



# Estonian Hydrogen Roadmap

**Estonian Hydrogen Roadmap** has been prepared in co-operation with the Ministry of the Environment and the Ministry of Economic Affairs and Communications. The roadmap outlines the current state of the field along with themes within which the role of hydrogen in achieving climate objectives, strengthening the competitiveness of the economy, and reducing carbon emissions in different sectors can be defined.

The roadmap was introduced and approved at the meeting of the steering group for the drafting of the Estonian Hydrogen Roadmap on 6 February 2023.

The roadmap will be reviewed in co-operation with stakeholders and, where necessary, updated every three years.

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## Summary

Based on the long-term development strategy 'Estonia 2035' and the European Green Deal, Estonia has set itself ambitious climate, environmental and energy objectives. To achieve these objectives, it is necessary to switch from fossil fuels to cleaner energy sources, including hydrogen. It is essential to maximise local socio-economic benefits in the development of new sustainable sectors. In a situation where the regulatory pressure and global demand for the introduction of hydrogen are increasing, it is important to make use of the opportunities: by encouraging renewable energy generation, the emerging industry, and services in Estonia, we have the potential to transform from an energy importing country into a hydrogen and hydrogen technology exporter.

In a national and European Union (EU) context, the viability of the hydrogen sector value chain depends on the availability of sufficient quantities of affordable, local, and renewable energy. The current technologies involve significant losses in conversion and storage, and the issues related to distribution and storage remain outstanding. It is therefore appropriate to start with actions required by the legal framework and to focus on areas where the environmental and socio-economic benefits are the greatest.

**The hydrogen roadmap is a vision document** that supports the attainment of strategic targets and objectives set in other development plans and programmes. It maps out the state of play in Estonia and outlines directions within which the introduction of hydrogen technologies should be assessed. Both the state, companies and other parties have drawn up plans and launched various activities which should all be considered in hydrogen-related policymaking, legislation creation, and infrastructure development.

The roadmap is divided into two parts:

- 1) description of the current situation;
- 2) activities in Estonia until 2030 that would lead, in the longer term, to the creation of a hydrogen value chain based on demand and renewable energy.

In both parts, key research, and development (R&D) activities, the availability of renewable energy, hydrogen production, distribution, storage and consumption, as well as regional co-operation and environmental impacts are described. Among other factors, the hydrogen sector is shaped by national and EU policies as well as the activities of market participants. On that basis, it is possible to plan support measures and investments.

The larger-scale adoption of hydrogen is planned in three stages. **This roadmap focuses on the pilot phase of the Estonian hydrogen sector from 2021 to 2030.** During this period, the primary focus is on the development of policies, R&D, implementation of pilot projects, and improving the availability of renewable energy. At the same time, the potential of hydrogen will be assessed to achieve political and socio-economic objectives. In addition, the ability to conduct applied research in Estonia will be increased. Although no significant reduction in emission will be achieved, the pilot projects serve as a basis for implementing further activities. It is expected that by 2030, the cost of green hydrogen in the world may range between €1.2 and €4.1 per kilogram<sup>1</sup>. Applied research capacities in Estonia will be enhanced. Moreover, appropriate analyses will be conducted, the legislation and standards necessary for the implementation of hydrogen projects will be adopted, and the roles of stakeholders will be determined for subsequent stages.

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<sup>1</sup> [IEA Global Hydrogen Review 2022](#), 23.01.2023.

Provided that favourable conditions and activities continue, piloting will be followed by a **scaling phase running from 2030 to 2035**. Based on the experience gained during the previous pilot phase, activities aimed at developing the value chain, removing identified barriers, and improving access to renewable energy will be continued. In the segments of hydrogen value chain where the local market covers the demand (e.g. piloted transport applications or the production of chemicals), technology should be capable of reducing the carbon emissions of the entire life cycle to zero or by a very substantial amount. From an economic impact point of view of hydrogen applications, it is essential that the applications can demonstrate financial break-even, even when assuming no public support and in a conservative estimation of available renewable energy generation capacities.

**The period from 2036 to 2050 could see the expansion phase of the Estonian hydrogen sector** which builds upon the availability of affordable renewable energy and the capacity of the hydrogen technology to cost-effectively reduce the carbon emissions of the value chain to zero in the following decade. According to current estimates, the possible installed capacity of offshore wind farms should exceed 7 GW by this period. This would allow for abundant renewable electricity for uses other than local direct electrification and past hydrogen value chain creation efforts could start to generate revenue. If green hydrogen becomes amply available and its transmission infrastructure is created, consideration may be given to broader use (e.g. in the energy sector, transport and chemical industry, or for converting hydrogen into electricity and heat), or of its export.

**The timeliness of the objectives and activities of this roadmap** will be assessed regularly, with three-year interval at most. An assessment of the progress which is carried out prior to the end of each stage will serve as the basis for updating the objectives and activities of the following stage.

## Roadmap at a glance

- At present, there is no commercial generation or use of hydrogen and there is no hydrogen market in Estonia. The implementation of necessary activities relies on long-term EU policies and market mechanisms to divert conventional value chains.
- Hydrogen concerns several policy areas. To ensure economic viability, it is vital to foster activities with high added value that can develop autonomously. For the achievement of climate policy objectives, it is particularly crucial to promote the production and use of carbon-neutral hydrogen derived from renewable sources. As the geopolitical situation has become tense, dependency on unreliable external partners must be avoided.
- In the case of hydrogen energy storage, only about one third of the initial energy is available for use; and half is released as heat. Therefore, its use for electricity storage is up for debate.
- To reduce greenhouse gas (GHG) and air pollutant emissions, hydrogen may in the long term be used in ferry transport, aviation, or long-distance transport where mass, volume, and long loading times exclude the use of battery power.
- By 2030 at the latest, hydrogen refuelling stations must be built every 100–200 km along the TEN-T core network. Each refuelling station must have a production and storage capacity of at least 2 tonnes of hydrogen per day. For Estonia, this means a minimum of 3 to 5 hydrogen refuelling stations with a capacity of about 2,000 tonnes of hydrogen per year. The location and actual number of refuelling stations must be further assessed.<sup>2</sup>
- The most important prerequisite for the development of the local green hydrogen value chain is adequate access to affordable renewable energy. Therefore, depending on electricity and hydrogen market developments, the production potential of green hydrogen in 2030 lies between 2,000<sup>3</sup> and 40,000<sup>4</sup> tonnes per year.
- Green hydrogen and its derivatives may replace imported and fossil energy carriers, goods, and materials, however, it is conditional on the development of entirely new industrial opportunities (ammonia, methanol, fertilisers, synthetic fuels, polymers).
- The introduction of hydrogen in Estonia requires the creation of relevant requirements, standards, and know-how in Estonia.
- Since 2020, more than 120 million euros have been provided in public support for the development of hydrogen production technologies and supply chains.
- Potential further analyses:
  - assessment of the need for the introduction of hydrogen and refuelling points in transport (land, air, and sea transport).
  - assessment of activities necessary for the industrial production of hydrogen technologies.
  - assessment of the use of hydrogen-based system services and emergency power in terms of security of supply.
  - assessment of technical-economic alternatives to hydrogen distribution and storage.

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<sup>2</sup> The final agreement of AFIR reached 28 March 2023 set the requirement to provide for hydrogen refuelling stations for road transport that are located at a maximum distance of 200 km along the TEN-T core network (closer than 10 km away from the road) with an on-site storage capacity of 1t of hydrogen per day, at 700 bar.

<sup>3</sup> According to the requirements of the trans-European transport network (TEN-T and AFIR).

<sup>4</sup> According to the estimates of Estonian Hydrogen Association and Hydrogen Valley Estonia.

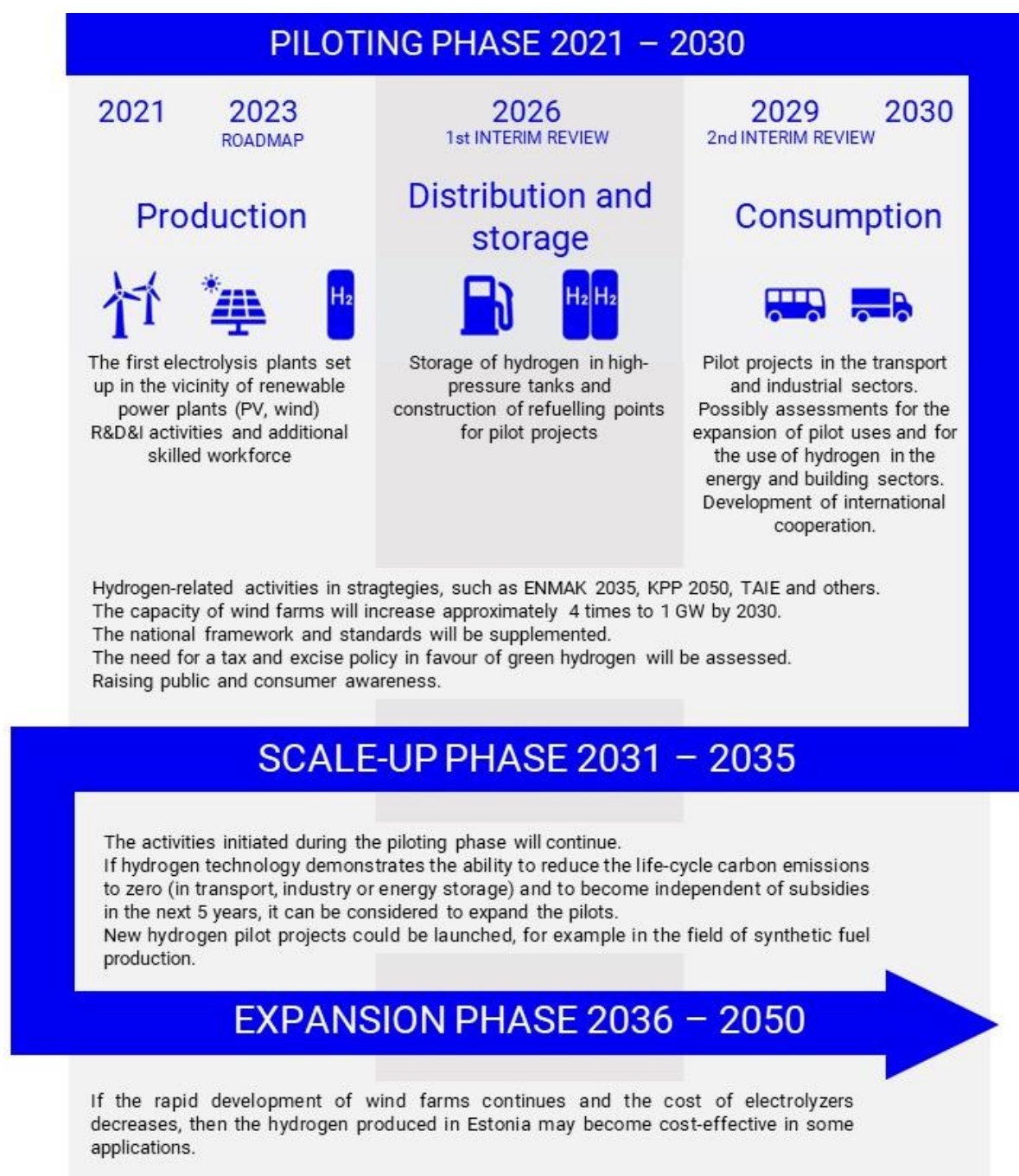


**Figure 1:** Schematic diagram of the Estonian Hydrogen Roadmap

## Roadmap monitoring

Objectives must be agreed to develop the hydrogen sector, which can be monitored, for example, by:

- the amount of hydrogen produced (including green hydrogen);
- the number of hydrogen refuelling stations;
- the nominal capacity of electrolyzers;
- the reduction of GHG and air pollutant emissions;
- the number of hydrogen experts working in Estonia or the number of people employed in the hydrogen sector.

## Introduction

The long-term development strategy 'Estonia 2035'<sup>5</sup> sets out that by 2050 Estonia will be a competitive, climate-neutral country with a knowledge-based society and economy and a high-quality and an environment that is rich in species, that is ready to mitigate and adapt to the adverse effects of climate change. According to the Estonian Research and Development, Innovation and Entrepreneurship Strategy<sup>6</sup>, supporting the hydrogen economy is done via strengthening R&D, offers climate policy solutions, and facilitates the introduction of state-of-the-art technologies. These objectives dovetail with the European Green Deal<sup>7</sup> that, among other things, sets out EU-wide climate neutrality and zero pollution objectives for 2050.

The Estonian Hydrogen Roadmap defines the role of hydrogen in achieving climate neutrality. The prerequisite for this is the establishment of production capacities together with the development of storage solutions as well as the improvement of economic competitiveness by cost-effective carbon emission reduction of different sectors. It is based on the gradual reduction of the use of fossil fuels in energy production and the development and introduction of new climate-neutral generation and storage solutions. As of 2021, the GHG emissions from energy production in Estonia have decreased by 76% compared to 1990 levels<sup>8</sup>. During the same period, transport GHG emissions have decreased by only 5%.

By 2030, the share of renewable energy is set to increase from 38% to 65%<sup>9</sup> and the Effort Sharing Regulation (ESR) sets a target for Estonia to reduce GHG emissions by 24% compared to 2005. Among other things, the regulation also covers the sectors of transport, industrial processes and small-scale energy production.

The targets for 2035 (compared to 2019)<sup>5</sup> are:

- to reduce GHG emissions from 14 million tonnes CO<sub>2</sub>-eq in 2019 to 8 million tonnes CO<sub>2</sub>-eq in 2035 (-42%);
- to increase the share of sustainable mobility from 38.7% to 55%;
- to move up in rank from 10th place in 2019 in the Sustainable Development Goal Index.

In the context of Estonia, green hydrogen can be produced from sustainable biomethane or from water through electrolysis using renewable energy. The most important prerequisite for this is the availability of sustainable feedstock, i.e. renewable energy, and technology. For example, the delivery times for electrolyzers can be long and the cost of establishing and operating hydrogen storage facilities can be high.

There are several countries in the world which have already accumulated great experience in the primary and industrial use of hydrogen. In the field of transport, Japan is one of the world's leading developers of hydrogen and fuel cell technologies and is expected to have 200,000 fuel cell vehicles in operation by 2025<sup>10</sup>. National hydrogen strategies highlight the transport sector as one of the key hydrogen usage areas<sup>11</sup>. The second most important area is the industrial sector (Germany, the Netherlands), with the power-generating sector ranking third (France, the UK). Some countries pay

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<sup>5</sup> [Long-term development strategy 'Estonia 2035'](#), 2021.

<sup>6</sup> [Estonian Research and Development, Innovation and Entrepreneurship Strategy 2021–2035](#).

<sup>7</sup> [The European Green Deal](#), 2019.

<sup>8</sup> [Greenhouse Gas Inventory 1990–2021](#) (preliminary estimates; 18.01.2023).

<sup>9</sup> [Energy Sector Organisation Act](#), 22.10.2022.

<sup>10</sup> [Analysis of opportunities for hydrogen deployment in Estonia](#), 2021.

<sup>11</sup> [Analysis of opportunities for hydrogen deployment in Estonia](#), 2021.

particular attention to the use of heat and energy generated during hydrogen conversion (e.g. the UK, Japan, Korea) and the production of hydrogen for export (e.g. Chile, Spain, Australia, Russia).

At present, green hydrogen is a very precious commodity on global markets. Having already attracted attention in Estonia as well, its importance in meeting the strategic objectives of the EU increased even further in early 2022 when Russia invaded Ukraine. Since Russia accounted for more than 40% of EU's natural gas imports, a rapid transition to clean energy derived from local sources has become an even more urgent matter. Having this in mind, the European Commission presented the REPowerEU<sup>12</sup> action for more affordable, secure, and sustainable energy. The action calls for a supply of 20 million tonnes of green hydrogen by 2030, with half of it being produced in Europe and the other half imported.

In view of the war in Ukraine, the 2022 Energy Report of the expert group within the Estonian Green Policy Steering Committee also emphasised the need for accelerated implementation of mature energy projects and for a time limit for maximum transition to local renewable energy from imported fossil natural gas.

Although, at present, there is neither hydrogen demand nor supply on the Estonian market, several companies are developing hydrogen production technologies and have prepared projects for the production, distribution, tank storage, and use of hydrogen in the value chain. Given that the actors in the value chain either act independently or under different umbrella organisations, the situation could be improved if stakeholders were to strengthen their co-operation in terms of both communication and project implementation. Companies generally support the gradual development of pilot projects, the creation of standards and legislation enabling such development, and growth in long-term demand. The preliminary studies for the development of the transmission infrastructure are planned to be launched in co-operation with neighbouring countries in 2023 and they will be conducted by the Estonian transmission network operator Elering.

In line with the Important Projects of Common European Interest (IPCEI) Communication, the state has decided to provide state aid in the form of grants to three hydrogen value chain technology projects for R&D purposes in the total amount of nearly 67 million euros, which, if successful, would hopefully result in the creation of large-scale industrial production capacity in Estonia (21 ideas were submitted to the pre-selection round of IPCEI hydrogen projects). In addition, the state supports projects aimed at creating a hydrogen value chain in the transport sector and chemical industry with nearly 54 million euros. Calculation of the share of renewable energy available for hydrogen production and the potential final consumption is part of the process of updating the Estonian National Energy Development Plan 2035 (ENMAK 2035) which will be finalised by 2026.

For the emerging hydrogen market to become an economically sustainable industry, co-operation between market participants, skills and competences, strategic policies, legal clarity, and investments in key sectors is needed.

The Estonian Hydrogen Roadmap was compiled based on scientific literature, expert interviews, previous research<sup>13</sup>, sectoral statistics and data sources. Moreover, the roadmap considers national development plans and the proposal for the Estonian Hydrogen Roadmap 2021–2050<sup>14</sup> prepared in 2021. In the use and interpretation of the roadmap, it is essential to consider that hydrogen technology and the opportunities for hydrogen production, storage and consumption are rapidly evolving. To this end, the state will review and update the Estonian Hydrogen Roadmap at least every three years.

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<sup>12</sup> [REPowerEU: Joint European action for more affordable, secure and sustainable energy](#), 2022.

<sup>13</sup> [Analysis of opportunities for hydrogen deployment in Estonia](#), 2021.

<sup>14</sup> [Proposal for Estonian Hydrogen Roadmap 2021–2050](#), 2022.

## State of play of the sector in Estonia

### Research and development

Thanks to the work of the European Union, the state and companies, more hydrogen-related research is conducted in Estonia than ever before. In close co-operation with the private sector, researchers in the University of Tartu (UT) and the National Institute of Chemical Physics and Biophysics (NICPB) are devoting special attention to electrolyser and fuel cell research. For example, in co-operation with AS Elcogen, the UT and NICPB are developing solid oxide fuel cells. Currently, the UT is conducting preliminary research on the next-generation proton exchange membrane (PEM) fuel cell for a self-driving vehicle for AUVETECH AS and testing of electrode materials for Stargate Hydrogen to create a new generation of alkaline electrolysers. Additionally, the UT is developing high-temperature solid oxide electrolysers along with hydrogen storage devices for H2Electro AS. In early 2023, AS Metrosert was tasked with creating opportunities for applied research in five focus areas, including hydrogen technologies. Nevertheless, there are areas, such as the use of hydrogen in the production of chemicals, technologies for CO<sub>2</sub> capture and storage from renewable sources or maintenance services for different devices, where the lack of commercial interest and know-how has hindered policy development.

Most of the hydrogen produced in R&D institutions is used by these same institutions and startups to research hydrogen storage solutions and develop hydrogen fuel cell solutions.

EU funding programmes (e.g. InvestEU, IPCEI, ERDF and the Cohesion Fund) have been developed to support the green transition and promote the production of chemicals from green hydrogen, such as ammonia or methanol.

Since there is virtually no hydrogen production, consumption or development (e.g. for the production of synthetic fuels or other hydrocarbons) in Estonia, the Estonian State has mainly contributed to R&D on exported technologies in the hydrogen value chain. The establishment of the remaining capabilities depends on the decisions necessary to meet climate and security objectives.

### Access to renewable energy

Estonia has set itself a target that, by the year 2030, renewable energy will account for 100% of the final consumption of electricity.<sup>15</sup> To this end, the state works to eliminate any barriers and restrictions on the maximum permitted height of civil engineering works or interconnection capacity bookings under which no actual transmissions are made. In the Action Programme of the Government of the Republic 2022–2023, it was agreed that the process of planning, environmental impact assessment and permit granting will be audited under the leadership of Green Transition Policy Coordinator of the Government Office of Estonia. The aim of this is to accelerate the implementation of renewable energy projects. One steering group and four working groups were created under the Government Office to carry out the audit and develop solutions. The steering group decided to focus on identifying priority development areas for wind power and accelerating permit granting procedures.

In 2022, the onshore wind capacity installed in Estonia totalled 319 MW, solar capacity approximately 500 MW, and combined heat and power capacity 351.8 MW. A year earlier, in 2021, onshore wind farms generated 824 GWh and solar parks 119 GWh of electricity. The wind capacity connected to the electricity network may double by 2025 and, in the distribution network of Elektrilevi, solar capacity

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<sup>15</sup> [Energy Sector Organisation Act](#), § 32<sup>1</sup>

has increased from 38 MW in 2018 to more than 600 MW largely thanks to state aid, and the volumes are projected to more than double by 2030.<sup>16</sup>

Due to the price increase in the European Union Emissions Trading System (EU ETS), Estonia has become an energy importing country because of power generation from fossil fuels. Since Estonia uses large volumes of highly polluting and carbon-intensive oil shale in its energy sector, the European Union Allowance (EUA) price increase has significantly weakened our competitiveness compared to cleaner energy producers. In 2020, approximately 42% of electricity was imported and, in 2021, the same figure was 30%.

Currently, negotiations between the EU institutions on the Fit for 55 package are underway. The package sets very high expectations for the development of renewable energy which will also be taken into consideration in the updating process of ENMAK 2035.

### Hydrogen cost and efficiency

The potential of hydrogen can be realised when there is a significant surplus of very affordable renewable energy. The wholesale price of fossil hydrogen is around €1 per kilogram, depending heavily on the price of the energy carrier used as input. With carbon capture and storage (CCS) technologies, hydrogen costs €5–8 per kilogram, which compares to the current green hydrogen cost price of €4–8 per kilogram<sup>17</sup>.

According to estimates, by 2030, the price of green hydrogen in the world may fall to €1.2–4.1 per kilogram<sup>18</sup>, depending heavily on the price of electrolyzers and renewable energy. As of today, the most cost-effective way to produce green hydrogen in Estonia is in large-scale solar parks with a cost price of approximately €4.5–5.2 per kilogram. It is estimated that by 2030 the most affordable cost price will be €3.4–4.2 per kilogram<sup>19</sup>.

While it is more affordable than hydrogen produced with CCS technologies, it is roughly five times more expensive than the fossil hydrogen produced today and two to three times more expensive compared to the expected price of green hydrogen in global markets in 2030<sup>20</sup>. An overview of estimated hydrogen prices is presented in Table 1.

Although the price of wind energy is likely to remain higher compared to that of solar energy, its potential production capacity is significantly higher and more consistent throughout the year. Therefore, in the context of Estonia, it is possible to make use of electricity from different renewable sources in the introduction of green hydrogen.

**Table 1:** Overview of hydrogen price per 1 kg

|                                | 2023   |       |                    |                                | 2030               |                  |
|--------------------------------|--------|-------|--------------------|--------------------------------|--------------------|------------------|
| Hydrogen production technology | Fossil | CCS/U | Green in the world | Green in Estonia (theoretical) | Green in the world | Green in Estonia |
| Price of 1 kg                  | €1     | €5–8  | €4–8               | €4.5–5.5                       | €1.2–4.1           | €3.4–4.2         |

<sup>16</sup> The sources used for this paragraph include Elektrilevi, Elering, and the Ministry of Economic Affairs and Communications.

<sup>17</sup> [IEA Global Hydrogen Review 2022](#), 23.01.2023.

<sup>18</sup> [IEA Global Hydrogen Review 2022](#), 23.01.2023.

<sup>19</sup> [Analysis of opportunities for hydrogen deployment in Estonia](#), 2021.

<sup>20</sup> [IEA Global Hydrogen Review 2022](#), 23.01.2023.

Although hydrogen production via electrolysis generates no CO<sub>2</sub> emissions, its efficiency varies greatly depending on the technology used. On average, 30% (20–45%) of the energy used is lost during electrolysis. To store and distribute hydrogen, it must first be cooled and compressed. On average, this process depletes 20% (5–35%) of the energy stored in hydrogen. However, if the hydrogen is used for power generation, roughly half of the energy will be lost. Thus, in the case of electricity-hydrogen-electricity storage, only about a third of the initial energy will be available for use as electricity and half as heat. This means that the sooner and faster the hydrogen is consumed after production, the more sustainable it is.

## Production, industry and consumption

Today, there is no market for hydrogen production and consumption in Estonia. Hydrogen is not used in the transport sector and there is also no large-scale industry making use of hydrogen as a raw material (e.g., to produce fertilisers, ammonia or steel). The last industrial company (chemical company Nitrofert that was engaged in the production of mineral fertilisers using hydrogen made via steam-methane reforming) closed in 2017. At present, hydrogen is produced in the University of Tartu (2 kg per day; planned to be increased to 8–10 kg per day by 2024) and in Narva by Eesti Energia for the cooling of thermal power station generators. Utilitas Eesti AS and UG Investments are developing a green hydrogen pilot project for public transport due to be completed in 2024.<sup>21</sup>

The technology company Elcogen manufactures high-temperature fuel cells and electrolytic cells (basic components of fuel cells and cell stacks) and is in the process of constructing a globally unique fuel cell stack production plant in Tallinn. PowerUP Energy Technologies is engaged in the manufacture of low-temperature fuel cells and generator systems based on fuel cells. Stargate Hydrogen offers alkaline electrolyzers and is developing more efficient ceramics-based elements and electrolysis systems. In co-operation with the University of Tartu, H2Electro is developing a prototype high-temperature electrolyser. Skeleton Technologies is developing a short-term high energy density storage solution that increases the efficiency of fuel cells in transport applications.

Linde Gas has the knowledge and know-how necessary for hydrogen production via steam-methane reforming, and Eesti Energia via electrolysis. Today, Estonia already has the experience necessary in electrolyser, methane reformer and gasifier operation for small-scale production. The Port of Sillamäe has the capacity to receive and export ammonia.

By the end of 2022, it was possible to order two hydrogen fuel cell vehicles in Estonia: Toyota Mirai and Hyundai NEXO, with prices starting from 71,000 euros. Mobile hydrogen refuelling solutions have been introduced as pilot projects and Alexela AS has assessed the possibility of offering hydrogen on a commercial basis and making refuelling stations available once the demand arises.

## Distribution and storage

At present, there is no hydrogen distribution infrastructure or refuelling network in Estonia. Hydrogen is currently stored as a gas in special small cylinders that are transported by truck. Technological feasibility studies regarding the integration of hydrogen into the existing natural gas transmission and distribution network are planned to be carried out in 2023.

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<sup>21</sup> [Utilitas Eesti AS](#), 2021.

## Standards, legislation and support

At present, there is no legislation governing hydrogen refuelling stations or hydrogen production equipment in Estonia, which may complicate the implementation of hydrogen projects (e.g. the assessment of required free space for hydrogen production and refuelling equipment should be based on the specific risk assessment of each project, not legislation). It is also not clear under what conditions hydrogen will be integrated into national and EU transport fuels or the renewable energy certificates market.

In 2022, on the initiative of the Estonian Centre for Standardisation and Accreditation, a technical committee for hydrogen technologies<sup>22</sup> was set up within the centre to standardise hydrogen production, storage, transport, measurement and exploitation systems and equipment, including hydrogen refuelling stations, fuel cells, and electrolyzers. The objective of the committee is to represent Estonia in international standardisation and to accelerate the introduction of hydrogen in Estonia through the adoption and adjustment of relevant standards.

## EU framework

The following provides an overview of the main hydrogen initiatives of the EU. In 2020, the European Commission presented its '**Hydrogen strategy for a climate-neutral Europe**'<sup>23</sup> that set as a priority the development of green hydrogen and provided for its gradual and widespread deployment by 2050 along with the creation of new renewable energy capacities. The objectives outlined in the strategy also serve as a basis for the '**Fit for 55**' package of the European Commission to help meet the EU's target of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990. The Commission Communication '**REPowerEU**'<sup>24</sup> aims for a more affordable, secure, and sustainable energy supply, with 20 million tonnes of renewable hydrogen production and imports by 2030. The **Renewable Energy Directive (REDIII)**<sup>25</sup> currently under revision seeks to accelerate the establishment of a complete hydrogen chain and sets targets for the consumption of green hydrogen in industry and transport. The directive will be supplemented by an article that establishes a target for the use of hydrogen in industry. According to that provision, the share of renewable fuels of non-biological origin (RFNBOs) in industry, particularly that of hydrogen, should account for at least 50% of the hydrogen consumed in the country by 2030. In addition, REDIII provides for a transport sub-target that a certain amount of RFNBOs must be consumed of all the energy directed at transport. A delegated act has been drawn up based on the Renewable Energy Directive laying down the conditions under which renewable fuels can be considered an RFNBO.<sup>26</sup> In support of the delegated act, the revised directive will be supplemented by an article further specifying RFNBOs: when they are counted towards national renewable energy targets and how the emissions savings of RFNBOs are calculated.

According to the proposal for a **Directive on the Deployment of Alternative Fuels Infrastructure**<sup>27</sup>, Member States must build hydrogen refuelling stations (suitable for both light-duty and heavy-duty vehicles) every 100–200 km along the **TEN-T** core network and in all urban nodes. This initiative seeks to increase the use of clean and renewable fuels in the EU transport sector and to ensure the availability of a dense, widespread network of alternative fuels storage and refuelling infrastructure on EU TEN-T roads, ports and airports.

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<sup>22</sup> [Estonian Centre for Standardisation and Accreditation EVS/TC 80 \(Hydrogen technologies\)](#), 2023.

<sup>23</sup> [A hydrogen strategy for a climate-neutral Europe](#), 2020.

<sup>24</sup> [REPowerEU: Joint European action for more affordable, secure and sustainable energy](#), 2022.

<sup>25</sup> [Renewable Energy Directive 2018/2001/EU](#), 2022.

<sup>26</sup> Delegated act under the Renewable Energy Directive pending approval

<sup>27</sup> [Revision of the Directive on Deployment of Alternative Fuels Infrastructure](#), 20.01.2023

In early 2023, the new **Regulation on CO<sub>2</sub> Emission Performance Standards for New Passenger Cars and New Light Commercial Vehicles**<sup>28</sup> was adopted at EU level, which, among other things, provides for a ban on the sale of new internal combustion engine vehicles from 2035, and the European Commission has additionally proposed 2030 **targets to stimulate zero-emission heavy transport**<sup>29</sup>, including making intra-urban buses fully emission-free.

A draft **Directive on the Taxation of Electricity** is in negotiation between EU institutions, the principal objective of which is to establish an internal logic in minimum rates of excise duty. The proposal intends to make minimum rates of excise duty be fully based on energy content, expressed in euros per net calorific value of the energy product. While the minimum rates of excise duty on fossil hydrogen are equal to those of other fossil fuels, renewable hydrogen and low-emission fuels will be subject to lower levels of taxation<sup>30</sup>.

The amendments proposed in the 'Fit for 55' package provide for the extension of the **EU ETS** requirements to hydrogen production, regardless of the production technology used (including green hydrogen). Upon the entry into force of these amendments (most likely from 2024), an installation producing hydrogen will be able to apply for the free allocation of EUAs which, in turn, helps to increase the competitiveness of green hydrogen production compared to grey hydrogen.<sup>31</sup>

**The Industrial Emissions Directive (IED)** governs the production of hydrogen without making a distinction between the different production methods. The IED is the main EU legislative instrument in the prevention and monitoring of pollution and is currently applied to 50,000 large industrial installations in Europe (137 of which are in Estonia). These installations must comply with the set emissions requirements and apply the best available techniques. As the production of renewable hydrogen via electrolysis is virtually emission-free, Estonia proposed, during the discussions on the IED amendment published in April 2022, that the production of such hydrogen be excluded from the scope of the IED. The decision on whether hydrogen produced via electrolysis will be included in or excluded from the scope of the IED will be made by the end of 2023.<sup>32</sup>

The criteria for hydrogen production are laid down in the **EU Taxonomy Regulation**<sup>33</sup>. In addition, the European Commission is planning to launch the **European Hydrogen Bank initiative**<sup>34</sup> in mid-2023. The Hydrogen Bank will invest 3 billion euros to help establish the future green hydrogen market and most likely also provide funding for novel hydrogen projects. An EU-wide pilot auction with a budget of up to €800 million is planned for autumn 2023 to create green hydrogen markets. This would guarantee financial support to the most economically advantageous tenderers for the next ten years per each kilogram of green hydrogen produced.

## National framework

In view of the war in Ukraine, the 2022 Energy Report of the expert group within the Estonian Green Policy Steering Committee emphasised the need for accelerated implementation of mature energy projects. It was concluded that to ensure legal clarity, a time limit for transition to local renewable

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<sup>28</sup> [Position of the European Parliament on the CO<sub>2</sub> emission performance standards for new passenger cars and new light commercial vehicles](#), 20.01.2023

<sup>29</sup> [Regulation on CO<sub>2</sub> Emission Performance Standards for New Heavy-duty Vehicles](#), 20.01.2023

<sup>30</sup> [Directive on the taxation of energy products and electricity](#), 2021.

<sup>31</sup> [Updating of the European Union Emissions Trading System](#), 2023.

<sup>32</sup> [Views on the Industrial Emissions Directive](#), 2022.

<sup>33</sup> [EU Taxonomy Regulation](#), 2019

<sup>34</sup> [Call for large-scale projects under the EU Innovation Fund with a budget of €3 billion](#), 2022.

energy from imported fossil natural gas must be set. In this context, it is essential to promote the production of biomethane, hydrogen and synthetic fuels.

By 2026, Estonia plans to invest 49.1 million euros from RRF funds to promote the deployment of complete hydrogen technologies. The support measure will be organised with an open round for applications so that market participants can propose the best solutions. In addition, since 2022, the state provides funding from state budget and ETS auction revenue to IPCEI projects for R&D on pan-European value chains and to hydrogen technology companies in the total amount of €67 million.

Regarding the hydrogen sector specifically, the support measures do not include any tax measures, for example, or any wider national policy objectives or levers to reduce investment costs. Before the limited resources of the state are put into use, the local strengths of Estonia are assessed, and the resources will be targeted at highest socio-economic added value areas and activities.

### Regional co-operation

The European Hydrogen Backbone initiative launched in 2021 involves the creation of an EU-wide hydrogen transmission infrastructure by 2040. The network is expected to expand 40,000 km across 21 European countries. At present, 31 transmission network operators have joined the initiative, and opportunities for the establishment of the hydrogen transmission capacity of €20 million tonnes by 2030 specified in the RePowerEU initiative are being assessed<sup>35</sup>. Estonia is represented by its transmission network operator Elering. In 2022, Elering concluded a co-operation agreement with Finland, Latvia, Lithuania, Poland, and one German gas system operator to jointly explore the creation of a hydrogen transmission pipeline from Finland through Estonia to Germany.

Estonia submitted two projects from different partners to Horizon Europe's call for Hydrogen Valleys<sup>36</sup>. One application was submitted with the participation of the Estonian Hydrogen Cluster<sup>37</sup> and the other with the Estonian Hydrogen Association<sup>38</sup>, both of which focused on collaborative projects, the development of a common hydrogen infrastructure, and information exchange. In January 2023, the European Commission decided to support the application of the Estonian Hydrogen Cluster with €25 million for the next five years.

In neighbouring countries, hydrogen value chain planning and the related legislative processes are still in the early stages. Therefore, the national framework for regional co-operation is still being developed.

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<sup>35</sup> [Five hydrogen supply corridors](#), 2022.

<sup>36</sup> [Horizon Europe's call for large-scale Hydrogen Valleys](#), 2022.

<sup>37</sup> [Estonian Hydrogen Cluster](#), February 2023.

<sup>38</sup> [Estonian Hydrogen Association](#), February 2023.

## SWOT analysis of Estonian hydrogen sector

Table 1: The short-term strengths, weaknesses, opportunities, and threats of Estonia in the development of the hydrogen sector

### STRENGTHS

- Estonia has great offshore wind energy potential (at least 7 GW)
- Baltic and Nordic electricity markets are relatively well connected
- Favourable business environment for the development of innovative startups
- Barriers to the growth of renewable energy are being removed
- Co-operation with neighbours allows for a large number of pilot solutions to be developed
- Willingness of the private sector to show initiative and contribute
- Many national measures supporting R&D, technologies for hydrogen production and the development of value chains

### WEAKNESSES

- Rapid development of renewable energy is curbed by the network's capacity to receive increased volumes
- At present, the production and consumption of hydrogen is marginal
- Lack of trained specialists and experts
- Hydrogen does not play a key role in any industry
- Estonia lacks the capacity to store and distribute hydrogen
- No legal framework or standards in Estonian
- Permit-granting procedures for renewable energy and hydrogen projects are vague and unnecessarily long

### OPPORTUNITIES

- Public support for hydrogen supply chains (€49.1 million, RRF) and IPCEI projects for hydrogen production technologies (€10 million, state budget; €57 million, Atmospheric Air Protection Act)
- Surplus renewable energy can be used for hydrogen production
- BalticSeaH2 application was approved in the pan-European Hydrogen Valleys funding round of Horizon Europe
- Both the EU and state reduce fossil fuel imports
- Active co-operation between businesses and R&D institutions
- Estonia's compactness allows for rapid implementation of pilot projects
- Export of hydrogen technologies and products
- Industry can accelerate the introduction of renewable hydrogen through power purchase agreements (PPAs)

### THREATS

- Hydrogen technologies remain too expensive and unattainable
- Energy-efficiency and cost-effectiveness of hydrogen technologies remain low
- Sustainable energy (offshore wind farm) capacities are added slowly
- Market participants do not co-operate or invest
- National legal framework inhibits hydrogen sector development
- Hydrogen technologies fail to gain public trust
- More favourable conditions for hydrogen sector development in other countries
- International co-operation does not work

## Expected development of the sector in Estonia until 2030

**The pilot phase of the Estonian hydrogen sector from 2021 to 2030** focuses on the development of policies and the implementation of pilot projects. The hydrogen value chain is unlikely to be cost-effective in any of the segments during this period, thus, it will depend on public support. The state will allocate at least €67 million from the state budget to support investments in hydrogen technology and €49 million from RRF funding to support the introduction of hydrogen. Local emission reductions are not significant. Pilot projects serve as essential input for further action and allow for valuable experiences to be gained through the economic and technological base necessary for the functioning of value chains as well as through international co-operation opportunities, and judicial development needs. During this period, we lay down the foundation for the development of green hydrogen and its production technologies over the coming decades.

### Research and development

Engineering skills and the training of specialists and experts are needed to create a local maintenance and development capacity of hydrogen technology. Increased co-operation between Estonian research institutions and the hydrogen sector companies bridges the gap between academic research and business R&D, subject to support from the growing capacity to conduct various research projects (including applied research). National focus areas include the development of green hydrogen production based on solid oxide electrolyzers that allow for CO<sub>2</sub> capture and storage<sup>39</sup>.

### Access to renewable energy

To meet the renewable energy targets<sup>40</sup>, wind farm capacity would have to be increased approximately fourfold to 1 GW by 2030. With the reverse auctions carried out in 2021–2022, a total of 400 MW of solar capacity will be added by the end of 2023 and 300 MW of wind capacity by the end of 2025.

However, it is possible that developers will expand the capacity at a faster rate: the addition of generation capacities depends on the terms and conditions for connecting to the distribution network and the need for energy storage. Therefore, offshore wind capacity could reach an estimated 3 GW by 2030. Although the potential of solar parks is difficult to estimate, the emergence of a hydrogen economy would also lead to the growth of generation capacities of renewable energy.

### Production, industry and consumption

The use of hydrogen as seasonal energy storage to balance the energy system is unlikely before 2030. Estonia has the potential to produce between 2,000<sup>41</sup> and 40,000<sup>42</sup> tonnes of green hydrogen per year, depending on the volume of national renewable energy generated, the ability to minimise peak consumption, the use of flexibility and energy-efficient technologies, growth in hydrogen demand, and market conditions.

As things stand, the estimated volume of accessible green hydrogen electricity on the grid in 2023 is approximately 400 GWh per year, which would require electrolyzers with a total capacity of around 150 MW<sup>43</sup>.

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<sup>39</sup> [Estonian Research and Development, Innovation and Entrepreneurship Strategy 2021–2035](#).

<sup>40</sup> [Energy Sector Organisation Act](#), 20.01.2023

<sup>41</sup> [Trans-European transport network: streamlining measures for advancing its realisation](#), 20.01.2023.

<sup>42</sup> According to the estimates of Estonian Hydrogen Association and Hydrogen Valley Estonia.

<sup>43</sup> Provided that around 50 kWh of electricity are used to produce 1 kg of hydrogen via electrolysis.

## Distribution and storage

To keep the cost price of hydrogen at a reasonable level, it should be produced at or relatively close to the point of consumption<sup>44</sup>. Spearheaded by Elering, the study on the integration of hydrogen into the natural gas transmission network is planned to be completed in 2023. Estonia does not have the geological conditions (salt caverns) that would allow for hydrogen storage in the future. The Latvian gas system operator intends to explore the possibility of storage in the Inčukalns Underground Gas Storage in the near future. In Estonia, hydrogen is currently stored as a gas in special small cylinders that are transported by truck. In the context of Estonia, due to the short distances involved, this is the best method for the storage and transport of gaseous or liquid hydrogen. For more efficient storage of hydrogen, its energy density should be increased either by compressing, liquefying, or synthesising it into other energy carriers, such as ammonia, methane, methanol or liquid hydrocarbons. In addition to hydrogen storage, these compounds also have their own specific value in the chemical industry and could be exported over long distances (more than several thousand kilometres).

In the selection of hydrogen storage technology, its complete value chain, and the energy resources necessary for ensuring security must be taken into account to determine where, how much and for what purposes hydrogen is used. Within Estonia, cylinders and heavy-duty vehicles would be the best option for the transport of pure hydrogen. In the event the volumes increase, consideration may be given to connecting the point of production to a nearby point of consumption via a special pipeline. The choice of the most appropriate mode of transport depends on the distance, volume of hydrogen transported, and final consumption. The use of old oil shale mines could be explored for long-term storage.

Pursuant to the requirements for hydrogen refuelling infrastructure arising from the TEN-T Regulation<sup>45</sup> and the proposal for Directive on the Deployment of Alternative Fuels Infrastructure<sup>46</sup>, at least 3 to 5 refuelling points with a storage and production capacity of 2 tonnes per day must be constructed in Estonia. Based on the estimated growth in demand in built-up areas and the areas between them, the actual need for refuelling points must be assessed along with their technical feasibility and cost.

## Sustainability

Special attention should be given to such resources necessary for hydrogen production which must be sustainably sourced: in particular, to water which breaks down into hydrogen and oxygen during electrolysis, and to CO<sub>2</sub> if it is used in the production of chemicals, synthetic fuels or synthetic methane. Moreover, close attention should also be paid to minimising hydrogen leakage because hydrogen is an indirect greenhouse gas (GWP = 11)<sup>47</sup>.

## Regional co-operation

International co-operation must be fostered along with the exchange of information regarding the need for the deployment of renewable energy and investment opportunities for large-scale projects. Since priority is given to the development of hydrogen production and conversion technologies and the exploitation of the potential of Estonia in hydrogen-related co-operation and pilot projects, partner

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<sup>44</sup> [Analysis of opportunities for hydrogen deployment in Estonia](#), 2021

<sup>45</sup> [Trans-European transport network: streamlining measures for advancing its realisation](#), 20.01.2023.

<sup>46</sup> [Revision of the Directive on Deployment of Alternative Fuels Infrastructure](#), 20.01.2023.

<sup>47</sup> [Atmospheric implications of increased hydrogen use](#), 2022.

organisations must be found in target markets (mainly Germany, Nordic and Baltic countries) to develop the technology. In addition, it is crucial to explore potential co-operation opportunities for business and knowledge sharing (good examples are initiatives such as BalticSeaH2<sup>48</sup> and Hansa Hydrogen Hubs<sup>49</sup>).

## Activities until 2030

List of national activities planned until 2030.

| Objective                                                                                                                                             | Possible activities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Legal framework and policy vision</b>                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Inclusion of the necessary preconditions for the development of green hydrogen in national development documents (energy, transport, renovation, etc) | <ul style="list-style-type: none"> <li>• Integration of hydrogen-related activities into ENMAK 2035, General Principles of Climate Policy until 2050 (KPP 2050), and other relevant development documents</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Creation of a legal framework                                                                                                                         | <ul style="list-style-type: none"> <li>• Establishment of legal expertise in green hydrogen</li> <li>• Mapping of weaknesses and opportunities necessary for the creation of the legal framework supporting green hydrogen</li> <li>• Correction of any shortcomings identified in the legal framework during pilot projects.</li> <li>• Establishment of technical requirements for hydrogen projects and the planning of permanent installations (including the need for a certification system and activity licences)</li> <li>• Establishment of safety requirements</li> <li>• Standardisation of hydrogen technologies</li> </ul> |
| Assessment of the implementation of the Hydrogen Roadmap, adjustment of further steps where necessary                                                 | <ul style="list-style-type: none"> <li>• Assessment of pilot phase activities (2029)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>National support measures</b>                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Implementation of support measures for hydrogen value chain pilot phase                                                                               | <ul style="list-style-type: none"> <li>• Assessment of the need for a tax and excise policy supporting green hydrogen production and use</li> <li>• Support for the development of local hydrogen technologies from EU ETS auction revenues (IPCEI projects; approximately €67 million)</li> <li>• Support for the piloting of green hydrogen value chain (approximately €54 million)</li> <li>• Consideration of the imposition of taxes and state fees on grey hydrogen and hydrogen with a large carbon footprint</li> </ul>                                                                                                         |
| <b>Education and awareness</b>                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

<sup>48</sup> [BotH2nia announces Horizon Europe funding for BalticSeaH2](#), 06.02.2023.

<sup>49</sup> [Hansa Hydrogen Hubs concept, Patrick Cnubben](#), 01.11.2022.

Raising of awareness of the benefits, opportunities and risks of green hydrogen

- Raising of public awareness of the opportunities of hydrogen economy
- Organisation of green hydrogen information visits and training programmes
- Identification of consumer, regional stakeholder and community barriers and preferences with regard to hydrogen projects through engagement events organised as part of pilot projects and stakeholder surveys
- In co-operation with market participants, defining the role of hydrogen storage from the perspective of energy security
- Increasing the awareness of companies with regard to support organisations and support measures for the introduction of hydrogen technology both in Estonia and the EU (Horizon Europe, EU Innovation Fund, LIFE, Invest EU, CEF, etc)

## Production

Increasing of the generation capacity of renewable energy used for green hydrogen production

- Fostering of international co-operation and exchange of information regarding the need for the deployment of renewable energy and investment opportunities for large-scale green hydrogen projects

Acquisition of green hydrogen production experience

- Promotion of R&D in hydrogen technology
- Enabling the establishment of production plants for hydrogen technology and its components in Estonia
- Facilitating the establishment of hydrogen centres near R&D institutions, renewable energy production facilities or distribution and consumption points
- Improvement of co-operation with neighbouring countries in green hydrogen trade, import and export of machinery, equipment and spare parts, and promotion of skill and knowledge sharing
- Support for co-operation between foreign technology experts and Estonian universities and companies

## Distribution and storage

Starting of the construction of green hydrogen storage and distribution infrastructure

- Enabling of the establishment of storage, distribution, and transmission infrastructure (e.g., hydrogen refuelling stations for pilot projects and TEN-T)
- Construction of TEN-T hydrogen refuelling stations in Estonia in accordance with the EU agreement
- Assessment of the use of hydrogen as a locally produced transport fuel and energy carrier in the

establishment of national reserves in the context of crisis management and security

| Consumption                                                                          |                                                                                                                                                                                                                                                     |
|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Launching of green hydrogen pilot projects in the transport sector                   | <ul style="list-style-type: none"> <li>• Analysis for possible procurement of fuel cell ferries</li> </ul>                                                                                                                                          |
| Promotion of regional co-operation to identify technological and regulatory barriers | <ul style="list-style-type: none"> <li>• Mapping of potential business, knowledge sharing and skills training activities between neighbouring countries</li> <li>• Inclusion of partners through diplomatic channels and export advisors</li> </ul> |
| Increasing of the use of green hydrogen in the transport sector                      | <ul style="list-style-type: none"> <li>• Providing advice to companies in applying for EU funding in the transport value chain</li> </ul>                                                                                                           |

### List of proposed market participant activities until 2030

| Legal framework and policy vision                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• Participation in the establishment and work of cross-border hydrogen networks</li> <li>• Participation in standardisation activities under the Technical Committee for Hydrogen Technologies</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Awareness                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <ul style="list-style-type: none"> <li>• Raising of public awareness of the opportunities and risks of green hydrogen, including through pilot projects</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Production                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <ul style="list-style-type: none"> <li>• Creation of co-operation opportunities for green hydrogen production pilot projects between Estonia and other countries</li> <li>• Production of electrolyzers, fuel cells and their parts in Estonia in a competitive manner</li> <li>• Implementation of hydrogen technology and value chain pilot projects</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Distribution and storage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <ul style="list-style-type: none"> <li>• Participation in transnational discussions on the development of hydrogen infrastructure (e.g. construction of joint hydrogen terminals, co-operation in the area of green hydrogen trade through ports development, development of joint underground storage)</li> <li>• Development of the Estonian natural gas and hydrogen distribution and transmission network according to the developments on the trans-European network and the needs of the local market</li> <li>• Assessment of the technical capacity of distribution networks in terms of safe transport of blended hydrogen and natural gas via pipelines</li> <li>• Assessment of the technical capacity of end-user gas pipelines in terms of safe transport of blended hydrogen and natural gas</li> <li>• Assessment of the readiness of end-user equipment to consume blended hydrogen and natural gas</li> <li>• Analysis of the technical-economic feasibility of the distribution of liquid or other forms of hydrogen (e.g. ammonia)</li> <li>• Integration of pilot projects into technical innovation activities</li> </ul> |
| Consumption                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <ul style="list-style-type: none"> <li>• Analysis of what role or value, if any, hydrogen could play or have in realising the industrial potential of Estonia</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

- Development of new hydrogen-based industries in Estonia – aviation fuels, ammonia/oxygen, methanol, etc – to reduce the carbon footprint of EU value chains
  - Assessment of the feasibility of hydrogen solutions in reducing the carbon emissions of the transport sector to achieve climate neutrality in Estonia by 2050
  - Promotion of co-operation with neighbouring countries for the introduction of sustainable aviation fuels
  - Assessment of the use of hydrogen-based system services and emergency power in terms of security of supply
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## Scaling phase: from 2031 to 2035

In the scaling phase of the Estonian hydrogen sector running from 2031 to 2035, research and development of the hydrogen value chain designed in the piloting phase will be continued along with the development of the economic model and implementation of measures to take advantage of any new opportunities. In order for supply and demand to grow hand in hand, market participants must foster regional co-operation, and solutions for production, end-use, distribution and storage must be developed. Specialists and experts will continue to be trained.

In addition, the development of applied research capacity and the value chain will continue along with the elimination of any barriers based on the market situation, access to renewable energy, technological progress, and experiences gained from the pilot projects. In the segments of hydrogen value chain where local production covers the demand (e.g. piloted transport applications, energy storage or the production of chemicals), technology should be capable of reducing the carbon emissions of the entire life cycle to zero and prove over a five-year period that its profitability will improve to such an extent that it can become financially autonomous. This should be the case even if access to local renewable energy does not increase significantly. New hydrogen pilot projects may be launched, for example, in the field of synthetic green fuel production.

## Expansion phase: from 2036 to 2050

The expansion phase of the Estonian hydrogen sector running from 2036 to 2050 will be based on the success of previous phases. If the rapid development of wind farms continues and the cost of electrolyzers decreases, locally produced hydrogen may become competitive in some applications compared to other energy carriers and technologies. A prerequisite for the wider deployment of hydrogen in transport, for example, is that, compared to other technologies, new hydrogen vehicles are affordable, existing vehicles can cost-effectively be retrofitted for hydrogen consumption, and the price of green hydrogen in the global market does not exceed the price of natural gas. In the case of constant surplus of green hydrogen, its use in other sectors could be considered (e.g. in the energy sector, chemical industry, heating of buildings and industry with fuel cells).

## Terms and abbreviations

CO<sub>2</sub> – carbon dioxide

EHB – European Hydrogen Backbone. The initiative is a group of 31 energy infrastructure operators. Its objective is to accelerate the reduction of Europe's carbon dioxide emissions by identifying the critical role of the hydrogen infrastructure based on existing and new pipelines in the development of a competitive, liquid, renewable and low-carbon hydrogen market

ENMAK 2035 – Estonian National Energy Development Plan 2035, the aim of which is to update the energy trends, targets and activities in the energy development plan currently in force until 2030 and to describe the vision of development of Estonian energy sector together with its objectives, bottlenecks, and policies in progressing towards climate neutral energy production and consumption as well as in ensuring energy security

EU ETS – European Union Emissions Trading System

FCEV – fuel cell electric vehicles

GWP – global warming potential; climatic warming potential of greenhouse gas relative to that of carbon dioxide, calculated as the ratio of warming potential of 1 kg of greenhouse gas to the warming potential of 1 kg of CO<sub>2</sub> per 100 years

H<sub>2</sub> – hydrogen

Grey hydrogen – hydrogen obtained from fossil natural gas using steam methane reformation

IPCEI – Important Projects of Common European Interest

GHG – greenhouse gas

PEM electrolyzers – proton exchange membrane electrolyzers

RFNBO – renewable fuel of non-biological origin, i.e. renewable liquid or gaseous transport fuels for which none of the energy content of the fuel comes from biological sources

Green hydrogen – hydrogen obtained by electrolysis using renewable energy (e.g. solar, wind)

RRF – Recovery and Resilience Facility

Blue hydrogen – hydrogen obtained from fossil fuels with carbon capture and storage (CSS)

TEN-T – Trans-European Transport Network