

Gas Decarbonisation Pathways for Estonia

(3 Baltic States + Finland)

Deliverable 5: Report on the risk analysis of the scenarios for a decarbonized Baltic regional gas market

Final report

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**Study team members**

Louise Aeby (Trinomics)

João Gorenstein Dedecca (Trinomics)

Luc van Nuffel (Trinomics)

Javad Keypour (SEI)

**Contact person**

Luc van Nuffel

T: +32(0)478 65 26 37

E: luc.vannuffel@trinomics.eu

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**Rotterdam, 31 August 2023**

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**In association with:**





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# Introduction

In the previous Deliverables, the three Gas decarbonisation scenarios for the Baltic Regional Gas Market countries have been identified and characterised (DLV 3), and their impacts on the economy and energy system have been assessed per country (DLV4). In this Deliverable 5, we focus on the specific risks related to the three decarbonisation scenarios compared to the BAU scenario.

The objective of this exercise is to

* Identify the relevant risks related to the identified gas decarbonisation scenarios;
* Assess the likelihood, severity and mitigation measures of each identified risk;
* For the Baltic Regional Gas Market countries, pinpoint any risks specific to a sub-set of countries;
* Assess and pinpoint for each identified risk the extent to which it would apply to the different gas decarbonisation scenarios.

For this risk assessment, the following approach has been implemented:

* Risk categorisation;
* Assessment based on desk research;
* Validation of the results via a consultation with the steering group and stakeholders from the concerned countries.

This report is structured as follows:

* Chapter 2 comprises an inventory of (potential) risks and concludes by presenting a short list of the most relevant risks of the considered decarbonisation scenarios for the Baltic countries;
* Chapter 3 comprises for each short-listed risk a detailed description, its rating per scenario and mitigation measureswhich could be employed to reduce the risk’s likelihood and/or severity;
* Chapter 4 presents a summary of the risks’ assessment and conclusions.

# Inventory of risks

## Background for the risks’ categorisation

The literature on risks for the energy system has a long history, with broad attention being paid to this topic mainly since the oil crisis in the 70s.

In recent years, increased attention has been paid not only to risks associated with the supply of energy commodities but also to those related to the energy technology supply chains. These risks derive from various factors such as dependencies on the supply of critical raw materials or components for strategic energy technologies from a small number of (non-EU) suppliers.

However, other threats can impact the energy system, including more frequently occurring extreme weather events affecting the manufacturing, logistics, installation or the operation of energy production, transport, storage or demand assets. Other threats such as cyber-attacks or global pandemics can also disrupt the EU energy system.

The European Commission publishes since 2014 a list of critical raw materials, based on an assessment of their importance to the EU economy, availability and existence of possibilities for e.g. recycling and substitution. The current (fourth) list includes 30 critical raw materials.[[1]](#footnote-2)

Trinomics and Artelys (2021)[[2]](#footnote-3) have assessed major threats to the EU energy technology supply chains. The study identified a number of vulnerable materials as well as components and O&M functions for several energy technologies. As can be seen in Table 1‑1 several technologies relevant for the decarbonisation of the Baltic regional gas system are deemed both strategic to the EU energy system and vulnerable to a number of threats. These technologies include the supply chain for gas infrastructure, hydrogen production, energy storage and use, as well as digital technologies used throughout the energy supply chain.

The Trinomics study has also considered other technologies such as those used for biogas and biomethane production, but these were not deemed strategic at the EU level. However, this does not mean that these technologies are not important in the context of this study, nor that they don’t exhibit vulnerabilities.

Table 2‑1 Overview of the vulnerability of energy technologies supply chain stages

|  |  |  |  |
| --- | --- | --- | --- |
| Strategic supply chains | Raw & Processed Materials | Manufacturing & Assembly | O&M |
| **Wind energy** | Cu, **Dy**, **Nd**; electrical steel | Permanent magnets | Vulnerability to cyber-attacks due to increased digitalisationAvailability of installation vessels for offshore wind |
| **Solar PV** | **B,** Cu, **Ga, Ge**, **In**, Se, **Si**, Te | PV cells and modules | Potential for vulnerability to cyber attacks due to remotely controlled inverters  |
| **Nuclear fission** | Ar, Cr, N, Zn;Ni-Cr-Fe alloys | Nuclear-grade certified suppliers (primary circuits, rods and other components/services for the nuclear island) | Certified service providers |
| **H2 production / storage / use** | **PGMs (Pt, Pd, Ru, Rh, Ir), REEs, Ti**CFC, (PFSA) | (HFC stack assembly, with decreasing vulnerability) |  |
| **Gas infrastructure** |  | Ball valves, filters, and purifiers | Cyber security of control systems / 3rd party service providers |
| **Electricity networks** | Al**,** Cu, **Mg**, **Si**;electrical steel |  | Cyber security of control systems / 3rd party service providers |
| **Batteries** | Al**, Co, Li, Nb,** Ni**, Si**, **Ti, graphite** | Li-ion cells, cathode, anode, electrolyte, separator |  |
| **Smart buildings** | **B, Co, Ga, Ge, In, Li, Mg, graphite, PGMs, REEs, Si, W** | Home energy management systems | Cyber security of home/building energy management systems and decentralised devices |
| **Digital technologies** | **B, Co, Ga, Ge, In, Li, Mg, graphite, PGMS, REEs, Si, W** | Electronic boards, semiconductors and processorsServers and data storage equipment | Related to cyber-security of digital technologies use in other supply chains |

*Legend:*

***yellow*** *- supply chain stage with one to a couple of elements identified as vulnerable;*

***orange*** *– supply chain stage with a few vulnerable elements / with high risk vulnerabilities;*

***green*** *– supply chain stage without vulnerable elements;*

***bold*** *– critical raw materials (CRMs) based on EC list for 2020.*

Not only specific risks to the EU, regional and Estonian energy system must be considered in this context. Other global threats to the economy and society overall can have a strong impact on local and regional energy systems, as has been demonstrated by the COVID pandemic. Socio-economic disruptions such as economic depressions can significantly impact the national/regional economies’ ability to properly develop and operate their energy system. Disruptions to the energy system can also directly impact the overall economy, as has been demonstrated by the Russian aggression against Ukraine and the associated energy crisis.

The World Economic Forum’s Global Risks Report[[3]](#footnote-4) illustrates the diversity of risks which can impact the global economy, and by consequence the Baltic regional energy systems. A survey of over 900 experts globally revealed a number of severe risks in the next 10 years (Figure 1). It is emblematic that out of the 10 most severe risks identified in the report, 5 are of an environmental nature. This illustrates the strong energy-economy-environment interdependency.

Moreover, a survey of over 12 000 global leaders pinpoints the highest risks for the Baltic region in their opinion (Table 2). It can be noted that interstate conflicts were identified as the most important risk for the Baltic countries.[[4]](#footnote-5) Furthermore, economic risks due to asset bubbles, commodity shocks and debt crises are also highly ranked.

Figure 2‑1 Most severe risks in the next 10 years according to experts[[5]](#footnote-6)



Table 2‑2 Top five risks identified by the World Economic Forum’s Executive Opinion Survey[[6]](#footnote-7)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Risk 1 | Risk 2 | Risk 3 | Risk 4 | Risk 5 |
| Estonia | Interstate conflict | Debt crises in large economies | Asset bubble bursts in large economies / Fracture of interstate relations | Human-made environmental damage |
| Latvia | Interstate conflict | Asset bubble bursts in large economies | Digital inequality | Debt crises in large economies / Prolonged economic stagnation |
| Lithuania | Interstate conflict | Severe commodity shocks | Debt crises in large economies / Failure of cybersecurity measures | Human-made environmental damage |
| Finland | Prolonged economic stagnation | Debt crises in large economies | Climate action failure | Asset bubble bursts in large economies | Infectious diseases |

The severity of a risk is generally measured by its impact and its likelihood as explained in IEA (2022)[[7]](#footnote-8). A likely risk may not be severe, as long as its impacts are mild. In contrast, a rare risk might have far-reaching consequences in the energy system, if it has significant impacts. Therefore, it is important to consider both the likelihood as well as the impacts when assessing risks.

## Selection of key risks related to gas decarbonisation scenarios

Based on a number of studies on risks and barriers to the energy system and the overall economy of the Baltic region, the EU and the world more broadly, we identify a long-list of risks that are potentially relevant for the decarbonisation of the gas system in the Baltic region. The sources employed comprise:

1. World Economic Forum (2022) The Global Risks Report 2022 – Insight report
2. Trinomics (2022) Transitioning to a climate neutral electricity generation. Deliverable 5 Report: Risk analysis of climate-neutral pathways
3. Trinomics, Pilvero, Finantsakadeemia, SEI (2022) Transitioning to carbon neutral heating and cooling in Estonia by 2050 - Socioeconomic impact assessment, risk and sensitivity analysis report
4. Trinomics and Artelys (2021) Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis
5. Oxford Institute (2019) Narratives for Natural Gas in Decarbonising European Energy Markets[[8]](#footnote-9)
6. E3G (2020) Pathway to a climate neutral 2050: Financial risks for gas investments in Europe[[9]](#footnote-10)

Based on these documents (numbered 1-6 in the list below), a long-list of risks has been identified as presented in Table 2‑3.

Table 2‑3 Long-list of risks identified in the literature

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Category | Risk | [1] | [2] | [3] | [4] | [5] | [6] |
| **Economic** | EU or global economic crisis results in market volatility and limited spending potential | **✓** | **✓** | **✓** |  |  |  |
| Changes in resource prices, i.e., biomass price increase | **✓** |  | **✓** |  |  |  |
| **Energy markets and infrastructure** | Fragmentation of energy networks and/or markets |  |  |  |  | **✓** |  |
| Security of energy supply threatened due to system instabilities |  | **✓** |  |  |  |  |
| Unexpected developments in global fossil energy markets |  | **✓** |  |  |  |  |
| Energy system development plans stall in neighbouring countries |  | **✓** |  |  |  |  |
| Lack of renewable technology and energy (fuels) competitiveness |  |  | **✓** |  |  | **✓** |
| Lack of resources (human and/or financial) | **✓** | **✓** | **✓** |  | **✓** | **✓** |
| **Regulatory** | Local policies present barriers to implementation |  | **✓** | **✓** |  |  |  |
| National policies present barriers to implementation |  | **✓** | **✓** | **✓** |  | **✓** |
| EU or international policies present barriers to implementation  |  | **✓** | **✓** | **✓** |  | **✓** |
| Weak/lack of planning on local level |  |  | **✓** |  |  |  |
| **Social** | Local opposition to new infrastructure/"NIMBY-ism" |  | **✓** | **✓** |  |  |  |
| Lack of widespread public acceptance of new infrastructure |  | **✓** | **✓** |  |  | **✓** |
| Lack of widespread public acceptance of the actions required |  |  | **✓** |  |  | **✓** |
| Low uptake of renewable energy solutions |  |  | **✓** |  |  |  |
| Lack of RES installation performance and quality |  |  | **✓** |  |  |  |
| Social cohesion erosion | **✓** |  |  |  |  |  |
| **Environmental & health** | (Lack of) consideration of the associated environmental effects | **✓** |  | **✓** |  | **✓** | **✓** |
| Extreme weather | **✓** |  |  |  |  |  |
| Biodiversity loss | **✓** |  |  |  |  |  |
| Climate action failure | **✓** |  |  |  |  |  |
| Infectious diseases | **✓** |  |  |  |  |  |
| **Technological** | Delayed/different pace of technological development of key decarbonisation technologies |  | **✓** | **✓** |  |  | **✓** |
| Key decarbonisation technologies do not reach economies of scale, such that their costs remain higher than projected |  | **✓** | **✓** |  |  |  |
| Delayed infrastructural development, preventing integration of key decarbonisation technologies |  | **✓** | **✓** |  |  |  |
| Cyber-attacks |  |  |  | **✓** |  |  |
| **Geopolitical** | Geoeconomic confrontation | **✓** |  |  | **✓** | **✓** |  |

A tailored list of risks related to the decarbonisation of the Baltic regional gas market is presented based on the list above, also considering the following points:

* Some of the risks above have been adapted as they originally focused on the electricity or heating & cooling sectors;
* Given the recent developments following the Russian aggression against Ukraine and the past dependence of the Baltic region on Russian gas, a specific geopolitical risk is included to consider the overall impacts on the economy and policy priorities. A specific energy markets and infrastructure risk is also added focused on the external energy dependence risks to security of supply;
* Supply chain bottlenecks impacting the prices of commodities and e.g. semiconductors have recently increased the costs for a number of energy technologies.[[10]](#footnote-11) As future renewable-based energy systems will increasingly shift from being OPEX to CAPEX-intensive, supply dependencies related to energy technologies will increase. Hence, a risk related to supply chains is added;
* Some risks have been combined in order to maintain the total number manageable; considering too many individual risks would not be feasible due to resource and cognitive limitations.

Table 2‑4 Final list of risks related to the decarbonisation of the Baltic regional gas system

|  |  |  |
| --- | --- | --- |
| Category | Section | Risk |
| **Economic** | 3.1 | Economic turndown and instability can limit ability local of gas producers, users, network operators and authorities to invest in gas decarbonisation measures |
| 3.2 | Supply dependence and bottlenecks for energy technologies can increase costs/slow down transition |
| 3.3 | Fossil gas decarbonisation can negatively affect competitiveness of industrial users |
| **Energy markets** | 3.4 | Developments in global energy markets impact competitiveness of gas decarbonisation solutions |
| 3.5 | Fragmentation of regional/national gas networks and markets |
| 3.6 | Infrastructure cannot be adequately or timely developed, including repurposing or adaptation of natural gas infrastructure |
| 3.7 | Security of gas supply can be threatened due to adequacy/flexibility issues of domestic/regional energy system |
| 3.8 | Security of gas supply can be threatened due to external energy dependence |
| 3.9 | Available inputs for production of renewable/low-carbon gases, e.g. renewable electricity or biomass can be insufficient |
| 3.10 | Investments in methane infrastructure can lead to lock-in on natural gas or asset stranding |
| **Regulatory** | 3.11 | Policies and regulations can present barriers to implementation of gas decarbonization actions |
| **Social & environmental** | 3.12 | Some specific gas decarbonisation actions can result in adverse environmental and climate impacts |
| 3.13 | Public opposition, due to (perception of) negative impacts |
| **Technological** | 3.14 | Key gas decarbonisation technologies may not reach sufficient cost or performance improvements |
| 3.15 | Safety risks or their perception restrict infrastructure development or certain supply/demand solutions |
| **Geopolitical** | 3.16 | Geopolitical events can divert resources and attention from gas decarbonisation measures |

## Additional risks identified by stakeholders

A stakeholder consultation was launched on 4 July 2023 to receive feedback on (among others) the risks analysis of gas decarbonisation scenarios. In total, 43 stakeholders (i.e., 20 from Estonia, 8 from Finland, 7 from Lithuania, 6 from Latvia and 2 regional stakeholders) have been contacted; the key takeaways from the stakeholders responses are the following:

* The availability of funding to develop/adapt required infrastructure to decarbonise the gas system is by some stakeholders considered as one of the major risks. As some network operators are private companies regulated by the State, stakeholders mention the risk that adequate decarbonisation funds may not be (timely) available to these companies.

Stakeholders also indicate that gaseous fuels may be not (or significantly less) competitive against other energy carriers and thus demand would be too low to maintain a national gas network. This would lead to stranded assets.

* The risk of energy poverty due to increased energy prices is also mentioned by stakeholders. They indicate that it may lead to safety issues (e.g. if households cannot heat their homes appropriately).
* Another risk identified by stakeholders is that renewable electricity production capacity may be too low to achieve gas decarbonisation scenarios.

The risk analysis presented in Chapter 3 represents the assessment of the consultants. However, the additional risks mentioned by stakeholders could also play a role in the achievement of decarbonisation scenarios to a certain extent.

# Risk assessment

This chapter presents the detailed assessment of the 16 individual risks selected in the previous chapter (see section 2.2). The assessment of each risk is structured as follows:

* **Description of the risk**, covering the Baltic Regional Gas Market and presenting the underlying/root causes of the risk as well as the different channels through which the risk could impact the decarbonisation of the gas system;
* **Rating of the risk** according to likelihood, severity, applicable scenarios and eventual differences between the Baltic Regional Gas Market countries;
* **Identification of mitigation measures** which could be employed to reduce the risk likelihood and/or severity.

To guide the **rating of the risk severity**, the following scale is employed:

* **Low severity**: would increase the cost of/hinder decarbonisation, but not beyond the capacity to pay of the countries/stakeholders and/or alternatives are available
* **Medium severity**: would compromise the achievement of the decarbonisation goals but alternatives are available, or would increase the cost of the transition
* **High severity**: would significantly compromise the achievement of decarbonisation goals and it is probable there are no alternatives to compensate

To guide the **ranking of the risk likelihood**, the following scale is employed:

* **Low severity**: More likely than not that the risk will not occur
* **Medium severity**: More likely than not to occur at least once in study horizon (up to 2050)
* **High severity**: More likely than not to occur multiple times in study horizon (up to 2050)

## Risk 1: Economic turndown and instability can limit ability of local gas producers, users, network operators and authorities to invest in decarbonisation measures

#### Description of the risk, covering the Baltic Regional Gas Market

The decarbonization of the gas sector will require unprecedented large-scale investments in technological innovations and clean energy. Economic recessions and instabilities can however limit the ability of economic actors such as domestic gas producers, gas users, network operators and national and local authorities to invest in decarbonization measures.

In the past three years, the global economy has faced severe adverse shocks. The outbreak of Covid-19 in 2020 has caused a large global economic crisis, characterized by amongst others, a reduction in new investments due to the implementation of lockdown measures as well as high uncertainty regarding the economic outlook.[[11]](#footnote-12)

In 2022, the Russian invasion of Ukraine and the associated ongoing war triggered severe commodity and energy price shocks as well as trade disruptions.[[12]](#footnote-13) The unprecedented increases in fossil fuel prices paved the way for a global energy crisis.[[13]](#footnote-14) While high energy prices have pushed European consumers to cut gas demand and contributed to the acceleration of the transition towards renewable energy, a transition that is driven by high and volatile fossil fuel prices is likely to present certain challenges. As indicated by the European Investment Bank (2022) volatile fossil fuel prices are likely to increase the cost of capital. This may lead to delayed investments in (clean) energy projects at the supply side.[[14]](#footnote-15) In addition, high energy bills limit the ability of citizens and businesses to invest into decarbonization measures on the demand side.

Although energy prices have been slowly decreasing since the beginning of 2023, the global economy is still going through a period of great uncertainty which is a consequence of the cumulative effects of the past three years’ negative shocks manifesting themselves in unexpected ways.[[15]](#footnote-16) The inflation has reached a peak level,[[16]](#footnote-17) which has led central banks to use tightening monetary policy in order to bring it back towards their targets. However, as stated by the European Central Bank (2023), high interest rates (and hence increased cost of capital) make renewable energy less competitive in comparison with fossil-fuel based power plants which have lower upfront costs and are less capex-intensive. This discourages economic actors to invest in renewable and low-carbon energy. On the other hand, if rising inflation is not contained by tightening monetary policy and remains high, there is a risk of decreased willingness of economic actors to invest as inflation acts as a tax on investments.[[17]](#footnote-18)

The IMF World Economic Outlook 2023 indicates that it is becoming increasingly unlikely for the global economy to return to the pace of economic growth that prevailed before the above mentioned series of shocks.[[18]](#footnote-19) Many economies are still recovering from the consequences of the Covid-19 pandemic and the Russian invasion of Ukraine. Their recovery is nevertheless hindered by the recent financial tightening. The Outlook states that the prospects for growth are less likely than in the past decades. In addition, with more frequent natural disasters and a continued dependency on limited resources (e.g. fossil fuels and energy technologies), our economies will remain exposed to the risks of persistent inflationary pressures and economic shocks.[[19]](#footnote-20)

#### Rating of the risk based on likelihood and severity

The **severity of this risk is assessed as ‘medium’** as the decrease in the ability to invest in gas decarbonization measures would depend on the depth of the economic turndown and instability. The impact of the economic turndown would materialize along the entire value chain and take the form of reduced ability to invest in decarbonization measures by economic actors and in turn, a decelerated transition towards a carbon-neutral economy. In order to minimize the severity of this risk, policymakers can respond to economic shocks with increased climate and energy ambitions.

There is no specific moment at which an economic turndown or instability is expected in the next three decades, but it is certain to occur as a consequence of economic, environmental or social shocks (e.g. financial speculation, excessive production, natural disasters, pandemics, geopolitical tensions, etc.). Hence, we would rate the **likelihood of this risk as ‘high’** as more frequent shocks can be expected as a consequence of climate change which may lead to economic recessions.

All energy scenarios would be affected by an economic turndown. Nevertheless, the gas decarbonization scenarios would be more affected by a decrease in ability of economic actors to invest in decarbonization technologies, as significant investments are needed in comparison with the BAU scenario. In addition, as the Cost minimal scenario requires significant investment in the next decade (until 2030) compared to the REN-Methane and REN-Hydrogen scenarios (see Deliverable 4 – Figure 3-12), it could be more exposed to long-term effects of the above-mentioned shocks (i.e. Covid-19 pandemic and post-crisis, Russian invasion of Ukraine and energy crisis).

The four Baltic Regional Gas Market countries are subject to a similar level of risk.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Economic turndown limits ability to invest | **✓** | **✓** | **✓✓** | **High** | **Medium** |

#### Potential mitigation measures

The following measures could be considered to mitigate the severity and likelihood of this risk to occur:

* Economic and financial measures to prevent an economic turndown or reduce its impact, e.g. through monetary policy.
* Providing adequate price signals to economic actors to stimulate investments in decarbonisation measures, such as carbon pricing, energy taxation reform, financial support (through subsidies, loans and fiscal measures), risk sharing (support from financial institutions), public-private project partnerships (e.g. biomethane producers and DSOs/TSOs – with support from NRAs - to develop and share infrastructure costs for the connection of biomethane plants to the gas grid).

## Risk 2: Supply dependence and bottlenecks for energy technologies can increase costs/slow down transition

#### Description of the risk, covering the Baltic Regional Gas Market

Timely availability of adequate technologies for the production, transport, storage and consumption of renewable and low-carbon gases will be important for the attainment of the climate and energy goals of the EU as well as the Member States of the BRGM. Some of these technologies may be reliant on critical components, materials and equipment, and processes. The supply of these elements may be vulnerable to disruption due to a number of reasons, including climate change, geopolitical & trade issues, and pandemics.[[20]](#footnote-21)

A number of factors may increase the vulnerability of these technologies, including a (forecasted) high demand in the EU, associated high growth rate in the manufacturing to meet demand, and (foreign) market concentration.[[21]](#footnote-22) While not necessarily impacting the deployment and operation of renewable and low-carbon gas equipment in the short-term, more sustained supply disruptions of vulnerable elements could have long-term impacts and compromise the decarbonisation of the regional gas system.

Concerning **hydrogen technologies**, the main equipment concerned refers to fuel cells (mobile and stationary) and electrolysers. While Asia and the United States lead in the manufacturing of fuel cells, EU manufacturing is also important and domestic producers are well-placed for the production of several main components. EU manufacturers are furthermore leaders in the manufacturing of electrolysers. The policy targets for the deployment of electrolysers are significant and could lead to supply chain bottlenecks in case of delays in developing the manufacturing facilities – including due to the lack of sufficient skilled labour. Furthermore, dependencies could increase in the sourcing of critical raw materials.[[22]](#footnote-23)

Concerning **biogas and biomethane technologies**, the EU has leading manufacturers of equipment for the anaerobic digestion of biomass into biogas as well as for the upgrading into biomethane.[[23]](#footnote-24) However, regarding the BRGM countries, only Finland has a significant manufacturing and services base for biogas and biomethane technologies.[[24]](#footnote-25)

Regarding the **technologies for the production of** **renewable fuels of non-biological origin**, the main dependencies relate to the availability of renewable electricity at competitive prices. Supply chain dependencies are low, as several manufacturers for catalysts exist. However, these are especially located in the Benelux and Germany, with lower presence in the BRGM region.

It must be noted that the localisation of the industries within the EU is not as important from a supply chain dependence perspective as the dependence on non-EU manufacturers and service providers (although the localisation would affect the macro-economic impacts of the technologies’ deployment). Nonetheless, the large-scale deployment of dispersed gas production facilities would require sufficient skills for not only manufacturing but also installation and operation.

#### Rating of the risk based on likelihood and severity

Based on the information presented above, we assess the **severity of the risk as medium** due to the significant policy targets for the deployment of electrolysers which could lead to manufacturing bottlenecks and due to the dependence on critical raw materials for hydrogen technologies. In contrast, the supply chain dependences for biogas/biomethane and RFNBO technologies are limited given the important activities of EU companies in this sector, including a presence in Finland of companies active in biogas/biomethane technologies.

The **probability of the risk is assessed as low** given the existence of several policy initiatives at the EU level aimed at addressing the potential manufacturing and critical raw materials bottlenecks.

This risk would affect especially the REN-H scenario as high dependencies were identified for electrolyser and fuel cell technologies. All four countries would be similarly affected in case of any supply chain disruptions given the free trade of products and services within the EU, even if Finland disposes of a more important manufacturing and services base for biogas/biomethane technologies.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Supply dependence and bottlenecks for energy technologies can increase costs/slow down transition | **✓** | **✓✓** | **✓** | **Low** | **Medium** |

#### Potential mitigation measures

A number of measures could be considered by the BRGM countries to mitigate any potential risks from technology supply chain disruptions, complementing related actions at the EU level:

* Coordination on the planning of deployment of renewable and low-carbon gases technologies at the regional and EU level, building from national targets, in order to provide high visibility and predictability to (potential) investors, both at the supply (providers of technologies) and demand side (users of technologies);
* (Re)skilling programs to develop the necessary human resources for installing and operating the renewable and low-carbon gases aspects.

## Risk 3: Fossil gas decarbonisation can negatively affect competitiveness of industrial users

#### Description of the risk, covering the Baltic Regional Gas Market

International competitiveness is determined by a number of factors, among which producing at an affordable cost. For industries and in particular for energy-intensive industries, energy (including gas) costs are important determinants of their competitiveness. [[25]](#footnote-26) The transition towards decarbonized production technologies will require significant investments from industrial users. Even though numerous technologies are available that can contribute to the transition towards carbon-neutral production processes, these technologies are characterized by high upfront and operational costs and are not all (yet) competitive with conventional production processes.[[26]](#footnote-27) [[27]](#footnote-28) In a hydrogen-based economy, investments by industrial users will be substantial as where natural gas is replaced by hydrogen, equipment will need to be adapted or replaced. In addition, short- to mid-term renewable (and low-carbon) hydrogen costs are likely to be higher than natural gas prices. Deliverable 3 analysed the impacts of hydrogen blending on equipment in the industry. Investment costs will be the highest for production processes where methane gas is used as feedstock (e.g. refinery processes or fertilizer industry) because fluctuations in gas purity can disrupt the other series of processes while impacting the reactor kinetics.

As energy represents an important share of the overall industrial production costs, the availability and cost of energy in general, and gas in particular, impact the competitiveness of industrial users. The Trinomics’ study on Energy Prices and Costs (2020) showed that energy costs and their drivers (i.e. energy prices output and energy intensity) vary significantly between sectors, which in turn affect their competitiveness.[[28]](#footnote-29) The share of energy costs varies among industries: in the most energy-intensive industries, they represented up to 10% of production costs in 2010-2017. In less energy-intensive industries, this share was between 1% and 3%. Since 2021, the share of energy in the overall industrial production costs has of course substantially increased. Another study commissioned by the ITRE committee on the challenges and opportunities in energy transition faced by energy-intensive industries (2020) suggests that although EU energy-intensive industries are competitive on international markets, concerns remain with respect to energy costs.[[29]](#footnote-30) These are likely to become increasingly important for the competitiveness of the industry in the short and medium term as the EU and its Member States adopt in general more ambitious climate targets and policies than other continents (e.g. carbon emission taxes). As shown in Deliverable 4, the decarbonization of the gas sector is likely to increase the energy costs in the short and medium term in the Baltic Regional Gas Market, including for industrial users. The average gas cost will be lower in the BAU scenario (13 650 €/year for commercial users in 2030) than in the decarbonization scenarios (between 13 850 €/year and 15 611 €/year for commercial users in 2030). However, the decarbonization of the gas sector will lead to lower energy costs in the long run (10 185 €/year in the BAU vs. between 4 665 EUR/year and 8 234 EUR/year in the decarbonization scenarios for commercial users in 2050).

To mitigate the negative impact of the decarbonization policies, including the substitution of fossil gas by renewable energy, on the competitiveness of the EU industry, the EU has recently adopted the Carbon Border Adjustment Mechanism (CBAM) regulation.[[30]](#footnote-31) The CBAM aims to prevent carbon leakage by putting a fair price on carbon emitted during production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries. In this way the CBAM should protect to some extent the competitiveness of the EU industries that are included in the scope[[31]](#footnote-32), at least for production destined for the internal market.

#### Rating of the risk based on likelihood and severity

An increase in investments and energy costs in the industry due to gas decarbonization policies might cause a decrease in competitiveness of industries in the Baltic Regional Gas Market in the absence of further measures. In addition, gas decarbonization policies can also have a negative impact on trade as domestic production of goods (and to some extent also services) may become less competitive. Finally, if local industries face a decrease in competitiveness, consumers might shift their consumption towards foreign products and services. As several parts of the value chain are impacted, we rate the **severity of the risk as ‘medium’**.

The **likelihood of the risk of decreased industry competitiveness can be assessed as ‘low’ to ‘medium’**. A decline in competitiveness is more likely to occur in the short and medium term because production costs of industries are expected to increase due to higher investments and energy costs. However, in the long term decarbonisation of the gas sector can have a positive impact on the competitiveness of industries, in particular if foreign countries do not decarbonise at the same pace.

The negative impact of the decarbonisation scenarios on the industry’s competitiveness is more likely in the short to medium term and in particular in the Cost minimal scenario, where investments will be significantly higher up to 2030 (see Deliverable 4 – Figure 3-12). As the share of natural gas in total industrial energy consumption is high in Estonia and Lithuania (respectively 26% and 27% in 2021), the industries in these two countries are likely to be more impacted by the gas decarbonisation scenarios than in Finland and Latvia (respectively 7% and 12% in 2021).

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Fossil gas decarbonisation can negatively affect competitiveness of industrial users | **ü** | **ü** | **üü** | **Low/Medium** | **Medium** |

#### Potential mitigation measures

The following measures could be considered to mitigate the severity and likelihood of this risk to occur:

* Public financial support (preferably investment aid rather than operational support) for industrial users to reduce their dependence on fossil gas by energy efficiency and substitution measures (e.g. subsidies for energy audits, energy efficiency investments, replacement of production equipment, and resource-efficient green technologies);
* Information exchange and technical assistance on specific technologies and best practices via sector associations and technology clusters;
* Applied research and demonstration/pilot projects for renewable/low-carbon gas based technologies/applications that have not yet reached technical maturity (TRL < 9) but that are promising solutions to decarbonise the industry.

## Risk 4: Developments in global energy markets impact competitiveness of gas decarbonisation solutions

#### Description of the risk, covering the Baltic Regional Gas Market

The competitiveness of gas decarbonization solutions can be defined as the ability to produce and use affordable, reliable and accessible renewable and low-carbon gas alternatives, which compete against fossil fuel-based solutions. This competitiveness has been affected in different ways by developments in global energy markets. Since 2021, there has been high volatility in energy prices on global energy markets. To some extent, this was expected considering the economic recovery and relaxation of lock-down measures in many countries following the Covid-19 pandemic. Nevertheless, energy prices have reached peaks that were not anticipated. The increases in gas prices on the global markets (more than 170% increase in 2021) and in the EU (more than 150% increase between July 2021 and July 2022) can be attributed to several factors/events: [[32]](#footnote-33)

Disrupted pipeline gas supply from Russia;

Extreme climate conditions, including summer heatwaves and droughts across Europe which push up energy demand for cooling and add pressure on electricity generation;

Increased demand for LNG and a consequent spike in its price;

Greater consumption of gas in Asia due to the economic recovery;

Lower availability of nuclear and hydropower electricity generation, partly linked to climate conditions.

Energy prices increases have in particular been aggravated by the Russian invasion in Ukraine in 2022. [[33]](#footnote-34) As Russia has ceased supplying natural gas to several EU countries, the supply uncertainty increased which pushed gas prices further up. Electricity prices also increased steeply as they are to some extent based on the gas prices in the EU energy market.

The European Commission issues every year since 2020 a report on the competitiveness of clean energy technologies. This report presents the current and projected state of play of different technologies, including gas decarbonization solutions (i.e. renewable hydrogen production through water electrolysis, biomethane). The 2022 report considers the impact of the energy crisis. Developments in global energy markets have impacted the competitiveness of gas decarbonization solutions (mainly hydrogen) in the following ways:[[34]](#footnote-35)

**High electricity prices** – As the production of renewable hydrogen through water electrolysis is highly dependent on the availability and cost of renewable electricity, the economic viability of electrolysers has been affected by the energy crisis.

* **Supply chain disruptions** - Disruptions in some global supply chains of materials and resources have arisen due to the Covid-19 pandemic and current geopolitical tensions, which have increased raw material prices. Prices of commodities like lithium and cobalt increased by more than 50% in 2021 and those of copper and aluminium rose between 25% and 40% in 2021. Being highly dependent on such raw materials, the cost of renewable energy technologies has increased. The price of wind turbines and solar PV modules increased in 2022 by 9% and 16% respectively compared to 2021, and the price of batteries rose by 15% between 2021 and 2022. As the deployment of renewable electricity technologies is crucial for the production of renewable hydrogen, these cost increases have impacted its development.

#### Rating of the risk based on likelihood and severity

If developments on global energy markets negatively impact the competitiveness of gas decarbonisation solutions, the achievement of the gas decarbonisation scenarios may be hindered as investments in fossil fuel technologies remain more attractive. However, an energy crisis leading to high fossil gas prices can also contribute to the acceleration of the energy transition, and in turn increase the competitiveness of gas decarbonisation technologies. Therefore, we assess **the severity of the risk as ‘medium’**.

The **likelihood can be rated as ‘medium’**. Energy crises are more likely to occur in the short- and medium term, when the energy system is still majorly fossil fuels-based, and the energy import dependence is still high and thus easily impacted by geopolitical tensions. The competitiveness of decarbonised gas solutions is likely to increase over time thanks to further decreasing production costs and favourable climate and energy policies, including carbon taxation.

As the REN-Hydrogen scenario leads to the highest renewable electricity requirements in the 4 countries (with notably Lithuania requiring as much or more electricity than Estonia, Latvia and Finland combined), it is likely to be more impacted by the high electricity prices in the short-term. In the long-term, the BAU scenario will be more impacted by this risk than the decarbonisation scenarios as fossil-fuel technologies will in that scenario continue to play a significant role, and gas decarbonisation solutions will thus face more difficulties to become competitive.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Developments in global energy markets impact competitiveness of gas decarbonisation solutions | **✓** | **✓✓** | **✓** | **Medium** | **Medium** |

#### Potential mitigation measures

The developments in global energy markets cannot be directly addressed by national or regional measures. However, policies and scenarios that reduce the energy import dependency of the BRGM countries will also reduce the severity (impacts) of this risk for the considered countries. Another relevant mitigation measure is to implement mechanisms to stabilize energy prices, such as feed-in tariffs or long-term power purchase agreements. This will provide economic certainty and mitigate the risk of price fluctuations for renewable electricity, ensuring the financial viability of both hydrogen and biomethane production.

The risk's likelihood cannot be mitigated by specific national or regional measures.

## Risk 5: Fragmentation of regional/national gas networks and markets

#### Description of the risk for the Baltic Regional Gas Market

Due to the decarbonisation of gas supply, the paradigm of all methane networks within the regional Baltic gas market, transporting a quite homogeneous methane product may gradually transform into a patchwork of networks carrying different gases including hydrogen. Methane networks will transport natural gas, biomethane and in some cases limited hydrogen volumes (blending), and cross-border physical trade may not be possible any more if the quality specifications are not harmonized. This may impact the single regional gas market and could make redundant some pipeline interconnections which have been established. A transition to national (and sub-national) networks carrying different gas products could significantly impact the regional gas market liquidity and security of gas supply arrangements in place as, in the case of a supply shortage, it may disrupt the solidarity principles governing sharing of available gas between the BRGM countries. This risk would emphasise the advantages of a transition to synthetic methane of a defined calorific value - derived from hydrogen - rather than different gases. Such an approach would also remove the necessity to convert existing networks and end-users to a different non-methane product. However, these advantages would be counter-balanced - and most probably outweighed - by the increased costs and energy losses from the conversion processes.[[35]](#footnote-36)

#### Rating of the risk based on likelihood and severity

The fragmentation of the gas networks/markets as a consequence of the introduction of different gases with non-harmonised qualities would negatively affect the domestic and cross-border gas trade and hence have a negative impact on the regional gas market liquidity, competition and security of supply.

All steps of the value chain would be affected by this risk, including local gas production, transport and distribution, trade and supply, and end-use.

**We consider both the severity and likelihood of this risk as ‘medium’**, but mitigation measures (mainly by harmonizing the gas quality specifications at regional level) can proactively be taken to reduce the likelihood of the risk. The risk will gradually occur to the extent that natural gas will be substituted by renewable gases (biomethane and hydrogen) other than synthetic methane. The qualitative impacts of early versus late occurrence of this risk would be similar, but late occurrence may have lower global impacts as the overall gas use is expected to decrease due to energy saving measures and electrification.

All gas decarbonisation scenarios are affected by this risk, but the methane based scenario would be the least affected while the hydrogen based scenario would be most impacted.

This risk will be the highest in the BRGM countries with a relatively high share of hydrogen (blended in methane networks or transported in dedicated pipelines); Lithuania and Finland will hence be relatively more exposed to this risk than the other 2 BRGM countries.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Fragmentation of regional/national gas networks and markets | **✓** | **✓✓** | **✓** | **Medium** | **Medium** |

#### Potential mitigation measures

The following measures can be considered to reduce the likelihood and/or severity of this risk:

* Coordinated supra-national planning of methane network investments (refurbishment, repurposing, other adaptations) and of hydrogen network investments.
* Fully harmonised (at Baltic regional level) gas quality specifications for methane networks, hydrogen blending in methane networks and for dedicated hydrogen networks. As the current gas quality specifications (oxygen content) for the transport grid are considered as a barrier for biomethane injection, the implementation of harmonized specifications should also address this aspect. The proposed EU gas package that is currently in the approval phase is expected to introduce new rules requiring firm network access capacity for hydrogen and renewable gases, hydrogen blending with other gases (including an obligation for TSOs to accept a hydrogen content of up to 5 % from 1 October 2025), and cross-border coordination on gas quality (assisted by an ENTSOG monitoring report on gas quality every 2 years). These new firm capacity requirements will apply to both TSOs and DSOs.[[36]](#footnote-37) The transposition of these new rules in national legislation and regulation in the Baltic countries will have to be properly coordinated and harmonized in order to avoid market fragmentation, which would also hinder security of gas supply.
* Consider the possibility of creating a regional virtual trade hub for renewable hydrogen and biomethane in order to enhance the market liquidity and competition and to have a transparent price formation system.

## Risk 6: Gas network and storage infrastructure cannot be adequately or timely developed, including repurposing or adaptation of natural gas infrastructure

#### Description of the risk, covering the Baltic Regional Gas Market

The implementation of gas decarbonisation measures may be hindered or delayed by long lead times to build new dedicated hydrogen infrastructure or refurbish/repurpose existing methane infrastructure, which can be exacerbated by the lack of an adequate planning process at the regional level. The gas decarbonisation process presents indeed an existential threat particularly for existing methane networks, and private companies may not want to timely invest in dedicated hydrogen networks because of the high uncertainties. The gas decarbonisation policy will hence require strict regulation and appropriate public involvement in networks, in particular in cases where these need to be refurbished, repurposed, or newly built. An alternative could be a franchise monopoly for investors in new infrastructure with guaranteed regulatory returns over a long period of time. One of the most controversial propositions of this narrative for governments and regulators will be that, although there will be competition in relation to project selection, gas-to-gas competition will almost certainly not operate in the initial stages of establishing a decarbonised gas market. For many years there will be too few sources of biomethane and hydrogen to create a fully competitive market. A major challenge will be to reintegrate a fragmented value chain in order to launch such projects. Market players will indeed be less interested in producing renewable (or low-carbon) hydrogen for commercial purposes if networks are not able to transport it. Enabling this will require an appropriate planning framework and adequate cooperation and coordination between all parties, in particular the national authorities and (methane and hydrogen) TSOs/DSOs of the Baltic regional gas market countries.

#### Rating of the risk based on likelihood and severity

If adequate network/storage infrastructure for renewable gases would not be timely developed, the substitution of natural gas and grey hydrogen by renewable gas will be delayed/hindered, as potential local gas production plants will not be able to be timely connected to the grid, and renewable gas imports and trade across the Baltic regional gas market will be hindered. This might lead to increased off-network gas production and use (e.g. biogas, hydrogen) which can be a sub-optimal solution from an economic and energy system perspective.

The materialization of this risk, e.g. a bottleneck in the network and storage infrastructure for renewable gas, will impact both the downstream (supply, end-use) and upstream (production) steps in the value chain.

**The severity of this risk is considered as ‘high’**. The risk is likely to mainly occur in the initial gas transition phase (up to 2030) when renewable gas volumes are still low and regulatory and market uncertainties quite high. Next to the specific risks related to ‘late’ deployment of renewable gas network and storage infrastructure, an ‘early’ deployment may also present risks due to the higher uncertainties regarding the expected renewable gas supply and demand. An appropriate timing of infrastructure investments is hence required, in order to reduce the risks of overinvestments (asset stranding), while also not hindering or delaying investments in supply or demand. Infrastructure planning should hence be based on realistic market prospectives to properly anticipate expected market developments while reducing the risks of wrong investment choices.

Assuming that the Baltic authorities (and TSOs) will timely take initiatives to develop/adapt the infrastructure, **we consider the likelihood that this risk will effectively occur, as ‘low’**. If the initiatives to properly develop/repurpose the gas grid are however not timely taken, the likelihood of this risk may increase.

All gas decarbonisation scenarios are in principle affected by this risk, as in any scenario there is a shift to renewable energy, but the timing and intensity are different depending on the scenario. The methane based scenario would be the least impacted, while the hydrogen based scenario would be the most exposed to this risk.

The likelihood and severity of this risk are expected to be similar in the 4 BRGM countries. However, the likelihood can be substantially reduced if national authorities and operators adopt a proactive approach.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Adequate renewable gas network and storage infrastructure is not timely developed |  | **✓✓** |  | **Low[[37]](#footnote-38)** | **High** |

#### Potential mitigation measures

The following measures can be considered to reduce the likelihood and/or severity of this risk:

* Proactive national and supra-national planning of methane network investments (refurbishment, repurposing, other adaptations) and of hydrogen network investments;
* Regular market studies for the Baltic region to identify and assess the expected developments in supply and demand of renewable gases, based on contacts with large market operators and sector associations. These studies should underpin the renewable gas network and storage investment planning, and help to reduce the risk for investment delays and for over- or under-investments.
* Ensure appropriate regulation and public control of gas networks, in particular when these are partially or fully privately owned and need to be refurbished or repurposed, in order to ensure timely investments in renewable or decarbonized gas transport (and large-scale storage) infrastructure.

## Risk 7: Security of gas supply can be threatened due to adequacy/flexibility issues of the regional energy system

#### Description of the risk, covering the Baltic Regional Gas Market

This risk is focused on security of supply issues arising from disruptions in the domestic/regional energy system. Risk 8, presented in section 3.8, discusses security of supply from the external dependence perspective.

With the accelerating deployment of variable renewable electricity generation, the flexibility needs of the energy system in the Baltic States and Finland will rise significantly. The JRC (2022)[[38]](#footnote-39) indicates that the daily, weekly and monthly flexibility requirements will in 2030 and 2050 be multiple times higher than the current levels. This will require the further deployment of flexibility solutions such as storage and demand response, including from the flexible operation of electrolysers. The JRC modelling indicates a significant number of hours would be characterised by moderate electricity prices (with almost 80% of the hours exhibiting prices between 40 and 80 EUR/MWh), while during 15% of the hourly prices would be below 40 EUR/MWh. If electrolysers would be operating flexibly based on these price signals, there is a non-marginal risk that grid-connected electrolysers would have a low load factor, affecting their economic feasibility. Moreover, if other flexibility solutions (batteries, demand response,..) are deployed at large scale, the low price opportunities may be captured by other market operators and further affect the business case of electrolysers. Deliverable 3 assumes renewable electricity cost (as input for electrolysers) at almost 60 EUR/MWh in 2021 and reaching around 35 EUR/MWh in 2050. The modelling also considers a relatively high utilisation factor for the electrolysers, as it is assumed that dedicated wind energy plants would be used for electrolytic hydrogen production.[[39]](#footnote-40)

Given the flexible operation of electrolysers following the profile of dedicated wind energy generation capacities and the demand profile of end-use sectors such as industry and heavy-duty transport, hydrogen storage will also be necessary to provide flexibility to the hydrogen system. Deliverable 3 estimates that between 148 GWh (in the REN-Biomethane scenario) and 293 GWh (in the REN-Hydrogen scenario) of hydrogen storage will be necessary by 2050. Other studies assume much higher hydrogen storage needs, e.g. 6.3 TWh in Finland and 0.4 TWh in Estonia by 2050 according to Guidehouse (2021).[[40]](#footnote-41) While large underground hydrogen storage could be deployed in the REN-Hydrogen scenario once a hydrogen backbone is developed, the other decarbonisation scenarios do not foresee such backbone, and thus would rely on above-ground storage which has a significantly higher cost. The absence of a backbone between the hydrogen clusters would also imply that a lower number of hydrogen producers and consumers would be connected, thus comparatively increasing the flexibility needs of each hydrogen cluster.

Regarding energy system adequacy, the 2022 European Resource Adequacy Assessment states that Estonia and Lithuania will face see a relatively high loss of load expectation (LoLE) risk by 2030 in the absence of capacity mechanisms (while this risk is much lower in Latvia and Finland).[[41]](#footnote-42) However, it can be expected that, as a potential flexibility solution, power-to-gas-to-power would rather provide a contribution to addressing any energy system adequacy concerns rather than being negatively impacted.

Regarding biogas/biomethane, matching supply and demand can also in some cases be a challenge, depending on the feedstock type and its use. For example biogas/biomethane production may be higher in summer for some biomass feedstocks, especially lignocellulosic biomass from agricultural crops/residues,[[42]](#footnote-43) while demand for heating purposes is concentrated in the winter season. The storage of biomethane in the existing Inčukalns underground gas storage in Latvia could be considered for this purpose, but the repurposing of regional methane gas pipelines to hydrogen in the REN-Hydrogen scenario would also necessitate local storage of methane gases, in addition to other flexibility solutions. If large-scale storage of biomethane at regional level would not be possible, local storage of biomass feedstocks as well as of biogas/biomethane can be considered, increasing the ability to adapt the production profiles, and to match demand and supply. While the supply of some biomass feedstocks has a seasonal profile, other types such as non-lignocellulosic biomass have much more constant supply profiles throughout the year. This is in line with the assumption of Deliverable 3 of the present study which assumes a biomethane plant utilisation rate of 85% (constant throughout the year).[[43]](#footnote-44)

#### Rating of the risk based on likelihood and severity

Given the analysis above, **the severity of the risk is classified as ‘low’.** For biogas and biomethane, we assume that feedstock and gas storage options will be available to match supply and demand, particularly in the REN-Biomethane and Cost Minimal scenarios where the cross-border methane gas network would remain available allowing the use of the Latvian gas storage site. The flexibility risks would be higher for the hydrogen production, due to the need for electrolysers to operate flexibly following the wind energy generation (in the case of dedicated RES capacity) and the associated hydrogen storage needs, or due to the risk of a low number of hours with relatively low spot electricity prices (in the case of grid-connected hydrogen production). However, options would exist to provide the necessary flexibility to the hydrogen system, albeit at a cost. **The likelihood of this risk is classified as ‘high’**, as in the case of the REN-Hydrogen scenario it is very likely that significant flexibility resources will be required both for the electricity system (due to increased deployment of renewable electricity for hydrogen production) and the hydrogen system (which will require more hydrogen storage capacity).

This risk would become more significant towards 2040 and 2050 as the energy system will reach a higher penetration of renewables and as the hydrogen sector will develop further. For the reasons mentioned above, the risk is expected to impact mainly the REN-Hydrogen scenario. All 4 countries would be affected in a similar manner, although Lithuania might be particularly affected given the higher levels of wind deployment for hydrogen generation.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Security of gas supply can be threatened due to adequacy/flexibility issues of the regional energy system |  | **✓✓** |  | **High** | **Low** |

#### Potential mitigation measures

The main risk to be addressed is the high flexibility requirements in the REN-Hydrogen scenario (both in the electricity and hydrogen systems). To address these requirements, the following measures can be considered:

* Incentivise the provision of flexibility to the power system by electrolysers and other solutions, through the identification and removal of barriers to the participation of flexibility providers in the different electricity markets;
* Develop energy interconnectors to further integrate the regional electricity and (if a hydrogen backbone develops) also hydrogen markets;
* Assess the expected hydrogen storage needs at a cluster and regional level and evaluate the options to cover them.

## Risk 8: Security of gas supply can be threatened due to external energy dependence

#### Description of the risk, covering the Baltic Regional Gas Market

Security of energy supply, which is defined by the IEA (2023) as the uninterrupted availability of energy sources at an affordable price,[[44]](#footnote-45) is crucial for the well-being of citizens as well as for businesses and social services to function properly.[[45]](#footnote-46) Countries with a heavy reliance on imported fuels have less control on their security of energy supply. The Russian invasion in Ukraine in 2022 is a very good example of an event that threatened the security of energy supply of many countries, particularly in the EU. As around 45% of the EU natural gas imports came from Russia, when the latter stopped delivering gas to a number of EU countries, the EU had to take urgent measures to reduce its dependency on Russian gas.

Deliverable 2 showed that the current gas consumption in Estonia, Latvia, Lithuania and Finland is mainly dominated by natural gas, and as there is no natural gas production in any of these countries, they are highly dependent on foreign supply. Natural gas has historically been mostly imported in the region via pipelines from neighbouring countries (i.e. mainly Russia and Belarus) or via LNG terminals.[[46]](#footnote-47) Reducing the energy dependency of the Baltic Regional Gas Market on import is key to ensure security of supply and strengthen its resilience and autonomy in the event of energy shortages arising from geopolitical tensions in the future. In addition, it also represents an opportunity to accelerate the green transition by reducing the overall gas demand and deploy renewable energy sources, which are often locally generated/produced and may thus decrease energy dependency.

As indicated in Deliverable 3, the gas imports of the Baltic Regional Gas Market from foreign countries will decrease between 2030 and 2050 (thanks to increased domestic gas production) in all scenarios but more substantially in the REN-Methane, REN-Hydrogen and Cost minimal scenarios than in the BAU scenario. The gas decarbonization scenarios hence ensure a lower external energy dependence and thus a greater security of supply. The cross-border regional gas flows will however increase over the same period in all decarbonization scenarios, which means that the four countries will have a greater dependence on each other.

#### Rating of the risk based on likelihood and severity

Gas supply disruptions can have major impacts on a country’s economic and social wellbeing. In the residential sector, gas is mainly used for heating and a supply disruption can thus highly affect households, and more specifically vulnerable people who often live in low energy performant dwellings without alternative heating sources. In addition, electricity supply would be impacted by a disruption in gas supply, which would affect all sectors of the economy (particularly in Latvia and Finland where the largest natural gas consumer is electricity generation). Therefore, we consider the **severity of this risk as ‘high’**.

The **likelihood of the risk can be assessed as ‘low’**. The risk is more likely to occur in the short and medium term as the external dependence of the Baltic Regional Gas Market is expected to decrease. However, the four countries will be increasingly reliant on each other which may also have negative implications if tensions would arise within the region.

Dependence on foreign imports will obviously decrease in all decarbonization scenarios to a higher extent than in the BAU scenario. As the gas consumption is higher in Estonia, Latvia and Lithuania (9%, 9% and 11% of total energy consumption in 2021[[47]](#footnote-48)), their security of supply would be more affected by disruptions in gas imports than Finland (only 3% of total energy consumption in 2021[[48]](#footnote-49)).

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Security of gas supply threatened due to external energy dependence | **✓** | **✓** | **✓** | **Low[[49]](#footnote-50)** | **High** |

#### Potential mitigation measures

The following measures can be considered to reduce the likelihood and/or severity of this risk:

Work on further solidarity arrangements aimed at ensuring that protected customers (e.g. households, hospitals, electricity generation) have continued access to gas in times of crisis; Estonia already concluded two bilateral agreements, with Latvia (on 4 January 2022) and with Finland on (25 April 2022).

Decrease the overall natural gas consumption by implementing energy efficiency measures (insulation, highly performant equipment) and by shifting towards locally generated renewable energy sources (electricity, biogas/biomethane, district heating).

* Pool gas demand of the BRGM countries to have a greater bargaining power in procurement negotiations with exporting countries. This can also be done together with other EU Member States via the EU Energy Platform.

## Risk 9: Available inputs for production of R/LC gases, e.g. renewable electricity or biomass can be insufficient

#### Description of the risk, covering the Baltic Regional Gas Market

One of the significant risks associated with replacing natural gas with biomethane for decarbonisation is the availability and adequacy of biomass feedstock. Biomethane production heavily relies on biomass resources, such as organic waste, agricultural residues, and dedicated energy crops. If the Baltic States and Finland cannot ensure a sustainable and sufficient supply of biomass, it could hinder the production of biomethane at the required scale. Insufficient biomass availability may limit the potential for decarbonisation through biomethane, impacting the overall energy transition goals. Moreover, Biomethane production processes require advanced technologies, such as anaerobic digestion or gasification, to convert biomass into usable fuel. The risk lies in the technological limitations and scalability of these conversion methods. Limited efficiency, and high production costs may impede the large-scale production of biomethane. Also, biomethane production requires an adequate infrastructure for collection, transportation, and distribution. The lack of a well-developed infrastructure network can hinder the growth and deployment of biomethane projects. Without the indicated necessary technological support, the desired decarbonisation goals in the Baltic States and Finland's gas market may be challenging to achieve.

As mentioned in Deliverable 2, multiple studies have varying perspectives on the biomethane potential in the Baltic states and Finland. Thus, the renewable gas production potential estimation of Baltic-Finnish regional gas market in this study for each country have been based on input from ministry representatives of each country, combined with authors’ estimations using existing literature sources[[50]](#footnote-51). Although the provided potential estimation from different resources varies, it could show that the potential is sufficient to meet the demand in 2050 perspective, as calculated in Deliverable 3. However, the success of biomethane as a decarbonisation solution depends on market demand and competition in the RGMCG region. The Baltic and Finnish states may become dependent on biomass imports to other countries if the demand overcome the production, and reliance on external sources can introduce supply chain risks, including price fluctuations, geopolitical factors, and logistical challenges. On the other hand, if the market demand for biomethane is low in the region or if other low-carbon alternatives emerge, it could limit the economic viability of biomethane projects.

One of the risks associated with hydrogen production and its impact on the RGMCG region is the uncertainty surrounding hydrogen infrastructure development and market demand. Hydrogen production also requires a well-developed and interconnected infrastructure for its supply of renewable electricity to the production unit, transportation, storage, and distribution of hydrogen to end users. The region may face challenges in establishing the necessary infrastructure to support large-scale domestic hydrogen production because to produce green hydrogen, the region would need to deploy large-scale renewable electricity plants, mainly offshore wind energy, which will require huge investments. Moreover, the establishment of a regional hydrogen network would require collaboration between neighbouring countries, which could involve complex negotiations and an adequate regulatory framework.

#### Rating of the risk based on likelihood and severity

The **likelihood of the risk can be assessed as ‘medium’**. This is because while the region has the potential to develop renewable electricity and biomass resources, there may be challenges in scaling up production to meet the demand for renewable gases such as hydrogen and biomethane. Factors such as limited biomass availability, competing uses for renewable electricity, and the need for significant investments in infrastructure and technology can pose constraints on the availability of inputs for gas decarbonisation. However, with appropriate policies, investments, and regional cooperation, it is possible to mitigate this risk and ensure an adequate supply of inputs for the production of renewable/low carbon gases.

We consider **the severity of this risk as ‘high’**. This is because a shortage of inputs can hamper the scaling up of renewable gas production, potentially limiting the ability to meet decarbonisation targets and transition away from traditional fossil fuels. The availability of renewable electricity and biomass is crucial for the production of renewable gases like hydrogen and biomethane, which are key components to decarbonising the gas sector. Insufficient inputs of biogas or renewable electricity can lead to delays, reduced green gas production capacity, increased costs, and continued reliance on conventional fossil fuel sources. However, with proactive measures to address the input shortage, such as diversifying renewable energy sources and enhancing biomass availability, the impact can be mitigated and the timely transition to a decarbonised gas market can still be achieved.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Available inputs for production of R/LC gases can be insufficient | **üü** | **üü** | **üü** | **Medium** | **High** |

#### Potential mitigation measures

List of Actions and Policy Recommendations for Mitigating Risks in Hydrogen and Biomethane Production includes but not limited to:

Increase Investment in Renewable Energy Infrastructure: Allocate adequate funding and incentives to promote the development of renewable energy sources, including solar, wind, and biomass. This will ensure sufficient electricity supply for electrolysis processes in hydrogen production and biomass availability for biomethane production.

Upgrade Power Grid Infrastructure: Invest in upgrading and expanding the power grid infrastructure to accommodate the increasing penetration of renewable energy sources. This will facilitate the transmission and distribution of renewable electricity required for both hydrogen and biomethane production.

Streamline Legal and Regulatory Frameworks: Develop clear and supportive legal frameworks and regulations for renewable energy and low-carbon gas production. Streamline permitting processes, provide incentives for project development, and ensure compliance with environmental standards to expedite the deployment of hydrogen and biomethane projects.

Promote Research and Development: Increase investments in research and development (R&D) to advance renewable energy technologies, energy storage, biomass conversion processes, and availability of alternative feedstock sources (e.g. algae-based feedstocks that could be available in the Baltic Sea). This will enhance the efficiency and scalability of both hydrogen and biomethane production methods, making them more cost-effective and commercially viable.

Enhance Climate Resilience Measures: Implement climate resilience strategies to address the potential impact of natural fluctuations on renewable energy production. This includes improving forecasting capabilities, investing in energy storage systems, and promoting diversification of renewable energy sources to ensure a consistent and reliable supply of electricity for hydrogen and biomethane production.

Establish Sustainable Biomass Management Practices: Promote sustainable biomass sourcing and cultivation practices to ensure a reliable and environmentally responsible feedstock supply for biomethane production. Encourage circular economy approaches, waste-to-energy initiatives, and land-use planning that prioritizes sustainable biomass production.

By implementing these actions and policy recommendations, policymakers and stakeholders can effectively address the identified risks and create an enabling environment for the successful adoption and deployment of hydrogen and biomethane as clean and sustainable energy alternatives.

## Risk 10: Investments in methane infrastructure can lead to lock-in on natural gas or asset stranding

#### Description of this risk for the Baltic Regional Gas Market

The Baltic Regional Gas Market countries have already taken multiple initiatives to diversify their natural gas sourcing in particular through existing and new LNG infrastructure. While three-quarters of the region’s natural gas imports came from Russia before the invasion of Ukraine, the Baltic states have succeeded in replacing this source mainly through the new shared Estonia-Finland LNG terminal in Inkoo, Finland, as well as the Klaipeda LNG terminal in Lithuania. A new LNG terminal was considered in Latvia. An international group of investors had committed to invest € 150 million in a floating regasification unit in the Skulte Port area, 2.5 km offshore off the coast, with a 34 km pipeline connection to the vast Inčukalns underground gas storage facility. The investors have demanded state guarantees in case the gas demand would fall below the current estimates.[[51]](#footnote-52) Meanwhile, the Latvian government has decided not to pursue this project, and the Estonian and Latvian authorities have reached an agreement on a potential floating LNG terminal in Estonia.[[52]](#footnote-53) Recent investments in the Balticonnector pipeline (Finland-Estonia) and in the gas interconnector between Poland and the Baltic States (commissioned in 2022), are also a key pilar in the region’s strategy to enhance its security of gas supply while remaining independent from Russia’s gas imports.

These recent, ongoing and planned investments in natural gas infrastructure (and the expectation that natural gas prices will, after having reached their peak level in 2022, further decrease to structurally lower and hence more competitive and affordable levels) may lead to a structural lock-in on natural gas and delay the transition to decarbonization options including electrification of building heating and switching to renewable gas. Investments in floating LNG installations are in principle flexible and present lower risks than fixed installations for asset stranding, but they still include the risk for a fossil fuel lock-in from a global perspective. However, fixed LNG terminals, pipelines and related equipment have a long technical and economic lifetime, and present higher stranding risks than floating installations, also taking into account that at this point it is still unsure whether and at what cost this infrastructure can be repurposed for dedicated hydrogen use. The risk is hence that for technical and economic reasons the substitution of natural gas will be hindered and delayed. On the other hand, if the natural gas volumes traded and consumed in the Baltic region rapidly decrease, part of the natural gas import and transport infrastructure may become redundant, and may need to be decommissioned. The economic consequences and potential to repurpose (part of) the infrastructure should be timely assessed, and adequate measures should be taken to anticipate and reduce the above-mentioned risks.

This risk is substantially higher in the BAU than in the decarbonization scenarios, as the required investments (CAPEX) in LNG terminals between 2022 and 2050 are estimated at 6.7 billion EUR, 3.1 billion EUR and 3.5 billion EUR respectively in the BAU, REN-Hydrogen and REN-Methane scenarios. The 4 countries will continue to have large OPEX related to LNG imports in all scenarios, including the Cost Minimal scenario. These are estimated at 144 million EUR in the BAU scenario, 109 million EUR in the REN-Hydrogen scenario, 101 million EUR in the REN-Methane scenario and 54 million EUR in the Cost Minimal scenario.

#### Rating of the risk based on likelihood and severity

A lock-in on natural gas could hinder the decarbonisation of the gas market and delay investments in electrification and renewable gas deployment. The risk for asset stranding mainly concerns regulated methane networks and LNG terminals which would not be suitable for repurposing, either for technical or for economic (market related) reasons.

Taking into account the potentially high economic consequences of a materialisation of this risk (depending on the residual accounting value of the concerned assets), **the severity of this risk is considered ‘high’**. This risk is expected to mainly occur from 2040 to 2050, when natural gas would in principle be completely phased out.

An early occurrence of this risk is not plausible. The recent and ongoing high investment levels in natural gas infrastructure to replace gas imports from Russia increase of course this risk, which would mainly become visible after 2030, when the load factor of existing infrastructure will gradually start to decrease.

The **likelihood that this risk materialises (at least for some assets) is considered ‘medium’**, but the rating can be reduced by ensuring that any new investment is future-proof (see mitigation actions).

All decarbonization scenarios foresee further investments in LNG terminals and present hence such risks; the risks are the highest in the REN-Methane and in the REN-Hydrogen scenarios, which foresee the highest reliance on LNG imports. In principle the Baltic countries with LNG terminals and a dense natural gas network on their territory present the highest risks for natural gas lock-in and asset stranding.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Lock-in on natural gas or asset stranding | **✓✓** | **✓✓** | **✓** | **Medium** | **High** |

#### Potential mitigation measures

The following measures can be considered to reduce the likelihood and/or severity of this risk:

* Reduce investments in new natural gas network infrastructure (new pipelines and fixed LNG terminals, extension of existing transport and distribution networks) to the strict minimum (i.e., to ensure security of supply), and ensure that any new asset is future-proof, i.e. can technically be repurposed for biomethane or hydrogen at “reasonable” costs;
* Introduce a legal ban on connecting new residential and tertiary buildings to the natural gas grid, potentially unless they commit to mainly use renewable gases; such a legal ban has already been implemented in other EU Member States to stimulate renewable or low-carbon energy based alternatives such as heat pumps and district heating;
* Assess whether and how the natural gas network tariffs can be reviewed to anticipate the consequences of reduced natural gas use and stranded assets.

## Risk 11: Policies and regulations can present barriers to implementation of gas decarbonization actions

#### Description of the risk, covering the Baltic Regional Gas Market

The other sections in this chapter address the role of policies and regulations in mitigating the identified risks. The present risk focuses on the potentially negative impacts that policies and regulations themselves can have on the decarbonisation of the gas system.

Uncertainty regarding policies and regulations targeting or affecting the gas sector can defer investment decisions. A number of recent examples exist which illustrate the issue:

* Given the need for a regulatory framework for the hydrogen sector, the EU as well as a number of national governments have adopted or are in the process of adopting such a framework, addressing specific issues such as unbundling between competitive and regulated activities, imposing regulated third-party access to hydrogen infrastructure and other aspects. The European Commission has proposed the Hydrogen and Decarbonised Gas Market Package in December 2021, and the Council and Parliament have in May 2023 adopted their positions.[[53]](#footnote-54) A number of other related legislation proposed under the Fit for 55 package or subsequently is also subject to trilateral negotiations.[[54]](#footnote-55)
* A number of Member States such as Belgium[[55]](#footnote-56) and Germany[[56]](#footnote-57) have proposed regulatory frameworks for hydrogen, anticipating the revision of the regulatory framework at EU level for gas and hydrogen. However, various other Member States are awaiting an agreement on the revision of the EU gas regulatory framework, and it is possible that Member States that proactively adopt national frameworks will need to adapt at least part of it to comply with the final EU-level rules.
* Market actors require a clear definition of the rules for renewable hydrogen and other RFNBO, as well as in the future also low-carbon hydrogen and recycled carbon fuels, to understand which fuels will be able to obtain certificates of origin. To this end, the European Commission has adopted delegated acts on additionality and GHG emission savings from RFNBOs.

Regulatory reforms at EU, national or sub-national level in other areas such as permitting for renewable energy and infrastructure projects can likewise negatively impact the development of projects if they increase uncertainty, as investors will typically delay decisions until there is clarity on the framework. Integrated infrastructure planning is also necessary to ensure the appropriate investments in energy infrastructure while avoiding lock-in into unsustainable pathways or asset stranding, as discussed in the sections related to risks 5 and 6. More broadly, coordination is necessary between a wide range of policies from governance of the energy transition, infrastructure planning, market design, energy taxation, carbon pricing, and others.

#### Rating of the risk based on likelihood and severity

Based on the arguments above, we assess the **severity of this risk as ‘high’.** The materialisation of this risk would result in delays in investment decisions due to the long duration of the legislative processes for adopting a regulatory framework for hydrogen at the EU and national levels, as well as the possible need to adjust national frameworks to the EU-rules once adopted. Given the long lead times for development of hydrogen projects and associated supply chain, any projects to be commissioned by 2030 need a final investment decision in the short-term, which will only be possible with regulatory clarity. The **likelihood of the risk is assessed as ‘low’** as the main legislative pieces at EU level have already been proposed or even adopted, and once the EU-level framework is in place this will provide guidance to the national ones, thus reducing the chance of national policy processes delaying projects.

The present risk mainly affects scenarios that are highly reliant on hydrogen, and thus particularly the REN-Hydrogen scenario. The CM and REN-Methane scenarios could also be affected by this risk (as the whole EU legislation on renewable gases is currently under development), but to a lower extent as the development of a dedicated hydrogen backbone is not foreseen in these scenarios. All four countries in the Baltic Regional Gas Market are subject to a similar level of risk.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Policies and regulations can present barriers to implementation of gas decarbonization actions | **✓** | **✓✓** | **✓** | **Low[[57]](#footnote-58)** | **High** |

#### Potential mitigation measures

As this risk is related to uncertainties regarding the policy cycle and the consequences for timely investment decisions by market parties, the main proposed mitigation measure is the development of a coordinated strategy for the gas and hydrogen sectors in the BRGM region as well in the individual concerned Member States. The new National Energy and Climate Plans (for which the draft updated plan had to be submitted by 30 June 2023) could form a basis for identifying the necessary policy actions at the national level, but they would not cover them with the required level of detail. Hence, a dedicated gas strategy or roadmap at the regional level defining the necessary actions and potentially supported by a memorandum of understanding between the BRGM countries would provide further clarity to market parties on the planned measures and facilitate the necessary investment decisions. In addition, we would recommend developing clear and supportive legal frameworks and regulations for renewable energy and low-carbon gas production by streamlining permitting processes, providing incentives for project development, and ensuring compliance with environmental standards to accelerate the deployment of hydrogen and biomethane projects. Finally we recommend evaluating (new) policies and planning by using standard processes with appropriate impact assessments to eliminate or reduce the possibility of ad hoc decisions about policies that produce adverse consequences for the decarbonisation efforts.

## Risk 12: Some specific gas decarbonisation actions can result in adverse environmental and climate impacts

#### Description of the risk, covering the Baltic Regional Gas Market

The use of biomass feedstocks for the production of renewable gases would increase demand for those feedstocks and potentially lead to negative environmental impacts due to the utilisation of pesticides, nitrogen emissions to air and water from livestock and use of fertilisers, particulate matter emissions, and loss of biodiversity.[[58]](#footnote-59) It must be noted that biogas and biomethane production can also provide environmental benefits, besides the climate benefits of reduced GHG emissions compared to natural gas and other fossil-based alternatives.[[59]](#footnote-60) The production, transportation, storage and end-use of methane-based renewable and low-carbon gases will also have associated levels of methane emissions, a potent greenhouse gas.

According to the analysis conducted in DLV3[[60]](#footnote-61), the additional biogas/biomethane production in the Baltic Regional Gas Market countries will be derived from agricultural residues and/or waste-derived biomass (biowaste). Latvia would rely particularly on biowaste, while the remaining three Member States would employ both feedstock types (with municipal wastewater making a small contribution to biomass inputs for biogas/biomethane production).

The main impacts from biogas and biomethane production relate to the biomass storage and digestate management steps, as well as to methane leakage associated with biogas upgrading. However, best practices exist to address those potential negative impacts.[[61]](#footnote-62) The production of biogas/biomethane from biowaste could present environmental benefits compared to the alternative of landfilling the biowaste.[[62]](#footnote-63)

The renewable hydrogen value chain may also lead to global warming, as hydrogen is an indirect greenhouse gas capable of depleting atmospheric ozone. However, while leakage rates in the hydrogen supply chain can be similar to those of natural gas on a MWh basis, the global warming potential (GWP) of hydrogen is significantly lower than of methane.[[63]](#footnote-64)

Natural gas-based low-carbon hydrogen (from e.g. SMR, ATR or partial oxidation processes combined with carbon capture and/or storage) as well as biomass-based hydrogen would have their own associated radiative forcing effect due to upstream methane leakage as well as downstream hydrogen leakage. However, the scenarios developed in this study focus on renewable electrolytic hydrogen.

#### Rating of the risk based on likelihood and severity

Based on the arguments above, we assess the **severity of the risk as ‘medium’** due to the potential negative environmental and climate impacts associated with the supply chain of biogas and biomethane, while the hydrogen supply chain exhibits lower risks. The risks are identified especially in the production stage of the value chain (including biomass storage) as well as the use of digestates resulting from the anaerobic digestion of biomass feedstocks. However, the **probability of the risk is assessed as ‘low’** given the existence of mature technical best practices for the mitigation of potential emissions of methane and other pollutants.

The present risk is clearly mainly associated with the REN-Biomethane and Cost Minimal decarbonisation scenarios, where biogas and biomethane are the main carriers to decarbonise the region’s gas system. All four countries in the Baltic Regional Gas Market are subject to a similar level of risk, given their similar reliance on agricultural residues and biowaste as feedstocks for biogas and biomethane production under the decarbonisation scenarios.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Adverse environmental and climate impacts | **✓✓** |  | **✓** | **Low** | **Medium** |

#### Potential mitigation measures

A number of technical best practices exist for minimising the emissions of methane, hydrogen and other pollutants in the biogas/biomethane and hydrogen value chains. Policymakers could consider the following measures to incentivise the adoption of such best practices:

* Information and training campaigns to increase the awareness of biogas/biomethane producers to adopting best available techniques;
* Introduce or extend national carbon pricing mechanisms to cover methane value chain emissions of biogas/biomethane production;
* Introduce strict biomass sustainability standards respecting the hierarchy of biomass uses;
* Implement monitoring, reporting and verification mechanisms for the greenhouse gas and other pollutant emissions of the projects;
* Incorporate renewable gas production facilities within environmental regulations on pollutant emissions, if not yet applicable.

## Risk 13: Public opposition, due to (perception of) negative impacts

#### Description of the risk, covering the Baltic Regional Gas Market

The importance of a just transition is acknowledged by EU and national stakeholders. The Council, based on a proposal from the European Commission, adopted a Recommendation on ensuring a fair transition towards climate neutrality.[[64]](#footnote-65)

Energy poverty is a significant issue across the EU and also in the BRGM, an issue which was exacerbated by the energy crisis following the Russian invasion of Ukraine. A relevant portion of the population was unable to keep its house warm in 2022 (17.5% in Lithuania, 7.1% in Latvia, 3.4% in Estonia, and 1.4% in Finland).[[65]](#footnote-66) The European Investment Bank (2022)[[66]](#footnote-67) highlighted that the current energy crisis has indeed strong distributional impacts. Energy bills have become unaffordable for many citizens in the EU. Vulnerable people and low-income groups are those who suffer the most from energy price peaks as they spend a relatively higher share of their income on energy and food.[[67]](#footnote-68) This puts at risk the political consensus around the idea of just transition.

As shown in Deliverable 4,[[68]](#footnote-69) the gas decarbonization of the BRGM would lead in the long-run to lower gas commodity prices for households and commercial users, compared to the business-as-usual scenario. However, depending on the decarbonization scenario the prices in the short-run would be higher than in the BAU scenario, and savings in the long-run may be less significant, also taking into account that other costs associated with the scenarios, such as network costs were not taken into account (except investments for the development of a dedicated hydrogen network). Moreover, the energy transition will undoubtedly require significant investments and vulnerable consumers could in certain countries face difficulties in paying their energy bills depending on the policies in place, which would reduce public acceptance for the transition in general and renewable gas projects in particular. This may be compounded by other policy developments such as the extension of the EU-ETS to transport and buildings, unless impacts are well offset via the Social Climate Fund.

A number of just transition projects are currently in place in the Baltic Regional Gas Market countries, as part of the Just Transition Mechanism. The BRGM countries are significant beneficiaries of the Just Transition Fund[[69]](#footnote-70) and all have territories eligible for funding – including a majority of the territory in Finland and Latvia, as shown in the figure below.

Figure 3‑1 Eligible Just Transition Fund territories as of June 2023



Source: European Commission, [Just Transition Platform](https://ec.europa.eu/regional_policy/funding/just-transition-fund/just-transition-platform_en)

Estonia might be particularly sensitive to the social impacts of the energy transition due to the current role that shale oil plays in the Estonian energy supply. The Estonia Just Transition Plan is focused on addressing the impacts on the Ida-Virumaa region of the shale oil phase-out by 2040[[70]](#footnote-71).

Public opposition could also impact the development of new renewable energy projects. The European Commission has included in its Biomethane Action Plan[[71]](#footnote-72) specific actions regarding a forum promoting sustainable production and use, participatory multi-stakeholder engagement and accelerated permitting, illustrating the importance of public acceptance for the development of biogas and biomethane projects.

The Baltic Energy Area – A Planning Perspective project looked among other issues on how to increase public acceptance for renewable energy projects, including biogas/biomethane.[[72]](#footnote-73) The project highlights the importance of involving stakeholders early on and interactively in the spatial planning and specific projects and providing comprehensive information.[[73]](#footnote-74)

Potential future public opposition to hydrogen projects should also not be overlooked.[[74]](#footnote-75) Land availability and public opposition to renewable energy projects, including hydrogen, could make hydrogen imports (derivatives or hydrogen gas through cross-border pipelines) more attractive than local production.[[75]](#footnote-76) In this respect, offshore wind energy would face lower public opposition than onshore wind energy or other renewable energy sources as input for hydrogen production.[[76]](#footnote-77) Nonetheless, public opposition from environmental and consumer NGOs exists, based on arguments of negative sustainability impacts of hydrogen production and use, and the need to restrict hydrogen use to hard-to-decarbonise applications.[[77]](#footnote-78)

The presumption of overriding public interest for renewable energy projects as included in a Council regulation published in 2022[[78]](#footnote-79) should lead to an accelerated permitting process. However, if the public consultation steps do not succeed in properly involving the affected communities and other stakeholders in the project development, there is a risk that the deployment will be delayed despite the project’s overriding public interest. Thus, accelerated permitting needs to be combined with appropriate consultation processes for renewable energy and related infrastructure projects.

Social, economic and environmental impacts can hence either lead to public opposition or improve acceptance, depending on their specific impacts, underlying causes and how they are managed. The energy transition will indeed lead to specific social and economic impacts on certain sectors, citizens and businesses, which should be properly addressed. A number of channels leading to lack of public acceptance can be identified, in particular if adequate measures are not adopted to mitigate negative impacts:

* The phase-out of fossil fuel-based energy production may lead to deindustrialization and unemployment in specific regions;
* The energy transition may lead to higher energy bills for specific consumers and disproportionately affect vulnerable consumers;
* Renewable energy projects may lead to negative impacts to the environment, landscape and specific economic sectors.

#### Rating of the risk based on likelihood and severity

Based on the arguments above, we assess the **severity of the risk as ‘low’** due to the various channels and instruments through which public opposition can be mitigated and the fact that the phase-out of fossil fuels and development of renewable energy projects will lead to visible positive economic and environmental benefits, which should improve public acceptance. The **probability of the risk is assessed as ‘high’** in particularfor hydrogen infrastructure, due to the impacts of significant additional renewable energy projects for electrolytic hydrogen production as well as higher safety concerns (detailed in risk 15).

The present risk affects all scenarios given the general need to significantly develop renewable energy in order to phase-out fossil gas. While investments in biogas and biomethane would in general lead to limited public opposition, hydrogen investments could face lower public acceptance due to the reasons mentioned above.

All four countries in the Baltic Regional Gas Market are subject to a similar level of risk. However, there may be differences in the channels potentially leading to public opposition, since, as discussed above, Latvia and especially Lithuania exhibit higher levels of energy poverty, while Estonia’s current reliance on shale oil will require tailored just transition measures.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Public opposition due to perceived adverse environmental and climate impacts | **üü** | **üü** | **üü** | **High** | **Low** |

#### Potential mitigation measures

Early and inclusive spatial and energy planning as well as adequate project permitting consultation processes form the cornerstone of initiatives to improve public acceptance of energy infrastructure, and particularly renewable gas projects. The following specific measures can be considered:

* Assess and revise where appropriate the public consultation requirements and processes (including information exchange) for renewable energy projects and related grid connection and transport infrastructure;
* Ensure an enabling legal framework for setting up local or renewable energy communities and promote the participation of citizens in local energy projects. Such cooperative financing schemes that allow benefit sharing of energy projects will also enhance public acceptance;
* Anticipate and reduce potential local opposition based on potential negative environmental impacts by designing and implementing the project in such a way that local concerns are properly taken into account.

## Risk 14: Key gas decarbonisation technologies may not reach sufficient cost or performance improvements

#### Description of the risk, covering the Baltic Regional Gas Market

The capacity to reach full decarbonization of the gas sector and the pace at which it is reached will highly depend on the competitiveness of key gas decarbonization technologies compared to fossil fuel-based technologies, which is related to their cost and technical performance, as well as to external (e.g. market price) and policy factors (e.g. carbon pricing).

An overview of cost and technology maturity considerations as well as other critical issues to consider is presented in Table 3‑1 for key decarbonization technologies. This table summarizes information from several sources, including previous Deliverables of this project and the 2022 report of the European Commission on the competitiveness of clean energy technologies which analyses the current and projected status of play of several technologies.[[79]](#footnote-80)

Table 3‑1 Cost and technology maturity and other key considerations of key gas decarbonization technologies

| Parameters | Description |
| --- | --- |
| **Renewable hydrogen technologies** |
| **Cost maturity** | * Capex costs of electrolysers are expected to fall for high temperature electrolysis, from 2,130 EUR/kW in 2020 to 520 EUR/kW in 2030.
* Cost targets of Alkaline and PEM electrolysers for 2030 are 500 EUR/kW and 300 EUR/kW, respectively.
* As per Deliverable 3, the average hydrogen LCOE in the Baltic Regional Gas Market is expected to decrease by between 46% and 64% (depending on the scenario) from 2030 to 2050.
* Economic viability of electrolysers highly depends on the cost of input electricity. Hence, high electricity prices remain a key challenge.
 |
| **Technology maturity** | * Two commercial forms of electrolysers (Alkaline and PEM) are already being deployed worldwide (Deliverable 2).
* Production of renewable hydrogen highly depends on the deployment of renewable energy sources. As per Deliverable 2, the renewable electricity potential in 2050 in the Baltic Regional Gas Market is estimated at 26.4 TWh, 121.8 TWh, 89.3 TWh and 183.4 TWh in Estonia, Lithuania, Latvia and Finland respectively.
* Storage, transport, distribution and use of hydrogen will require adaptation/repurposing/retrofitting of natural gas infrastructure/technologies or construction and development of new infrastructure/technologies to accommodate hydrogen.
 |
| **Other considerations** | * Water consumption associated with rollout of renewable hydrogen will increase the stress on freshwater resources.
* Reliance on imports of critical raw material needed for the production of hydrogen with electrolysers is concentrated in a few suppliers.
 |
| **Biomethane technologies** |
| **Cost maturity** | * Cost of advanced biofuels is currently around 1.5 to 3 times higher than the market price of traditional fuels.
* There is significant potential to cut capital costs by 25 to 50% and feedstock costs by 10 to 20% via R&D&I, large scale deployment and co-processing in existing plants.
* As per Deliverable 3, the average biomethane LCOE in the Baltic Regional Gas Market is expected to decrease by between 19% and 30% (depending on the scenario) from 2030 to 2050.
 |
| **Technology maturity** | * Anaerobic digestion technology is in operation at large scale worldwide (Deliverable 2). Innovative versions of digesters are also developing and closely arriving at market maturity.
* As per Deliverable 2, the biomethane potential in 2050 in the Baltic Regional Gas Market is estimated at 2.4 TWh, 8 TWh, 2.7 TWh and 11 TWh in Estonia, Lithuania, Latvia and Finland respectively.
 |
| **Other considerations** | * Biomethane production is linked to the availability of sustainable feedstock.
 |
| **SNG technologies** |
| **Cost maturity** | * Different options of SNG production reactors have different investment costs and hence different cost learning curves (Deliverable 2).
* As per Deliverable 3, the average SNG LCOE in the Baltic Regional Gas Market is expected to decrease by 80% (in the scenarios which consider the production of SNG – REN-Methane and Cost minimal) from 2030 to 2050. The SNG LCOE is very high compared to biomethane and hydrogen LCOEs.
 |
| **Technology maturity** | * Methanation technology is available but not yet proven for large scale application (Deliverable 2). Although the technology is still in demonstration phase, the fixed-bed reactor has a high readiness level of TRL 8/9.
 |

#### Rating of the risk based on likelihood and severity

The **severity of this risk can be rated as ‘high’** as the decarbonisation of the gas sector in the Baltic Regional Gas Market is very reliant on the development of key gas decarbonisation technologies and improvement of their cost and performance.

The **likelihood that this risk will materialize is ‘medium’.** Although biomethane and hydrogen technologies are already reaching sufficient technological maturity, costs are still high but could be improved. In addition, there are several other considerations that may hinder the development of these technologies. Hydrogen production highly depends on the deployment of renewable electricity. It also relies on critical raw material imports and water availability. Biomethane relies on the availability of sustainable feedstock. Both cost and technology maturity of SNG are not yet sufficient, and the cost is expected to remain high as per the decarbonization scenarios presented in Deliverable 3.

The maturity in terms of cost and performance of all decarbonization technologies cannot be ensured at this moment. Hence all decarbonization scenarios will be similarly impacted.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Key gas decarbonisation technologies may not reach sufficient cost or performance improvements | **üü** | **üü** | **üü** | **Medium[[80]](#footnote-81)** | **High** |

#### Potential mitigation measures

The following measures can be considered to reduce the likelihood and/or severity of this risk:

Publicly funded R&D&I programs focused on the development and improvement of gas decarbonisation technologies, renewable energy technologies, energy storage and biomass conversion processes. This will enhance the efficiency and scalability of both hydrogen and biomethane production methods, making them more cost-effective and commercially viable.

* Reducing subsidies to fossil fuel-based technologies to increase the competitiveness of gas decarbonisation technologies.
* Transparent ambitions and clear planning at national level to reduce the uncertainty and risks for investing in gas decarbonization technologies.

## Risk 15: Safety risks or their perception restrict infrastructure development or certain supply/demand solutions

#### Description of the risk, covering the Baltic Regional Gas Market

This is currently a major (perceived) risk related to the deployment of hydrogen and hydrogen derivatives. While the use of these fuels in industry is very mature, the upscaling of production and demand, transportation over large distances and use in new applications raise the need for new risk studies and adequate safety standards. The European Commission and other stakeholders have taken measures to increase the knowledge regarding hydrogen safety for years now.[[81]](#footnote-82)

The European Hydrogen Safety Panel was set up in 2017 to:

* “Assist the JU at programme and project levels, and beyond, in assuring that hydrogen safety is adequately addressed and managed;
* Promote and disseminate hydrogen safety knowledge and culture within and outside of the JU's programme” [[82]](#footnote-83)

Hydrogen safety risks can be considered higher than for other fuels such as gasoline or natural gas due to the low ignition energy required, flammable range, high storage pressures and containment issues.[[83]](#footnote-84) However, the Clean Hydrogen Joint Undertaking and experts indicate that “Hydrogen systems can be as safe as systems based on conventional energy carriers, provided the specific properties of hydrogen and the hydrogen system are properly addressed”.[[84]](#footnote-85)

Still, the expected changes in the hydrogen industry (particularly the use in consumer-facing applications) combined with the lack of familiarity of consumers until now can lead to a perception of safety risks by the general public.[[85]](#footnote-86) There is, despite this, still limited research on the public perception of the hydrogen economy,[[86]](#footnote-87) although more recent programs are addressing this.[[87]](#footnote-88) One must consider that in any case the use of hydrogen and derivatives for hard-to-decarbonise applications, such as in industry, heavy-duty transport and potentially power generation system (as back-up) means that the general public should in most cases not be in frequent contact with hydrogen applications.

As for biogas/biomethane technologies, risks exist requiring appropriate handling practices.[[88]](#footnote-89) Nonetheless, technologies for biogas and biomethane production as well as the transport, storage and use of methane gases are mature. Concerning public perception, a study[[89]](#footnote-90) compared the general and local acceptance of biofuels (liquid and gaseous), hydrogen refuelling stations and batteries in Germany. It indicates that publicly perceived safety-related risks for hydrogen refuelling stations and batteries are significantly higher than for biofuels (although public perception of biofuels is strongly affected by other non-safety factors).

#### Rating of the risk based on likelihood and severity

Considering the analysis above, we rank the **severity of this risk as low.** While safety risks for hydrogen effectively exist as for other fuels, the ongoing actions by public and private actors should allow to ensure a sufficient level of safety comparable to the other fuels. While work is required also for improving the public perception of hydrogen technologies, citizens will likely not come in direct contact on a frequent basis with hydrogen applications, except where it is employed for e.g. urban public transport. In any case, awareness campaigns and other engagement activities could provide assurance to the public and reduce opposition based on safety concerns. As for biogas/biomethane technologies, safety risks are also manageable which may reduce the safety perception issues. The **probability of the risk is assessed as medium:** as the deployment of hydrogen and biogas/biomethane technologies will increase, this risk is expected to arise more frequently and the public will have to be further informed on the safety issues.

Given these considerations, the risk would affect particularly the REN-H scenario, given the more significant levels of hydrogen production and consumption, and the development of a dedicated cross-border hydrogen network in the Baltic Regional Gas Market. The risk is similarly relevant for all Member States in the region.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Safety risks or their perception restrict infrastructure development or certain supply/demand solutions |  | **✓** |  | **Medium** | **Low** |

#### Potential mitigation measures

Actions are needed to address the concrete issues related to the safety of hydrogen when its production is upscaled and new applications will be developed. Nonetheless, such actions are already being undertaken by public and private stakeholders at EU level and in Member States. Specific additional mitigation measures could be focused on addressing any negative public perception issues related to hydrogen (due to safety and environmental concerns) as well as to biomethane/biogas (mainly due to environmental concerns).

## Risk 16: Geopolitical events can divert resources and attention from gas decarbonisation measures

#### Description of the risk, covering the Baltic Regional Gas Market

Different geopolitical events can distract the policymaker’s attention to the gas decarbonisation plans in the Baltic States and Finland by 2050, including but not limited to:

1. Rise of Euroscepticism and nationalism: The rise of Eurosceptic sentiments and nationalist movements in the European Union (EU) member states, including the Baltic States and Finland, can hinder cooperation and coordination in gas decarbonisation efforts. This could result in slower decision-making processes, reduced willingness for joint investments, and fragmented policy approaches, impeding the development of a unified and efficient decarbonisation strategy.
2. Geopolitical Tensions and Energy Security Concerns: Ongoing geopolitical tensions, particularly those related to the relationship between the EU and Russia, can have implications for energy security and resource allocation. Disruptions in energy supply chains, political disputes, or trade restrictions can impede the availability and affordability of resources necessary for gas decarbonisation, including hydrogen production infrastructure and biomass feedstock for biomethane production, including because resources are dedicated to immediate reactions (e.g., constructing more natural gas interconnectors and importing pipelines, LNG terminals and other resources like coal, as happened in Germany and Poland respectively shortly after the Russian invasion of Ukraine). In a broader scene, major geopolitical tensions between global powers, such as territorial disputes or conflicts like the one between Taiwan and China, can have far-reaching consequences for international trade, supply chains, and economic stability. These tensions can impact resource availability, disrupt energy markets, and divert attention and resources away from gas decarbonisation efforts in the Baltic States and Finland, especially considering that Finland has recently joined NATO and may be pushed to contribute to transregional missions, in this scenario.
3. Trade Disputes and Tariffs: Heightened trade disputes and the imposition of tariffs between countries or trading blocs can disrupt global supply chains and increase the cost of importing necessary technologies and equipment for gas decarbonisation. Higher costs and trade barriers can hinder the deployment of renewable energy infrastructure and slow down the transition to hydrogen and biomethane production.
4. Cybersecurity Threats and Disruptions: The increasing reliance on digital infrastructure and interconnected systems in the energy sector makes it vulnerable to cyberattacks and disruptions. Geopolitical events that result in cyber threats or breaches can disrupt energy supply, compromise critical infrastructure, and undermine confidence in the reliability and security of gas decarbonisation technologies and systems, especially with higher digitalisation of energy resources.

#### Rating of the risk based on likelihood and severity

The **likelihood of the risk can be assessed as ‘medium’**. This is due to the potential for various geopolitical factors, such as rise of Euroscepticism, tensions between Ukraine and Russia, and major transregional geopolitical tensions, to impact the focus and priorities of governments and energy stakeholders. While geopolitical events are inherently unpredictable, the region's proximity to geopolitical hotspots and its interconnectedness with global economies make it susceptible to geopolitical shifts that may divert resources and attention from gas decarbonisation efforts. Recent events have however shown that geopolitical issues can also provide stimuli for changes and accelerate the uptake of decarbonisation measures.

We **consider the severity of this risk as ‘medium’**. The diversion of resources and attention can result in delays, disruptions, and reduced momentum in implementing decarbonisation plans. It can hinder the allocation of necessary investments, slow down policy development and regulatory frameworks, and create uncertainties for investors and industry stakeholders. Furthermore, geopolitical tensions may affect the stability of energy supply routes and trade relationships, potentially impacting the availability and cost of resources required for gas decarbonisation. While the severity may vary depending on the specific geopolitical event, the overall impact is considered medium given the potential disruptions and challenges it can pose to the region's decarbonisation objectives.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| Geopolitical events can divert resources and attention from gas decarbonisation measures | **✓** | **✓** | **✓** | **Medium** | **Medium** |

#### Potential mitigation measures

To address the geopolitical challenges and mitigate their impact on gas decarbonisation in the Baltic States and Finland, the following recommendations and solutions can be considered:

Strengthen Regional Cooperation: Enhancing regional cooperation among the Baltic States and Finland can promote joint efforts in gas decarbonisation. Establishing collaborative platforms, sharing best practices, and coordinating investment strategies can leverage collective resources and expertise, leading to more efficient and effective decarbonisation initiatives.

Diversify Energy Sources and Supply Routes: Reducing dependence on specific energy sources and diversifying supply routes can enhance energy security and mitigate geopolitical risks. This includes expanding the portfolio of renewable energy sources beyond hydrogen and biomethane, such as wind and solar power, and developing interconnections with neighbouring energy markets for increased resilience.

Develop Domestic Resources: Investing in the development of domestic (regionally integrated) renewable energy resources, such as offshore wind farms, biomass production, and solar installations, can enhance energy self-sufficiency and reduce reliance on imported resources. This reduces vulnerability to geopolitical disruptions and ensures a stable supply for gas decarbonisation efforts.

Strengthen Resilient Infrastructure: Building resilient energy infrastructure is essential to withstand geopolitical tensions and potential disruptions. This includes upgrading and expanding the power grid, enhancing cybersecurity measures, and ensuring redundancy in energy supply systems. Resilient infrastructure will enhance the reliability and security of gas decarbonisation technologies and maintain continuous operations in the face of geopolitical challenges.

Foster International Partnerships: Establishing strategic partnerships with other countries and organizations can enhance resource sharing, technological collaboration, and knowledge exchange. Engaging in international agreements and initiatives, such as the European Green Deal or international climate agreements, can provide a supportive framework for gas decarbonisation efforts and help navigate geopolitical challenges collectively.

Strengthen Energy Diplomacy: Engaging in energy diplomacy can help navigate geopolitical challenges by fostering dialogue, resolving conflicts, and promoting mutual understanding. Strengthening diplomatic relationships with neighbouring countries, energy suppliers, and international organizations can facilitate resource access, address trade disputes, and mitigate potential barriers to gas decarbonisation.

By implementing these recommendations, the Baltic States and Finland can navigate geopolitical challenges more effectively, ensuring a resilient and sustainable transition to a decarbonised gas market. It requires a proactive approach, diplomatic engagement, and long-term planning to overcome barriers and seize the opportunities presented by gas decarbonisation in a rapidly evolving geopolitical landscape.

# Risk assessment synthesis

## Comparison of identified risks

Table 4‑1 presents the assessment for all identified risks, including the applicable scenarios, the likelihood and the severity (for more details, see the description at the start of chapter 3). This section summarizes the **main risks** potentially impacting each decarbonisation scenario.

Main risks are defined as those which are rated as having a ‘high’ severity or a ‘high’ likelihood coupled with a ‘medium’ severity rating. **The results indicate that the main risks for the decarbonisation scenarios are related to various economic, regulatory and technical factors which may hinder the deployment of decarbonisation assets.** According to the risk assessment, the main risks potentially impacting the scenarios for the decarbonisation of the Baltic Regional Gas Market are:

* **Risk 1 – Economic turndown and instability can limit the ability of local gas producers, users, network operators and authorities to invest in gas decarbonisation measures**

Economic turndown and instability can occur as a consequence of economic, environmental or social shocks, which can be increasingly expected due to climate change. This will in turn decrease the ability and willingness of stakeholders to invest because of higher prices (e.g. due to inflation), lower available financial resources (e.g. due to economic recessions) or limited competitiveness of renewable energy projects.

* **Risk 6 – Infrastructure cannot be adequately or timely developed, including repurposing or adaptation of natural gas infrastructure**

Implementation of gas decarbonisation measures can be hindered or delayed by long lead times to build new or refurbish/repurpose existing infrastructure. This can result from a lack of adequate planning at the regional level, or a lack investments into dedicated networks due to high uncertainties.

* **Risk 8 - Security of gas supply can be threatened due to external energy dependence**

External shocks (e.g. arising from environmental disasters or geopolitical tensions) can lead to gas supply disruptions. Countries that are highly dependent on foreign gas supply are more likely to face security of supply issues as they have less control on their energy mix.

* **Risk 9 - Available inputs for production of R/LC gases, e.g. renewable electricity or biomass can be insufficient**

Decarbonisation of the gas system via the replacement of natural gas with biomethane can only be achieved if the availability and adequacy of biomass feedstock is sufficient. Similarly, decarbonisation through hydrogen production is highly dependent on hydrogen infrastructure development and market demand, as well as the availability of renewable energy.

* **Risk 10 - Investments in methane infrastructure can lead to lock-in on natural gas or asset stranding**

Ongoing and planned investments in natural gas infrastructure may lead to a structural lock-in on natural gas and delay the transition to decarbonization options including electrification of building heating and switching to renewable gas.

* **Risk 11 - Policies and regulations can present barriers to implementation of gas decarbonization actions**

Although policies and regulations allow to enhance the decarbonization of the gas sector, they can potentially also have negative impacts. This is mainly linked to the fact that policy and regulatory uncertainties can defer investment decisions.

* **Risk 14 - Key gas decarbonisation technologies may not reach sufficient cost or performance improvements**

The capacity to reach full decarbonization of the gas sector and the pace at which it is reached will highly depend on the competitiveness of key gas decarbonization technologies compared to fossil fuel-based technologies, and on whether their cost and performance can be improved.

Each scenario can either be affected in a high (**✓✓**) or low (**✓**) way, or not affected at all. The impacts of the different risks on the gas decarbonisation scenarios are as follows:

The **REN-Methane scenario** is highly affected by five risks, two of which are main risks (10 and 14).

The **REN-Hydrogen scenario** is highly affected by ten risks, four of which are identified as main risks (6, 9, 10, 11 and 14).

The **Cost Minimal scenario** is highly affected by five risks, two of which are main risks (1 and 14).

The REN-Hydrogen scenario is clearly the riskiest scenario as it is affected by more risks than the REN-Methane and Cost Minimal scenarios. The required investments for building new hydrogen infrastructure or repurposing/retrofitting existing natural gas infrastructure are significant (**Risk 6**). In addition, the scenario still requires large capital investments into LNG terminals as is will be significantly reliant on LNG gas imports until 2040. This can lead to a lock-in on natural gas or asset stranding (**Risk 10**). Adopting an appropriate regulatory framework for hydrogen at EU and national levels is key for the achievement of the REN-Hydrogen scenario, but this may take some time. The uncertainty about policies and regulation may delay investments in hydrogen development projects (**Risk 11**). Finally, there is no certainty about the maturity of hydrogen technologies and whether their cost and performance will be competitive (**Risk 14**).

Table 4‑1 Overview of risk assessment for gas decarbonization scenarios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Category | No | Risk | Applicable scenarios | Likelihood | Severity |
| REN-M | REN-H | CM |
| **Economic** | 1 | Economic turndown and instability can limit ability local of gas producers, users, network operators and authorities to invest in gas decarbonisation measures | **ü** | **ü** | **üü** | **High** | **Medium** |
| 2 | Supply dependence and bottlenecks for energy technologies can increase costs/slow down transition | **ü** | **üü** | **ü** | **Low** | **Medium** |
| 3 | Fossil gas decarbonisation can negatively affect competitiveness of industrial users | **ü** | **ü** | **üü** | **Low/****Medium** | **Medium** |
| **Energy markets** | 4 | Developments in global energy markets impact competitiveness of gas decarbonisation solutions | **ü** | **üü** | **ü** | **Medium** | **Medium** |
| 5 | Fragmentation of regional/national gas networks and markets | **ü** | **üü** | **ü** | **Medium** | **Medium** |
| 6 | Infrastructure cannot be adequately or timely developed, including repurposing or adaptation of natural gas infrastructure |  | **üü** |  | **Low** | **High** |
| 7 | Security of gas supply can be threatened due to adequacy/flexibility issues of domestic/regional energy system |  | **üü** |  | **High** | **Low** |
| 8 | Security of gas supply can be threatened due to external energy dependence | **ü** | **ü** | **ü** | **Low** | **High** |
| 9 | Available inputs for production of R/LC gases, e.g. renewable electricity or biomass can be insufficient | **üü** | **üü** | **üü** | **Medium** | **High** |
| 10 | Investments in methane infrastructure can lead to lock-in on natural gas or asset stranding | **üü** | **üü** | **ü** | **Medium** | **High** |
| **Regulatory** | 11 | Policies and regulations can present barriers to implementation of gas decarbonization actions | **ü** | **üü** | **ü** | **Low** | **Medium/****High** |
| **Social & environmental** | 12 | Some specific gas decarbonisation actions can result in adverse environmental and climate impacts | **üü** |  | **ü** | **Low** | **Medium** |
| 13 | Public opposition, due to (perception of) negative impacts | **üü** | **üü** | **üü** | **High** | **Low** |
| **Technological** | 14 | Key gas decarbonisation technologies may not reach sufficient cost or performance improvements | **üü** | **üü** | **üü** | **Medium** | **High** |
| 15 | Safety risks or their perception restrict infrastructure development or certain supply/demand solutions |  | **ü** |  | **Medium** | **Low** |
| **Geopolitical** | 16 | Geopolitical events can divert resources and attention from gas decarbonisation measures | **ü** | **ü** | **ü** | **Medium** | **Medium** |

## Synthesis of main risk-mitigation strategies and no-regret options

The possible mitigation measures are identified for each of the assessed risks in Chapter 3. Table 4‑3 summarises these mitigation measures for the main risks. These mitigation measures also allow to address other assessed risks (see last column).

While the underlying causes of the main risks are of diverse nature (economic, technical or social), the main channel through which they impact the decarbonisation scenarios is by affecting the deployment of the necessary decarbonisation assets. As such, besides mitigation measures to address the individual root causes of the risks, measures for coordinating the deployment of the required assets and addressing the various risks (not only the main ones) are essential – besides coordination measures such as a regional strategy or roadmap being identified as mitigation measures for specific risks.

Table 4‑3 Mitigation measures for main identified risks

| No | Risk | Mitigation measures | Other risks addressed |
| --- | --- | --- | --- |
| 1 | Economic turndown and instability can limit ability local of gas producers, users, network operators and authorities to invest in gas decarbonisation measures | * Economic and financial measures to prevent an economic turndown or reduce its impact
 | 4, 13, 16 |
| * Provide adequate price signals to economic actors to stimulate investments in decarbonisation measures, such as carbon pricing, energy taxation reform, financial support, risk sharing, public-private partnerships
 | 3, 4, 6, 13, 14 |
| 6 | Infrastructure cannot be adequately or timely developed, including repurposing or adaptation of natural gas infrastructure | * Proactive national and supra-national planning of methane network investments and of hydrogen network investments
 | 7, 10, 11, 14 |
| * Regular market studies for the Baltic region to identify and assess the expected developments in supply and demand of renewable gases, based on contacts with market operators and sector associations
 | 7, 9 |
| * Ensure appropriate regulation and public control of gas networks, in particular when these are partially or fully privately owned and need to be refurbished or repurposed, in order to ensure timely investments in renewable or decarbonized gas transport (and large-scale storage) infrastructure
 | 2, 5, 11, 15 |
| 8 | Security of gas supply can be threatened due to external energy dependence | * Work on further solidarity arrangements aimed at ensuring that protected customers have continued access to gas in times of crisis
 | 4, 13, 16 |
| * Decrease the overall natural gas consumption by implementing energy efficiency measures and by shifting towards locally generated renewable energy sources
 | 3 |
| * Pool gas demand of the BRGM countries to have a greater bargaining power in procurement negotiations with gas exporting countries
 | 4, 16 |
| 9 | Available inputs for production of R/LC gases, e.g. renewable electricity or biomass can be insufficient | * Allocate adequate funding and incentives to promote the development of renewable energy sources, including solar, wind, and biomass.
 | 3, 4, 8, 14 |
| * Invest in upgrading and expanding the power grid infrastructure to accommodate the increasing penetration of renewable energy sources.
 | 7 |
| * Implement climate resilience strategies to address the potential impact of natural fluctuations on renewable energy production. This includes improving forecasting capabilities, investing in energy storage systems, and promoting diversification of renewable energy sources.
 | - |
| * Promote sustainable biomass sourcing and cultivation practices to ensure a reliable and environmentally responsible feedstock supply for biomethane production. Encourage circular economy approaches, waste-to-energy initiatives, and land-use planning that prioritizes sustainable biomass production.
 | 12 |
| 10 | Investments in methane infrastructure can lead to lock-in on natural gas or asset stranding | * Reduce investments in new natural gas network infrastructure to the strict minimum, and ensure that any new asset is future-proof
 | - |
| * Introduce a legal ban on connecting new residential and tertiary buildings to the natural gas grid (unless the concerned buildings will mainly use renewable energy).
 | - |
| * Assess whether and how the natural gas network tarification can be reviewed to anticipate the consequences of reduced natural gas use and stranded assets.
 | 11 |
| 11 | Policies and regulations can present barriers to implementation of gas decarbonization actions | * Development of a coordinated strategy for the gas and hydrogen sectors in the BRGM region as well in the individual concerned Member States
 | 3, 4, 5, 6, 7, 8, 10, 13, 14 |
| * Develop clear and supportive legal frameworks and regulations for renewable energy and low-carbon gas production. Streamline permitting processes, provide incentives for project development, and ensure compliance with environmental standards to expedite the deployment of hydrogen and biomethane projects
 | 9 |
| 14 | Key gas decarbonisation technologies may not reach sufficient cost or performance improvements | * Publicly funded R&D&I programs focused on the development and improvement of gas decarbonisation technologies, renewable energy technologies, energy storage and biomass conversion processes. This will enhance the efficiency and scalability of both hydrogen and biomethane production methods, making them more cost-effective and commercially viable.
 | 1, 3, 4, 9, 11, 13 |
| * Reducing subsidies to fossil fuel-based technologies to increase the competitiveness of gas decarbonisation technologies.
 | 3, 4, 16 |
| * Transparent ambitions and clear planning at national level to reduce the uncertainty and risks for investing in gas decarbonization technologies.
 | 3, 4, 5, 6, 7, 8, 10, 13, 14 |

Trinomics B.V.

Mauritsweg 44

3012 JV Rotterdam

The Netherlands

T +31 (0) 10 3414 592

[www.trinomics.eu](http://www.trinomics.eu)

KvK n°: 56028016

VAT n°: NL8519.48.662.B01



1. See DG GROW (s.d.) Critical raw materials. <https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en> [↑](#footnote-ref-2)
2. Trinomics and Artelys (2021) Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis [↑](#footnote-ref-3)
3. World Economic Forum (2022) The Global Risks Report 2022 – Insight report [↑](#footnote-ref-4)
4. The survey was conducted between May and September 2021, hence before the Russian aggression against Ukraine. [↑](#footnote-ref-5)
5. World Economic Forum (2022) The Global Risks Report 2022 – Insight report [↑](#footnote-ref-6)
6. World Economic Forum (2022) The Global Risks Report 2022 – Insight report [↑](#footnote-ref-7)
7. IEA (2022) Securing Clean Energy Technology Supply Chains [↑](#footnote-ref-8)
8. [Narratives-for-Natural-Gas-in-a-Decarbonisinf-European-Energy-Market-NG141.pdf (oxfordenergy.org)](https://www.oxfordenergy.org/wpcms/wp-content/uploads/2019/02/Narratives-for-Natural-Gas-in-a-Decarbonisinf-European-Energy-Market-NG141.pdf) [↑](#footnote-ref-9)
9. [03\_03\_20\_E3G\_Gas\_Investment\_Transition\_Risk.pdf](https://www.e3g.org/wp-content/uploads/03_03_20_E3G_Gas_Investment_Transition_Risk.pdf) [↑](#footnote-ref-10)
10. IEA (2022) Securing Clean Energy Technology Supply Chains [↑](#footnote-ref-11)
11. [Scarring effects of the COVID-19 pandemic on the global economy – reviewing recent evidence (europa.eu)](https://www.ecb.europa.eu/pub/economic-bulletin/focus/2021/html/ecb.ebbox202107_01~f8314090a4.en.html) [↑](#footnote-ref-12)
12. [World Economic Outlook, April 2023: A Rocky Recovery (imf.org)](https://www.imf.org/en/Publications/WEO/Issues/2023/04/11/world-economic-outlook-april-2023#:~:text=Advanced%20economies%20are%20expected%20to,growth%20falling%20below%201%20percent.) [↑](#footnote-ref-13)
13. [How does the energy crisis affect the transition to net zero? (eib.org)](https://www.eib.org/en/stories/energy-crisis-net-zero-transition) [↑](#footnote-ref-14)
14. *Ibid.* [↑](#footnote-ref-15)
15. [World Economic Outlook, April 2023: A Rocky Recovery (imf.org)](https://www.imf.org/en/Publications/WEO/Issues/2023/04/11/world-economic-outlook-april-2023#:~:text=Advanced%20economies%20are%20expected%20to,growth%20falling%20below%201%20percent.) [↑](#footnote-ref-16)
16. Since the invasion of Russia in Ukraine, the inflation rates in the Baltic countries were among the highest in the euro area (with an average inflation rate of 17.1% in Latvia, 18.8% in Lithuania and 19.4% in Estonia in 2022, compared to 8.4% on average in the euro area), which has a negative impact on the purchase power and hence on the capacity to invest in renewable or low-carbon energy equipment. Source: [Euro area statistics (euro-area-statistics.org)](https://www.euro-area-statistics.org/inflation-rates?cr=eur&lg=en&page=0&charts=ICP.M..N.000000.4.ANR+ICP.M..N.010000.4.ANR+ICP.M..N.020000.4.ANR&template=1) [↑](#footnote-ref-17)
17. [World Energy Outlook 2022 (windows.net)](https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf) [↑](#footnote-ref-18)
18. [World Economic Outlook, April 2023: A Rocky Recovery (imf.org)](https://www.imf.org/en/Publications/WEO/Issues/2023/04/11/world-economic-outlook-april-2023#:~:text=Advanced%20economies%20are%20expected%20to,growth%20falling%20below%201%20percent.) [↑](#footnote-ref-19)
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26. [Energy-intensive industries (europa.eu)](https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652717/IPOL_STU%282020%29652717_EN.pdf) [↑](#footnote-ref-27)
27. [decarbonization-of-industrial-sectors-the-next-frontier.pdf (mckinsey.com)](https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/how%20industry%20can%20move%20toward%20a%20low%20carbon%20future/decarbonization-of-industrial-sectors-the-next-frontier.pdf) [↑](#footnote-ref-28)
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30. [Carbon Border Adjustment Mechanism (europa.eu)](https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en) [↑](#footnote-ref-31)
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32. [Energy prices and security of supply - Consilium (europa.eu)](https://www.consilium.europa.eu/en/policies/energy-prices-and-security-of-supply/) [↑](#footnote-ref-33)
33. *Ibid.*  [↑](#footnote-ref-34)
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36. [Recast EU Regulation on Gas and Hydrogen Networks (europa.eu)](https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/729302/EPRS_BRI%282022%29729302_EN.pdf) [↑](#footnote-ref-37)
37. In the stakeholders’ consultation, stakeholders mentioned the difficulty to find financial means to renew the aging gas infrastructure in Estonia (39% of pipelines over 50 years old). Hence they suggested to rate the likelihood of this risk as ‘medium’. [↑](#footnote-ref-38)
38. JRC (2022) [Flexibility requirements and the role of storage in future European power systems](https://publications.jrc.ec.europa.eu/repository/handle/JRC130519) [↑](#footnote-ref-39)
39. SEI (2023) Gas Decarbonisation Pathways for Estonia - Deliverable 3: Report on relevant scenarios for a decarbonised Baltic Regional Gas Market by 2050 [↑](#footnote-ref-40)
40. Guidehouse (2021) [Picturing the value of underground gas storage to the European hydrogen system](https://www.gie.eu/wp-content/uploads/filr/3517/Picturing%20the%20value%20of%20gas%20storage%20to%20the%20European%20hydrogen%20system_FINAL_140621.pdf) [↑](#footnote-ref-41)
41. ENTSO-E (2022) [European Resource Adequacy Assessment - 2022 Edition](https://www.entsoe.eu/outlooks/eraa/2022/) [↑](#footnote-ref-42)
42. O’Connor et al. (2023) [Decision support tool for the construction and seasonal operation of farm-scale anaerobic digestion plants](https://www.sciencedirect.com/science/article/pii/S2590123023002244). Results in Engineering Volume 18 [↑](#footnote-ref-43)
43. SEI (2023) Gas Decarbonisation Pathways for Estonia - Deliverable 3: Report on relevant scenarios for a decarbonised Baltic Regional Gas Market by 2050 [↑](#footnote-ref-44)
44. [Energy security – Topics - IEA](https://www.iea.org/topics/energy-security) [↑](#footnote-ref-45)
45. [\*Energy Supply and Security (europa.eu)](https://www.europarl.europa.eu/RegData/etudes/BRIE/2018/630275/EPRS_BRI%282018%29630275_EN.pdf) [↑](#footnote-ref-46)
46. Deliverable 2: Baseline data collection report [↑](#footnote-ref-47)
47. Eurostat, 2023 [↑](#footnote-ref-48)
48. *Ibid.* [↑](#footnote-ref-49)
49. In the stakeholders’ consultation, stakeholders indicated that the likelihood of this risk to occur could be ‘medium’ to ‘high’ as several geopolitical events have recently been affecting the EU’s security of supply (Russian war in Ukraine, coup in Niger). [↑](#footnote-ref-50)
50. Deliverable 2: Technical potential of biogas/biomethane in the Baltic-Finnish region [↑](#footnote-ref-51)
51. [Baltic states ramp up investment in energy sector - Economist Intelligence Unit (eiu.com)](https://www.eiu.com/n/baltic-states-ramp-up-investment-in-energy-sector/) [↑](#footnote-ref-52)
52. <https://news.err.ee/1608964834/estonia-latvia-plan-joint-lng-crisis-supply-deal> [↑](#footnote-ref-53)
53. <https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-revised-regulatory-framework-for-competitive-decarbonised-gas-markets-2> [↑](#footnote-ref-54)
54. <https://www.ifri.org/en/publications/notes-de-lifri/guide-solve-eus-hydrogen-dilemmas> [↑](#footnote-ref-55)
55. <https://www.vrt.be/vrtnws/nl/2023/01/24/stemming-over-waterstofwet-wat-houdt-die-wet-precies-in/> [↑](#footnote-ref-56)
56. <https://www.bmwk.de/Redaktion/DE/Artikel/Service/Gesetzesvorhaben/entwurf-eines-gesetzes-zur-anpassung-des-energiewirtschaftsrechts-an-unionsrechtliche-vorgaben.html> [↑](#footnote-ref-57)
57. In the stakeholders’ consultation, stakeholders have suggested to rate the likelihood of this risk as ‘medium’ as regulatory frameworks are a key factor for investors and system operators to set their decarbonisation objectives and make investment decisions. [↑](#footnote-ref-58)
58. <https://www.tandfonline.com/doi/full/10.1080/10934529.2018.1459076> [↑](#footnote-ref-59)
59. <https://www.europeanbiogas.eu/wp-content/uploads/2023/02/20230213_Guidehouse_EBA_Report.pdf> [↑](#footnote-ref-60)
60. SEI (2023) Gas Decarbonisation Pathways for Estonia - Deliverable 3: Report on relevant scenarios for a decarbonised Baltic Regional Gas Market by 2050 [↑](#footnote-ref-61)
61. <https://www.tandfonline.com/doi/full/10.1080/10934529.2018.1459076> [↑](#footnote-ref-62)
62. <https://www.sciencedirect.com/science/article/abs/pii/S0016236121010322> [↑](#footnote-ref-63)
63. <https://www.sciencedirect.com/science/article/pii/S004896972201717X> [↑](#footnote-ref-64)
64. ST/9107/2022/INIT <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32022H0627%2804%29> [↑](#footnote-ref-65)
65. Eurostat, [Inability to keep home adequately warm - EU-SILC survey](https://ec.europa.eu/eurostat/databrowser/view/ILC_MDES01__custom_1485289/default/table?lang=en). ILC\_MDES01\_\_custom\_1485289 [↑](#footnote-ref-66)
66. *Ibid.* [↑](#footnote-ref-67)
67. [World Energy Outlook 2022 (windows.net)](https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf) [↑](#footnote-ref-68)
68. E3M, Trinomics and SEI (2023) Gas Decarbonisation Pathways for Estonia - Deliverable 3: Report on relevant scenarios for a decarbonised Baltic Regional Gas Market by 2050 [↑](#footnote-ref-69)
69. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021D1129&from=EN> [↑](#footnote-ref-70)
70. <https://ec.europa.eu/commission/presscorner/detail/en/fs_22_6006> [↑](#footnote-ref-71)
71. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230&from=EN> [↑](#footnote-ref-72)
72. <https://www.balticenergyareas.eu/images/achievements/wp3.1_regional_stakeholder_maps_and_ananalyses_of_decision_flows.pdf> [↑](#footnote-ref-73)
73. <https://www.balticenergyareas.eu/images/WP3/BEA-APP_Deliverable_33_revised.pdf> [↑](#footnote-ref-74)
74. Agora (2021) 12 Insights on Hydrogen. <https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf> [↑](#footnote-ref-75)
75. European Hydrogen Backbone (2021) [Analysing future demand, supply, and transport of hydrogen](https://gasforclimate2050.eu/wp-content/uploads/2021/06/EHB_Analysing-the-future-demand-supply-and-transport-of-hydrogen_June-2021.pdf) [↑](#footnote-ref-76)
76. <https://energy.ec.europa.eu/system/files/2022-05/COM_2022_230_1_EN_ACT_part1_v5.pdf> [↑](#footnote-ref-77)
77. Fraunhofer ISI and Karlsruhe Institute of Technology (2021) [The potential of hydrogen for decarbonising EU industry](https://www.europarl.europa.eu/RegData/etudes/STUD/2021/697199/EPRS_STU%282021%29697199_EN.pdf) [↑](#footnote-ref-78)
78. <https://www.consilium.europa.eu/en/press/press-releases/2022/11/24/eu-to-speed-up-permitting-process-for-renewable-energy-projects/> [↑](#footnote-ref-79)
79. [eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0643](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0643) [↑](#footnote-ref-80)
80. In the stakeholder consultation, a stakeholder has suggested to consider the likelihood of this risk for hydrogen specifically as ‘high’ rather than ‘medium’, as water electrolysis is the only large-scale renewable hydrogen production technology and it has a low energy efficiency and depends on the availability of renewable electricity. [↑](#footnote-ref-81)
81. European Parliament (2021) [Answer to a written question - Safety of the energy switch to hydrogen.](https://www.europarl.europa.eu/doceo/document/E-9-2021-003540-ASW_EN.pdf) [↑](#footnote-ref-82)
82. <https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0_en> [↑](#footnote-ref-83)
83. <https://www.slrconsulting.com/en/news-and-insights/insights/perception-or-reality-how-does-safety-concern-hydrogen-compare-other> [↑](#footnote-ref-84)
84. <https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0_en> [↑](#footnote-ref-85)
85. Emodi et al. (2021) [A systematic literature review of societal acceptance and stakeholders’ perception of hydrogen technologies](https://www.sciencedirect.com/science/article/abs/pii/S0360319921024988). International Journal of Hydrogen Energy 46. [↑](#footnote-ref-86)
86. Fraunhofer ISI and Karlsruhe Institute of Technology (2021) [The potential of hydrogen for decarbonising EU industry](https://www.europarl.europa.eu/RegData/etudes/STUD/2021/697199/EPRS_STU%282021%29697199_EN.pdf) [↑](#footnote-ref-87)
87. For example the [2022 Horizon Europe Hydrogen Valleys call HORIZON-JTI-CLEANH2-2022-06-01](https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-jti-cleanh2-2022-06-01;callCode=HORIZON-JTI-CLEANH2-2022-2;freeTextSearchKeyword=;matchWholeText=true;typeCodes=0,1,2,8;statusCodes=31094501,31094502,31094503;programmePeriod=null;programCcm2Id=null;programDivisionCode=null;focusAreaCode=null;destination=null;mission=null;geographicalZonesCode=null;programmeDivisionProspect=null;startDateLte=null;startDateGte=null;crossCuttingPriorityCode=null;cpvCode=null;performanceOfDelivery=null;sortQuery=sortStatus;orderBy=asc;onlyTenders=false;topicListKey=topicSearchTablePageState) [↑](#footnote-ref-88)
88. Findeisen (2015) [The importance of safety standards, risk assessment and operators training for a successful biogas market development](https://www.unido.org/sites/default/files/2015-07/11_The_importance_of_safety_standards__risk_assessment_and_operators_training_Findeisen_0.pdf) [↑](#footnote-ref-89)
89. Baur et al. (2022) [Assessing the social acceptance of key technologies for the German energy transition](https://doi.org/10.1186/s13705-021-00329-x) [↑](#footnote-ref-90)