels–are fully scalable.

5.4.4.2. Conditional Acceptability

Nowhere is the tension between security and sustainability more acute than in Estonia's shale oil sector. Oil shale has historically covered a dominant share of Estonia's energy supply and is explicitly linked in international assessments to national energy security and supply autonomy. At the same time, Estonia has been repeatedly identified as one of the most carbon-intensive energy systems in the European Union, with greenhouse gas intensity roughly twice the EU average in 2020, largely

[364] International Energy Agency (2025). *Countries & Regions – Lithuania*
[365] International Energy Agency (2025). *Countries & Regions – Estonia*
[366] European Union (2023). *Regulation (EU) 2023/851.* https://eur-lex.europa.eu/eli/reg/2023/851/oj/eng

due to shale oil extraction and processing.[367] In 2022 Estonia's GHG emissions were 14 347 tonnes of CO_2 of which 8 635 (approx. 60 %) tonnes went to the Energy sector. After decoupling away from Russia, these emissions decreased, but still remained high at 5 471 tonnes.[368] Oil remains a strategic asset for safeguarding sovereignty and resilience, while simultaneously representing a liability under EU climate policy. Its continued social acceptability is tied to the socio-economic stability of the Ida-Viru region, where thousands of jobs have historically depended on the sector and where EU Just Transition Fund resources are explicitly targeted at managing the decline.[369]

In response, Estonia has adopted a managed-transition strategy, under which shale oil is tolerated as a temporary bridge, while firms reorient investment toward chemical upgrading, co-processing, and compliance with tighter environmental standards, as reflected in Estonia's updated National Energy and Climate Plan and industry strategies. [370]A parallel logic applies to oil refining hubs in Lithuania and Finland, where acceptability increasingly hinges on strategic and transitional value rather than traditional refining economics. Lithuania's Mažeikiai refinery, the only refinery in the Baltic States, has been reframed by both national authorities and its operator as a critical node of regional supply security, buffering the region against external disruptions. [371]

However, its long-term legitimacy depends on technological transformation. ORLEN Lietuva's investments in deep conversion and residue hydrocracking are explicitly designed to eliminate high-sulphur fuel oil production, align with international environmental standards, and reposition the facility within a lower-carbon, circular-economy context rather than expand fossil throughput.

Finland demonstrates a more advanced version of this transition. At Porvoo, existing oil infrastructure has been leveraged to scale up renewable diesel and sustainable aviation fuel (SAF) production, with capacity expansions framed as central to Finland's bio-economy strategy rather than conventional oil refining.[372] This reinforces a broader regional pattern: oil infrastructure remains acceptable only insofar as it facilitates the integration of low-carbon fuels. Looking ahead, the future acceptability of the oil sector in the Baltic–Nordic region is increasingly shaped by the risk of stranded assets. There is growing international consensus–most clearly articulated by the International Energy Agency–that achieving climate neutrality requires no new long-lived oil and gas supply projects beyond those already committed, shifting the focus toward managing decline rather than expansion.

For the region, this implies a narrow corridor of legitimacy: existing oil assets are tolerated as long as they enhance crisis resilience and enable transition, effectively serving as an insurance mechanism during decarbonization. Once they cease to perform that function, their political and social acceptability is likely to erode rapidly.

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[367] OCED (2025). Environment at a Glance: Estonia. https://www.oecd.org/en/publications/environment-at-a-glance-country-notes_59ce6fe6-en/estonia_8133b0e9-en.html
[368] OCED (2025). Environment at a Glance: Estonia. https://www.oecd.org/en/publications/environment-at-a-glance-country-notes_59ce6fe6-en/estonia_8133b0e9-en.html
[369] International Energy Agency (2023). *Estonia 2023: Energy Policy Review.* https://iea.blob.core.windows.net/assets/8b462840-c9a6-4f71-81eb-d5acd1213e68/Estonia2023.pdf
[370] European Comission (2025). Estonia - Final updated NECP 2021-2030. https://commission.europa.eu/publications/estonia-final-updated-necp-2021-2030-submitted-2025_en
[371] International Energy Agency (IEA) (2025). *Lithuania 2025 Energy Policy Review.* https://www.iea.org/reports/lithuania-2025-energy-policy-review
[372] Neste (2023). *Neste's crude oil refinery in Finland to be gradually transformed into a renewables and circular solutions refining hub*. https://www.neste.com/news/neste-s-crude-oil-refinery-in-finland-to-be-gradually-transformed-into-a-renewables-and-circular-solutions-refining-hub#:~:text=Neste%20has%20completed%20the%20strategic,President%20and%20CEO%20of%20Neste.

5.4.5. Hydrogen sector

In the Baltic–Nordic hydrogen sector, **Acceptability** is characterized by a uniquely positive but untested social license. Unlike fossil fuels, which face "transition rejection," or wind power, which often faces "NIMBY" (Not in My Backyard) opposition, hydrogen currently enjoys broad political and industrial endorsement as a "future-proof" solution. It is framed not just as a climate necessity but as a strategic industrial opportunity–a vector for re-industrialization, export revenue, and energy sovereignty. However, this high level of acceptability is largely theoretical; because the sector is in its infancy, it has not yet faced the public scrutiny associated with large-scale infrastructure deployment, water usage, or land allocation for massive renewable energy parks required to feed electrolyzers.

The acceptability of hydrogen is anchored in its promise to revitalize national industries. In Finland, the "Hydrogen Cluster" strategy positions the molecule as the key to retaining heavy industry (steel, refining, chemicals) in a carbon-constrained world. The narrative is explicitly patriotic: hydrogen is presented as a means to convert Finland's wind resources into high-value exports, targeting 10% of the EU's clean hydrogen production. Similarly, Lithuania frames green hydrogen as a tool to rescue its fertilizer and refining sectors from fossil dependence, thereby protecting jobs in Mažeikiai and Jonava while meeting decarbonization targets. This alignment of climate goals with industrial survival secures strong political backing from both green and conservative stakeholders.

5.4.5.1. National Hydrogen Strategies

From an energy security perspective, hydrogen production and use in Estonia, Latvia, Lithuania and Finland are more meaningfully assessed by their potential contribution to system reliability, supply diversification and resilience under stress conditions than by installed capacity figures or project announcements alone. This assessment is shaped by a global context in which green hydrogen remains limited in supply and strategically significant, attracting sustained policy attention across the European Union, including the Baltic region. Hydrogen's prominence in EU energy policy increased notably following Russia's invasion of Ukraine in early 2022, which highlighted the Union's structural reliance on imported fossil fuels, particularly natural gas, of which Russia had previously supplied more than 40%. In response, the European Commission introduced the REPowerEU[373] initiative, identifying renewable hydrogen as one of several instruments to reduce external energy dependencies and support the long-term transformation of the energy system, with an indicative target of 20 million tonnes of renewable hydrogen by 2030, half produced within the EU and half imported. This push was subsequently reinforced by the revised Renewable Energy Directive (RED III)[374], which makes hydrogen demand more policy-backed through sectoral RFNBO requirements: in industry, Member States must ensure that RFNBOs (including renewable hydrogen and its derivatives) account for 42% of industrial hydrogen consumption by 2030 and 60% by 2035 (Article 22a). In transport, RED III sets a combined sub-target of 5.5% for advanced biofuels and RFNBOs by 2030, with a minimum 1% to come specifically from RFNBOs (which in practice includes renewable hydrogen-based fuels), thereby creating a clearer uptake signal for hydrogen and e-fuels in hard-to-electrify transport segments. At the same time, the International Energy Agency (IEA), in

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[373] European Commission (2022). *REPowerEU Plan*. https://commission.europa.eu/publications/key-documents-repowereu_en

[374]European Commission (2018-2022*). Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413&qid=1699364355105

its 2025 Global Hydrogen Review[375], notes that such ambitious targets are unlikely to be fully met within the set timeframe, it nevertheless confirms that measurable progress has been made, with green hydrogen production expanding since 2021. Including both currently operational and under-construction electrolysis projects results in a total installed capacity of 2.3 GW by 2027. If electrolyser capacity continues growing at the currently reported rate of 50% per year, total capacity in 2030 could reach around 7 GW, enabling the production of approximately 510,000 tonnes of renewable hydrogen[376].

Countries across the Baltic region and Finland recognise green hydrogen as a strategic enabler of industrial decarbonisation and green economic transformation. National hydrogen targets and policy directions are embedded in different types of documents, from government resolutions and dedicated hydrogen roadmaps to long-term climate neutrality strategies or integrated energy and climate plans, however, the main direction is the same: all countries aim to replace fossil-based hydrogen, scale green hydrogen production, and accelerate the transition toward green industrial feedstocks, fuels, and export-ready hydrogen derivatives.

Table 8. Status of National Hydrogen Strategy Documents and 2030-2035 Targets in the Baltic Sea Region

Country	Finland	Lithuania	Latvia	Estonia
National hydrogen strategy document	✓	✓	✗	✓
Year of adoption	2023	2024	✗	2023
Green hydrogen target	150 kt/year	129 kt/year	✗	40 kt/year

This shift is also driven by growing demand signals in Central Europe, where industries such as refining, fertilisers, green steel, and transport are expected to require substantial volumes of green hydrogen and low carbon products. The region also sees economic opportunity in cross border hydrogen value chains, corridors, and port infrastructure that could enable competitive production and future exports to European markets. Despite differences in national policy architecture, strategic alignment is evident: governments and industry clusters alike are positioning green hydrogen as part of their long-term transition pathways.

Key Finnish Hydrogen Policy and Strategy Documents

1) Finnish Government Resolution on Hydrogen (2023)[377].

[375] IEA (2025). *Global Hydrogen Review*. https://www.iea.org/reports/global-hydrogen-review-2025
[376] ACER (2025). *European Hydrgogen Markets*. https://energyonsummit.pl/media/ajepesr4/acer-2025-european-hydrogen-markets_compressed.pdf
[377] Finnish Government (2023). *Government resolution on hydrogen*. https://julkaisut.valtioneuvosto.fi/items/1f6194fb-1730-408c-9537-4ebed67ac28c

2) Finland's Integrated National Energy and Climate Plan (NECP) 2021–2030 (submitted 2024)[378].

3) Clean Hydrogen Economy Strategy for Finland (Hydrogen Cluster Finland)[379].

Finland's 2023 hydrogen resolution frames hydrogen as a strategic industrial and energy-security opportunity, aiming for EU leadership and potentially 10% of EU zero-emission hydrogen production by 2030 (if markets support it), backed by faster permitting, infrastructure development via Gasgrid, EU-regulatory engagement, innovation funding, and consideration of CCfD style instruments to unlock demand and investment. Resolution positions hydrogen as a tool for energy security, green transition, and industrial renewal, enabled by Finland's strong potential for clean electricity (especially renewables) and a stable power system. However, Finland prioritises producing clean hydrogen and electric fuels for Finnish industry, transport, and the energy system, while enabling exports of higher value-added products (and potentially hydrogen/e-fuels in the longer term). There is a target of at least 3% e-fuels in transport fuels by 2030 and considers raising it after RED updates are completed. Finland also explores risk- and cost-sharing instruments, explicitly including CCfD, and assesses potential national use.

Finland's updated NECP frames hydrogen primarily as an industrial decarbonisation and export opportunity enabled by abundant renewable electricity. The plan highlights a government objective to position Finland as a leader in the European hydrogen value chain by 2030, supported by large-scale deployment of hydrogen production and transport capacity and the development of a dedicated hydrogen market legal framework (a Hydrogen Market Act is anticipated alongside EU gas package implementation). The NECP also links hydrogen to RED III implementation, noting that Finland expects its national demand for RFNBOs to be met mainly through domestic production rather than imports, while also acknowledging significant longer-term export potential beyond domestic needs. On infrastructure, the NECP emphasises Gasgrid Finland's mandate to develop hydrogen and derivative gas transport and describes plans for a large national hydrogen network in the 2030s, including major cross-border pipeline initiatives with PCI status (e.g., the Nordic-Baltic Hydrogen Corridor and the Baltic Sea Hydrogen Collector) designed to connect Finland to Central European markets.

Finland's Hydrogen Cluster strategy is an industry-driven strategic framework designed to position Finland as Europe's leading high-value hydrogen economy by 2035, while expanding Finland's global climate impact through exportable hydrogen technologies and industrial products. The document emphasises that hydrogen should be scaled using Finland's major structural strengths: very high renewable and nuclear electricity potential, low grid carbon intensity, strong industrial know-how (metal, chemical, maritime, refining, and forest industries), and domestic mineral and CO_2 resources needed for hydrogen derivatives and P2X product manufacturing. The strategy identifies three core focus areas: (1) growth of domestic clean hydrogen production, (2) rapid ramp-up of clean hydrogen-based industries with the highest value-add for Finland, and (3) large-scale exports of hydrogen technologies, services, and industrial commodities instead of pure hydrogen alone. It also highlights Finland's opportunity to replace 140–150 kt/year of grey hydrogen with clean alternatives,

[378] Ministry of Economic Aairs and Employment Energy (2024). *Finland's Integrated National Energy and Climate Plan Update.* https://commission.europa.eu/document/download/069886e9-7a50-4df1-b523-9eb7bf7308c3_en?filename=FI_FINAL+UPDATED+NECP+2021-2030+%28English%29.pdf
[379] H2 Cluster Finland (2023). *Clean hydrogen economy strategy for Finland.* https://h2cluster.fi/wp-content/uploads/2023/06/H2C-H2-Strategy-for-Finland.pdf

reducing import dependence and improving energy self-sufficiency. Additionally, the document links hydrogen development to major Nordic-Baltic cross-border pipeline projects (Nordic Hydrogen Route, Baltic Sea Hydrogen Collector, Nordic-Baltic Hydrogen Corridor) as key enablers for market liquidity, supply diversification, and access to Central European demand hubs. Overall, the strategy aims to reduce investment and regulatory bottlenecks, increase industrial demand certainty, prioritise high-value hydrogen derivatives such as synthetic fuels, clean steel, ammonia, and fertilisers, and accelerate ecosystem-wide collaboration across local, regional, and European stakeholders.

The Government-approved Guidelines for Hydrogen Development in Lithuania 2024–2050 Implementation Plan in 2024 sets a national pathway to build a green hydrogen ecosystem and reduce dependence on imported fossil fuels, especially natural gas, which is currently the main source for hydrogen production in Lithuania. The plan establishes two strategic phases: by 2030, Lithuania aims to deploy early hydrogen projects in fertiliser production, transport, and oil refining, install 1.3 GW of electrolysis capacity operating 57% of the time, and produce 129 kt/year of green hydrogen, covering domestic demand of 110 kt/year with an additional 33 kt/year potentially available for export. By 2050, hydrogen technologies are expected to reach all hard-to-abate sectors, electrolysis capacity should expand to 8.5 GW, and renewable hydrogen derivatives will form a significant share of future exports. The plan also outlines infrastructure targets, including the construction of two hydrogen valleys, at least 10% hydrogen blending limit in the gas grid during transition pilots, a feasibility study for a regional hydrogen transit corridor, and a network of at least 10 hydrogen refuelling stations by 2030, starting with the first multi-use stations for light and heavy transport by 2026. Demand certainty is considered essential, with emphasis on stable regulatory conditions, state support mechanisms, land availability for new projects, and the evaluation of CO_2 pricing instruments such as Carbon Contracts for Difference (CCfD) to incentivise industrial hydrogen uptake and generate tradable carbon reduction credits.

Key Lithuanian Hydrogen Policy and Strategy Documents

1) Guidelines for Hydrogen Development in Lithuania for 2024–2050 (2024)[380].
2) The Government-approved Action Plan for the Implementation of the Guidelines for Hydrogen Development in Lithuania in 2025–2027 (2024)[381].
3) Lithuania's National Energy and Climate Plan NECP 2021–2030 (submitted 2024)[382].
4) Lithuanian National Energy Independence Strategy (NENS) (2024)[383].

The Hydrogen Development Action Plan for Lithuania 2025–2027 complements Lithuania's long-term hydrogen guidelines by translating strategic directions into concrete short-term measures. Its

[380] Lithuanian Ministry of Energy. (2024). *Hydrogen Development Guidelines in Lithuania for 2024–2050.* https://enmin.lrv.lt/media/viesa/saugykla/2024/4/ZNrRbiZ96Hs.pdf
[381] Lithuanian Government (2024). *On the approval of the action plan for the implementation of the guidelines for the development of hydrogen in Lithuania in 2025–2027.* https://www.e-tar.lt/portal/lt/legalAct/210b82d2b7b911ef88c08519262548c4?utm
[382] Lithuanian Ministry of Energy (2024). *National Energy and Climate Plan.* https://commission.europa.eu/publications/lithuania-final-updated-necp-2021-2030-submitted-2024_en
[383] Ministry of Economics and Innovation, Ministry of Energy (2024). *Nacionalinė Energetinės Nepriklausomybės Strategija [National Energy Independence Strategy]* https://enmin.lrv.lt/public/canonical/1740735085/5963/NENS%202024-2.12_EN.pdf

main goal is to establish a stable regulatory and investment environment, accelerate early market creation, and build the foundations for hydrogen production, storage, and transport infrastructure. Key priorities include: updating legal acts across the hydrogen value chain, integrating a national green hydrogen certification system, simplifying permitting procedures, assessing groundwater resources for future hydrogen production, conducting feasibility studies for a regional hydrogen transit corridor, launching the first multi-use hydrogen refuelling stations for light and heavy transport by 2026, deploying 177 MW of electrolysis capacity by 2027 using Modernisation Fund support, enabling industrial uptake in fertilisers and refining, promoting CO_2 capture for hydrogen-based synthetic products, testing Gas-to-Power/Power-to-Gas flexibility pilots via system operators, and running two national information or education campaigns per year to support ecosystem awareness and skills development.

Lithuania's NECP 2021–2030 explicitly addresses hydrogen, mainly in the context of transport decarbonisation and green fuels. The plan frames hydrogen as part of a wider portfolio of alternative fuels (alongside advanced biofuels, biomethane and electrification), aiming to raise the combined share of biogas and renewable fuels of non-biological origin (RFNBOs) in transport energy consumption to at least 5.2%, supported by policy measures that include green hydrogen production development as a dedicated measure. It also references the national legal and planning framework for hydrogen infrastructure: Lithuania's Alternative Fuels Law and related guidelines foresee hydrogen refuelling infrastructure development, with alongside actions to promote hydrogen-powered vehicles. Beyond direct hydrogen use, the NECP highlights the role of hydrogen derivatives (e.g., synthetic green fuels, potentially ammonia) both for domestic decarbonisation and exports, indicating an ambition to produce at least 2 TWh of hydrogen derivatives by 2030 and at least 9 TWh by 2050.

Finally, the National Energy Independence Strategy (NENS) 2024 clearly mentions hydrogen and treats it as a strategic technology for both system flexibility and industrial transformation. The document links hydrogen to the European Green Deal context, noting that hydrogen is expected to help reduce fossil-fuel dependence in industry and transport. It also embeds hydrogen in Lithuania's long-term energy transition scenarios to 2050: in the "climate-neutral energy" pathway, hydrogen production is foreseen mainly to meet national needs and as a flexibility option alongside storage and demand response, while more ambitious scenarios ("hydrogen production region" and "green energy products") expand domestic hydrogen production capacity and use hydrogen to support energy-intensive industry growth, including the production of higher value-added green products such as synthetic fuels or fertilisers (with carbon capture and utilisation becoming an enabling element in the most ambitious case). Quantitatively, the scenario framework includes large-scale hydrogen electrolysis capacity (up to 8.5 GW in the more ambitious pathways) and assumes that by 2050 around 20% of transport could rely on hydrogen or its derivatives, complementing widespread electrification.

Key Estonian Hydrogen Policy and Strategy Documents

1) Estonian Hydrogen Roadmap (ENG) (2023)[384].

2) Estonia's National Energy and Climate Plan NECP 2021–2030 (2023)[385].

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[384] Estonian Ministry of Climte (2025). *Estonian Hydrogen Roadmap.* https://kliimaministeerium.ee/sites/default/files/documents/2025-11/Estonian%20hydrogen%20roadmap%20ENG.pdf

[385] Estonian Ministry of Climte (2023). *National Energy and Climate Plan.* https://commission.europa.eu/system/files/2023-08/Estonia_Draft_Updated_NECP_2021-2030_en_1.pdf

3) Energy Sector Development Plan 2035 (ENMAK)[386].

Estonia's Hydrogen Roadmap is a vision and coordination document that sets out how hydrogen could support Estonia's climate-neutrality goals and competitiveness, and it structures development in three phases: a pilot phase (2021–2030) focused on policy design, R&D and demonstration projects; a scaling phase (2031–2035) aimed at proving economic viability and removing barriers; and an expansion phase (2036–2050) depending on renewable electricity build-out and cost reductions. For the near term, the roadmap notes that Estonia's green hydrogen production potential by 2030 is estimated at roughly 2–40 kt/year (range depends on assumptions such as TEN-T/AFIR-driven infrastructure needs and market development). It highlights enabling actions up to 2030: establishing a legal and safety framework (including standards, licensing and a certification approach), integrating hydrogen into national development plans, launching support measures for the pilot value chain, and building initial storage and distribution infrastructure. The roadmap also records that more than €120 million in public support had been allocated since 2020 for hydrogen production technologies and supply chains, and it points to future opportunities in hydrogen derivatives (e.g., ammonia, methanol, synthetic fuels, fertilisers, polymers) if new industrial capabilities emerge.

Estonia's NECP 2021–2030 mentions hydrogen mainly in the context of transport decarbonisation and alternative-fuels infrastructure, and it explicitly links national planning to EU requirements (AFIR and the Renewable Energy Directive). The NECP notes that Estonia's hydrogen roadmap was finalised in spring 2023 and refers to the launch of green hydrogen pilot programmes alongside wider renewable-energy measures. For the transport sector, the NECP states that, in view of obligations under AFIR and RED regarding hydrogen production and consumption, Estonia has projected the construction of at least three hydrogen refuelling stations on main national roads by 2030. To meet the resulting demand, the plan estimates that 1,095 tonnes of green hydrogen per year would be needed by 2030; it also indicates that, if demand exceeds this level, additional green hydrogen could be produced, providing an illustrative example that 450 MWh of renewable electricity could produce on the order of 8,000 tonnes of green hydrogen per year.

In Estonia's draft Energy Sector Development Plan to 2035 (ENMAK 2035), working version 13 Nov 2024), hydrogen is not presented as a stand-alone hydrogen strategy, but as a carbon neutral gaseous energy carrier that can support system reliability once oil-shale electricity is phased out and variable renewables dominate. The plan's core trajectory is a rapid build-out of renewables: by 2030 Estonia aims to produce 100% of annual domestic electricity consumption from renewable sources, requiring an estimated 2,850 MW of onshore wind and 1,500 MW of solar, backed by storage; by 2035 the system should secure around 1,200 MW of dispatchable (controllable) generation capacity to maintain adequacy and balancing. In this context, the draft explicitly points to hydrogen and biomethane as examples of emission-free and carbon neutral peak and dispatchable fuels needed to meet the goal that electricity and heat production become carbon neutral by 2040, including a requirement that new dispatchable units use sustainable fuels (e.g., hydrogen, biomethane) by that time. On the gas side, the plan foresees transformation of energy networks so that by 2035 at least one-third of gas in the gas network is renewable gas replacing natural gas, and it notes that activities

[386] Estonian Ministry of Climte (2024). *ENERGIAMAJANDUSE ARENGUKAVA AASTANI 2035 EELNÕU.* https://kliimaministeerium.ee/sites/default/files/documents/2024-11/ENMAK%202035%20eeln%C3%B5u%20t%C3%B6%C3%B6versioon%2013.november%202024.pdf

to develop hydrogen infrastructure (including transmission routes) should already be underway as part of the broader gas system transition.

Key Latvian Hydrogen Policy and Strategy Documents

1) Latvia's long-term Energy Strategy 2050 (2025)[387].

2) Latvia National Energy and Climate Plan 2021–2030 (NECP) (submitted 2024)[388].

3) Strategy of Latvia for the Achievement of Climate Neutrality by 2050 (Long-term strategy, 2019)[389].

Latvia has not adopted a stand-alone national hydrogen strategy, instead, hydrogen is addressed across broader planning documents such as the updated National Energy and Climate Plan and the Long-Term Energy Strategy to 2050.

In Latvia's long-term Energy Strategy 2050, hydrogen is recognised indirectly as part of the future decarbonised energy system, although the strategy does not yet contain detailed hydrogen targets or production forecasts. The strategy sets the overarching vision of achieving climate neutrality by 2050 and significantly reducing dependence on fossil fuels by increasing renewable energy and energy efficiency. Within this context, it highlights the importance of alternative low-carbon fuels, such as hydrogen, to support deep decarbonisation across sectors, particularly transport, industry and gas infrastructure, consistent with Latvia's NECP commitments and EU directives on hydrogen and RFNBOs. Hydrogen deployment in Latvia is planned to begin in 2035 under the optimistic national energy scenario, with projected hydrogen use reaching approximately 1.8 TWh per year by 2050, reflecting a targeted role in sectors where electrification alone is not sufficient. Such developments would require new market frameworks, infrastructure readiness, and cross-border integration across the Baltic region.

387 Latvian Ministry of Climate and Energy (2025). *Latvijas enerģētikas stratēģija līdz 2050. gadam* https://likumi.lv/ta/id/361135-latvijas-energetikas-strategija-lidz-2050-gadam
388 Latvian Ministry of Climate and Energy (2024). *National Energy and Climate Plan*. https://commission.europa.eu/publications/latvia-final-updated-necp-2021-2030-submitted-2024_en
389 Latvian Ministry of Climate and Energy (2019). https://unfccc.int/sites/default/files/resource/LTS1_Latvia.pdf

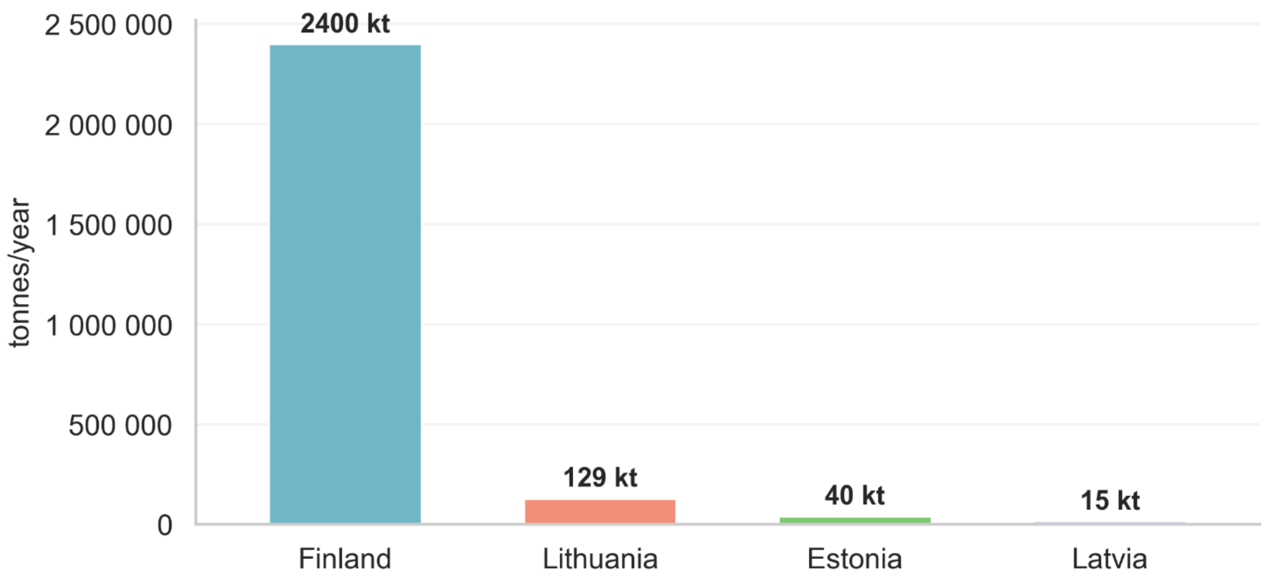

Figure 5.32. Green hydrogen production targets (kt/year) by country across strategic policy documents for 2035 (based on the figures provided in the strategies, without assessing the maximum potential)

Latvia's updated NECP 2021–2030 includes hydrogen as part of EU compliance measures, but only in clearly defined cases where hydrogen is used either as an industrial feedstock or for final energy purposes in hard-to-abate sectors. The Plan does not foresee cross-border trade in hydrogen or other RFNBOs before 2030. The main national challenge for hydrogen integration by 2030 lies in transport. Hydrogen is therefore treated as a limited, sector-specific instrument within the 2030 transition framework rather than a system-wide component of the energy mix. The same Latvia's Long-Term Strategy for the Achievement of Climate Neutrality by 2050 positions hydrogen primarily as one of several non-fossil options to decarbonise transport, alongside electrification, biomethane, advanced biofuels and synthetic fuels. In the 2050 vision, hydrogen (and biofuels) is highlighted as a solution for segments where full electrification is less straightforward, most explicitly for rail services on non-electrified lines, and as a potential fuel in maritime applications (including e-fuels and hydrogen used in pure form or blended with fossil fuels). The strategy also notes hydrogen's increasing role as an energy carrier produced from renewable electricity and the importance of hydrogen storage solutions.

Across all four countries, hydrogen production and use remain closely connected to electricity system conditions, but this linkage is not uniform. While part of future green hydrogen production may be supplied directly from dedicated renewable energy installations, thereby limiting direct pressure on the public grid, the sector remains constrained by the availability, cost and utilisation of renewable electricity. In practice, the dominant limiting factor is not only system integration, but the current cost structure of green hydrogen production. High electricity prices, capital-intensive electrolysis and immature supply chains result in green hydrogen remaining significantly more expensive than fossil-based alternatives. Therefore, market uptake is limited, and many industrial users continue to rely on grey hydrogen or conventional fuels where available. This cost gap constrains hydrogen's ability to function as a firm or autonomous energy carrier in the near to medium term, positioning it primarily as a complementary and transitional element within the broader energy transition rather than a fully competitive replacement.

5.4.6. Indicators: Acceptability

Sustainability and Climate Alignment

This dimension evaluates the environmental sustainability of the energy mix. While Finland is the clear leader, specific indicators for the Baltic States reveal structural challenges.

Table 9. Acceptability indicators and LEA EnSec scores

Indicator	Finland (FI)	Estonia (EE)	Latvia (LV)	Lithuania (LT)
NECP Target Progress	**5** (82%)	**3** (62%)	**4** (72%)	**3** (58%)
GHG Intensity (Adjusted)	**5** (198)	**2** (395)	**4** (249)	**4** (228)
Circular Material Use Rate	**1** (2.4%)	**5** (18.1%)	**2** (5.0%)	**1** (3.9%)
Average Score	**3.7**	**3.3**	**3.3**	**2.7**

Finland leads this dimension (3.7), driven by its advanced progress toward 2030 renewable targets (82% achieved) and the lowest Greenhouse Gas (GHG) emissions intensity in the group (198 gCO2e/€).

Estonia's performance is polarized. It scores a 5 on Circular Material Use Rate (18.1%), statistically exceeding the EU average. However, this figure is heavily influenced by the reuse of oil shale ash in construction rather than consumer recycling. Conversely, Estonia scores lowest (2) on GHG intensity, reflecting the lingering carbon footprint of that same oil shale industry.

Lithuania scores lowest in this dimension (2.7), primarily due to slower relative progress toward its 2030 renewable targets (58%) and a very low circular material use rate (3.9%), indicating a largely linear economy compared to the EU average.

6. Conclusions

The comprehensive analysis of the energy security in the Baltic States and Finland between 2022 and 2024 has shown a region that has successfully navigated one of the most difficult structural ruptures. The Russian invasion of Ukraine transformed and boosted energy policy and integration into a primary domain of national security. In answering how the region responded to this aggression, the study demonstrates that the Baltic States and Finland have effectively traded the low-cost stability of Russian supply chains for the higher volatility but assured independence of Western markets. This strategic move culminated in the synchronization of the Baltic electricity grids with the Continental European Network in February 2025, marking a historic milestone that physically ended the last technical links to the post-Soviet energy system and removed Moscow's technical leverage over the region. However, as the focus shifts from the immediate crisis of 2022 to the long-term outlook of 2024 and beyond, the definition of security has evolved across the four dimensions of Availability, Accessibility, Affordability, and Acceptability.

In terms of **Availability**, the region has managed to replace the supply lost after the end of Russian imports, though it has done so through divergent national strategies that have created a two-speed energy security architecture. Finland has emerged as the region's availability anchor, through the commissioning of the Olkiluoto 3 nuclear plant and a massive expansion of onshore wind. This capital-intensive strategy allowed Finland to transition from a deficit market to a net exporter, securing physical availability through domestic generation. In contrast, Lithuania, Latvia, and Estonia have adopted a model of hybrid resilience. While they successfully secured the availability of natural gas through the Klaipėda and Inkoo LNG terminals, preventing physical shortages even at the peak of the crisis, their electricity sectors remain structurally prone to deficits. The retirement of dispatchable fossil assets, such as Estonia's oil shale plants, without a one-to-one replacement with firm capacity has increased the Baltic States' exposure to weather-related supply risks. The primary threat to availability is no longer a geopolitical embargo, but the extended periods of low wind and solar output, during which the region lacks sufficient baseload to guarantee adequacy without heavy reliance on imports. In response, system adequacy is increasingly being addressed through the deployment of energy storage solutions, demand-side flexibility and cross-border balancing mechanisms, although these measures are not yet sufficient to fully offset prolonged low-renewable periods.

The dimension of **Accessibility** has shifted from a static focus on grid connections to a dynamic challenge of infrastructure resilience. The study highlights that the region has moved from a linear dependency on Eastern pipelines to a mesh-like network of Western and Nordic interconnectors. The construction of the GIPL gas pipeline and the enhancement of electricity links like LitPol Link and the EstLink corridors were the primary measures taken to pivot away from Russia. However, this new accessibility architecture has introduced a paradox of concentrated vulnerability. By diversifying suppliers, the region has inadvertently reconcentrated physical risk around a limited number of critical maritime nodes and subsea cables. The sabotage of the Balticconnector in 2023 served as a grim stress test, proving that maritime accessibility is fragile and susceptible to hybrid threats. Consequently, the security of accessibility is now defined not by the theoretical capacity of pipelines, but by the physical defense of the Baltic Sea's seabed infrastructure. The region has successfully built bridges to the West, but the integrity of those bridges is the new frontier of security policy.

Affordability has proven to be the most painful trade-off in the post-invasion landscape. The crisis of 2022 was not merely a supply shock but a structural price shock that fundamentally altered the economic competitiveness of the region. Moving from long-term, oil-linked gas contracts to the global LNG spot market has exposed domestic heating and industry to global price volatility. The study confirms that market clearing often occurred through demand reduction rather than supply flexibility, with energy-intensive industries, such as Lithuania's fertilizer sector, reducing output in response to unsustainable costs. A distinct divergence is evident here as well: Finland's access to low-cost nuclear generation, reinforced by the commissioning of Olkiluoto 3, helped dampen price pressures relative to the Baltic states, whereas the Baltics remained more exposed to the combined effects of elevated gas prices and import-driven price transmission during tight periods. While prices have moderated since the peak of the crisis, the era of cheap energy is over. The new affordability challenge is driven by the high fixed costs of maintaining security-driven infrastructure, such as LNG terminals and storage facilities, in a market where gas consumption has structurally declined. On the other hand, LNG terminals also constitute transition-ready infrastructure that can support bio-LNG, synthetic methane and maritime bunkering, partially mitigating long-term asset stranding risks.

Finally, the concept of **Acceptability** has been reshaped by the securitization of the energy sector. The expansion of renewable energy is increasingly justified on security grounds, particularly its role in limiting revenue flows to aggressor countries. This shift has reduced traditional opposition to infrastructure projects, enabling accelerated deployment of wind and solar assets that would have faced significant resistance a decade ago. However, this acceptability is not unconditional and involves underlying trade-offs. In Estonia, the continued role of the carbon-intensive oil shale industry is increasingly framed as a security bridge, creating tension between short-term resilience requirements and long-term decarbonisation commitments. Similarly, the study notes a renaissance in the acceptability of nuclear power, not just in Finland, but as a prospective solution for the Baltic baseload deficit, as Small Modular Reactors are increasingly incorporated into national energy strategies. Conversely, the oil sector faces a structural transition rather than an immediate crisis: while non-Russian oil remains essential for transport and security, refining assets are increasingly repositioned toward sustainable fuels, creating a complex adjustment between security functions and long-term climate objectives.

Ultimately, long-term goals and strategies for the region are now centered on managing the complexities of an interconnected, weather-dependent system. The integration into Western markets is complete, but the region must now address the internal imbalances of that market. Future security will depend on solving the dispatchable generation deficit, likely through a combination of nuclear ambitions, the development of the Nordic-Baltic Hydrogen Corridor, and massive investments in storage. The Baltic–Finnish region has largely insulated itself from Russian energy coercion, but it has entered a new phase in which energy security depends on sustained vigilance, deep regional coordination, and the ability to manage high capital costs to maintain system reliability during prolonged winter stress periods, with increasing emphasis on the physical security and protection of critical energy infrastructure.

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