



Clean hydrogen economy strategy for Finland



Table of contents

1. Forward	5
2. Executive summary.....	6
3. What is the scale of Finland’s opportunity to benefit from the hydrogen economy?	8
3.1 Global trends for hydrogen	8
3.2 Hydrogen demand in Europe	9
3.3 Hydrogen opportunity for Finland	9
4. Why is Finland well placed to be the European leader in the hydrogen economy?	10
4.1 Clean electricity and grid capabilities	11
4.2 Finnish natural resources	12
4.3 Existing capabilities and economic environment	13
5. What areas of the hydrogen economy should Finland focus on to yield the most benefits?	15
5.1 Expand clean hydrogen production	15
5.2 Accelerate the ramp up of domestic clean industries	18
5.3 Grow exports of hydrogen-related technologies and services	22
6. What does Finland need to do to become the leading hydrogen economy in Europe?	26
6.1 Recommendations to reach Finnish clean hydrogen goals	26
6.2 Roadmap for strategy execution	30

List of abbreviations

CCS – carbon capture and storage

CO₂ – carbon dioxide

EU – European Union

H₂ – hydrogen

ICT – information and communication technology

Mt – million tons

R&D – research and development

SMR – steam methane reforming

TWh/y – terawatt-hour per year

Glossary

Clean hydrogen – “Clean” is used to depict hydrogen produced from low-carbon or carbon-neutral. “Clean” hydrogen in Finland will most likely be produced via electrolysis from renewable and nuclear energy.

Synthetic fuels – is used to refer to synthetic methane, synthetic kerosene, and synthetic methanol produced using clean hydrogen. They are the three fuels that fall under this category for the purposes of this document.

1. Forward

Our ambition is for Finland to be the leading high-value hydrogen economy in Europe by 2035. We believe that by building a high-value hydrogen economy, Finland can unlock significant economic value that creates wellbeing for Finnish society and expands the Finnish climate handprint globally.

To rise and meet this ambition, we will need to harness our collective strengths, leverage our natural advantages, and work together. Across Finland today, there are numerous trailblazing hydrogen projects underway and even more taking shape. These projects are decarbonizing our existing industries, attracting new investments, generating new export opportunities, and creating new jobs.

The newly published Government Program, “A Strong and Committed Finland”, sets a vision for Finland to become a key player in the hydrogen economy and an attractive location for hydrogen refining projects. It also affirms Finland’s aim to account for 10 percent of the EU’s clean hydrogen production and for at least the same percentage of hydrogen use. The Finnish Hydrogen Cluster is pleased with the direction chosen by the new Government, which largely aligns with the vision outlined in this document. Next, it is crucial to turn this vision into reality by taking ambitious actions that will propel Finland rapidly towards these goals.

We have developed this Clean Hydrogen Economy Strategy for Finland to chart a course towards achieving the ambition to become Europe’s leading hydrogen economy ecosystem across the entire value chain, including technologies and services. This Strategy presents tactical actions needed to realize the opportunities the hydrogen economy in Finland offers to Finns, partners in Europe, and stakeholders around the globe. Achieving these ambitions, however, cannot be done by the Hydrogen Cluster Finland alone.

This strategy is a call for action. Work in concert with us. You and your organization play an important role in making this strategy a reality in your sphere of impact. In this document, Hydrogen Cluster Finland has recommended a few stakeholders to take these actions forward, but there are more who can contribute. Actions are needed at all levels—local to global. Throughout the strategy, Finland may often mean *you* in *your* role.

Finally, we hope this strategy can be a starting point. We wish to further plan these actions together through sessions in the second half of 2023. We also welcome collaboration with our international stakeholders and partners to progress and realize these opportunities.

2. Executive summary

Clean hydrogen will be an integral component of economy-wide decarbonization and is set to become one of the world’s largest markets as the energy transition ramps up across the globe. In 2050, the clean hydrogen market is expected to have annual revenues of €3 trillion because of its potential to decarbonize the world’s most difficult-to-abate industries. The scale-up of this global market for hydrogen creates an opportunity of €16-34 billion per year for the Finnish economy in 2035 and the potential for over 60,000 new jobs.¹ The 2035

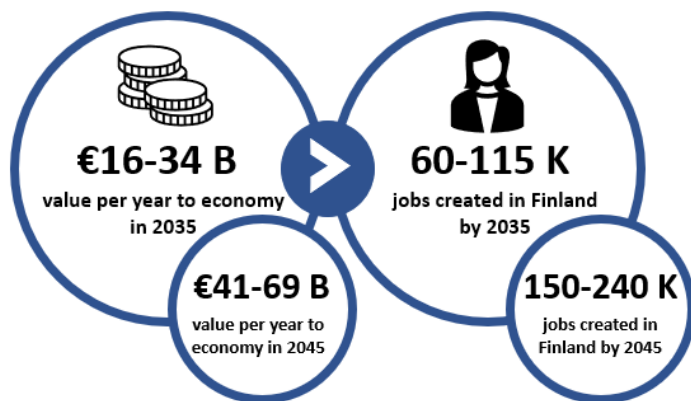


Figure 1: Potential hydrogen economy economy benefits for Finland¹

opportunity equates to 13% of Finland’s 2022 GDP (€267 billion).²

Finland is well-positioned to capture this opportunity due to its multiple competitive advantages: a robust and clean electricity system, cost-competitive renewable generation potential,

abundant natural resources in forestry, biogenic CO₂, metals, and water, a stable business environment, supportive government, a high-tech society, and existing expertise in industries expected to be large suppliers of technologies and services to the hydrogen economy, as well as users of hydrogen.

This strategy outlines three areas that Finland should focus on to capitalize on this up to €34 billion opportunity and become the leading high-value hydrogen economy in Europe by 2035:

1. Expand domestic clean hydrogen production
2. Accelerate the ramp-up of domestic clean industries
3. Grow exports of hydrogen-related technologies and services

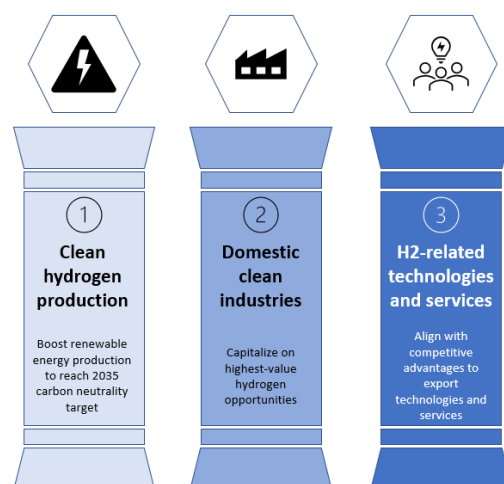


Figure 2: Focus areas for Finland

Finland must act now to capture this huge opportunity. While efforts to build a robust hydrogen economy in Finland are well underway, time is of the essence. Speed to market and rapid scaling will be critical to maximizing benefits for the Finnish companies and economy. Finland must swiftly execute on four recommended actions and twenty related practical measures to address existing barriers and accelerate the scale-up of the hydrogen economy:

- 1) **Build Europe’s leading hydrogen ecosystem** - Rapidly create favorable market conditions and regulation to accelerate the development of a hydrogen economy as outlined in the Government Resolution.³
- 2) **Drive progress through hydrogen valleys and cross-collaboration** - Establish hydrogen valleys to expedite projects based on regional strengths and ensure collaboration and sharing of best practices between these valleys.
- 3) **Accelerate and align decision-making** - Establish well-led public and private sector bodies to coordinate and drive hydrogen strategy implementation. Ensure these bodies have clear mandates and the ability to make timely, cross-sectoral, strategic decisions.
- 4) **Position Finland as a leader on the global hydrogen map** - Influence hydrogen development within the EU, attract investments to Finland, and promote Finnish technology and services worldwide. Continuously communicate Finland’s strengths, build strategic partnerships, and foster relationships with key countries.

	Actions	Practical measures				
1	Build Europe’s leading hydrogen ecosystem	1.1 Create a jointly prioritized set of policy measures and mandates.	1.2 Streamline the permitting process.	1.3 Develop integrated market frameworks, codes, and regulatory rules.	1.4 Identify workforce capability gaps.	1.5 Ensure implementation of the new R&D program and continued pilot funding.
2	Drive progress through hydrogen valleys and cross-collaboration	2.1 Generate several H ₂ valley concepts.	2.2 Engage value chain players to develop project consortia.	2.3 Create a structure to coordinate H ₂ valleys and promote collaboration.	2.4 Maximize likelihood of valley success through developing incentives.	2.5 Promote and provide application support for hydrogen-related public funding.
3	Accelerate and align decision-making	3.1 Align on firm commitments for H ₂ economy development.	3.2 Communicate and obtain stakeholder buy-in on commitments.	3.3 Establish inter-ministerial task force to drive delivery of national actions.	3.4 Establish a hydrogen working group to align on inter-sectoral actions and priorities.	3.5 Coordinate and monitor the execution of the hydrogen strategy.
4	Position Finland as a leader on the global hydrogen map	4.1 Define an engagement and communications strategy.	4.2 Advocate for Finland at the EU-level.	4.3 Attract capital investment through targeted engagement with key players.	4.4 Create strategic partnerships with countries and customers.	4.5 Engage local communities to gather support.

Figure 3: Recommended actions and practical measures to accelerate Finland’s hydrogen economy development

3. What is the scale of Finland’s opportunity to benefit from the hydrogen economy?

3.1 Global trends for hydrogen

Clean hydrogen is set to become one of the world’s largest markets as the energy transition ramps up across the globe. Over 1,000 hydrogen projects have been proposed globally, requiring €300 billion in investments through 2030.⁴ The hydrogen market value is expected to reach over €250 billion in 2030 with a combined annual growth rate of 7.3% forecasted from 2022 to 2030.⁵ By 2050, the clean hydrogen market is expected to reach annual revenue of €3 trillion because of its value in decarbonizing the world’s largest and most difficult-to-abate industries.⁶ These industries include fertilizer, steel, maritime and aviation.

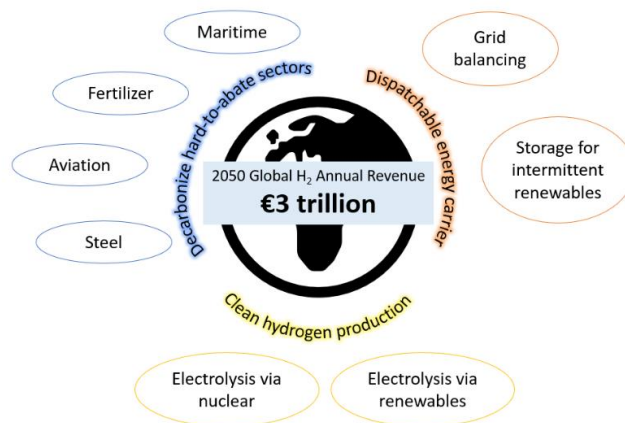


Figure 4: Revenue of global hydrogen market⁶

Hydrogen can be produced and utilized in many ways and offers a unique value proposition for the clean energy transition.

Currently, hydrogen is primarily produced from fossil fuels resulting in high emissions, but clean hydrogen can be produced via electrolysis powered with clean electricity as well as other production routes. Shifting hydrogen production to methods with low or no carbon emissions will be vital for hydrogen’s role in the clean energy transition.

Clean hydrogen will be key to decarbonizing difficult-to-abate industrial sectors. These sectors have industrial processes that make direct electrification difficult due to hot temperatures or current use of grey hydrogen as a feedstock. For example, hydrogen can be used to decarbonize steel making by replacing coal as the reducing agent in the manufacturing process. Simply electrifying the process is not possible because a reducing agent is needed to process the raw material, iron ore. The conventional reducing agent, coking coal, has a high emissions rate that clean hydrogen eliminates.

Hydrogen will also play a vital role in grid balancing. In the future energy system, there will be a high share of intermittent renewable energy generation in the grid mix. At times when electricity generation outstrips domestic electricity demand, hydrogen can be produced as a

means to balance the grid. In addition, when domestic electricity demand outstrips electricity generation, stored hydrogen can continue to serve its demand users while also being used as a fuel for power generation to secure electricity supply.

3.2 Hydrogen demand in Europe

Europe is anticipated to have high demand for clean hydrogen, making it an attractive market for clean hydrogen development. Projections show that clean hydrogen demand will be 490 TWh/y (15 Mt/y) in 2030, grow to 1,640 TWh/y (50 Mt/y) in 2040, and reach 2,300 TWh/y (70 Mt/y) in 2050.^{7,8} This represents demand growth of over 235% from 2030 to 2040 and over 46% from 2040 to 2050.

H₂ compared to electricity demand

The 2050 hydrogen demand is only slightly lower than net electricity generation for the entirety of Europe in 2022 at 2,641 TWh/y.¹

The ambitious climate goals of the European Union (EU) drive momentum for a continent-wide hydrogen economy. The proposed “Fit for 55” package legally obligates member states to reduce emissions by 55% by 2030, and clean hydrogen will be a critical component in meeting these ambitions. This is emphasized in the REPowerEU plan, which defines targets to help drive growth of the European renewable hydrogen market and support European security of supply. It sets a domestic production target of 10 million tons annually (330 TWh/y) and an import target of an additional 10 million tons per year by 2030.

Finland could potentially meet over 14% of the domestic RePowerEU target (10 million tons/y) by 2030 with its clean hydrogen production.¹ Regional networks will develop around industrial clusters to support new clean manufacturing and industry across the region. Excess clean hydrogen and hydrogen derivatives could also be exported from Finland to other demand centers, especially in Central Europe.

3.3 Hydrogen opportunity for Finland

The development of a hydrogen economy could unlock €16 to 34 billion in revenue per year in 2035 and €41 to 69 billion per year in 2045 for the Finnish economy.¹ The 2035 opportunity translates to up to 13% of Finland’s 2022 GDP (€267 billion).² While hydrogen has not played a significant role in Finnish industry or economic landscape to date, Finland has distinct advantages that strongly position it to become the leader in the European clean hydrogen economy.

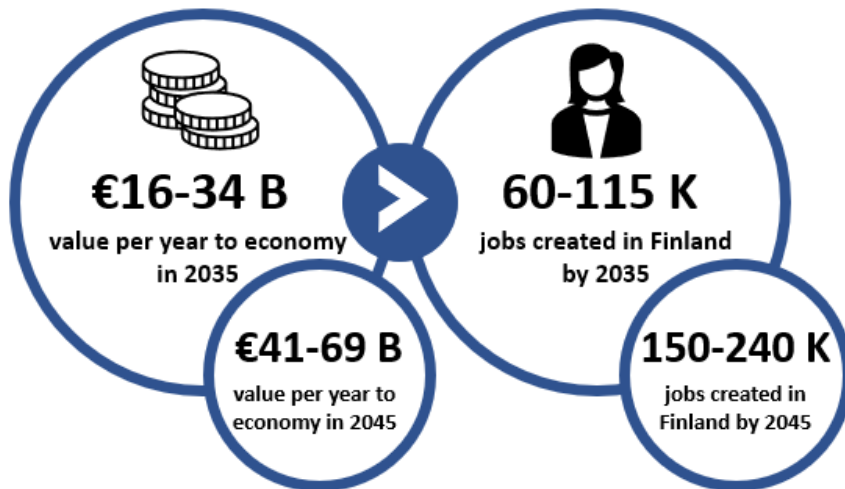


Figure 5: Potential hydrogen economy benefits for Finland¹

The clean hydrogen market creates huge opportunities for Finland in new and existing industries, technologies, and services. Finland can also reap further socio-economic benefits of participating in the clean hydrogen economy. Currently, Finland does not have any domestic natural gas or crude oil production and currently imports around 40% of all energy used.^{9,10} Clean hydrogen can be used in place of fossil fuels to decarbonize various processes. Being able to produce clean hydrogen via electrolysis provides Finland with increased security of supply and self-sufficiency by reducing import dependence. The development of the clean hydrogen economy will bring benefits for the entire country. Given how clean energy potential is distributed across Finland, it is anticipated that hydrogen production and investments will be deployed across both the north and south of Finland.¹¹

4. Why is Finland well placed to be the European leader in the hydrogen economy?

Finland is a trailblazer in the clean energy transition with an ambitious goal of reaching carbon neutrality by 2035. Committing to this rapid decarbonization encourages fuel switching to clean energy sources, such as clean hydrogen, and provides investor confidence in Finland’s ambition and backing for clean energy. This commitment to carbon neutrality gives Finland momentum to be the leader in the hydrogen economy as it encourages investment in clean technologies.

Finland is uniquely positioned to take on the leadership role in the European hydrogen economy. Finland’s competitive advantages come from its resource availability, expertise and cooperation in relevant industries, as well as political will to enact favorable policies.

Finland enjoys an abundance of renewable energy potential, biogenic CO₂, and natural resource reserves like base metals (copper, zinc, nickel, aluminum), ferrous metals (iron), precious metals (gold, platinum), and rare metals (cobalt, lithium).¹² Manufacturing hydrogen derivatives (e.g., synthetic fuels, clean steel) as well as technology needed across the hydrogen value chain requires inputs of these natural resources and having domestic reserves gives Finland a competitive advantage.

Finland has leading technology, solution, and service providers relevant in clean hydrogen and derivatives production. Finland also has deep expertise and an existing workforce in the forest, metal, maritime, chemical, and refining industries and strong collaboration with research and development (R&D) and academia. This existing expertise gives Finland a head start in developing hydrogen-related technology and service sectors.

Finally, Finland’s government is committed to becoming a leader in clean hydrogen, which helps provide investor certainty and an attractive economic environment. In February 2023, the Finnish government adopted a resolution to support and grow clean hydrogen and its associated products.³

4.1 Clean electricity and grid capabilities

The key to unlocking the clean hydrogen economy is access to low-cost, reliable clean energy. Finland’s share of renewables in final energy consumption was 44.6% in 2020, more than twice Europe’s average consumption over the same period (22.1% in 2020).^{13,14} Hydro, solar, and nuclear make up the largest portion of this energy mix, and these clean energy sources are low-cost.

During the first half of 2023, the cost of electricity fell below €0 on several occasions because of the overabundance of clean energy.¹⁵ The share of carbon neutral electricity is already 89% in Finland, and the grid emission are only 64 gCO₂/kWh.¹⁶ This creates a strong starting point for Finland in meeting green certification and additionality rules for hydrogen as outlined in the REDIII directive.¹⁷

While electricity demand in Finland is expected to grow, the renewable energy potential far exceeds this demand. A generous portion of this renewable potential comes from wind. Finland offers one of the most cost-competitive environments for wind energy development. As of May 2023, wind-power projects in various stages of development amount to over 120 GW of additional capacity.¹⁸ As a benchmark, Finland’s domestic power generation capacity available

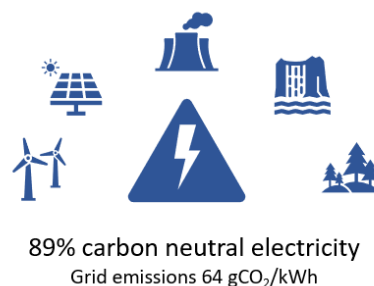


Figure 6: Finland’s current grid carbon intensity¹⁶

(including all forms of generation) was around 13 GW in 2023.¹⁹ The growth projection is therefore very strong. The excess clean electricity can be allocated to hydrogen production leading to a forecasted 12 to 98 TWh/y by 2035 and 80 to 212 TWh/y by 2045.¹ This abundance of clean energy could position Finland as a major player in the hydrogen economy. Additionally, waste heat from electrolyzers can be used in district heating networks, providing a clear benefit for Finland as opposed to countries in warmer climates. However, clean electricity supply and new demand sectors must develop in parallel. Missing either side of the development can hinder growth of the other considerably.

Finland boasts a robust and modern electricity grid, which makes it easier, faster, and less costly to integrate Finland's vast clean generation potential into the current energy grid. It is also important in measuring emission rates of hydrogen production and powering electrolysis. These digital capabilities can measure renewability and emission rates of electricity transmitted thus proving the production of clean hydrogen. Commercial scale electrolysis requires large amounts of electricity, so a modern, smart grid with exceptional frequency containment provides additional advantages to Finland in developing clean hydrogen production and its larger role in the hydrogen ecosystem.

4.2 Finnish natural resources

Finland's abundance of natural resources in forestry, metals, and water also position it well. Finland's leading forestry sector provides a strong foundation to produce synthetic fuels and bio-related products for domestic and export use. Biogenic CO₂ refers to carbon that was removed from the atmosphere by photosynthesis and would naturally cycle back to a replanted tree through the atmosphere. Finland has the second largest forest cover in Europe with 22 million hectares. This translates to almost 14% of European forest cover being found in Finland.²⁰ Therefore, Finland has a strong supply of biogenic CO₂ since 60% of its emissions are from biogenic sources (24.3 Mt in 2020).²¹ Finland has the third largest biogenic CO₂ availability in Europe which will be vital to scaling up production of synthetic fuels and chemicals.²²

High value products along the value chain and hydrogen production itself rely on access to various natural resources. Finland has a well-developed mineral industry, solid geological knowledge base, ore potential, and existing infrastructure. Finland has ferrous and precious metal reserves, particularly cobalt and lithium, which will see huge global demand growth from battery manufacturing. Finland is the only European country that possesses all the minerals necessary for battery production. Europe currently does not have a mine supply of rare earth elements but does have several areas with suitable geology with these resources,

including Sokli in Finland.²³ Ferrous metal reserves are important in steel manufacturing, and clean steel is a rapidly growing industry.

Clean hydrogen is produced via electrolysis which requires large quantities of freshwater. Finland is the water richest country in the world, thus removing the need for energy-intensive desalination, and has market-leading expertise in the water industry (e.g., wastewater usage, hydrogeology, etc.). This expertise provides hydrogen producers confidence in the country's ability to develop the infrastructure needed to meet electrolyzer water demands.

4.3 Existing capabilities and economic environment

Finland has expertise in energy intensive industries such as steel and chemicals which are forecasted to be large adopters of hydrogen. In Finland, these industries have already been working towards developing their processes and products to significantly reduce their carbon footprint while increasing their handprint. They are well positioned to take advantage of the ramp up of the clean hydrogen economy in Finland because they are already working towards sustainability. Adopting hydrogen into their processes can help to accelerate their clean transitions.

Additionally, Finland provides a stable business and economic environment because of its reliable and committed government, increasing investor confidence. According to the World Governance Indicators from the World Bank, Finland is among the top three countries in Europe for government effectiveness. In 2021, Finland scored 98.6% in the indicator that measures credibility of government commitment.²⁴ Finland ranks fifth globally in foreign direct investment per capita and ranks second lowest in the global corruption perception index.^{25,26} This environment will be particularly beneficial in attracting new supply chains with capital intensive infrastructure to the region. Many of the new and existing industrial and technological opportunities will require large upfront investments. For example, clean steel production, which is a primary sector for Finland, requires high upfront investments with the levelized cost of production ranging from €470 to €820 per ton. This is €200 to €500 more expensive per ton than conventional production methods.²⁷ Additionally, Finland belongs to the EUR currency which increases economic stability. Finland's stable and trusted economic environment will allow investors to make a stronger business case for investing large sums of capital.

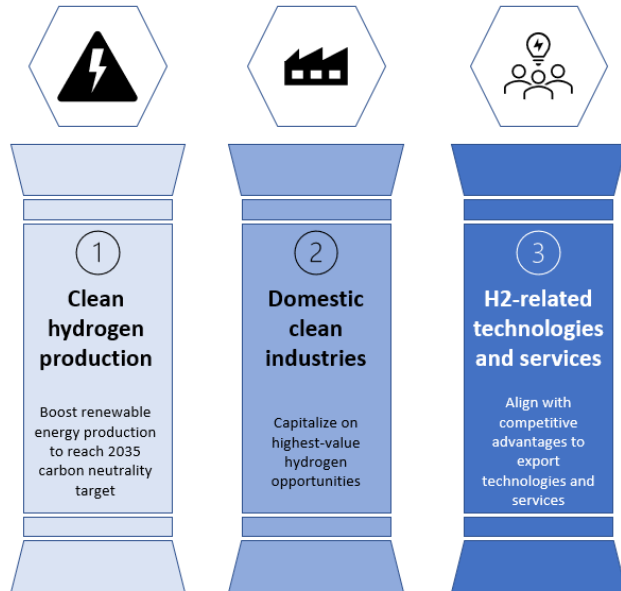
Finland's highly skilled and digitally literate workforce also play an important role in taking advantage of the new and existing industries, technologies, and services in the clean hydrogen economy. Finland's workforce excels in designing, building, and integrating complex industrial

systems and is the most digitally skilled workforce in Europe. Finland is among a few countries in the EU where about 80% of the population aged 16 to 74 have basic digital skills compared to the EU average of 54%.^{28,29} In 2021, Finland scored seventh globally in the IMD World Digital Competitiveness ranking, which assesses the capacity of economies to adopt and explore digital technologies as key drivers for economic transformation in business, government, and wider society.³⁰

Finland has existing capabilities across various technology industries. Finland has expertise in manufacturing processes and energy efficiency, marine technology, and mining and forestry machinery manufacturing, which will all be crucial in commercially scaling technologies and services associated with hydrogen. Many global players in power-to-X, heavy machinery, and process technology manufacturing have major developments in Finland. Additionally, Finland has a strong information and communication technologies (ICT) sector. The ICT sector employs 6.8% of the total workforce, which was the highest in the EU in 2017.³¹ All these technology capabilities will aid Finland in becoming the leader in the clean hydrogen economy.

In addition, Finland's active deep tech startup community and strong R&D and academia collaboration can foster innovation for hydrogen related industries. Finland's track record of innovation is exemplified by their ninth-place ranking in the global innovation index in 2022.³² The 2022 European Innovation Scoreboard indicated that Finland had the second-highest performance in innovation among EU member states and ranked twelfth globally in R&D expenditures per capita in 2022.^{10,33} Relative strengths that contribute to innovative strength include public-private collaboration, lifelong learning, innovative subject matter experts collaborating with others, and information and communications technology specialists.

5. What areas of the hydrogen economy should Finland focus on to yield the most benefits?



To capture the hydrogen economy opportunity, Finland should focus on the following three areas: 1) expand domestic clean hydrogen production, 2) accelerate the ramp up of domestic clean industries, and 3) grow exports of hydrogen related technologies and services.

Expanding clean hydrogen production will allow the ramp-up of domestic clean industries and provide near-term opportunities to reduce existing energy imports

and open pure hydrogen exports. Domestically producing hydrogen increases security of supply for Finland. Prioritizing the highest value add hydrogen opportunities, such as steel and chemicals, will allow Finland to make best use of its surplus hydrogen. Finally, growing exports of hydrogen-related technologies and services that align with existing competitive advantages will allow Finland to leverage current capabilities.

5.1 Expand clean hydrogen production

The first area of focus for Finland should be to expand clean hydrogen production. The low cost of clean electricity generation and efficient electricity transmission in Finland will make its hydrogen production highly competitive and it an attractive place for hydrogen investments. Finland’s electricity system has one of the lowest grid carbon intensities in the EU due to the availability of hydro, nuclear, wind, and bioenergy resources. In 2035, Finland could produce 12 to 98 TWh/y (3 Mt/y) of hydrogen, which equates to €0.2 to €3 billion in revenue generated in 2035 if sold as pure hydrogen for 1.6 €/kg and not transformed into any product.¹

This would translate to Finland exceeding its target to produce 10% of the EU’s green hydrogen in 2030. In 2045, Finland could produce between 80 and 212 TWh/y (6 Mt/y) of

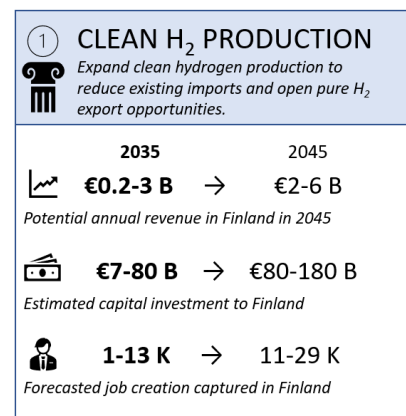


Figure 8: Benefits of clean hydrogen production opportunity ¹

hydrogen, which equates to €2 to €6 billion in revenue generated in 2045 from localized clean energy generation and hydrogen production if sold as pure hydrogen and not transformed into any product.¹

Electricity demand is forecasted to grow by 33 to 59 TWh/y by 2045 driven by the electrification of transport, heating, and industry.³⁴ These growing electricity needs are expected to be met through already permitted solar and onshore wind projects.

Finland’s wind, solar, and nuclear potential far exceeds future domestic baseline demand (i.e., without new industrial investments). Figure 9 shows the forecasted electricity generation in Finland through 2045. This electricity generation exceeds forecasted demand, which could enable 80 to 212 TWh/y of Finnish hydrogen production in 2045 assuming all excess electricity is converted.¹

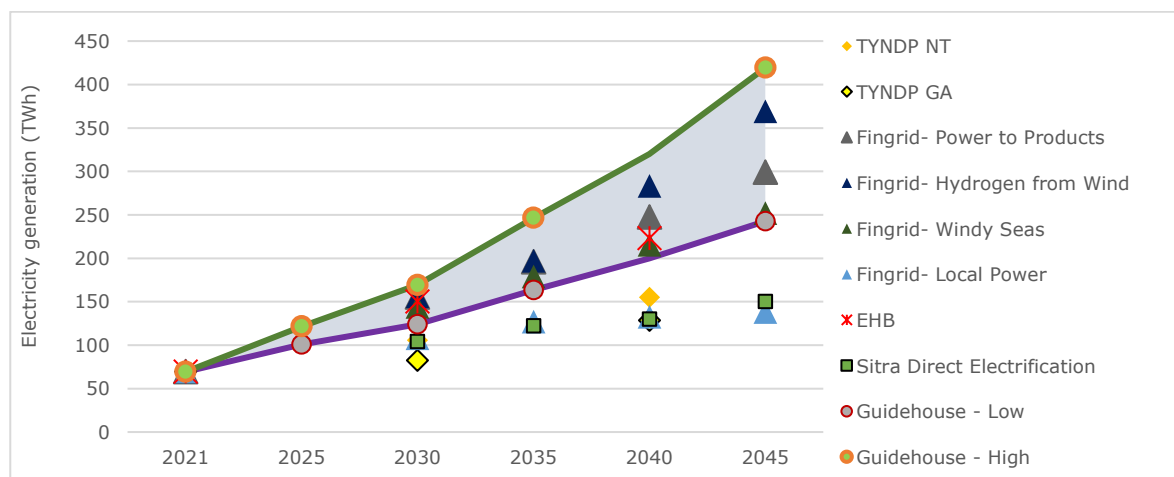


Figure 9: Comparison of electricity generation forecasts ¹

Reducing current natural gas imports that are used to produce grey hydrogen can catalyze the market as domestic industries ramp up. There is currently domestic demand of 5 TWh/y for grey hydrogen that could be replaced with clean hydrogen, which would save €260 million in imports.³⁵ These immediate demand users provide a business case for scaling clean hydrogen production today.

Hydrogen demand in Central Europe is projected to grow as industrial decarbonization ramps up, and clean hydrogen demand outpaces supply. Hydrogen demand is forecasted to be 200 TWh/y while supply is only 80 TWh/y in 2030 in Central Europe.⁸

Developing hydrogen pipeline infrastructure and markets around the Baltic Sea region is a key enabler for the development of a hydrogen ecosystem.

While Finland boasts a modern and robust electricity grid, the speed and scale of grid expansion needed to integrate Finland's clean energy potential and support hydrogen production is

challenging, especially from 2030 onwards. Joint studies carried out by Gasgrid Finland and Fingrid concluded that hydrogen pipeline and storage infrastructure can enable faster deployment of renewable electricity generation by overcoming bottlenecks in connecting to the electricity grid.

As well as supporting clean energy integration, hydrogen infrastructure connects regions domestically. This is important for accelerating market creation and scaling. Hydrogen pipelines allow multiple hydrogen production sources to connect to a single network, increasing supply diversification and allowing for the most competitively priced hydrogen to drive wholesale prices down. This enables the development of a single hydrogen market in Finland. Additionally, if there is a supply disruption, effects across the region will be more muted because hydrogen users have access to a larger supply pool. Pipelines also help develop regional clusters by connecting hydrogen producers to users that are not co-located. For example, biogenic CO₂ which is required for synthetic fuel production is often not co-located with clean hydrogen production locations. Being able to effectively transport hydrogen via pipelines to locations with biogenic CO₂ is therefore vital to expanding the synthetic fuels industry.

Hydrogen infrastructure also provides access to pure hydrogen demand markets and seasonal underground hydrogen storage in Central Europe. There are already multiple cross-border hydrogen transmission projects in the pre-feasibility phase that will make bi-directional hydrogen flows to and from Finland possible. This, alongside linepack storage within the pipeline infrastructure itself, will strengthen security of supply for hydrogen users located in Finland and increase market liquidity.

Infrastructure to enable market development

The Finnish Government has mandated Gasgrid Finland to develop national and cross-border hydrogen infrastructure. Gasgrid is spearheading multiple hydrogen pipeline projects, submitting three projects of common interest applications for the Nordic Hydrogen Route, Baltic Sea Hydrogen Collector, and Nordic Baltic Hydrogen Corridor. The Nordic Hydrogen Route connects Finland to Sweden in the northern parts of the countries. The Baltic Sea Hydrogen Collector connects Finland to Sweden, Denmark, and Germany through an offshore pipeline that collects hydrogen from offshore wind projects at strategically selected energy islands. The Nordic Baltic Hydrogen Corridor links Finland to Germany through the Baltic countries and Poland.

5.2 Accelerate the ramp up of domestic clean industries

The second area of focus for Finland should be to accelerate the ramp-up of domestic clean industries. Transformation of clean hydrogen into higher value products and commodities further down the value chain creates a much higher value-add for Finland than the export of pure hydrogen. If all the 212TWh/y of hydrogen produced in Finland were used for pure hydrogen exports, the maximum revenue generated in 2045 is estimated at €6 billion.¹ Finland should use the cascading principle, the idea of putting raw materials towards the highest value products, to inform how hydrogen should be used.

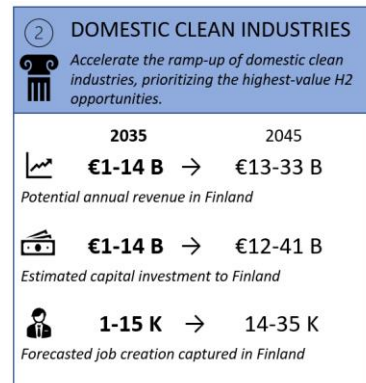


Figure 10: Benefits of domestic clean industries opportunity¹

If all the hydrogen were put towards clean steel, a higher value product, revenue is estimated at €75 billion per year in 2045 which is over 12 times higher than revenue generated from hydrogen exports.¹ However, putting all efforts into the most high-value industry is unwise given the uncertainty. Each hydrogen use would add significant value and benefit to Finland. A diversified strategy would best hedge risk and it would be prudent for Finland to diversify efforts across clean industries.

5.2.1 Clean steel

Clean steel production should be a primary focus area due to strong global demand, existing steel expertise, and supply chains in Finland. The global market for clean steel is forecasted to be €2 trillion by 2035 and to increase to €3 trillion by 2050. The EU market makes up a significant portion of that at €95 billion in 2035 and €140 billion in 2050.¹



Figure 11: Benefits of clean steel opportunity¹

Clean steel would bring significant value and investment into Finland as it is a high value product with one of the highest values per unit of hydrogen used. The high project capital expenditure associated with steel making facilities has the potential to bring large investments into Finland. The levelized cost of clean steel production ranges from €500 to €800 per ton.²⁷ This is anticipated to be at a premium to existing steel prices given the ESG benefits of clean steel. In addition, transitioning from current coke-based steel processes reduces the risk to producers of fluctuating carbon prices across the globe.

Steel production is currently one of the largest industrial sectors in Finland, therefore making clean steel a clear choice for investment and development. The steel sector currently employs more than 5,000 skilled workers in Finland. Prioritizing clean steel can retain this workforce and could create between 9,000 to 22,000 new jobs by 2045.¹ Additionally, steel supply chains are already present. Finland contains the natural resources required for steel making and has established export routes to Central Europe. The existing capabilities, resources, and infrastructure will make it easy for Finland to enter this highly lucrative emerging market.

Clean steel projects in Finland

Currently, clean steel manufacturing momentum is high in Finland with multiple ongoing projects in the region. For example, the Hybrit project from SSAB, LKAB, and Vattenfall includes a 2.6 Mt/y clean steel project in Raahе that will start up by 2040 with Conversion Step 1 planned for 2030. Additionally, Blastr Clean Steel plans to establish a clean steel plant with an integrated hydrogen production in Inkoo. Plug is also partnering with GravitHy to decarbonize reduced iron. There are also multiple research joint ventures in clean steel funded by Business Finland.

5.2.2 Synthetic fuels

The production of carbon neutral synthetic fuels (synthetic methanol, synthetic kerosene, and synthetic methane) also offers a strong opportunity for Finland. The global market for synthetic fuels is expected to generate revenues of €300 billion in 2035 and €580 billion in 2050, with the EU market making up a notable €35 billion in 2035 and €60 billion in 2050 of the global market.¹ Both the maritime and aviation industries, expected synthetic fuel users, are set to continue growing as global trade and travel increase. Finland’s biogenic CO₂ availability, existing refining expertise, and marine technology expertise align well with synthetic fuels production. Sector coupling across hydrogen generation, biogenic CO₂ capture and usage, and maritime engine manufacturing could give Finland a competitive market advantage.

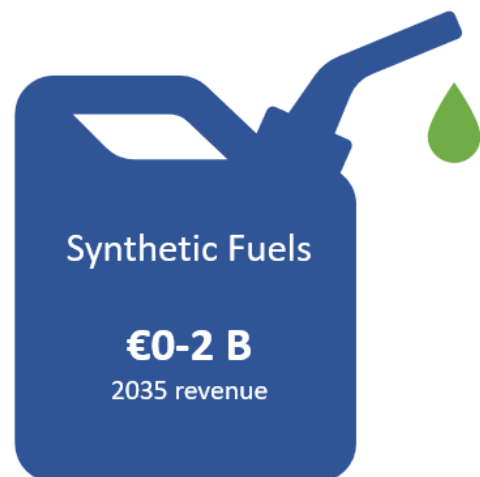


Figure 12: Benefits of synthetic fuels opportunity¹

Finland has an abundant supply of biogenic CO₂, which is a unique competitive advantage compared to other countries looking to produce and export synthetic fuels. In Finland, the CO₂ for synthetic fuel production does not need to be sourced from direct air capture or fossil fuels,

Opportunities across the value chain

Finland can leverage low-cost hydrogen and biogenic CO₂ availability to manufacture synthetic fuels. Synthetic methanol, a synthetic fuel, can be sold to logistics providers to decarbonize the maritime industry. Finland can also utilize their expertise in the maritime industry to build synthetic and hydrogen fueled ships. Additionally, Finland could produce forestry machinery that runs on hydrogen or synthetic fuels, and that machinery could then be used in procuring the biogenic CO₂ to produce synthetic fuels. Taking advantage of multiple areas across the hydrogen value chain can multiply the value to Finland.

leading to lower costs and less regulatory hurdles. Additionally, the storage and use of biogenic CO₂ ensures that the synthetic fuels are not emitting additional carbon thus supporting Finland’s carbon neutrality goal. Finland also has extensive expertise in refining, which is transferrable to synthetic fuels production.

Synthetic methanol has strong synergies with the large Finnish maritime sector, which is facing pressure to decarbonize. Carbon Neutral Finland 2035 identifies

methanol as a replacement fuel in the shipping sector, and the International Maritime Organization is currently exploring methanol as a potential ship fuel to meet decarbonization goals for the maritime sector. Despite cost differences, large logistics operators are already purchasing synthetic fuels. It could also unlock multiple chemical use case pathways.

Synthetic kerosene will be vital to decarbonizing the aviation industry, which is set to continue growing. Thus, the development of synthetic aviation fuels opens new market opportunities globally. Within the EU’s Fit for 55 package there are binding sustainable aviation fuel targets of 2% in 2025 and 5% in 2030.³⁶ Finland can take advantage of the increased demand for e-kerosene from these mandates.

Synthetic fuel projects

There is momentum from existing projects in synthetic fuel production. St1 is planning the first synthetic methanol plant in Finland with grant funding on €35 million from the Ministry of Economic Affairs and Employment. Additionally, Neste is placed as a global leader in sustainable aviation fuel production.

Synthetic methane’s compatibility with existing natural gas infrastructure supports early market entry. Synthetic methane can benefit from existing capabilities in Finland since it is a drop-in replacement for fossil natural gas. This will reduce reliance on natural gas imports. Finland imported 3 billion m³ of natural gas in 2021, although this demand fell by more than 50% in 2022 following the loss of Russian supply and related price increases.¹⁰ The market rules governing natural gas markets are mature and established, enabling synthetic methane

to be integrated into the energy mix with limited disruption. There are several synthetic methane projects today in Finland giving the industry momentum.

5.2.3 Clean ammonia and fertilizer

Clean ammonia and fertilizer production offer a high value proposition for Finland. Ammonia can be used as a zero-carbon fuel for maritime, for balancing power plants, and as the raw material for many products in the chemical industry (e.g., bioethanol, urea, enzymes, ammonium nitrate). The global markets for clean ammonia and fertilizer are forecasted to be €175 billion and €150 billion by 2035 and €375 billion and €200 billion by 2050, respectively. Of these totals, the EU market for clean ammonia is forecasted at €25 billion and fertilizer at €15 billion by 2035.¹ These huge markets offer significant opportunities for Finland to capitalize on.



Figure 13: Forecasted Finnish revenue in 2035 from ammonia and fertilizer¹

Clean ammonia and fertilizer production are a natural choice for Finland. Fertilizer demand is set to grow as population increases, and since ammonia is the main input for fertilizer production, the ammonia market will also continue to grow. Fertilizer, and therefore ammonia, are essential to Finland’s position in the agricultural industry. Currently, Finland relies on ammonia imports, leaving it vulnerable to fluctuating global ammonia supply. The ammonia that is currently produced domestically is manufactured in facilities that are reaching the end of their 50-year asset life. Additionally, government targets outlined in Carbon Neutral Finland 2035 and the Agriculture Action Plan are mandating reduction in ammonia, and therefore fertilizer, emissions.

Clean ammonia and fertilizer projects
 There are multiple clean ammonia and fertilizer projects that are propelling the industry’s growth in Finland. The Flexens project in Kokkola will begin producing clean ammonia in 2027 with hydrogen fed from a 300 MW co-located H2 plant. The ammonia produced will be converted to fertilizer. Clean NorthH2 is doing an R&D project that will produce 20 MW of clean ammonia in Naantali. Additionally, a Finnish shipping company Meriaura, engine maker Wärtsilä, and Clean NorthH2 Energy have signed a Letter of Intent to build a cargo vessel that runs on clean ammonia.

Clean ammonia and fertilizer production align well with Finland’s current capabilities and create additional benefits. There are existing demand users for ammonia in Finland who will be looking to decarbonize to comply with government mandates. Additionally, Finland has existing ammonia terminals and onshore transport routes. There is also an existing export industry for fertilizer, meaning that there are existing

inorganic fertilizer supply chains and export routes in Finland. The ammonia and fertilizer industries also benefit Finland by creating a potential of 2,000 to 6,000 new jobs in Finland.¹ Finland’s current alignment and the large associated benefits make ammonia and fertilizer a clear opportunity to take advantage of.

5.3 Grow exports of hydrogen-related technologies and services

The third area of focus for Finland should be expanding technologies and services related to hydrogen. Services around hydrogen will be required as the world works toward decarbonization. Finland can expand previous services excellence to the hydrogen ecosystem. There is a huge opportunity for Finland in these industries since hydrogen related technologies and services have potential annual revenues of €15-20 billion in 2035 and €31-39 billion in 2045.¹

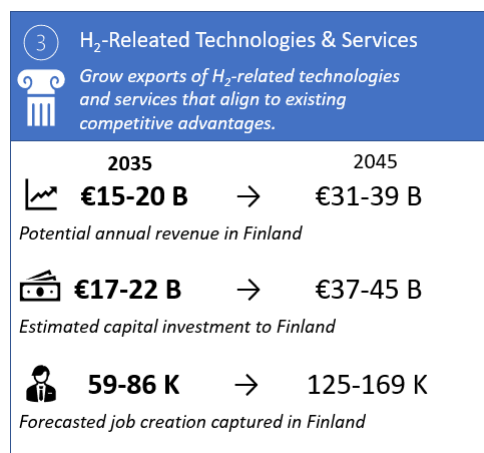


Figure 14: Benefits of hydrogen-related technology and services opportunity ¹

5.3.1 Technologies

Finland can also take advantage of technologies that will arise as clean hydrogen and its derivatives are adopted. There are technology opportunities in a variety of industries including ship building, bioproducts manufacturing, hydrogen powered mining and forestry machinery, and hydrogen or hydrogen derivative fueled combustion engines that closely align with Finland’s existing expertise. The global market size for these technologies associated with hydrogen is forecasted to be €1.5 trillion in 2035 and €3 trillion in 2045.¹ Finland is well-positioned to capitalize on these technology opportunities due to its current capabilities and competitive advantages.

Finland’s existing marine expertise positions it well to take advantage of growing opportunities in synthetic and hydrogen powered ship building. Finland has a strong market position in icebreaker and luxury cruise ship building. As the maritime industry begins to decarbonize, the demand for carbon-neutral ships is expected to increase significantly. This opportunity could generate annual revenues of €3 billion in 2035 and €7 billion in 2045 given Finland’s existing export revenues from ship building and anticipated market growth.¹

Finland also has existing expertise in heavy industry and an existing machinery export market. Coupling this relevant industry knowledge with activities to decarbonize these sectors creates clear synergies to develop new hydrogen and derivatives fueled forestry and mining machinery

manufacturing. This presents an annual revenue opportunity for Finland of close to €4 billion in 2035 and €5 billion in 2045.¹

There are also opportunities in bio-related products, and the forestry industry is well-versed in adapting to changing markets. Over the past few decades, the forestry industry has shifted their focus from paper to packing and pulp grades and has made forward looking investments into new bio-based products. Coupling Finland's forestry industry with the capture and use of biogenic CO₂ opens the opportunity for bioproducts such as biochar, biocoal, proteins, CO₂-captured concrete and cement, and bio-textile industry development. Additionally, the use of biogenic CO₂ ensures that synthetic fuels and chemicals are clean, so it will be vital to scale up the biogenic CO₂ industry. The bio-product domestic and export industry in Finland is anticipated to see strong growth with forecasted annual revenues of €4 billion in 2035 and €8 billion in 2045.¹

Separately, there will be a strong growth opportunity in hydrogen fuel cell, electrolyzer manufacturing, grid energy storage, and power distribution technology. The integration of renewable energy drives the need for energy storage to support electricity grid management and renewable energy integration. Finland is uniquely positioned to take advantage of this market opportunity because of their access to natural minerals needed for battery production. Hydrogen fuel cells will also see strong growth to support hydrogen-to-power applications. Finnish companies like Convion, in cooperation with VTT, are already delivering fuel cells to domestic and export companies.³⁷ Electrolyzer manufacturing will also see strong global growth. These opportunities could generate €2 billion for Finland in 2045.¹ Finland also has a strong manufacturing track record of producing and exporting power distribution related components. The need for components such as transformers, motors, drives and low voltage equipment for hydrogen production will increase as the world transitions to net zero. These technologies could generate additional revenues worth €3 billion in 2035 and €6 billion for Finland in 2045.¹

Finland can also take advantage of fuel switching to be leader in manufacturing hydrogen, ammonia, and powered combustion engines and hydrogen compression technology. Finland is already pioneering cutting edge combustion engines by manufacturing methanol and ammonia engines in ships. Multifuel combustion engines, turbines and equipment manufacturing could generate €1 billion in revenues in 2045.¹

Case study example

Meriaura, a Finnish shipping company, is partnering with Green North2 Energy and Wärtsilä to build cargo ships that run on green ammonia. Wärtsilä will provide a modular multifuel main engine that will be ordered and operated by Meriaura. Green North2 energy will supply green ammonia. The delivery of the vessel is targeted for 2024 and operation on green ammonia will start in 2026. Wärtsilä has entered into a joint development agreement with Hycamite TCD Technologies to enable cost-effective production of hydrogen from LNG onboard marine vessels. The concept design will be ready in mid-2023 and the prototype testing will begin in the second half of 2024.

5.3.2 Services

Service opportunities come from the intersection of clean industry value chain needs and Finland’s existing service exports. Existing service industries that have huge growth potential related to hydrogen include engineering & construction, digital solutions, process efficiency and automation, and process circularity. The global market size for these services could exceed €1 trillion in 2045.¹ Finland’s existing strengths and capabilities could lead to €1 to 5 billion in revenue in 2035 and €4 to 12 billion in revenue in 2045 from hydrogen-related domestic and export services.¹



Figure 15: Revenue from Finnish services related to the hydrogen economy ¹

Finnish technology companies possess expertise across the entire energy value chain. Finland is currently a frontrunner in leveraging its digital workforce capabilities to provide smart technology solutions and new business models for high-emitting industrial processes. As these industrial processes decarbonize, they will require updated digital solutions, new value networks, and development of existing value chains for new processes.

Digital solutions will be useful for grid balancing, renewable integration, maritime ship building, supply chain optimization, logistics planning and manufacturing. With hydrogen infrastructure investments of €600 billion needed by 2030 globally to be on track to net zero emissions by 2050, Finland can develop hydrogen-related digital solutions to take advantage of these growing worldwide investments.⁴

Finland's digitally skilled workforce, growing subject matter experts, and startups across the Internet of Things, process automation, and smart grid technologies provide a strong foundation for Finland on which to expand its global footprint in digital solution offerings. All these capabilities are key enabler of sector-integration.

Additionally, Finland has expertise in process efficiency and automation with a market-leading reputation in industrial process excellence and technology exports. Using clean hydrogen to decarbonize industrial processes requires new process optimization and automation. Additionally, clean hydrogen will likely be used in power generation in some regions which requires manufacturing of hydrogen engines. These manufacturing processes will require automation technologies to drive down costs of production.

Finland is renowned for its high material efficiency and integrated process circularity knowledge and implementation practices. Finland's expertise in process circularity can be leveraged across all direct and indirect hydrogen-related product opportunities. For example, in clean steel manufacturing this expertise will be vital in most efficiently using recycled steel, and related to the synthetic fuels industry, circular process solutions can be used for bioproducts. This knowledge should be first used domestically to bolster the Finnish economy and then can be expanded across the globe as other regions develop their clean hydrogen economies.

Finally, Finland's expertise in conventional engineering, construction, and operation and maintenance businesses also provide opportunities as the clean hydrogen economy gains speed. Hydrogen projects will require services related to all of these to effectively develop plants, processes, power networks, electricity storage, gas pipelines, and more.

Examples of H₂ related technologies and services being developed in Finland

- SpinDrive, a technology company, could leverage their process efficiency solutions to support hydrogen commodity manufacturing.
- ABB's Ability™ OPTIMAX® assists hydrogen producers optimize all aspects of the hydrogen plant lifecycle.
- Fortum and Metsä Group are collaborating to explore circular economy bioproducts and green businesses such as packaging, biocomposites, and biotextiles.

6. What does Finland need to do to become the leading hydrogen economy in Europe?

In the 2021 white paper, “[A systematic view on the Finnish hydrogen economy today in 2030 – Our common playbook for the way forward](#)”, the Hydrogen Cluster Finland defined a target state for the Finnish Hydrogen Economy. The Hydrogen Cluster Finland has now gone further to define and quantify the tangible hydrogen economy opportunities and benefits for Finland.

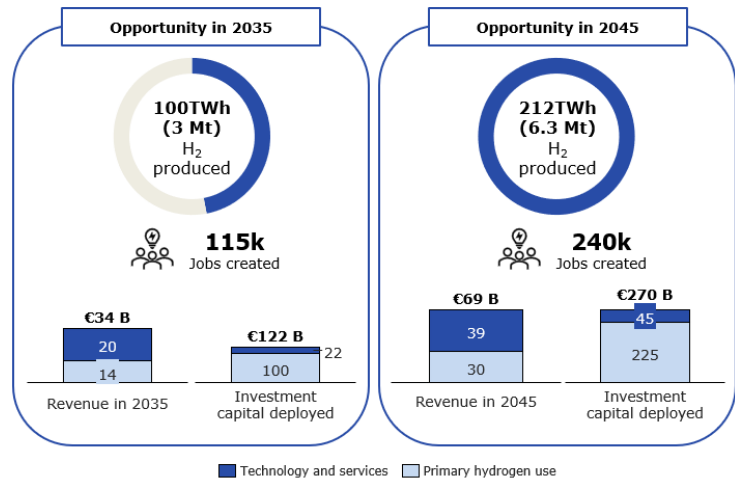


Figure 16: Finnish opportunities in 2035 and 2045 across the hydrogen value chain ¹

These opportunities are immense.

Finland has the potential to become the leading high-value hydrogen economy in Europe by 2035. But how does Finland accomplish this?

6.1 Recommendations to reach Finnish clean hydrogen goals

While the Finnish government and Finnish industry have taken initial steps to develop the clean hydrogen economy in Finland, much more needs to be done for Finland to become the leading high-value hydrogen economy in Europe by 2035. Acting with urgency and specificity will push Finland to harness its strengths and seize the clean hydrogen opportunity. Seeds of the hydrogen ecosystem have been sown globally and Finland must take action to be among the leading countries where industrial companies deploy investments.



Figure 17: Recommended actions to advance Finland's hydrogen economy.

The following recommended actions should be carried out with urgency to enable the develop of Finland's clean hydrogen economy: 1) build Europe's leading hydrogen ecosystem, 2) drive progress through hydrogen valleys and cross-collaboration, 3) accelerate and align decision-making, and 4) position Finland as a leader on the global hydrogen map.

6.1.1 Build Europe’s leading hydrogen ecosystem

Finland should rapidly create favorable market conditions and regulation to accelerate the development of a hydrogen economy as outlined in the Government Resolution.

Finland cannot compete with countries globally on public subsidies and project funding support alone. However, clear government backing for establishing the hydrogen economy and innovative policies can overcome this disadvantage and accelerate the hydrogen economy. The Finnish government’s decision in principle to adopt a resolution that sets a target of producing 10% of Europe’s renewable hydrogen was a clear statement of intent and important milestone in becoming a European hydrogen economy leader.³ Following this, the Government Programme, “A Strong and Committed Finland” published in June 2023, presents a vision for Finland to become a key player in the hydrogen economy based on the foundation the abundance of clean electricity provides for clean hydrogen. It also emphasizes the need to seek a competitive advantage by promoting a favorable general investment environment, RDI funding, streamlined permit procedures and energy transmission infrastructure instead of attracting investments through an influx in direct public support.³⁸ Carrying these actions forward and rapidly developing favorable market conditions is important to attracting the large amounts of capital investment needed to build Finland’s hydrogen economy.

Another important next step is the establishment of business models and governing codes for hydrogen and carbon capture storage (CCS). With at least €3.3 billion of industrial investment awaiting various permits in Finland, the government must continue to take action to streamline the permitting and appeals process. These instruments are key in lowering barriers to entry for market participants, promoting market integration, fairness, efficiency and providing commercial clarity for investors.

Building the leading hydrogen ecosystem must also include efforts to attract skilled workers as Finland is facing a labor shortage due to an aging population. Technology industries alone have an estimated need of 13,000 new people every year throughout the decade.

Practical measure	Lead	Support
Create a jointly prioritized set of policy measures and mandates across key areas, including fiscal, needed to accelerate hydrogen market development, setting a roadmap that is more ambitious than other EU countries to highlight Finland’s ambition.	Finnish Government	Hydrogen Cluster Finland
Develop and execute a roadmap of activities to streamline permitting. Activities should focus on digitalization, people capabilities, setting maximum	Finnish Government	Relevant ministerial authorities, Finnish industry

permit times, process simplification, and inter-ministerial decision making.		
Develop market frameworks, governing codes, and commercial and regulatory rules to create an attractive, liquid, and safe hydrogen economy that is integrated with electricity and heat markets.	Ministry of Economic Affairs and Employment	Energy Authority, Gasgrid, Fingrid, Finnish industry
Identify workforce capability gaps that need to be closed to establish a hydrogen economy, supporting the design of education and vocational programs and mechanisms to attract and retain skilled talent.	Finnish Government, Education and training institutes	Hydrogen Cluster Finland
Ensure an ambitious implementation of the new 6-year R&D program on Batteries and Hydrogen funded by Business Finland as well as continued funding for demonstrations and pilots after the Recovery and Resilience Facility to speed up the uptake of new technologies and business models in the hydrogen economy.	Finnish Government	Business Finland, Hydrogen Cluster Finland

6.1.2 Drive progress through hydrogen valleys and cross-collaboration

Finland should establish hydrogen valleys to expedite projects based on regional strengths and ensure collaboration and sharing of best practices between these valleys.

Fostering collaboration through hydrogen valleys will multiply local strengths and accelerate the growth of the hydrogen ecosystem. This increases Finland’s overall competitiveness against other regions and the likelihood of project success. However, these valleys should not be developed in a vacuum. Coordination across hydrogen valleys is needed to ensure timely knowledge sharing and that activities maximize every opportunity.

Practical measure	Lead	Support
Generate several H ₂ valley concepts through identifying locations across Finland with key companies and natural strengths.	Hydrogen Cluster Finland	Local and regional stakeholders
Engage value chain players to develop project consortia that drive the development of H ₂ valley concepts and link infrastructure deployment into valley implementation roadmaps.	Hydrogen Cluster Finland	Business Finland, RDI sector
Create a structure to coordinate H ₂ valleys and promote collaboration, shared learning, prioritization, and ecosystem building to create a unified voice at a local, national, and global level.	Hydrogen Cluster Finland	H ₂ valley actors and stakeholders
Maximize likelihood of valley success through incentives focused on RDI, global level talent acquisition, and private investment acceleration.	Finnish Government	Hydrogen Cluster Finland, Business Finland
Promote and provide application support for hydrogen-related public funding opportunities in Finland, the EU, and prioritized partner countries, carrying out regular funding	Hydrogen Cluster Finland	Business Finland

scans and sharing insights with relevant projects and stakeholders.		
---	--	--

6.1.3 Accelerate and align decision-making

Finland should establish well-led public and private sector bodies to coordinate and drive hydrogen strategy implementation. It should also ensure these bodies have clear mandates and the ability to make timely, cross-sectoral, strategic decisions.

Finland does not currently have clean hydrogen strategy in place. Jointly creating and swiftly executing on an agile strategy with Hydrogen Cluster Finland and Finnish industry and committing to its implementation will provide a clear signal of intent to the market and ensure the hydrogen economy is a strategic priority across government. There is no time to waste, so strategy development should be done quickly and then the Government should adopt an iterative process, where it is regularly updated, and course corrected as implemented.

Strong decision-making bodies are needed to coordinate timely delivery of the strategy and its related actions across stakeholders and to provide implementation oversight.

Practical measure	Lead	Support
Align on firm commitments for hydrogen economy development through public-private collaboration and formalize these commitments through the Finnish Government swiftly publishing an iterative Hydrogen Strategy and developing an agile Hydrogen Economy Program to deliver it.	Finnish Government	Hydrogen Cluster Finland, Finnish industry
Communicate and obtain stakeholder buy-in on commitments and actions required to deliver it.	Finnish Government	Hydrogen Cluster Finland, Finnish industry
Establish inter-ministerial task force to drive delivery of national related actions of the Hydrogen Economy Program and to ensure necessary coordination across the public sectors.	Finnish Government	
Create a 'Hydrogen Working Group' consisting of private sector actors to coordinate and make decisions on inter-sectoral priorities (e.g., organizations, companies, infrastructure platforms, R&D, etc.), operating in seamless collaboration with the ministerial working group.	Finnish Government, Hydrogen Cluster Finland	Finnish industry associations
Coordinate and monitor the execution of the hydrogen strategy in Finland through a Secretariat set-up to assist the inter-ministerial task force and private sector working group. The Secretariat should provide data and information for the Hydrogen Cluster Finland, Government, and other actors. It should also serve as a forum to monitor the progress of the Hydrogen Economy and should be used to align on further actions needed.	Finnish Government, Hydrogen Cluster Finland	Business Finland, Finnish Government, Finnish industry

6.1.4 Position Finland as a leader on the global hydrogen map

Finland should influence hydrogen development within the EU, attract investments to Finland, and promote Finnish technology and services worldwide. It should also continuously communicate Finland’s strengths, build strategic partnerships, and focus on foster relationships with key countries.

Support from stakeholders internal and external to Finland will be critical to becoming the leading hydrogen economy in Europe. Internally, Finns must understand and buy into the societal benefits of developing it, and externally, Finland’s attractiveness needs to be well articulated to other countries, companies, investors, and skilled workers.

Practical measure	Lead	Supporting
Define an engagement and communications strategy to best tell the story of “Why Finland” to different audiences, including local communities, policymakers at EU, strategic investment partners, and potential buyers of H ₂ products, technologies, and services.	Business Finland	Hydrogen Cluster Finland, BotH2nia, Team Finland, Ministry of Foreign Affairs
Advocate for Finland at the EU-level to ensure policies and regulation support and / or that policies and regulation do not unduly hinder the development of Finland’s hydrogen economy.	Finnish Government	Hydrogen Cluster Finland, Finnish industry
Attract capital investment through targeted engagement with key players who can help increase market credibility and generate momentum for locating new or relocating existing businesses to Finland.	Finnish industry	Finnish Government
Create strategic partnerships for high value hydrogen economy development. This could include countries and customers who are importers of Finnish value add, likely importers of Finland produced hydrogen products, technologies, and services as well as others with aligned strategic interests.	Ministry of Economic Affairs and Employment, Ministry of Foreign Affairs	Hydrogen Cluster Finland, Finnish industry
Engage local communities to gather support for clean energy asset development.	Finnish industry	H ₂ valley actors and stakeholders

6.2 Roadmap for strategy execution

Finland should prioritize the recommended actions and implement the practical measures above to accelerate its progress and become the leading high-value hydrogen economy in Europe by 2035. Acting with urgency and specificity will push Finland to harness its strengths and seize opportunities across the entire value chain, including technologies and services.

The twenty practical measures below should be acted upon as shown by the graphic below.

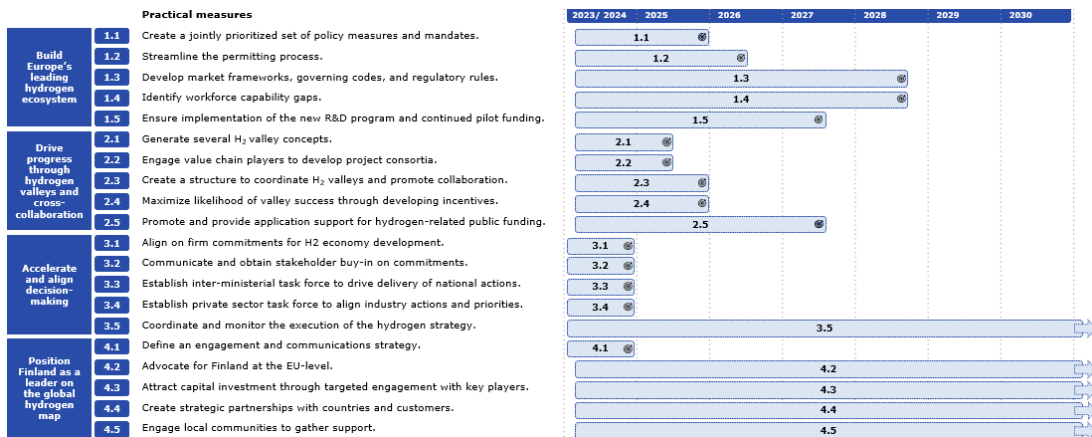


Figure 18: Roadmap for execution of clean hydrogen economy strategy

Following this roadmap will allow Finland to pursue a coordinated, effective strategy to capitalize on the highest value opportunities within the hydrogen economy and deliver the most benefits for Finns.

End notes

- ¹ Guidehouse, Clean hydrogen economy strategy for Finland supporting analysis report, June 2023, Unpublished
- ² Focus Economics, Finland GDP, 15 March 2023, <https://www.focus-economics.com/country-indicator/finland/gdp-eur-bn/>
- ³ Finnish Ministry of Economic Affairs and Employment, Government adopts resolution on hydrogen – Finland could produce 10% of EU’s green hydrogen in 2030, 9 February 2023, <https://valtioneuvosto.fi/en/-/1410877/government-adopts-resolution-on-hydrogen-finland-could-produce-10-of-eu-s-green-hydrogen-in-2030>
- ⁴ Hydrogen Council, Hydrogen Insights 2023, May 2023, <https://hydrogencouncil.com/wp-content/uploads/2023/05/Hydrogen-Insights-2023.pdf>
- ⁵ Business Wire, Hydrogen Generation Global Market Report 2022: Sector to Reach \$279.02 Billion by 2030 at a 7.3% CAGR, 25 January 2023, <https://www.businesswire.com/news/home/20230125005471/en/Hydrogen-Generation-Global-Market-Report-2022-Sector-to-Reach-279.02-Billion-by-2030-at-a-7.3-CAGR---ResearchAndMarkets.com#:~:text=The%20global%20hydrogen%20generation%20market,forecast%20from%202022%20to%202030.>
- ⁶ Hydrogen Council, Hydrogen for Net-Zero, November 2021, <https://hydrogencouncil.com/wp-content/uploads/2021/11/Hydrogen-for-Net-Zero.pdf>
- ⁷ European Hydrogen Backbone, Analysing future demand, supply, and transport of hydrogen, June 2021, https://gasforclimate2050.eu/wp-content/uploads/2021/06/EHB_Analysing-the-future-demand-supply-and-transport-of-hydrogen_June-2021_v3.pdf
- ⁸ European Hydrogen Backbone, Five hydrogen supply corridors for Europe in 2030 Executive Summary, May 2022, <https://ehb.eu/files/downloads/EHB-Supply-corridors-presentation-ExecSum.pdf>
- ⁹ Statistics Finland, Energy in Finland 2022, September 2022, https://www.doria.fi/bitstream/handle/10024/185778/yene_efp_202200_2022_25869_net.pdf
- ¹⁰ International Energy Agency, Finland 2023 Energy Policy Review, May 2023, <https://iea.blob.core.windows.net/assets/c77be693-2bb3-486c-8f8e-e33b0624bc7a/Finland2023-EnergyPolicyReview.pdf>
- ¹¹ Finnish Wind Power Association, Wind power map, <https://tuulivoimayhdistys.fi/en/wind-power-in-finland/map>
- ¹² U.S. Geological Survey, 2019 Minerals Yearbook, February 2023, <https://pubs.usgs.gov/myb/vol3/2019/myb3-2019-finland.pdf>
- ¹³ Statistics Finland, Finland Exceeded its target for 2020 – share of renewable energy in final consumption rose to 44.6 per cent, 16 December 2021, https://www.stat.fi/til/ehk/2020/ehk_2020_2021-12-16_tie_001_en.html
- ¹⁴ Eurostat, Renewable energy statistics, January 2023, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics
- ¹⁵ World Economic Forum, Finland is on track to meet some of the world's most ambitious carbon neutrality targets. This is how it has done it, 1 June 2023, https://www.weforum.org/agenda/2023/06/finland-carbon-neutral-2035-goals?utm_source=linkedin&utm_medium=social_video&utm_term=1_1&utm_content=30789_cost_electricity_Finland&utm_campaign=social_video_2023
- ¹⁶ Finnish Energy, Energy Year 2022, 12 January 2023, https://energia.fi/en/newsroom/publications/energy_year_2022_-_electricity.html#material-view

-
- ¹⁷ European Commission, Renewable energy directive, https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en
- ¹⁸ Suomen Tuulivoimayhdistys, Tuulivoimahankkeet Suomessa 05/2023, 12 May 2023, https://tuulivoimayhdistys.fi/media/tuulivoimahankkeet-05_2023.pdf
- ¹⁹ Fingrid, Estimate of electricity production and consumption during the winter season 2022–2023, December 2022 <https://www.fingrid.fi/ajankohtaista/tiedotteet/2022/fingrid-paivitti-arviota-sahkon-riittavyydesta-tulevana-talvena-kotimaista-tuotantokapasiteettia-odotettua-vahemman-saatavilla-sahkon-saastaminen-tarkeaa/>
- ²⁰ Eurostat, Forests, forestry and logging, December 2022, [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Forests, forestry and logging#:~:text=forestry%20and%20logging-,Forests%20in%20the%20EU,of%20the%20EU%20land%20area](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Forests,_forestry_and_logging#:~:text=forestry%20and%20logging-,Forests%20in%20the%20EU,of%20the%20EU%20land%20area)
- ²¹ Finnish Government, Report: Carbon dioxide use and removal present significant opportunities for Finland, 29 March 2023, <https://valtioneuvosto.fi/en/-/10616/report-carbon-dioxide-use-and-removal-present-significant-opportunities-for-finland>
- ²² Stuttgart Airport, Skyng, Schwenk, E4tech, Element Energy, and ERM, Assessment of European biogenic CO2 balance for SAF production, November 2022, <https://www.schwenk.de/wp-content/uploads/2022/12/Assessment-of-European-biogenic-CO2-balance-for-SAF-production-v3.0.pdf>
- ²³ EURARE, Rare earth element deposits in Europe, <https://www.eurare.org/countries/home.html>
- ²⁴ World Bank, Worldwide Governance Indicators, <https://info.worldbank.org/governance/wgi/Home/Reports>
- ²⁵ Global Data and Investment Monitor, Global FDI Annual Report 2022, https://www.investmentmonitor.ai/wp-content/uploads/sites/7/2022/08/Investment-Monitor_annual-report.pdf
- ²⁶ Transparency International, Corruption Perceptions Index, <https://www.transparency.org/en/cpi/2022>
- ²⁷ International Energy Agency, Simplified levelised cost of competing low-carbon technologies in steel production, 26 October 2022, <https://www.iea.org/data-and-statistics/charts/simplified-levelised-cost-of-competing-low-carbon-technologies-in-steel-production>
- ²⁸ Wiley, The Digital Skills Gap Index (DSGI), <https://dsqi.wiley.com/global-rankings/>
- ²⁹ Eurostat, How many citizens had basic digital skills in 2021?, 30 March 2022, <https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220330-1>
- ³⁰ International Institute for Management Development, World Digital Competitiveness Ranking, <https://www.imd.org/centers/wcc/world-competitiveness-center/rankings/world-digital-competitiveness-ranking/>
- ³¹ Privacy Shield Framework, Finland – Information and Communication Technology, <https://www.privacyshield.gov/article?id=Finland-Information-and-Communication-Technology>
- ³² Global Innovation Index, Analysis, <https://www.globalinnovationindex.org/analysis-indicator>
- ³³ The World Bank, Research and development expenditure (% of GDP), <https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS>
- ³⁴ Fingrid, Fingrid’s electricity system vision 2022 – draft scenarios for the future electricity system, 2022, https://www.fingrid.fi/globalassets/dokumentit/en/news/fingrid_electricity_system_draft_scenarios.pdf
- ³⁵ Business Finland, National Hydrogen Roadmap for Finland, <https://www.businessfinland.fi/4abb35/globalassets/finnish-customers/02-build->

[your-network/bioeconomy--cleantech/alykas-energia/bf_national_hydrogen_roadmap_2020.pdf](#)

³⁶ European Union Aviation Safety Agency, Fit for 55 and ReFuelEU Aviation, <https://www.easa.europa.eu/en/light/topics/fit-55-and-refueleu-aviation>

³⁷ VTT, Finnish fuel cell technology aims for the world, 7 June 2018, <https://www.vttresearch.com/en/news-and-ideas/finnish-fuel-cell-technology-aims-world>

³⁸ Finnish Government, "A strong and committed Finland" - Outcome of the negotiations on the Government Programme Excerpts, 16 June 2023,

[https://valtioneuvosto.fi/documents/10184/158702198/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf/f6c8c388-26c8-2712-4996-](https://valtioneuvosto.fi/documents/10184/158702198/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf/f6c8c388-26c8-2712-4996-789b511a37ec/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf?t=1686921846994)

[789b511a37ec/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf?t=1686921846994](https://valtioneuvosto.fi/documents/10184/158702198/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf?t=1686921846994) Finnish Government, "A strong and committed Finland" - Outcome of the negotiations on the Government Programme Excerpts, 16 June 2023,

[https://valtioneuvosto.fi/documents/10184/158702198/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf/f6c8c388-26c8-2712-4996-](https://valtioneuvosto.fi/documents/10184/158702198/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf/f6c8c388-26c8-2712-4996-789b511a37ec/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf?t=1686921846994)

[789b511a37ec/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf?t=1686921846994](https://valtioneuvosto.fi/documents/10184/158702198/Excerpts+of+the+outcome+of+the+negotiations+on+the+Government+Programme+16+June+2023.pdf?t=1686921846994)