



Five hydrogen supply corridors for Europe in 2030

EUROPEAN HYDROGEN BACKBONE

MAY 2022



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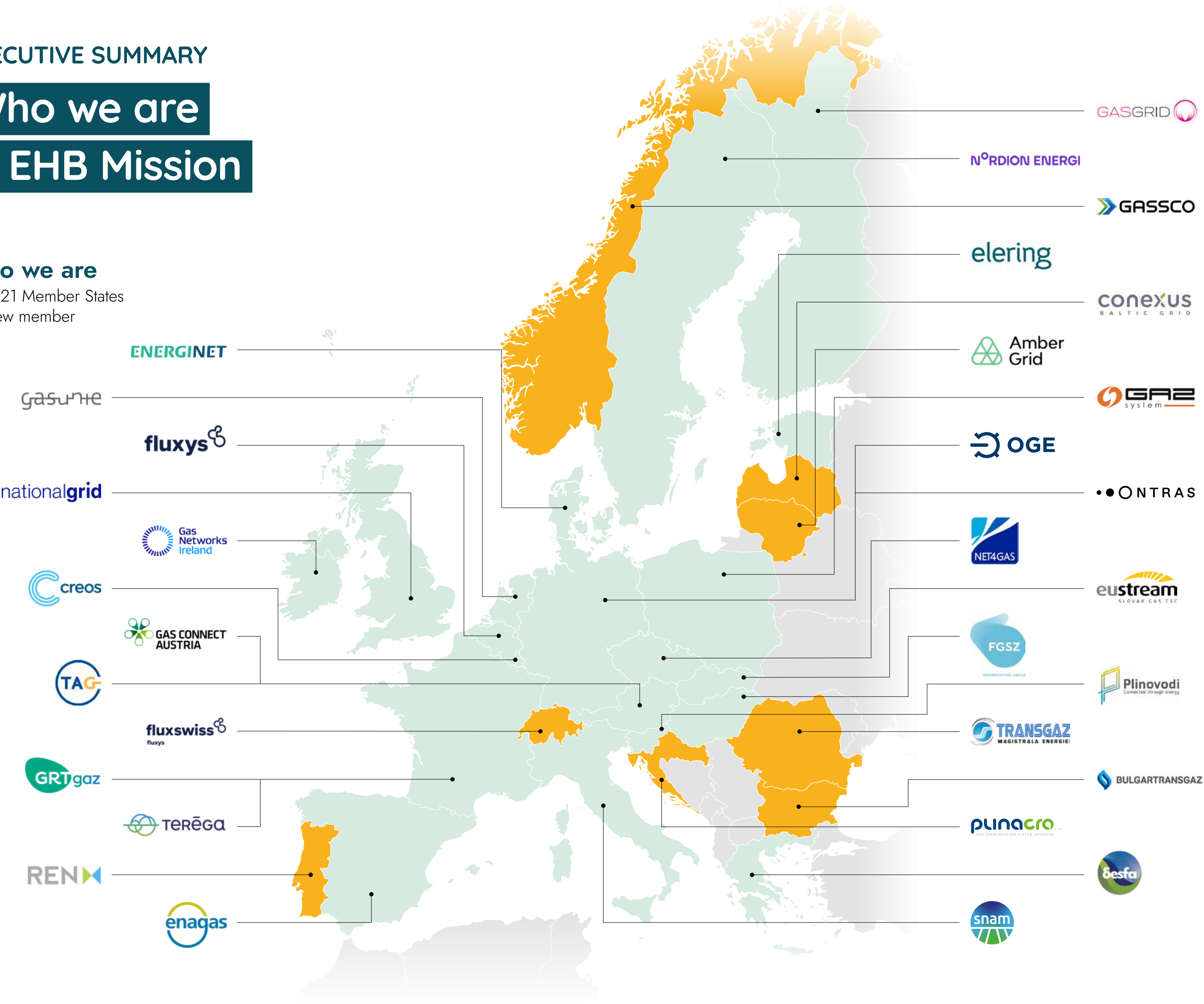
Corridor E: East and South-East Europe

3. Detailed methodology

Who we are & EHB Mission

Who we are

- 2021 Member States
- New member



EHB Mission

- **Accelerate** decarbonisation of the **European energy system**
- **Define** the critical role of **hydrogen infrastructure**
- **Support development** of a competitive and liquid **European hydrogen market**
- **Foster cross-border collaboration** between Europe and its neighbors

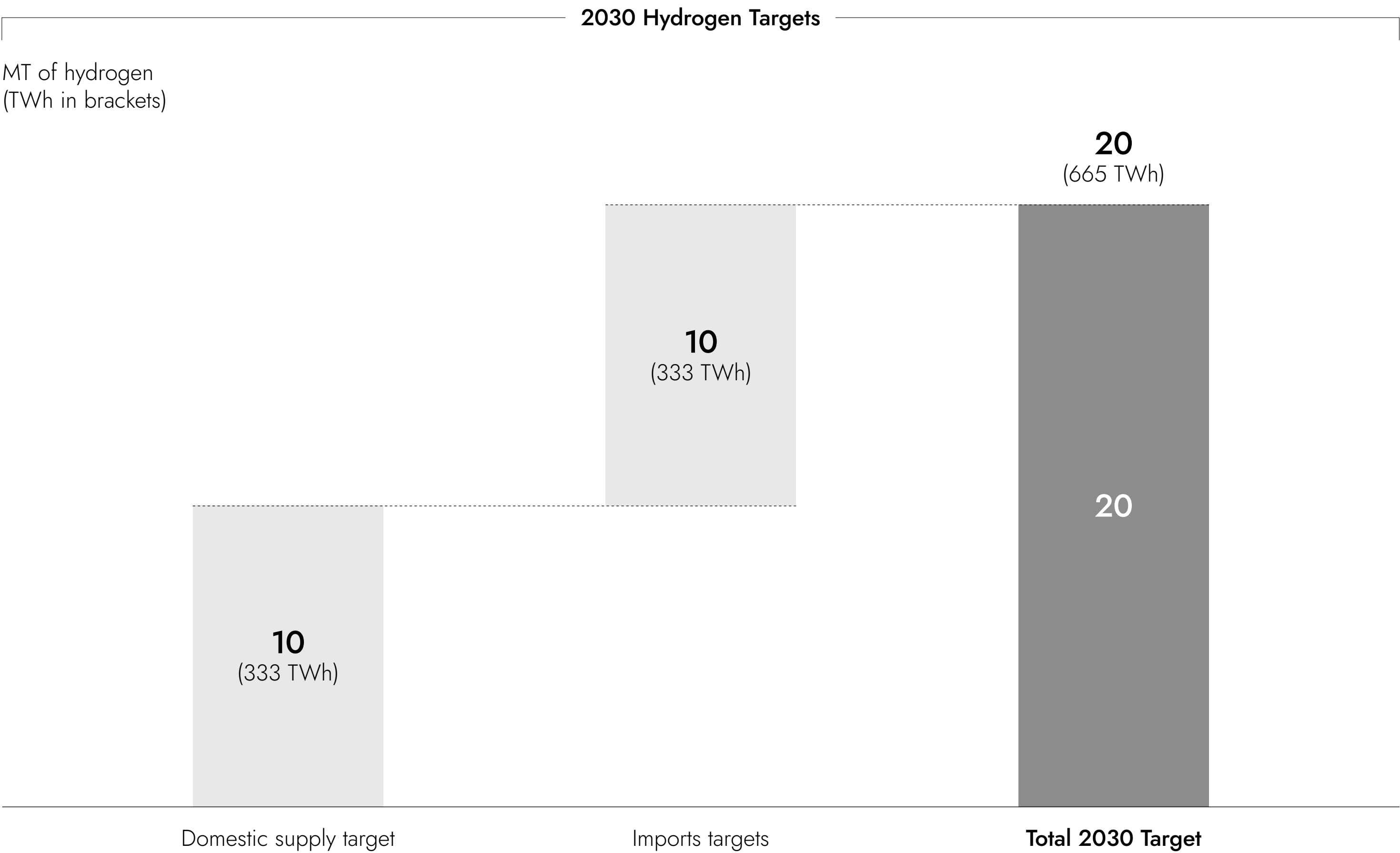
Europe’s accelerated 2030 climate targets define an aggressive role for hydrogen

Europe has defined a **bolder and more ambitious hydrogen target of 20 MT** by 2030 in response to the **RePowerEU plan** to phase out Russian fossil fuel imports well before 2030

This includes a **10 MT target of domestic EU hydrogen supply**, as well as a **10 MT target of hydrogen imports** from outside the EU.¹

These targets are strengthened by accelerated **national climate ambitions** as well as the accelerated development of the **European hydrogen market**.

Note: This study’s underlying analysis was largely completed prior to the publication of the detailed RePowerEU plan and its 2030 hydrogen targets. As such, this study’s supply and demand estimates were not intended to align with the 20 MT target by 2030.



¹ The RePowerEU target of 10 MT of imports includes 6 MT of renewable hydrogen and 4 MT of imported ammonia / derivatives.

The EHB initiative has identified sufficient hydrogen supply to exceed the 2030 domestic targets

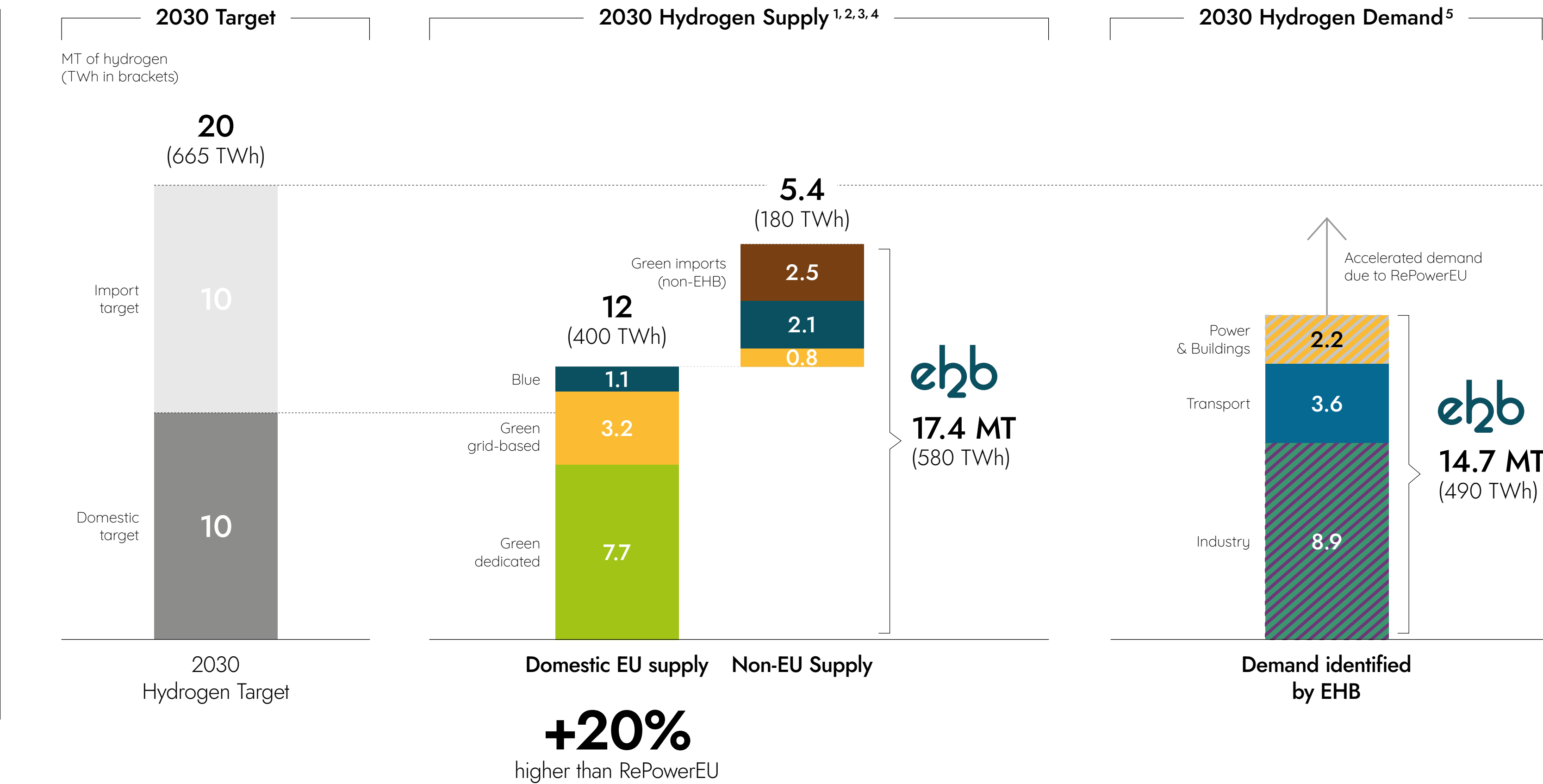
EHB identified **12 MT of domestic supply, exceeding the RePowerEU domestic target by 20%** and supporting European energy independence and security of supply.

EHB also identified **5.4 MT of supply** from non-EU neighboring countries, for a **total of 17.4 MT of supply**.

EHB also identified **14.7 MT of demand** based on a bottom-up assessment of demand by sector and country.

We expect this demand estimate to **increase and accelerate further** in response to the RePowerEU plan.

These supply and demand estimates represent **tangible and achievable projections** based on national targets, market developments and announced projects, primarily **prior to the release of the RePowerEU plan**.



1 EHB did not analyse ship imports of hydrogen or derivatives like ammonia and methanol. To meet the 20 MT target, an additional 2.6 MT of hydrogen or derivative imports would be needed.
2 The 5.4 MT of non-EU supply includes 2.5 MT (~80 TWh) of green hydrogen imports from non-EHB countries (Morocco, Algeria, Tunisia and Ukraine), along with 2.1 MT of blue hydrogen and 0.8 MT of grid-based hydrogen from EHB, non-EU countries (the UK and Norway). Blue hydrogen potential, and its economic viability, is subject to the evolution of gas markets, regulations and the uncertainty of natural gas prices.
3 Estimates of national green hydrogen supply for European countries are based on projections of renewable energy scaling up above and beyond supply levels needed to meet electricity demand.
4 Other imports may include pipeline or ship imports from other regions not analysed in this study.
5 Demand includes all EU countries and the UK and Norway. Demand estimates do not include domestic EU consumption of ammonia for shipping or other derivatives. For comparison, RePowerEU considered 4 MT of demand for ammonia and other derivatives.

Regional differences in supply and demand show the importance of connecting regions across Europe

Across different regions in Europe, there are **significant differences in the hydrogen supply-demand balance**. Some regions are characterised by a **net supply of low-cost, hydrogen resources**. These regions benefit from vast renewable energy potential, high capacity factors and substantial land availability.

Other regions will require hydrogen imports from other European or neighboring regions to meet their hydrogen demand.

Hydrogen pipeline infrastructure can bridge these regional supply-demand differences across Europe in a cost-effective manner.

The EHB vision delivers the infrastructure needed to connect hydrogen supply and demand across Europe.

1 Aggregated demand and supply are based on the 2030 figures determined in this study. Supply figures include imports from North Africa and Ukraine. Note: Demand and supply figures may increase further in response to more ambitious national policies and measures following the RePowerEU plan.

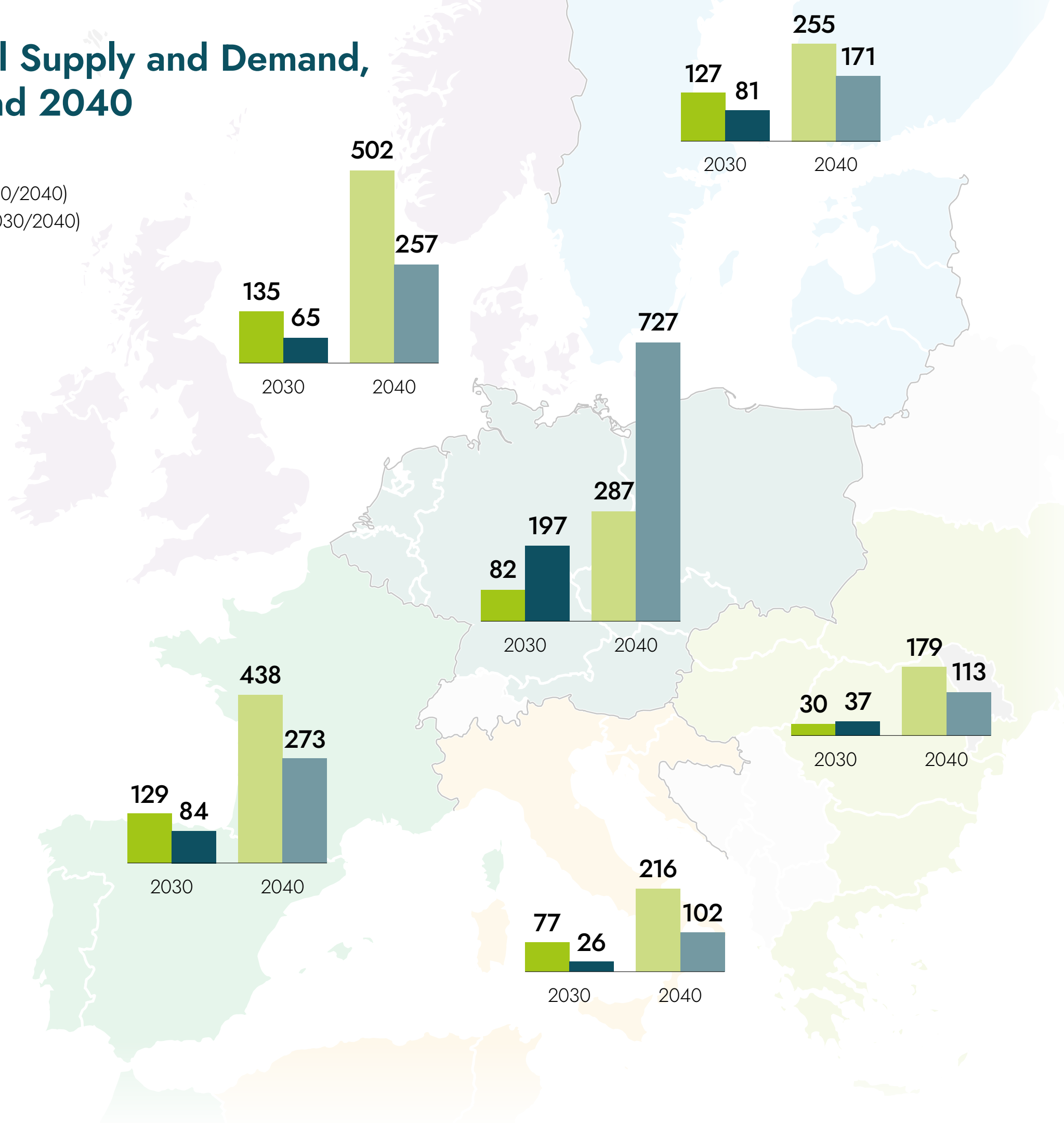
2 This analysis estimates ~490 TWh of demand and ~580 TWh of supply in 2030 and does not attempt to determine how hydrogen supply and demand will balance out across Europe, nor which hydrogen supply sources – or from which regions – will be used to meet demand.

3 Demand and supply figures may not align with figures presented in the rest of the report based on aggregation of countries into regions and due to rounding.

Regional Supply and Demand, 2030 and 2040

(TWh)^{1,2,3}

■ Supply (2030/2040)
■ Demand (2030/2040)



Five supply corridors are key to the EHB vision and can deliver access to abundant and low-cost hydrogen supply by 2030

To deliver the 2030 hydrogen demand targets set by the RePowerEU plan, **five large-scale pipeline corridors are envisaged**.

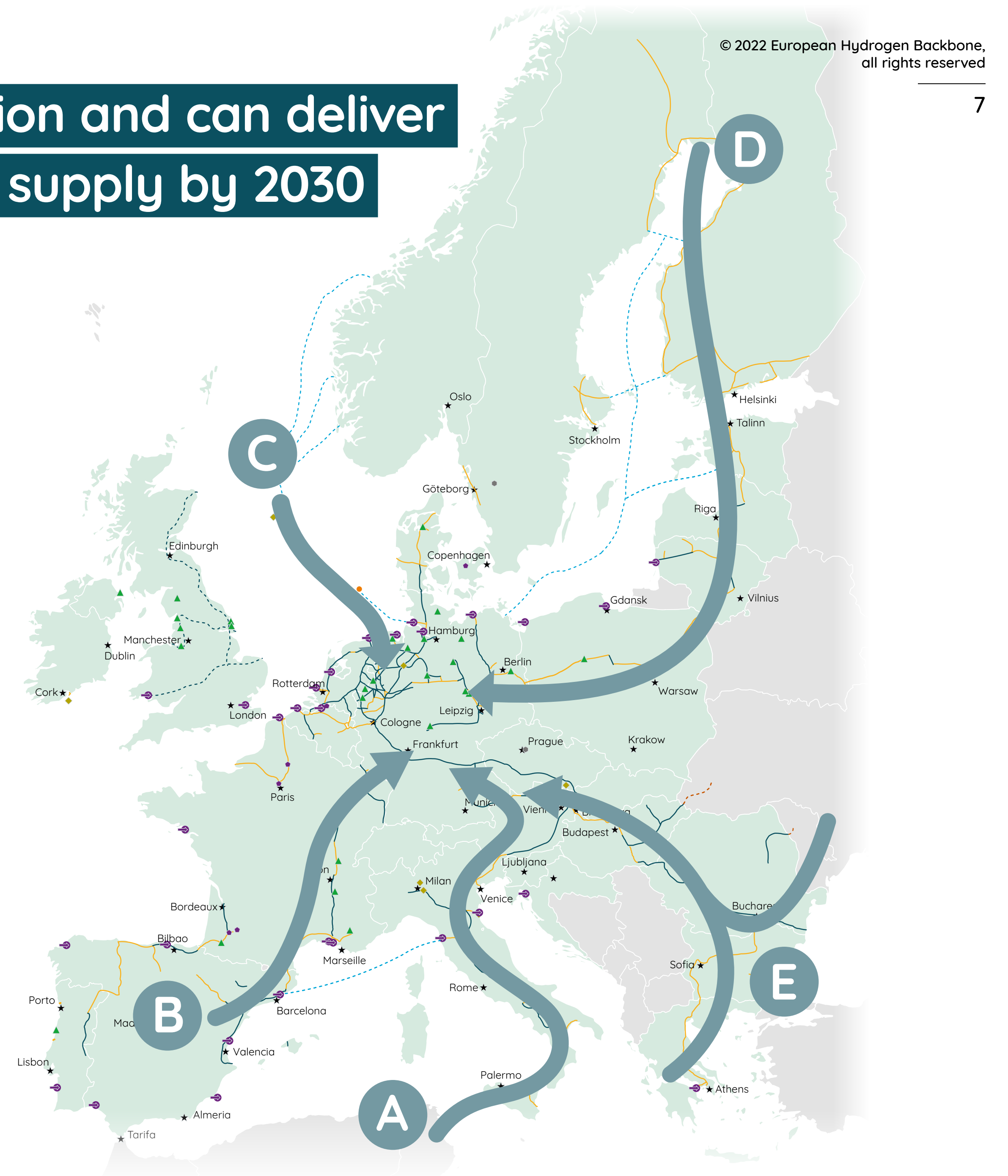
The corridors will **initially connect local supply and demand** in different parts of Europe, before expanding and **connecting Europe with neighboring regions** with export potential.

Certainty about the deployment of this infrastructure will **enable market actors to develop** supply and demand more rapidly

The five hydrogen supply corridors are:

- Corridor A: **North Africa & Southern Europe**
- Corridor B: **Southwest Europe & North Africa**
- Corridor C: **North Sea**
- Corridor D: **Nordic and Baltic regions**
- Corridor E: **East and South-East Europe**

These five corridors **span across both domestic and import supply markets**, consistent with the **three import corridors** identified by the RePowerEU plan, including a corridor via the **Mediterranean** (Corridors A and B), via the **North Sea** (Corridor C) and via **Ukraine** (Corridor E)



These five corridors represent the collective vision of the
31 gas infrastructure companies part of the EHB initiative

Corridor A
North Africa
& Southern Europe



Corridor B
Southwest Europe
& North Africa



Corridor C
North Sea



Corridor D
Nordic and
Baltic regions



Corridor E
East and South-East
Europe



Note: Since all corridors terminate in Germany, OGE and ONTRAS are presented in each corridor grouping.

Each corridor has a unique regional role in enabling the scale up of low-cost hydrogen supply and the decarbonisation of energy demand

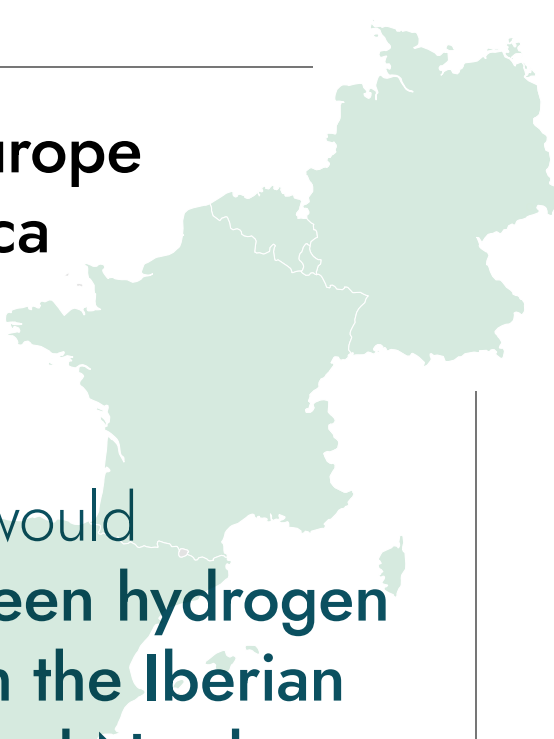
Corridor A —
North Africa
& Southern Europe



Corridor A would transport **large quantities of cost-competitive green hydrogen potential from Tunisia and Algeria** through Italy to central Europe leveraging existing gas infrastructure.

Corridor A would decarbonise **existing industries along the route in Italy and Central Europe as well as in Germany.**

Corridor B —
Southwest Europe
& North Africa



Corridor B would transport **green hydrogen supply from the Iberian peninsula and North Africa**, and gain **access to underground storage sites in France** to deliver stable hydrogen supply.

Corridor B would decarbonise **regional industry and transport clusters in Portugal, Spain, France and Germany.**

Corridor C —
North Sea



Corridor C includes hydrogen supply from ongoing and planned **offshore wind, blue hydrogen and large-scale integrated hydrogen projects in the North Sea.**

Corridor C would meet **demand from industrial clusters and ports in the UK, the Netherlands, Belgium and Germany.**

Corridor D —
Nordic and
Baltic regions



Corridor D would transport green hydrogen supply potential from **onshore and offshore wind from countries surrounding the Baltic Sea.**

Corridor D would be built around **regional networks around industrial clusters**, serving numerous new **green steel, e-fuel, fertilizer and green chemicals projects in the Nordics** as well as decarbonizing existing industry in the Nordics, Baltics, Poland and Germany along the corridor route.

Corridor E —
East and South-East
Europe



Corridor E would connect **high supply potential regions such as Romania, Greece, and Ukraine¹** — leveraging vast land availability and high-capacity factors for solar and wind.

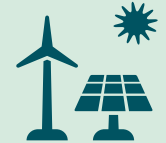
Corridor E would deliver hydrogen to **off-takers in Central Europe and Germany.**

1 While Ukraine is expected to be a hydrogen exporting region, there is significant uncertainty related to Russia's invasion of Ukraine and its impact on Ukraine's gas infrastructure and economic development.

These five supply corridors will enable the creation of a pan-European hydrogen market by 2030



- **Connect** substantial hydrogen supply and demand across European regions and **leverage** underground storage to deliver stable supply
- **Access** vast volumes of cost-competitive domestic hydrogen supply and hydrogen imports from neighboring regions
- **Foster** the creation of a liquid, pan-European, hydrogen trading market



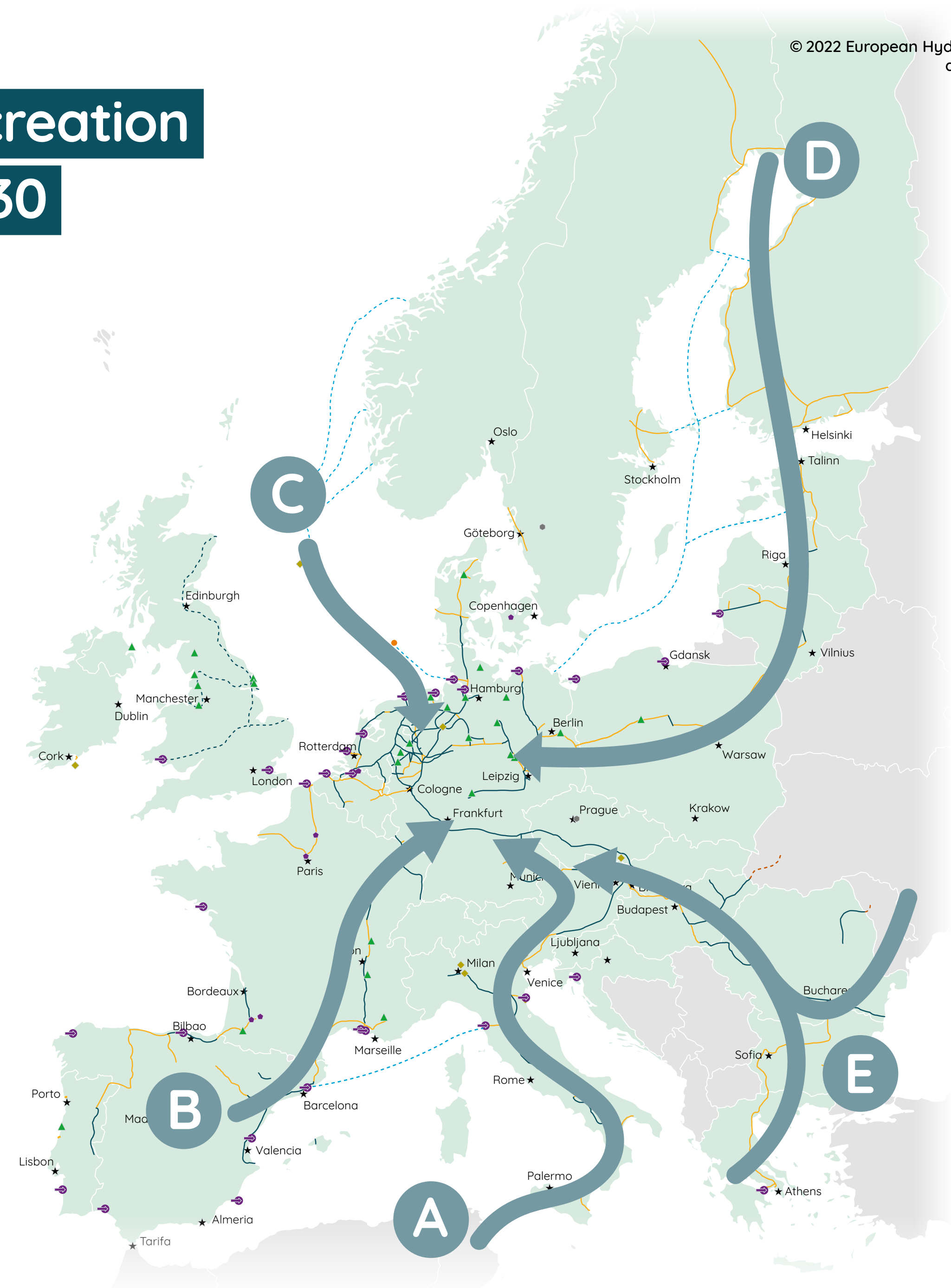
- **Accelerate** the deployment and integration of renewable energy resources
- **Support** scale-up of green, innovative European industries



- **Increase** the resiliency of Europe's energy system
- **Contribute** to European energy independence and diversity of supply.



- **Deliver** substantial and cost-effective emission reductions



To ensure the development of each corridor by 2030, there is a need for clear and concrete actions

Corridor A
North Africa
& Southern Europe



Corridor B
Southwest Europe
& North Africa



Corridor C
North Sea



Corridor D
Nordic and
Baltic regions



Corridor E
East and South-East
Europe



Fostering development of new and repurposed hydrogen infrastructure, for example, by unbundling rules facilitating the efficient use of TSO expertise and services and by allowing the adoption of different vertical unbundling models in the EU, as is the case with natural gas

Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions (including incentivizing the adoption of hydrogen by demand sectors)

Simplify and shorten planning and permitting procedures for the full value chain of renewable energies and hydrogen infrastructure projects.

Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure supporting the accelerated deployment and integration of renewable energy resources

Intensify energy partnerships with exporting, non-EHB countries (e.g., with Morocco, Algeria, Tunisia, Ukraine) providing financing support to reduce the cost of capital in export countries and identifying a common certification system for hydrogen exchanges

→ **However, speed will be of essence!**

The EHB initiative stands ready to deliver the hydrogen infrastructure needed to achieve Europe's 2030 hydrogen targets

We have identified a large share of the **demand and supply** needed to meet the **RePowerEU targets**.

We analysed and studied **five large-scale, hydrogen supply corridors** that will be critical in transporting the required amounts of hydrogen.

These five supply corridors have the potential to provide Europe with **access to abundant and low-cost hydrogen supply** by 2030.

To ensure the **development of these supply corridors** on time, we have identified **five key concrete actions**

Ultimately, to realise the hydrogen pipeline infrastructure required by 2030, **action is needed now**.

→ The EHB initiative and its members are ready to deliver

Our recommendation: Establish hydrogen supply corridors as enabler for hydrogen market creation

Answering to RePowerEU

This reports shows how all **31 members** are able to **accelerate the hydrogen infrastructure development** to enable the 20 MT of renewable hydrogen by 2030

EHB recommends introducing the **establishment of hydrogen supply & import corridors as front-running infrastructure,** including all infrastructure requirements, **as a political objective.**

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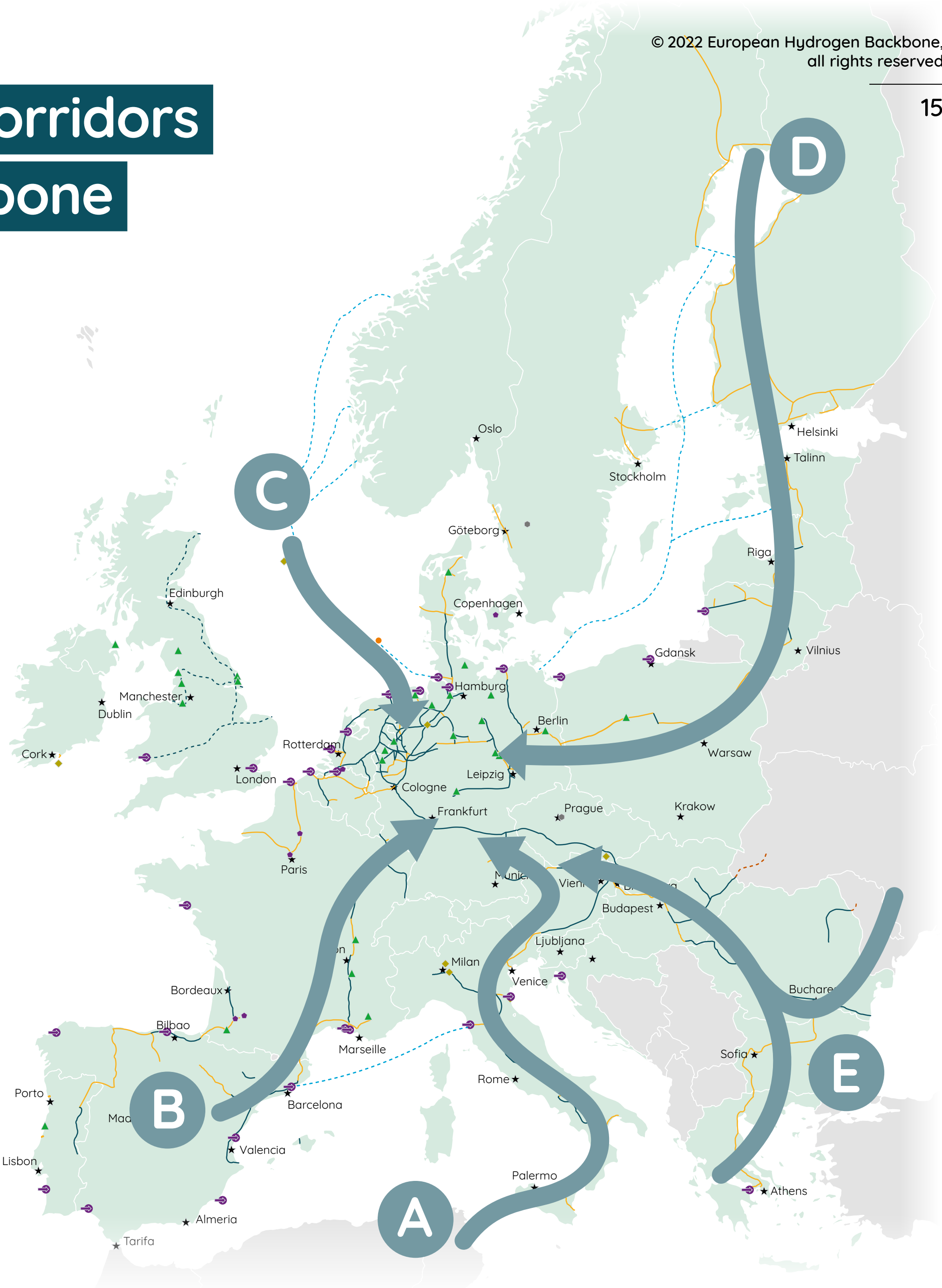
Corridor D: Nordic and Baltic regions

Corridor E: East and South-East Europe

3. Detailed methodology

This report analyses each of the five hydrogen corridors and their roles in enabling a pan-European backbone

Sections	Questions answered
1 Hydrogen Demand & Supply	<ul style="list-style-type: none">How will hydrogen demand and supply evolve over time in this corridor?Which countries and sectors will drive the development of hydrogen demand in this corridor?How will the hydrogen supply mix change over time?
2 Costs & Cost Competitiveness	<ul style="list-style-type: none">How competitive will hydrogen from this corridor be with fossil alternatives?What cost-levers can lower hydrogen cost?
3 National Strategies & Regulations	<ul style="list-style-type: none">What is the state of national hydrogen strategies and regulation in the countries of this corridor?
4 Actions Needed	<ul style="list-style-type: none">What near-term regulatory and planning actions are required to support the development of this corridor?



This study builds on previous EHB reports and findings, and incorporates new corridor-specific analysis

Key study inputs



Inputs are defined primarily over the 2030-2050 timeframe, building on the most recently published EHB reports and maps:

- **Hydrogen demand forecasts** by country, sector and year.
- **Realisable hydrogen supply potential** by country and year;
- **Existing gas pipeline infrastructure** (onshore and offshore) and **storage facilities**;
- **Hydrogen infrastructure development plans** by country; and
- **Costs assumptions** associated with green and blue hydrogen supply and pipeline repurposing.

Major study uncertainties



- **Uncertainty** on near- and long-term European **natural gas prices and supply mix**.
- **Uncertainty** related to Russia's invasion of Ukraine and its impact on Ukraine's gas infrastructure, economic recovery and development of a hydrogen market.
- **Uncertainty** regarding the **development of hydrogen pipeline infrastructure across Europe**, which is subject to developments in European and national energy policy, regulations and funding.
- **Uncertainty regarding future hydrogen demand and supply**, which may accelerate and increase further as a result of additional regulatory measures adopted in response to the RePowerEU plan.

Out of scope



- **This study does not incorporate detailed infrastructure planning** associated with the repurposing of existing natural gas pipelines, storage facilities, or gas import / export terminals.
- **This study does not account for ship imports** of hydrogen or hydrogen-derivatives like ammonia and methanol into Europe.

→ **Methodology Section:** Refer to the **Section 3: Methodology** for a description of the general supply and demand approach, key inputs, data sources, calculations, etc.

Since some corridors transit through the same countries,
key metrics – like corridor length, supply and demand – overlap

In this study, **when a corridor transit through a given country, even if only partially, it becomes part of the analysis of the corridor**, including its hydrogen demand, supply and transport infrastructure.

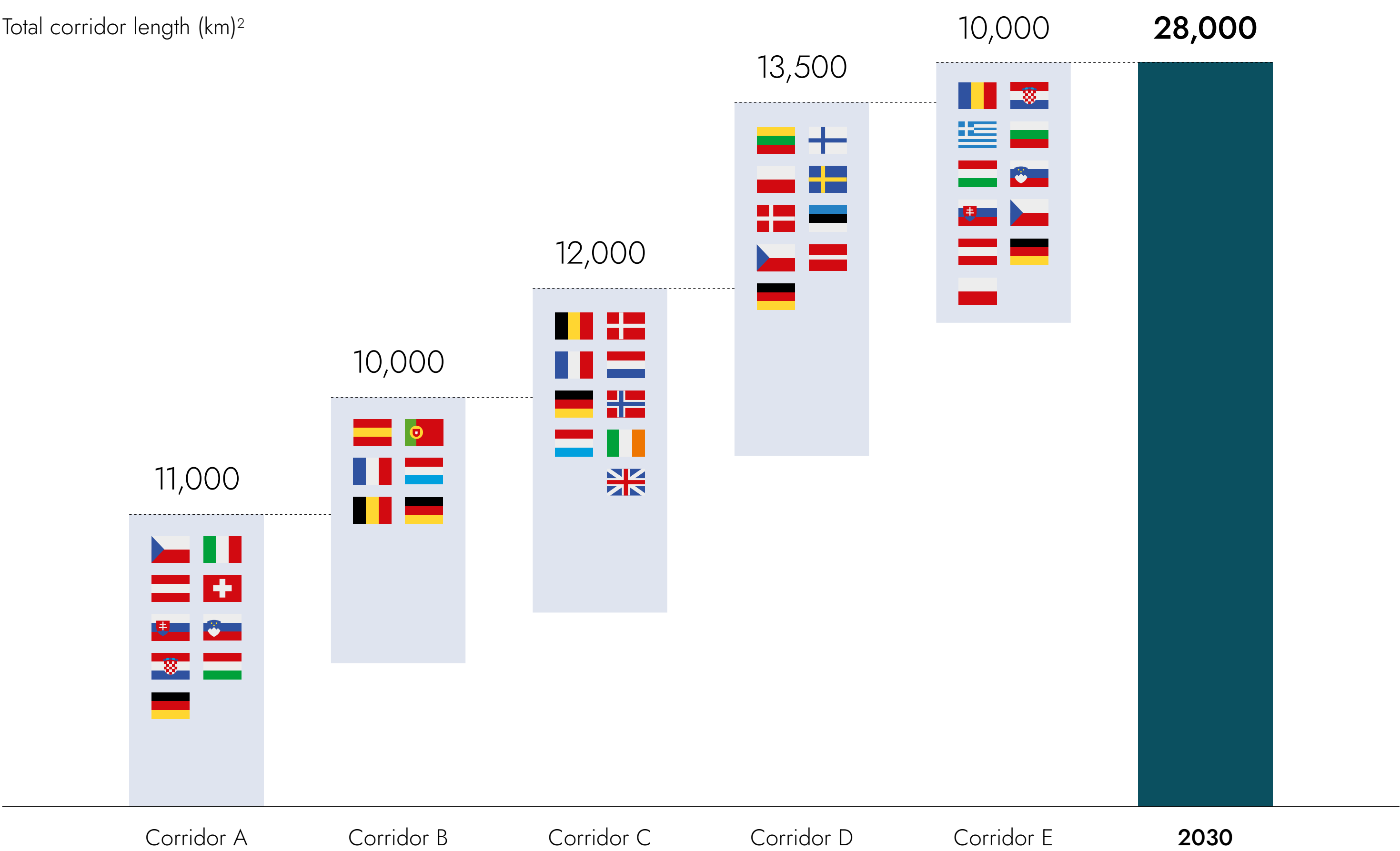
All five corridors of this study either: **(1) transit through some of the same countries, or (2) terminate in the same country**¹.

For example:

- **Corridor B** (Southwest Europe and North Africa) and **Corridor C** (North Sea) both transit through sections of **the Netherlands, Belgium and Germany**.
- **Corridor D** (Nordic and Baltic regions) and **Corridor E** (East and South-East Europe) both transit through section of **Germany, Czechia and Poland**.

This means that **all corridors partially overlap with other corridors. As a result, key metrics – like corridor length, supply and demand – overlap and are not mutually exclusive.**

This is illustrated on the right for corridor lengths.



Note: Since all corridors partially overlap, summing all individual corridor lengths – without adjusting for overlaps – adds up to ~56,000km, which is two times the combined length of 28,000 km in 2030².

¹ Since the largest demand clusters in Europe are concentrated in and around Germany, all five corridors terminate – and thus, overlap – in Germany
² The basis for these determining corridor lengths is the most recent publication of the EHB maps (April 2022).

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North Africa & Southern Europe

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3. Supply Costs & Cost-Competitiveness
4. National Strategies & Regulation
5. Actions Needed

North Africa
& Southern Europe



Corridor emerges in Southern Europe providing access to low-cost hydrogen supply from North Africa to demand clusters along the corridor

<div>Drivers & Opportunities</div>	Major driver of development is the need to meet hydrogen demand from industry, transport and power in Italy, Central Europe and Germany. Key opportunities include the high repurposing potential of gas pipelines from Italy to Central Europe , and pipeline interconnections with Algeria and Tunisia .																			
<div>Hydrogen Supply & Decarbonization Potential</div>	<div>H₂ supply potential¹ (TWh/year) </div> <div><table><tr><th>Year</th><th>Supply Potential (TWh/year)</th></tr><tr><td>2030</td><td>97</td></tr><tr><td>2040</td><td>340</td></tr></table></div>	Year	Supply Potential (TWh/year)	2030	97	2040	340	<div>Emissions Reductions (MtCO₂/year vs. 2019; % reduction) </div> <div><table><tr><th>Year</th><th>Emissions Reduction (MtCO₂/year)</th><th>% reduction</th></tr><tr><td>2030</td><td>-55</td><td>6%</td></tr><tr><td>2040</td><td>-160</td><td>18%</td></tr></table></div>	Year	Emissions Reduction (MtCO ₂ /year)	% reduction	2030	-55	6%	2040	-160	18%			
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<div>Supply Costs & Cost-Competitiveness</div>	<div>Cost of H₂ production¹ (€/kg of H₂) </div> <div><table><tr><th>Year</th><th>Cost of H₂ production (€/kg)</th></tr><tr><td>2030</td><td>2.1–3.8</td></tr><tr><td>2040</td><td>1.4–2.8</td></tr></table></div>	Year	Cost of H ₂ production (€/kg)	2030	2.1–3.8	2040	1.4–2.8	<div>Cost competitiveness² — Hydrogen delivered price vs. — natural gas price high/low, (€/MWh)</div> <div><table><tr><th>Year</th><th>Hydrogen delivered price (€/MWh)</th><th>Natural gas price high (€/MWh)</th><th>Natural gas price low (€/MWh)</th></tr><tr><td>2030</td><td>72</td><td>73</td><td>59</td></tr><tr><td>2040</td><td>42</td><td>69</td><td>62</td></tr></table></div>	Year	Hydrogen delivered price (€/MWh)	Natural gas price high (€/MWh)	Natural gas price low (€/MWh)	2030	72	73	59	2040	42	69	62
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<div>Actions Needed</div>	<ul style="list-style-type: none">— Fostering development of new and repurposed hydrogen infrastructure— Unlock financing to fast-track hydrogen infrastructure deployment— Simplify and shorten planning and permitting procedures— Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure— Intensify energy partnerships with exporting, non-EHB countries like Tunisia and Algeria																			

1 Figures reported reflect outputs for all countries included in the corridor. Even if a country is only partially in the corridor, results for the full country are included (e.g., supply potential and costs, demand, transmission network length).
2 Savings are based on the corridor's case study of hydrogen delivered in 2030 and 2040. The cost of natural gas includes CO₂ prices. Refer to Subsection 3 (Supply Costs & Cost-Competitiveness)

North Africa & Southern Europe

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1. Corridor Summary
2. Hydrogen Demand & Supply
3. Supply Costs & Cost-Competitiveness
4. National Strategies & Regulation
5. Actions Needed

Corridor offers access to low-cost hydrogen supply from North Africa to demand centers in Italy, Central Europe and Germany

Drivers & Opportunities

- The major driver behind the development of this corridor is the adoption of hydrogen associated with the **decarbonisation of industry, transport and power** in Italy, Central Europe and Germany. The speed of hydrogen adoption in these regions may be even faster than anticipated driven by increasing CO₂ prices in the EU and the RePowerEU ambitions to replace natural gas consumption.
- In the near term, the corridor offers **access to abundant low-cost, renewable production from Italy and Tunisia**. In the longer term, this corridor may also provide access to hydrogen imports from Algeria (via Tunisia) and additional supply from Central and South-Central Europe.
- A major opportunity of the corridor is the **ability to repurpose a large share of existing gas pipeline infrastructure** across Italy, Austria, Slovakia, and Czechia. Another key opportunity is the **potential repurposing of the Trans-Mediterranean pipeline** connecting Tunisia to Italy via Sicily, giving the corridor access to the abundant solar and wind resources of Northern Africa.
- Recently, RePowerEU identified the development of a new subsea pipeline connecting Spain and Italy, expected to be available for hydrogen transport by 2030.
- The corridor would be stood up by 2030, covering **11,000 km** of large-scale hydrogen pipelines across all countries of the corridor, of which approximately **60% will be repurposed pipelines**.

Hydrogen Demand & Supply

- **Total hydrogen demand** in the corridor reaches **~140 TWh by 2030**, increasing substantially to **~550 TWh by 2040**. Up to 2030, most hydrogen demand is driven by the industrial sector in Germany and Italy, along with some use of hydrogen in power generation. From 2040 to 2050, hydrogen demand expands into the transport sector and continues to ramp up in industry and power generation.
- Hydrogen adoption across all countries of the corridors enables an emissions reduction of ~220 MtCO₂/yr. by 2050, equivalent to a **25% emissions reduction**.
- The corridor enables access to **hydrogen supply potential of ~100 TWh by 2030, increasing to roughly 340 TWh by 2040**. Major sources of supply include hydrogen imports from North Africa and green hydrogen from Italy.

To successfully stand up this corridor by 2030, actions are needed to support infrastructure planning, financing and development

Costs & Cost-Competitiveness

- By 2030, the corridor provides access to hydrogen ranging in production costs from 2.1 to 3.8 €/kg. By 2040, as supply options increase, technology costs decrease, and increased imports from North Africa become available, hydrogen production costs decrease to 1.4 to 2.8 €/kg.
- Already by 2030, this corridor’s lowest-cost supply options are imports from North Africa.
- Based on a case-study of hydrogen supply and transport from Tunisia to Germany, the cost of delivered hydrogen – inclusive of transport and storage costs – can be lowered to achieve cost levels comparable to production costs by 2040. Lowering delivery costs can be achieved through various cost levers including optimised operation of the system and cost of capital reductions.

National Strategies & Regulation

- Most countries have developed – or are in the process of developing – national strategies. Moving forward, the development of hydrogen regulation in all countries will be key in enabling investment in infrastructure.
- In select countries, substantial funding has been allocated to support the development of the hydrogen market including funding for gas network infrastructure.

Actions Needed

- To support the buildout of this corridor by 2030, clear and concrete actions related to infrastructure planning, financing and development have been identified:
- Fostering development of new and repurposed hydrogen infrastructure.
 - Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions.
 - Simplify and shorten planning and permitting procedures for the full value chain of renewable energies and hydrogen infrastructure projects.
 - Establish integrated energy system planning of hydrogen, natural gas, and electricity infrastructure.
 - Intensify energy partnerships with exporting, non-EHB countries like Tunisia and Algeria.

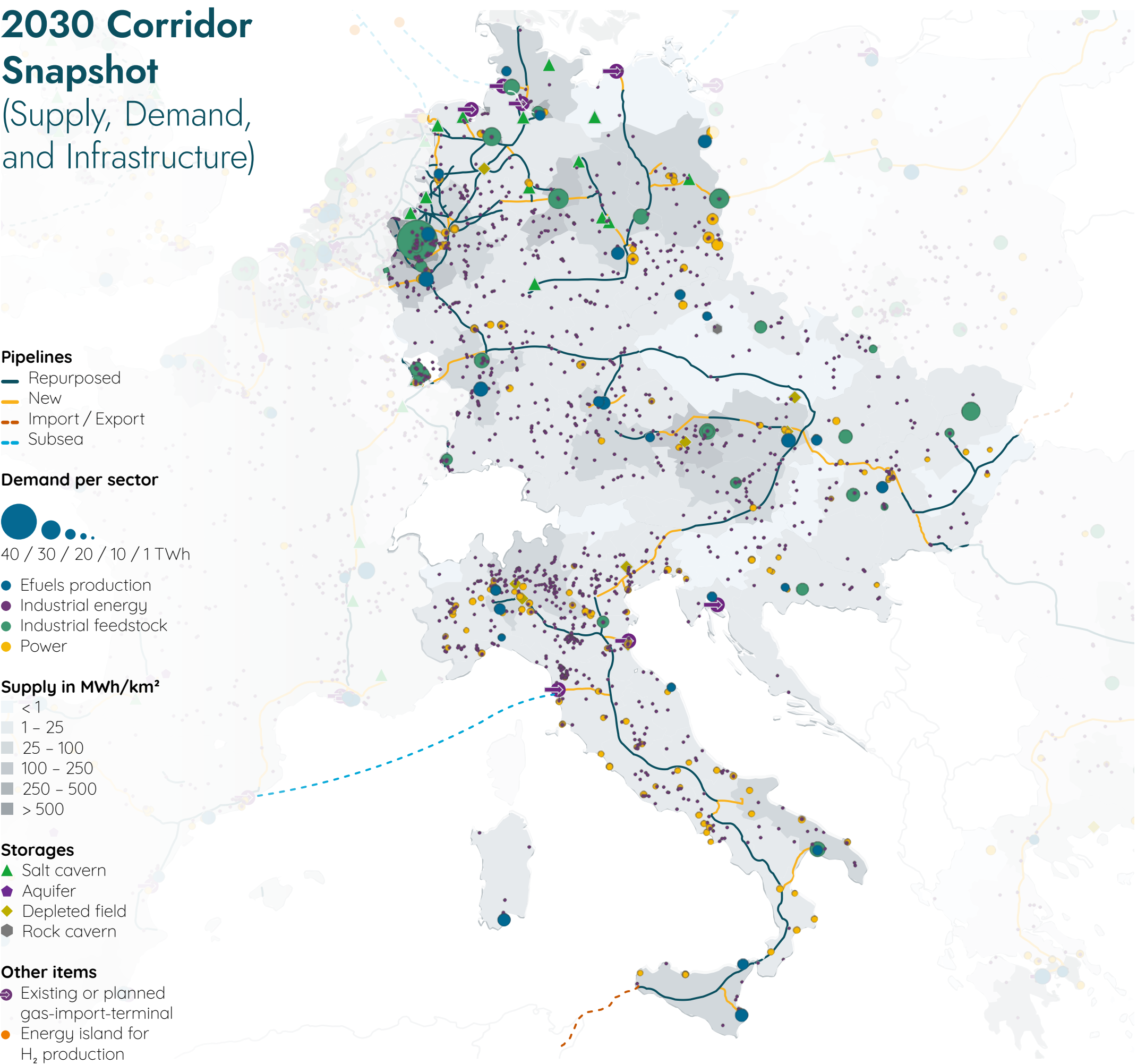
North Africa & Southern Europe

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- 2. Hydrogen Demand & Supply**
3. Supply Costs & Cost-Competitiveness
4. National Strategies & Regulation
5. Actions Needed

This section explores the development of demand, supply and transport infrastructure in the corridor from 2030 to 2050

2030 Corridor Snapshot
(Supply, Demand, and Infrastructure)



Hydrogen demand

By 2030, the corridor connects **all major industrial clusters** from Italy to Germany. **From 2030 to 2040**, the corridor expands to **all demand centers along its route**, increasing demand from 140 to ~550 TWh.

Hydrogen supply

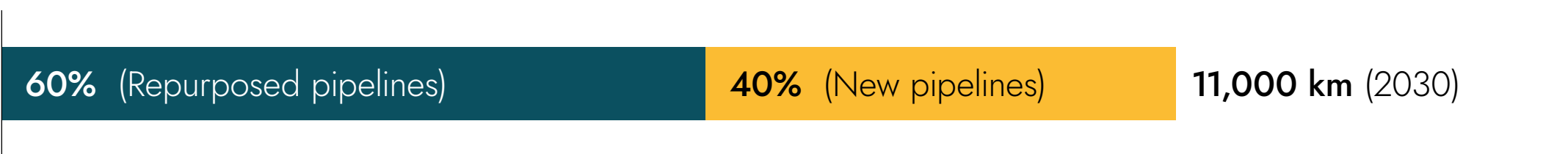
By 2030, the corridor enables access to low-cost supply from **Italy and Tunisia**. **By 2040**, the corridor gains access to **supply from Algeria (via Tunisia), Central and South-Central Europe**

In 2030, hydrogen supply is **~100 TWh**, of which more than 70% is imports. Hydrogen supply increases significantly by 2040, reaching 340 TWh.

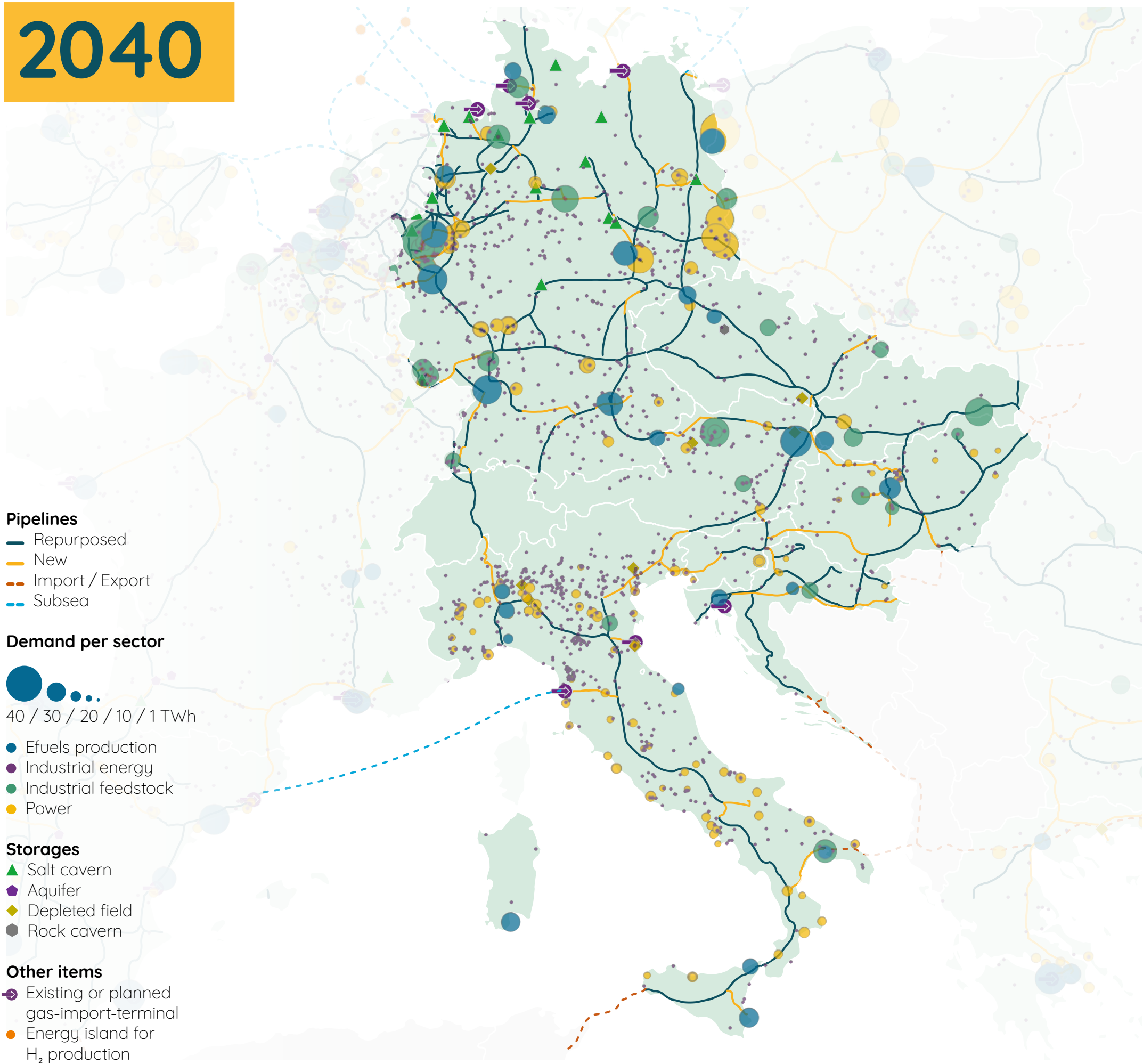


Hydrogen Infrastructure

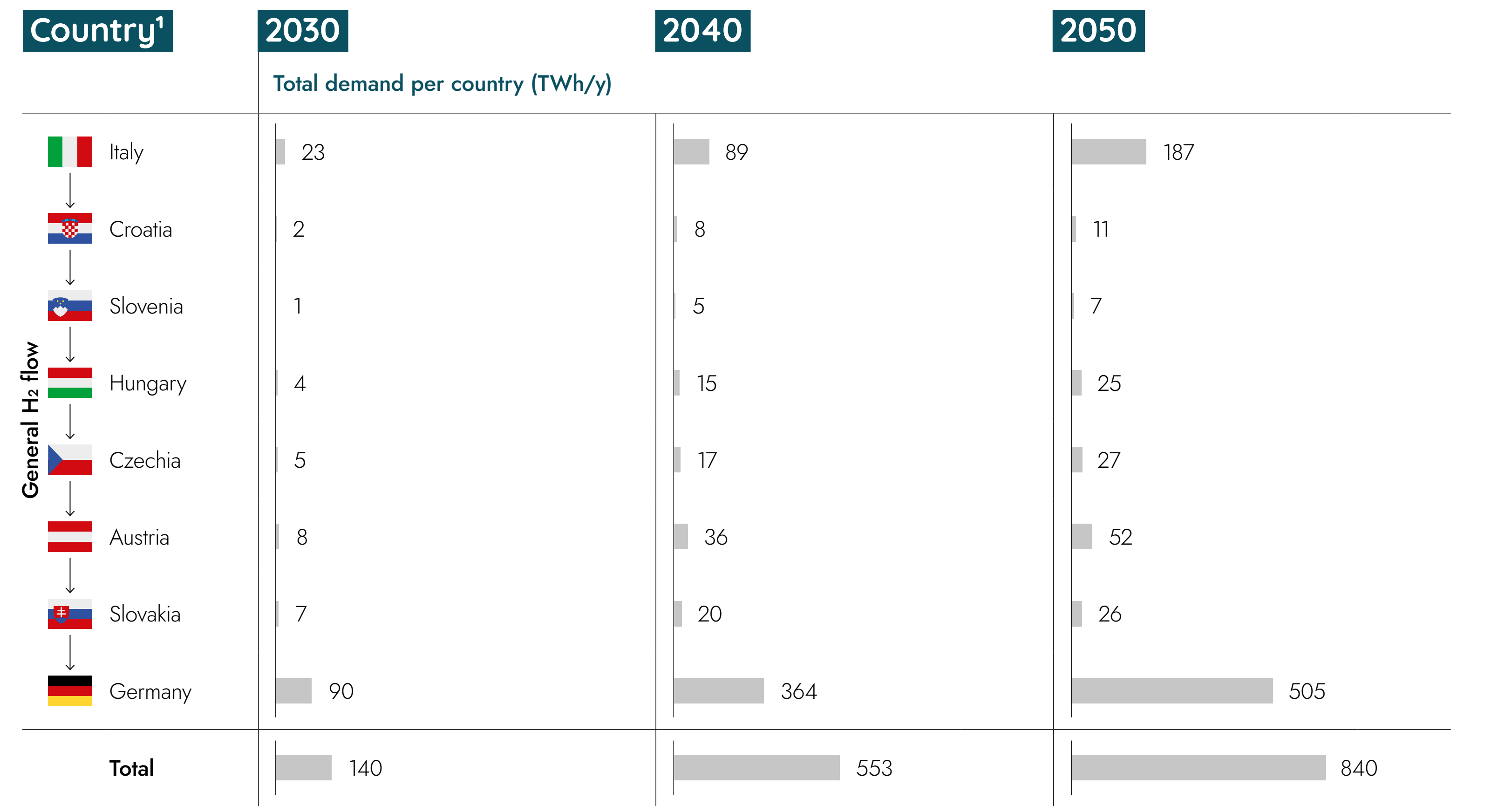
By 2030, the buildout of **pipeline infrastructure** across all countries of the corridor reaches **11,000 km** of large-scale pipelines. Corridor benefits from a **very large share of repurposed infrastructure**.



Corridor connects major hydrogen clusters across Italy and Central Europe by 2030, expanding to all demand centers by 2040



Hydrogen demand increases rapidly from 2030 to 2040, largely driven by Germany and Italy. Demand continues increasing to 2050



Hydrogen demand – across all countries of the corridor – increases significantly from 2030 to 2050. Demand reaches 140 TWh by 2030, increasing to 840 TWh by 2050.

Hydrogen demand may accelerate and increase further as a result of additional regulatory measures adopted in response to the RePowerEU plan.

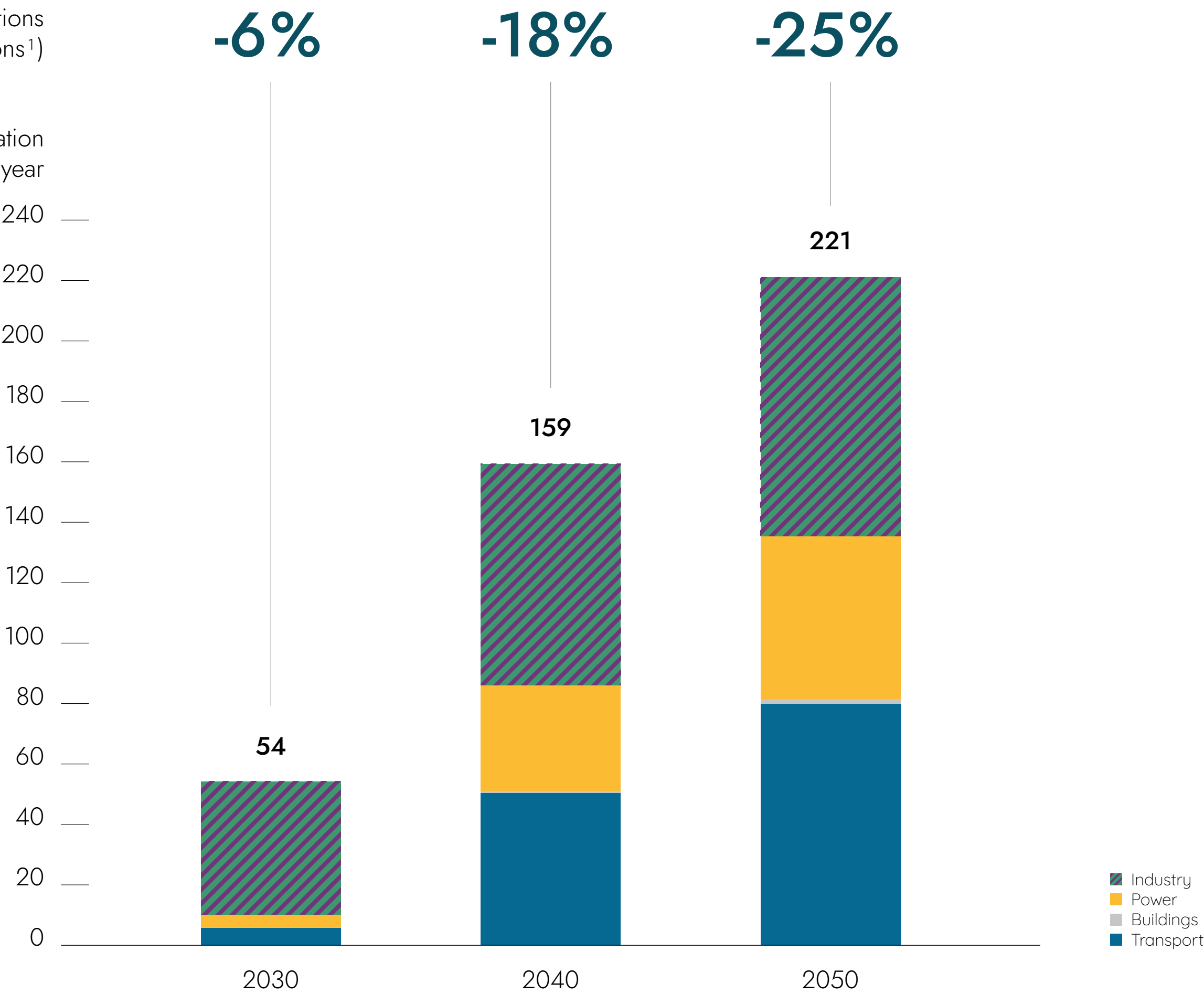
- Up to 2030, most hydrogen demand is driven by the industrial sector in Germany and Italy, along with some use of hydrogen in transport and power generation.
- From 2040 to 2050, hydrogen demand expands into the transport sector and continues to ramp up in industry and power generation.

¹ Switzerland is not included in the demand figures because as a non-EU member, Switzerland is not included in the datasets used to estimate hydrogen demand in 2030, 2040 and 2050.
Note: Does not include grey hydrogen demand. Numbers represent total demand by country, even if only parts of the country are included in the corridor.

Hydrogen adoption enables a reduction in emissions of 25% by 2050 across all countries of the corridor

Emissions reductions (vs. 2019 emissions¹)

Decarbonisation in MtCO₂ / year



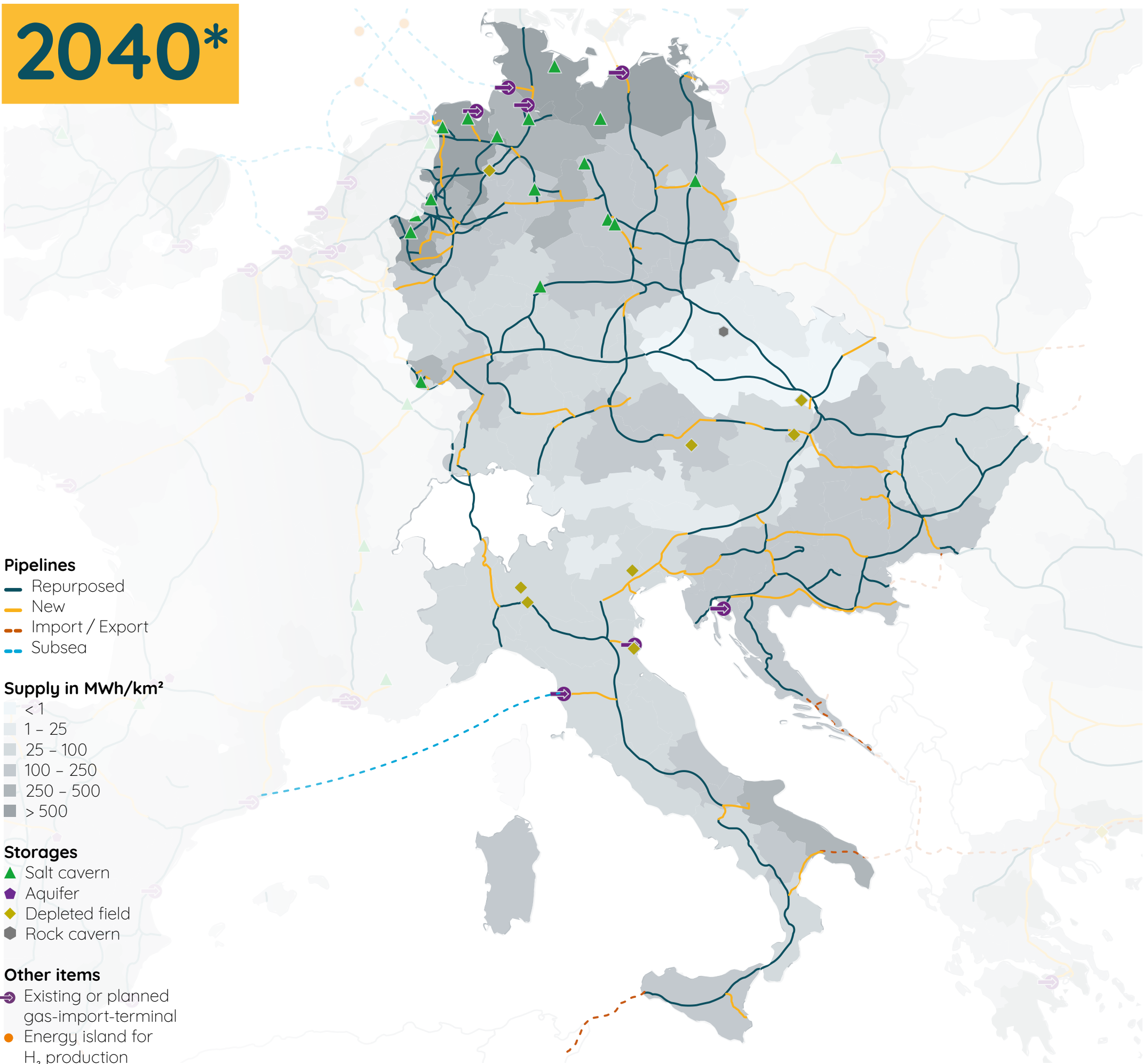
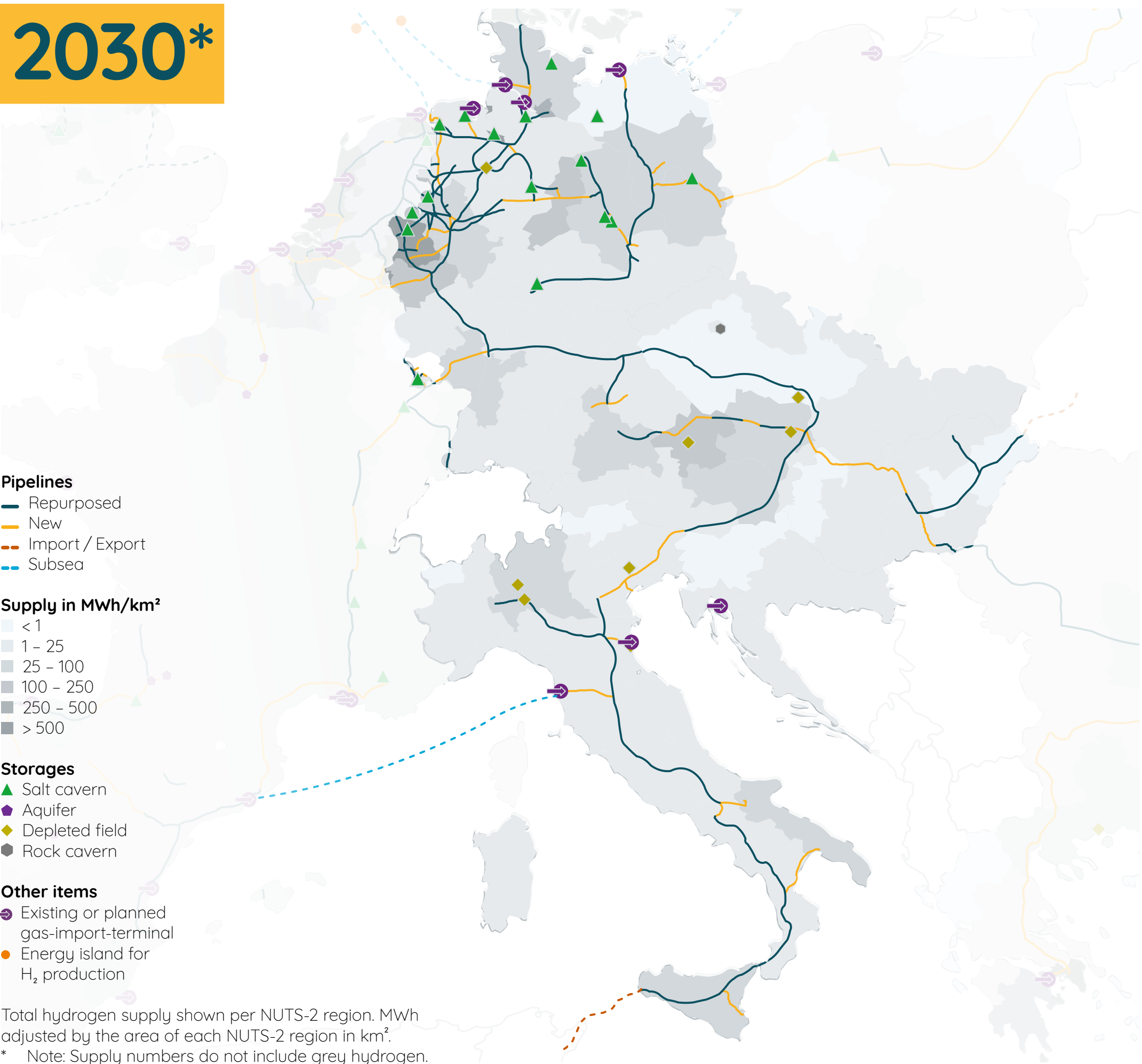
Hydrogen adoption across all demand sectors enables an **emission reduction of ~220 MtCO₂/yr. by 2050**, equivalent to a **25% reduction²**.

- **Up to 2030**, the decarbonisation of industry – largely the steel sector and refining – contributes 75% of the total emissions reductions.
- **By 2040**, emissions reductions from power generation and transport (road, shipping and aviation) increase substantially and combined account for 50% of emissions reductions.
- **By 2050**, most incremental emissions reductions are associated with hydrogen adoption in the power and transport sectors.

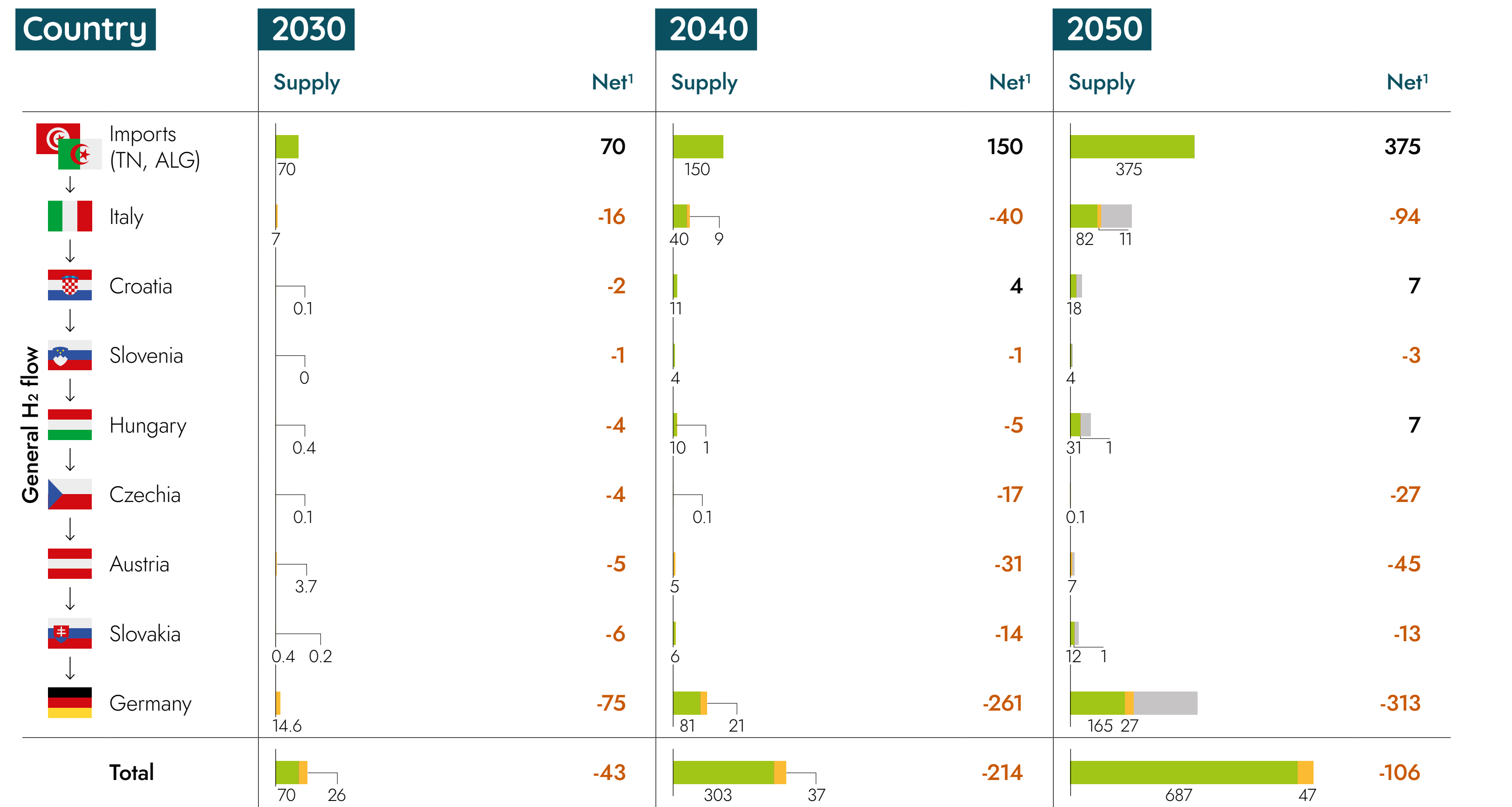
¹ CO₂-Emissions from countries and sectors included in corridor (0.89 bn t CO₂ / year). Source: EEA

² Emissions reductions are calculated compared to the baseline fossil fuel used in each sectors. For example, emissions reductions associated with the adoption of hydrogen by the primary steel sector are relative to the use of coal. Similarly, emissions reductions, for e-fuels production are relative to the use of fossil fuels in domestic transport, shipping and other uses.

Corridor enables access to supply from Italy and Tunisia by 2030,
expanding to supply from Central and South-Central Europe by 2040



Hydrogen supply increases significantly from 2030 to 2040, largely driven by green hydrogen supply from North Africa and Italy



Hydrogen supply includes a mix of supply options including **grid-based green hydrogen²** and **dedicated green hydrogen**.

- By 2030, hydrogen supply reaches ~100 TWh, largely from grid-based hydrogen.
- By 2040, hydrogen supply increases substantially to ~340 TWh, of which 90% is from dedicated green hydrogen. The remaining share is grid-based hydrogen.
- By 2050, hydrogen supply increases further to ~730 TWh. Dedicated green supply continues to account for the largest share at roughly 95%.

Hydrogen supply may accelerate and increase further as a result of additional regulatory measures adopted in response to the RePowerEU plan.

1 Net represents excess supply after subtracting demand;

2 Grid-based is estimated using national 2030 electrolyser targets which, by 2030, are assumed to be largely grid-connected rather than dedicated. Grid-based increases over 2030-2050 with increasing RES adoption;

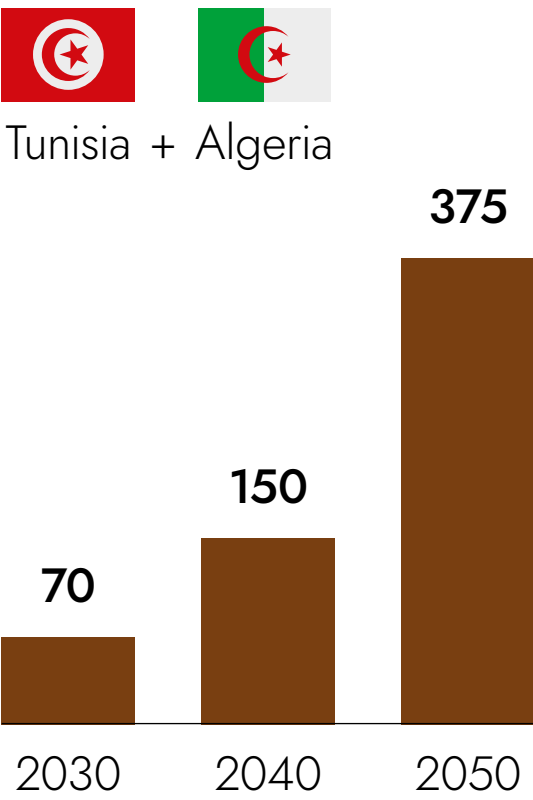
3 Switzerland is not included in the demand figures because as a non-EU member, Switzerland is not included in the datasets used to estimate hydrogen demand in 2030, 2040 and 2050.

Note: Hydrogen supply volumes do not include hydrogen imports by ship.

Tunisia and Algeria may become a potential sources of hydrogen imports to Europe as early as 2030

State of Gas Infra-structure	<ul style="list-style-type: none">North Africa connects to Italy via Tunisia with one interconnector: the Enrico Mattei – Transmed pipeline via Sicily (525km, 30 bcm/year)Two existing Algerian LNG export terminals: Arzew/Bethouia (20.8 mln tonne per year) and Skikda (7.7mln tonnes per year)Hydrogen export potential via this corridor focuses primarily on hydrogen supply from Tunisia and Algeria via the Transmed pipeline.
Market Attractive-ness	<ul style="list-style-type: none">Abundant renewable energy potential particularly solar PV and onshore windPartnerships: Germany has established partnerships with both Tunisia and Algeria exploring the potential of green hydrogen exportsMarket developments:<ul style="list-style-type: none">Tunisia is taking part in the HyDeal project, which could see 1.4Mt/year produced in the country and an investment of over 20bn €.Availability of Algerian hydrogen exports to Europe highly depends on repurposing natural gas pipelines between Algeria and Tunisia.
Market Barriers	<ul style="list-style-type: none">Limited renewable energy infrastructure, low renewables penetration in own energy system and strong reliance on hydrocarbons todayInadequate financing mechanisms on a state and local level for renewable projectsFuture growth in domestic hydrogen demand may impose limit on exports.

Hydrogen supply potential (TWh)¹



¹ Supply figures estimated based on hydrogen supply potential combined for Tunisia and Algeria. Export potential is dependent on development of demand and infrastructure.

Note: The high potential import from Algeria and Tunisia depends on development of both demand and infrastructure

North Africa & Southern Europe

Agenda

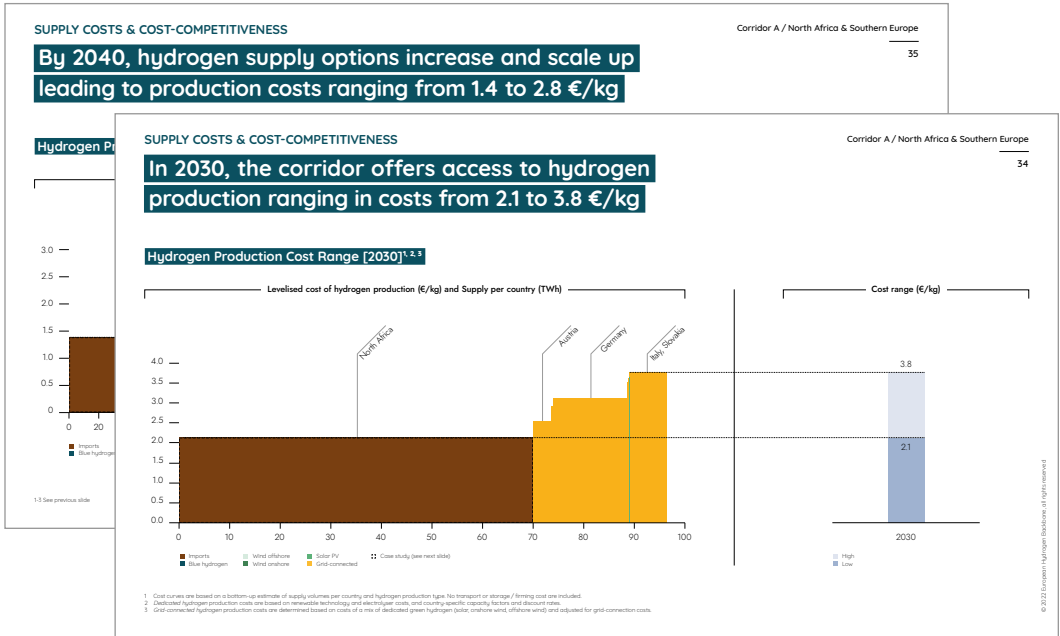
1. Corridor Summary
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4. National Strategies & Regulation
5. Actions Needed

This section explores the costs of hydrogen production and delivery for this corridor and their competitiveness with fossil fuels

Hydrogen production cost

Key Questions Answered

What is the range of production costs achieved by the corridor in 2030 and 2040?

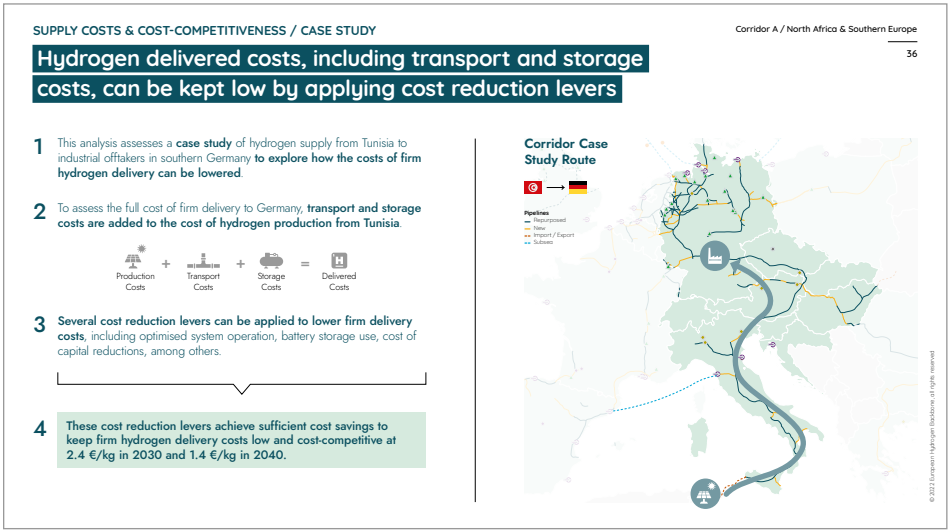


- By 2030, the corridor provides access to hydrogen production costs of **2.1 to 3.8 € / kg**.
- By 2040, hydrogen production costs decrease to the range of **1.4 to 2.8 € / kg**.

Hydrogen delivered costs

Based on a case-study of hydrogen supply from Tunisia to Germany:

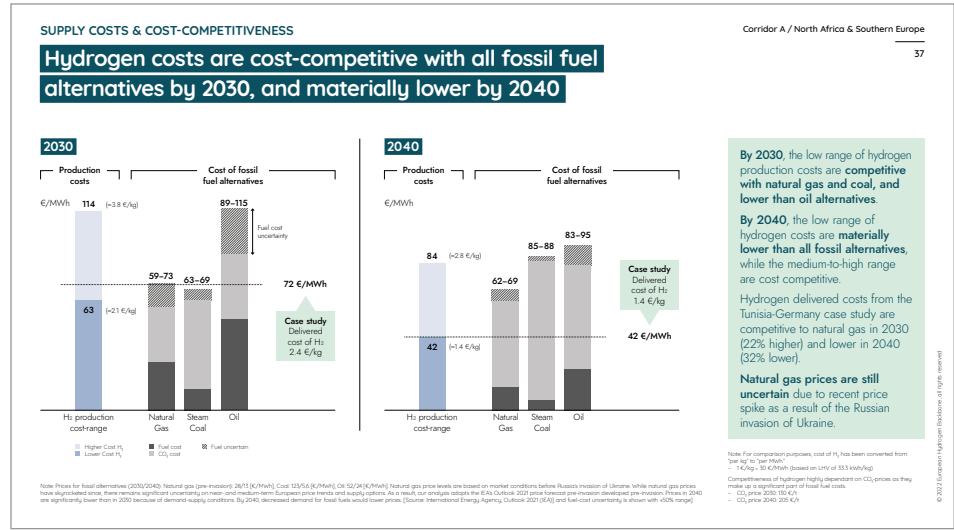
- What are the **full costs of firm hydrogen delivery** after accounting for **transport** and **storage** costs?
- What **cost levers** are available to lower the cost of hydrogen delivery?



- Several **cost reduction levers** can be applied to **lower the costs of hydrogen delivery**.
- For the Tunisia-to-Germany case study, **these levers achieve delivery costs that are low and cost-competitive**.

Comparison with fossil alternatives

How **competitive** is hydrogen supply from this corridor compared to fossil fuel alternatives?



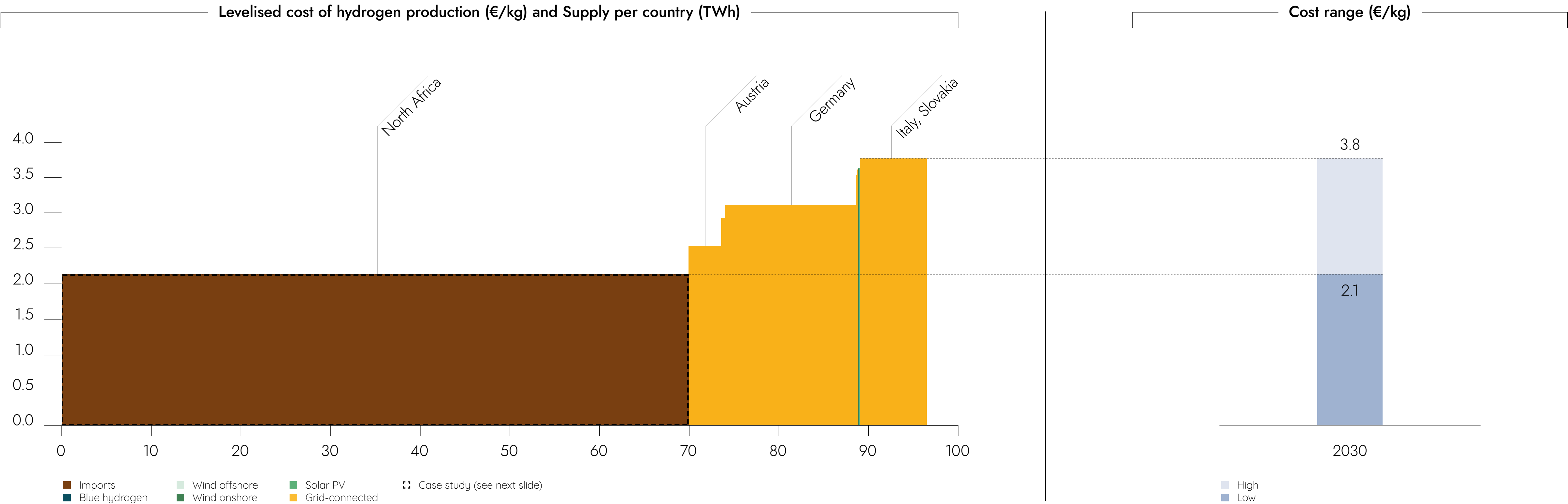
- Hydrogen costs are competitive with fossil fuel alternatives by 2030**, and lower by 2040.
- Fossil fuel costs are subject to **significant uncertainty**.

Content Material

Key Findings & Results

In 2030, the corridor offers access to hydrogen production ranging in costs from 2.1 to 3.8 €/kg

Hydrogen Production Cost Range [2030]^{1, 2, 3}



1 Cost curves are based on a bottom-up estimate of supply volumes per country and hydrogen production type. No transport or storage / firming cost are included.
2 Dedicated hydrogen production costs are based on renewable technology and electrolyser costs, and country-specific capacity factors and discount rates.
3 Grid-connected hydrogen production costs are determined based on costs of a mix of dedicated green hydrogen (solar, onshore wind, offshore wind) and adjusted for grid-connection costs.

By 2040, hydrogen supply options increase and scale up leading to production costs ranging from 1.4 to 2.8 €/kg

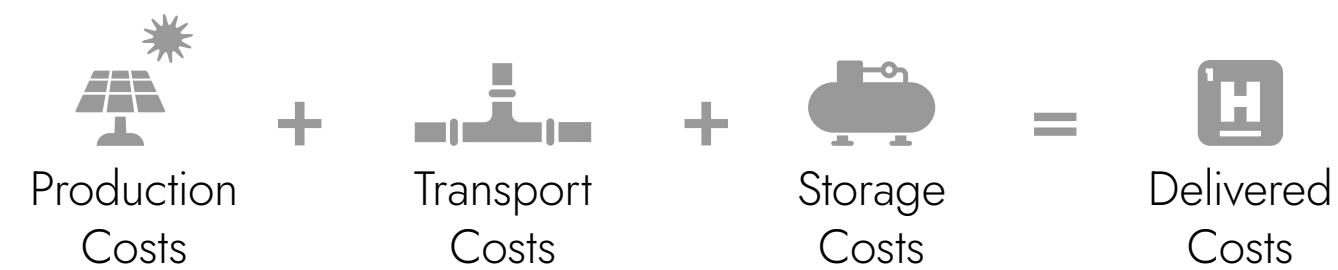
Hydrogen Production Cost Range [2040]^{1, 2, 3}



Hydrogen delivered costs, including transport and storage costs, can be kept low by applying cost reduction levers

1 This analysis assesses a **case study** of hydrogen supply from Tunisia to industrial off-takers in southern Germany **to explore how the costs of firm hydrogen delivery can be lowered.**

2 To assess the full cost of firm delivery to Germany, **transport and storage costs are added to the cost of hydrogen production from Tunisia.**



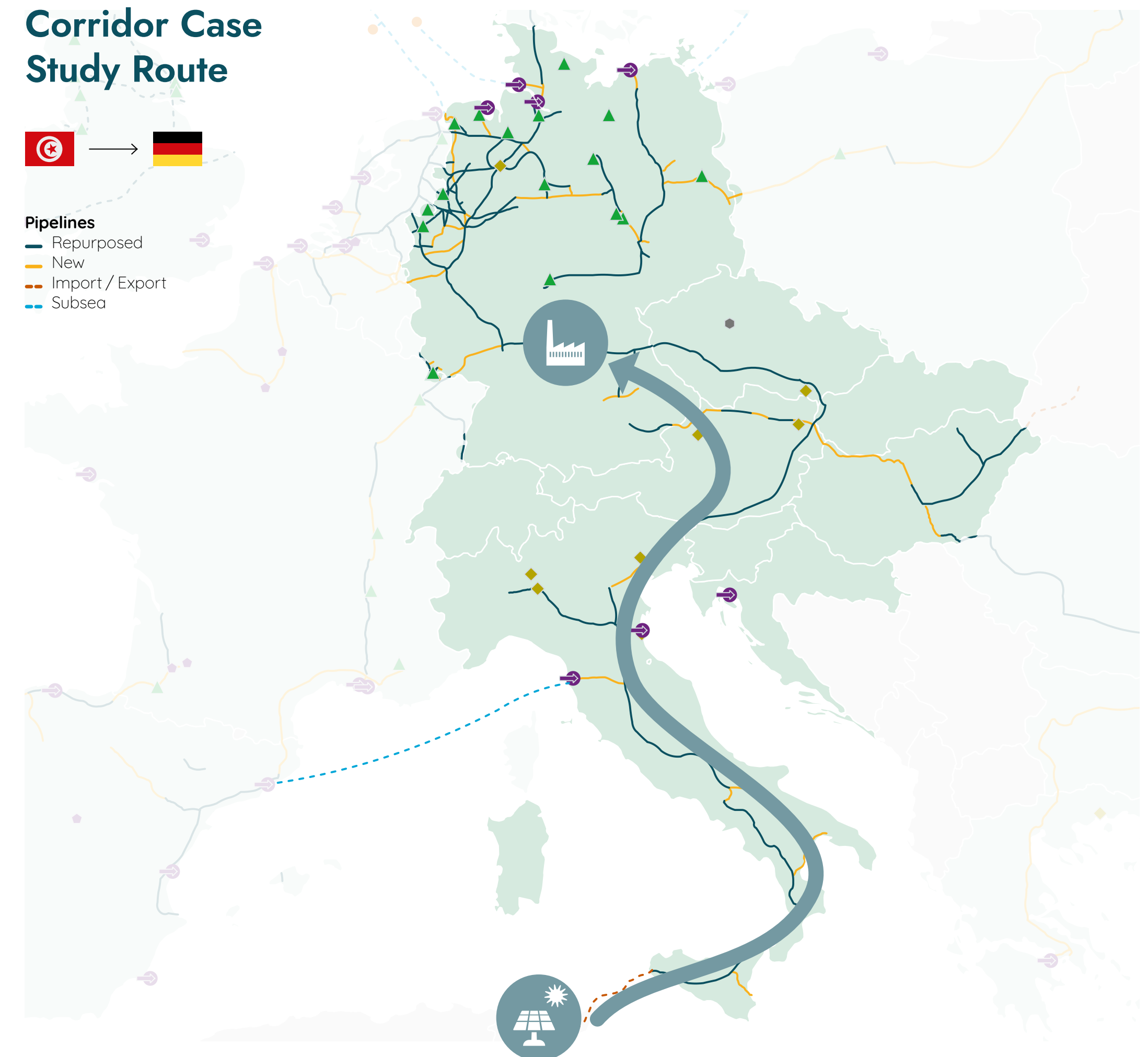
3 Several **cost reduction levers** can be applied to lower firm delivery **costs**, including optimised system operation, battery storage use, cost of capital reductions, among others.

4 These cost reduction levers achieve sufficient cost savings to keep firm hydrogen delivery costs low and cost-competitive at 2.4 €/kg in 2030 and 1.4 €/kg in 2040.

Corridor Case Study Route

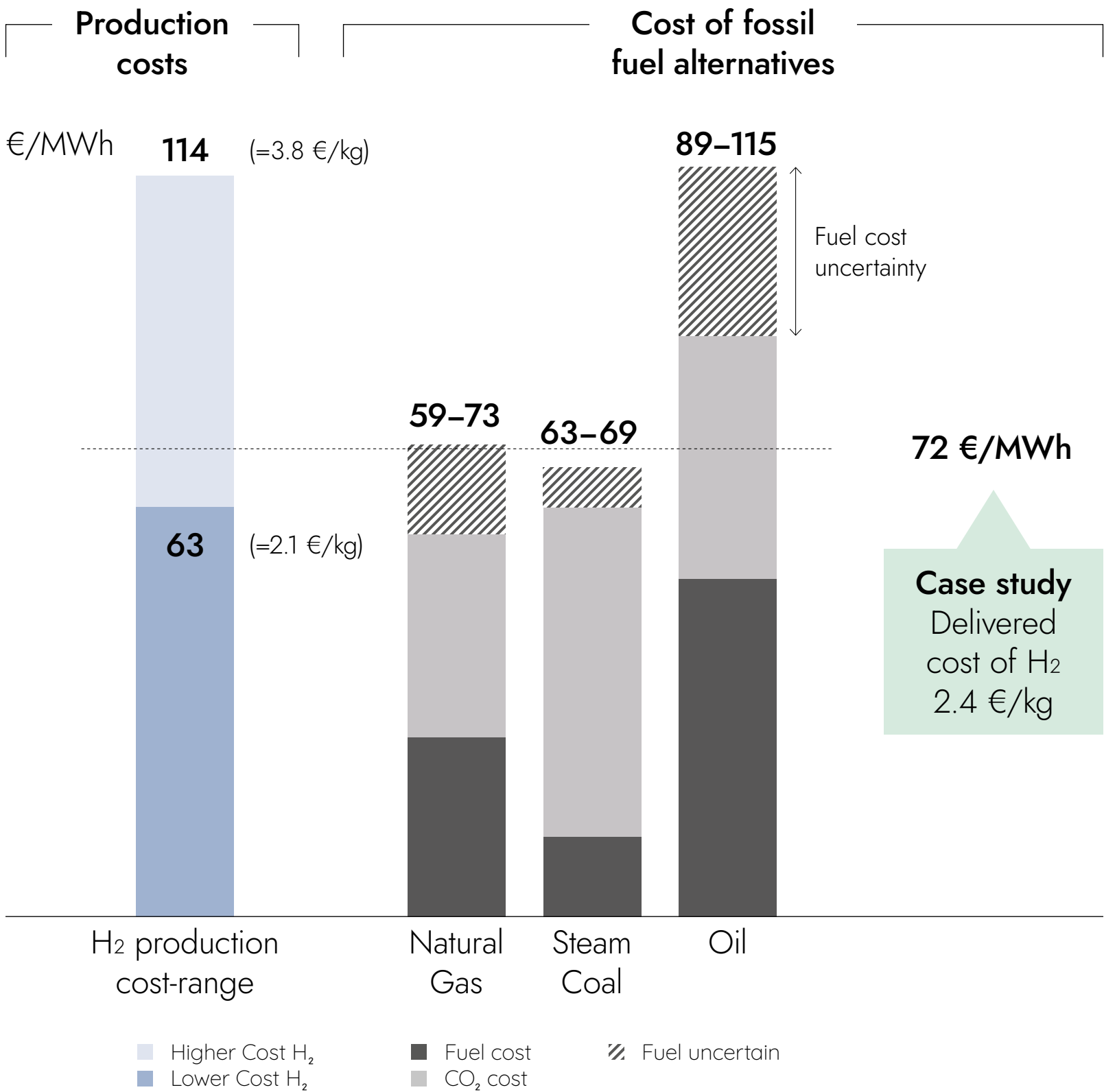


Pipelines
— Repurposed
— New
— Import / Export
— Subsea

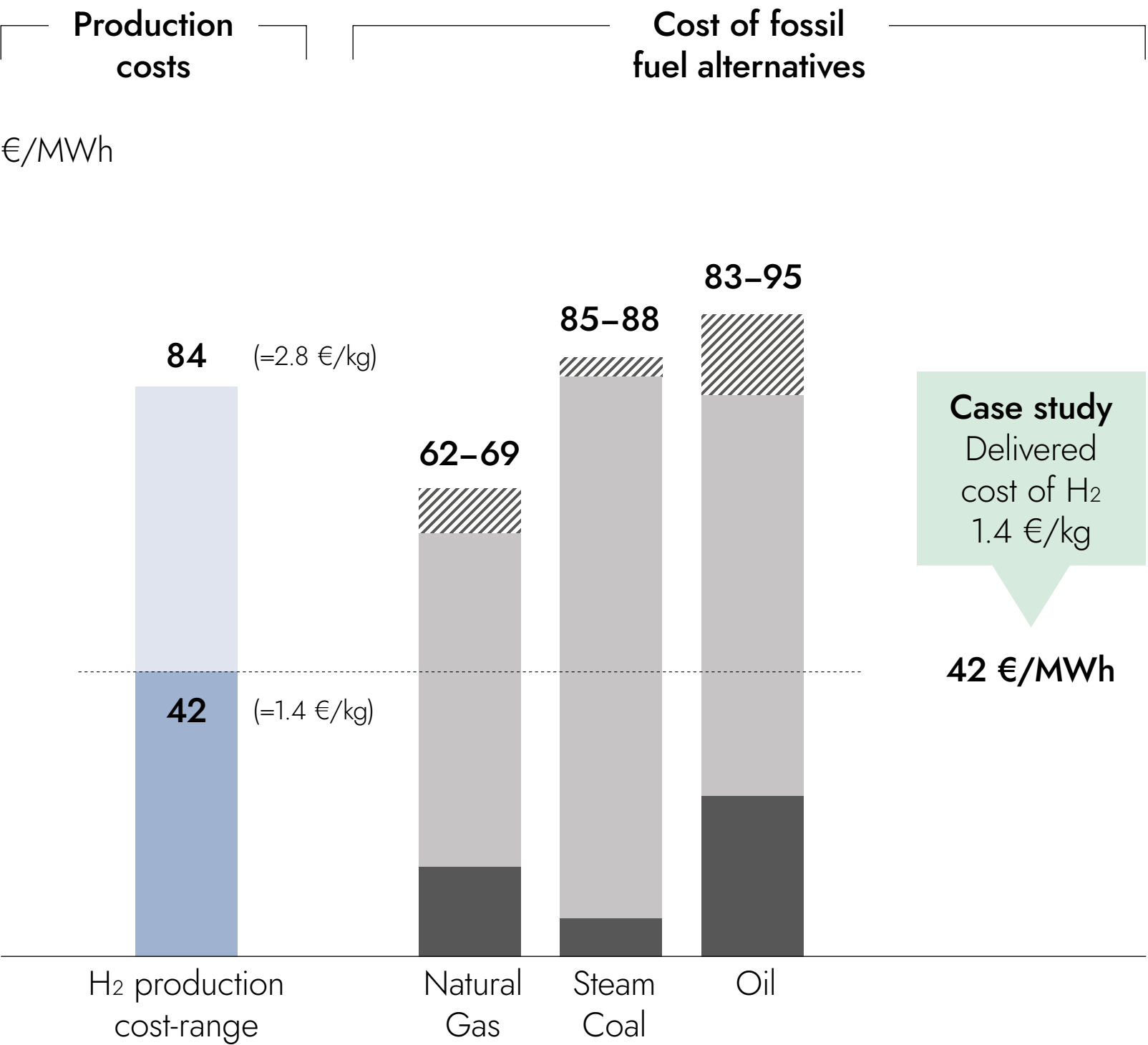


Hydrogen costs are cost-competitive with all fossil fuel alternatives by 2030, and materially lower by 2040

2030



2040



By 2030, the low range of hydrogen production costs are **competitive with natural gas and coal**, and **lower than oil alternatives**.

By 2040, the low range of hydrogen costs are **materially lower than all fossil alternatives**, while the medium-to-high range are cost competitive.

Hydrogen delivered costs from the Tunisia-Germany case study are competitive to natural gas in 2030 (22% higher) and lower in 2040 (32% lower).

Natural gas prices are still uncertain due to recent price spike as a result of the Russian invasion of Ukraine.

Note: Prices for fossil alternatives (2030/2040): Natural gas (pre-invasion): 28/13 [€/MWh], Coal: 123/5.6 [€/MWh], Oil: 52/24 [€/MWh]. Natural gas price levels are based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast pre-invasion developed pre-invasion. Prices in 2040 are significantly lower than in 2030 because of demand-supply conditions. By 2040, decreased demand for fossil fuels would lower prices. [Source: International Energy Agency, Outlook 2021 (IEA)] and fuel-cost uncertainty is shown with +50% range]

Note: For comparison purposes, cost of H₂ has been converted from "per kg" to "per MWh"
- 1 €/kg = 30 €/MWh (based on LHV of 33.3 kWh/kg)
Competitiveness of hydrogen highly dependant on CO₂-prices as they make up a significant part of fossil fuel costs.
- CO₂ price 2030: 130 €/t
- CO₂ price 2040: 205 €/t

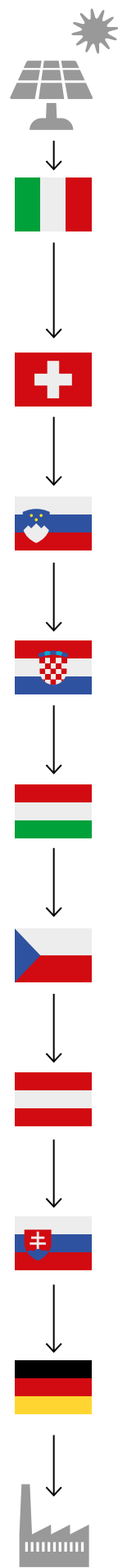
North Africa & Southern Europe

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1. Corridor Summary
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Most countries have developed, or are developing, national strategies. Moving forward, the development of regulation is key to enable infrastructure investment.

Pre-
RePowerEU
targets²



	National Hydrogen strategy (NHS)	Network regulation & policy	Funding ¹ (bn €)	Highlights
Italy	<ul style="list-style-type: none">NHS preliminary. 2% H2 share at final energy 2030 (20% in 2050) in transport, industry, refineries, blen.5 GW electrolyser installed until 2030Hydrogen valleys / industrial clusters	<ul style="list-style-type: none">Public consultation process in relation to pilot projects to optimise the innovative uses of existing natural gas transmission and distribution networks	<div><div></div>5.0</div>	<ul style="list-style-type: none">Focus on transport sector and hydrogen valleys for demand (industry) and productionFunding mainly to increase production of H299% of infrastructure is ready to transport H2
Switzerland	<ul style="list-style-type: none">The parliament currently developing national strategyExplicitly mentioned import strategy for H2	<ul style="list-style-type: none">N/A		<ul style="list-style-type: none">Hydrogen strategy is being developedEnergy plan: Industry & heavy duty transport
Slovenia	<ul style="list-style-type: none">In NECP is set indicative target to have 10 % of renewable methane or hydrogen in the network (2030)	<ul style="list-style-type: none">TSO is obliged to prepare the plan for acceptance of H2		<ul style="list-style-type: none">Foreseen demand sectors: Transport (2030), followed by industry & buildings (NECP)
Croatia	<ul style="list-style-type: none">Foresees demand in industry, buildings, transport and power, with a supply potential of 1.3 GW electrolysers	<ul style="list-style-type: none">N/A		<ul style="list-style-type: none">First production site by 2025
Hungary	<ul style="list-style-type: none">Production of 36k tons/a (incl. low carbon H2)240 MW of electrolyser capacityUse to decarbonize industry and transport	<ul style="list-style-type: none">Min. 2% volume blending to natural gas grid	<div><div></div>0.1</div>	<ul style="list-style-type: none">H2 infrastructure in focus. Funding for storage is available and blending to natural gas grid is envisioned
Czech Republic	<ul style="list-style-type: none">Focus Transport, then energy & chemical industryGreen H2 productionImport and transit country for H2	<ul style="list-style-type: none">N/A		<ul style="list-style-type: none">H2-Readiness of gas transmission system is urged, due to potential focal role in H2 transport (south to north and east to west)
Austria	<ul style="list-style-type: none">NHS is still in discussion; known elements are: 1 – 2 GW electrolyser capacity (2030), use in industry	<ul style="list-style-type: none">H2 mixtures of up to 10 % within Austria and 4-5 % on entry/exit points are allowed	<div><div></div>0.5</div>	<ul style="list-style-type: none">Production of green H2 is subsidisedPreferred use to decarbonise industryFocus: Transport sector and underground H2 storage
Slovakia	<ul style="list-style-type: none">H2 used in the chemicals, petrochemicals, steel and heating industries as well as in transport	<ul style="list-style-type: none">N/A		<ul style="list-style-type: none">Use H2 in industries/areas impossible or not cost-effective to directly use electricity
Germany	<ul style="list-style-type: none">National production & import focus due to supply gapIn place since 2020, currently reviewed towards increasing its ambition10 GW (2030) electrolyser in coalition plans	<ul style="list-style-type: none">H2 network potentially opt-in regulated and vertically unbundledFirst rules and standards for high pressure pipelines are formulated	<div><div></div>9</div>	<ul style="list-style-type: none">Strong focus on international cooperation to ensure sufficient supplyNational funding

Note: Sequencing of countries follows the general corridor direction but does not represent the hydrogen flows.
1 Cumulative public funding amount by the respective state until 2030
2 Strategies and funding is under evaluation of meeting latest targets



North Africa & Southern Europe

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This corridor plays a fundamental role in achieving a European backbone by 2040

The need for this corridor

- The development of **this corridor ensures access to abundant, low-cost hydrogen supply from Italy and Tunisia** by 2030, and by 2040 additional supply from Algeria (via Tunisia) and from Central and South-Central Europe.
- The **decarbonisation of the largest hydrogen demand centers along this corridor** — in **Italy, Central Europe and Germany** — is dependent on the buildout of this corridor by 2030, and its expansion towards 2040.

Actions required

- The buildout of this corridor by 2030 **requires national governments to take clear and concrete actions across**.
- This includes actions associated with **infrastructure development and planning, the development of cross-national initiatives** and **securing access to early funding and long-term, low-cost financing**.

2040

Pipelines

- Repurposed
- New
- Import / Export
- Subsea

Demand per sector

- 40 / 30 / 20 / 10 / 1 TWh
- Efuels production
 - Industrial energy
 - Industrial feedstock
 - Power

Supply in MWh/km²

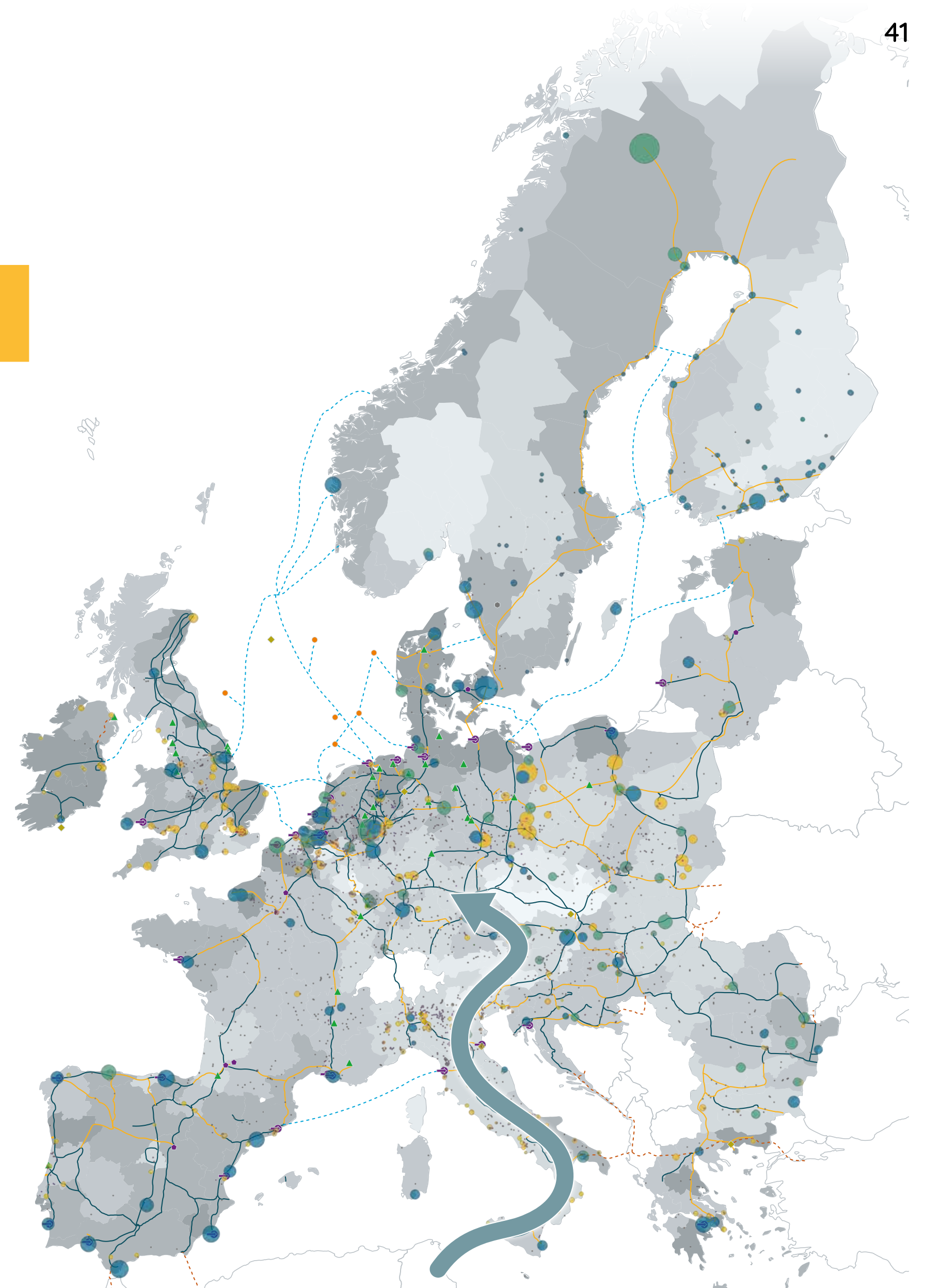
- < 1
- 1 – 25
- 25 – 100
- 100 – 250
- 250 – 500
- > 500

Storages

- ▲ Salt cavern
- ▲ Aquifer
- ▲ Depleted field
- ▲ Rock cavern

Other items

- Existing or planned gas-import-terminal
- Energy island for H₂ production



**To ensure the development of this corridor by 2030,
there is a need for clear and concrete actions**

Fostering development of new and repurposed hydrogen infrastructure, for example, by unbundling rules facilitating the efficient use of TSO expertise and services and by allowing the adoption of different vertical unbundling models in the EU, as is the case with natural gas

+

Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions (including incentivizing the adoption of hydrogen by demand sectors)

+

Simplify and shorten planning and permitting procedures for renewable energy and hydrogen infrastructure projects.

+

Intensify energy partnerships with exporting, non-EHB countries like Algeria and Tunisia, and providing financing support to reduce their cost of capital

+

Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure supporting the accelerated deployment and integration of renewable energy resources

→ However, speed will be of essence!

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Corridor B: Southwest Europe & North Africa

Corridor C: North Sea

Corridor D: Nordic and Baltic regions

Corridor E: East and South-East Europe

3. Detailed methodology

Southwest Europe & North Africa

Agenda


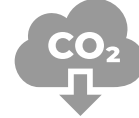


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Southwest Europe
& North Africa

- Portugal
- Spain
- France
- Belgium
- Luxembourg
- Germany



Corridor emerges in Southwest Europe providing access to low-cost hydrogen supply from the Iberian peninsula, and potentially Morocco.

<div>Drivers & Opportunities</div>	Major driver of development is the need to meet hydrogen demand from industry, transport and power in the Iberian peninsula, France and Germany. Key opportunities include the development of a new Spain-France interconnector and underground storage in France , and access to imports from Morocco .																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
<div>Hydrogen Supply & Decarbonization Potential</div>	<div><div>H₂ supply potential¹</div><div>(TWh/year)</div><div></div><div><table><tr><td>164 TWh</td><td>569 TWh</td></tr><tr><td>2030</td><td>2040</td></tr></table></div></div>	164 TWh	569 TWh	2030	2040	<div><div>Emissions Reductions</div><div>(MtCO₂/year vs. 2019; % reduction)</div><div></div><div><table><tr><td>-73 Mt (7%)</td><td>-211 Mt (21%)</td></tr><tr><td>2030</td><td>2040</td></tr></table></div></div>	-73 Mt (7%)	-211 Mt (21%)	2030	2040																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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<div>Supply Costs & Cost-Competitiveness</div>	<div><div>Cost of H₂ production¹</div><div>(€/kg of H₂)</div><div></div><div><table><tr><td>2.0–3.8</td><td>1.4–2.7</td></tr><tr><td>2030</td><td>2040</td></tr></table></div></div>	2.0–3.8	1.4–2.7	2030	2040	<div><div>Cost competitiveness²</div><div>— Hydrogen delivered price vs.</div><div> natural gas price high/low, 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1 Figures reported reflect outputs for all countries included in the corridor. Even if a country is only partially in the corridor, results for the full country are included (e.g., supply potential and costs, demand, transmission network length).
2 Savings are based on the corridor's case study of hydrogen delivered in 2030 and 2040. The cost of natural gas includes CO₂ prices. Refer to Subsection 3 (Supply Costs & Cost-Competitiveness)

Southwest Europe & North Africa

Agenda

1. Corridor Summary
2. Hydrogen Demand & Supply
3. Supply Costs & Cost-Competitiveness
4. National Strategies & Regulation
5. Actions Needed

Corridor offers access to low-cost hydrogen supply from the Iberian peninsula to demand centers in France and Germany

Drivers & Opportunities

- The major driver behind the development of this corridor is the adoption of hydrogen associated with the **early decarbonisation of the industry, transport and power** in the Iberian Peninsula, France and Germany. The speed of hydrogen adoption in these regions will accelerate driven by increasing CO₂ prices in the EU and the RePowerEU ambitions to replace natural gas consumption.
- The corridor offers **access to low-cost, renewable production from the Iberian peninsula**, currently the source of Europe’s lowest renewable auction prices. In the longer term, this corridor may also provide **access to hydrogen imports from Morocco and potentially Algeria**.
- A major opportunity of the corridor is the **potential development of a new interconnection between Spain and France through** the East Pyrenees. The development of this interconnection would allow both countries to benefit from the complementary nature of **low-cost, high-volume Spanish and Portuguese hydrogen production and French underground storage sites** to help provide stable supply for off-takers in the region. This development of this new interconnection would in turn require **infrastructure reinforcements** along the corridor.
- A key longer-term opportunity is the **potential repurposing of the currently-underutilised, Maghreb-Europe subsea interconnector** to enable low-cost hydrogen supply from Morocco and Algeria.
- Recently, RePowerEU identified the development of a new subsea pipeline connecting Spain and Italy, expected to be available for hydrogen transport by 2030.
- The corridor would be stood up by 2030, covering **10,000 km** of large-scale hydrogen pipelines across all countries of the corridor, of which approximately **60% will be repurposed pipelines**.

Hydrogen Demand & Supply

- Total hydrogen demand in the corridor reaches **200 TWh by 2030**, increasing substantially to **~720 TWh by 2040**. Up to 2030, the major demand sector is industry, with hydrogen being used as feedstock and for energy needs. From 2040 onwards, most hydrogen demand is for e-fuels production and the power sector.
- Hydrogen adoption across all countries of the corridors enables an emissions reduction of c.300 MtCO₂/yr. by 2050, equivalent to a **29% emissions reduction**.
- The corridor enables access to **hydrogen supply potential of ~160 TWh by 2030, increasing to ~570 TWh by 2040**. Major sources of supply include green hydrogen from the Iberian Peninsula and France by 2030, with a potential role for Moroccan imports by 2040.

Key needs for action identified to successfully stand up the hydrogen supply corridor until 2030

Costs & Cost-Competitiveness

- By 2030, the corridor provides access to hydrogen production costs ranging from a production cost of **2.0 to 3.8 €/kg**. By 2040, as supply options increase and technology costs decrease, hydrogen production costs decrease to **1.4 to 2.7 €/kg**.
- In the long term, this corridor’s lowest-cost supply options are imports from Morocco and solar PV hydrogen from Spain and Portugal.
- Based on a case-study of hydrogen supply and transport from Spain to Germany, **the cost of delivered hydrogen** – inclusive of transport and firming costs – **can be lowered to achieve cost levels comparable to production costs**. Lowering delivery costs can be achieved through various cost levers including optimised operation of the system and cost of capital reductions.

National Strategies & Regulation

- **National hydrogen strategies** have been developed by all countries in the corridor, providing clear direction and supply targets.
- In select countries, **substantial funding has been allocated** to support the development of the hydrogen market including funding for gas network infrastructure.

Actions Needed

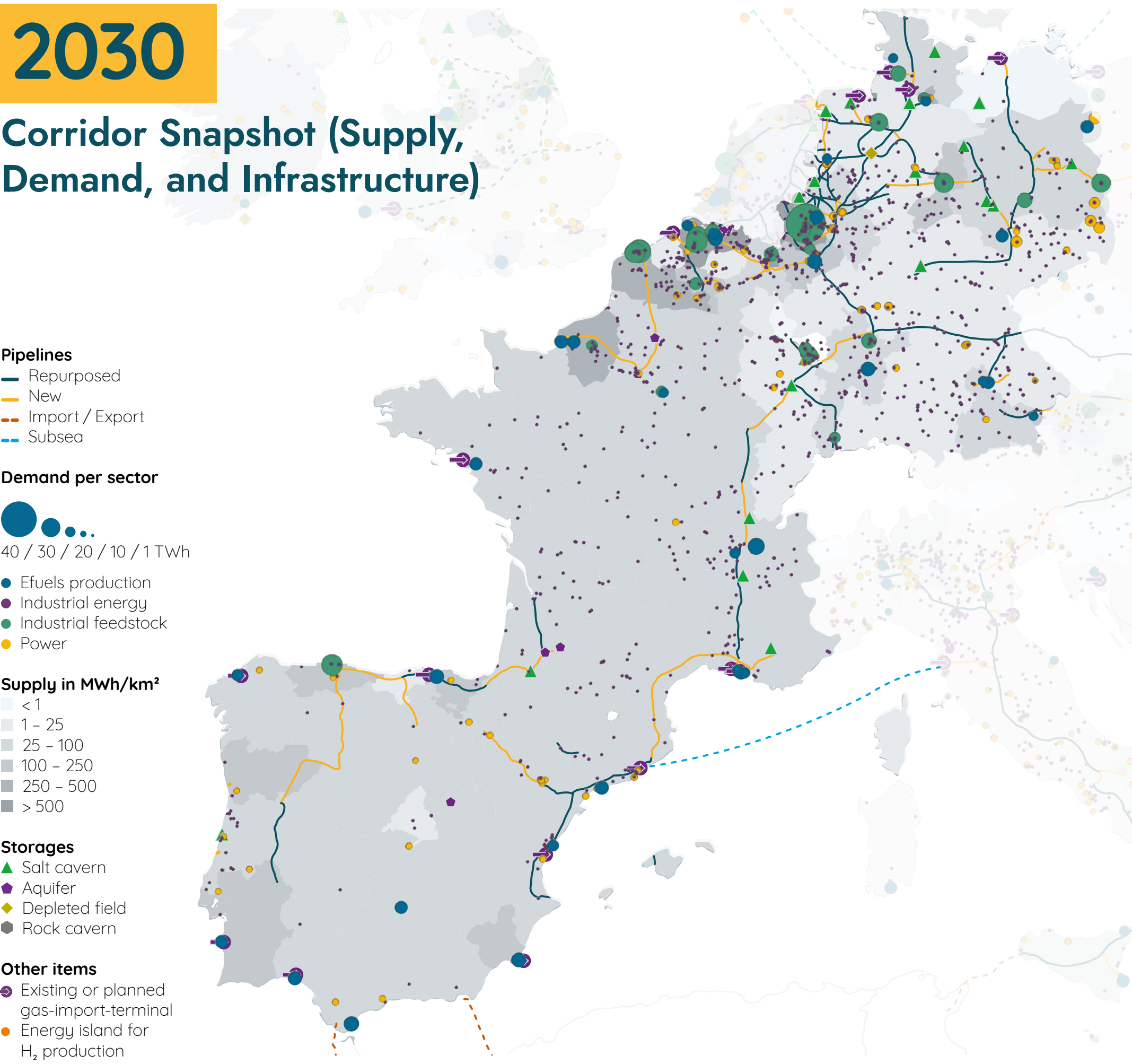
- Low-cost H₂ supply/demand, but for realization and build-out of this corridor until 2030, key needs for action has been identified:
- Fostering development of **new and repurposed hydrogen infrastructure**.
 - Unlock financing to **fast-track hydrogen infrastructure deployment** by applying regional regulatory flexibility and other pragmatic financing solutions.
 - Simplify and shorten **planning and permitting procedures** for the full value chain of renewable energies and hydrogen infrastructure projects.
 - Establish **integrated energy system planning** of hydrogen, natural gas, and electricity infrastructure.
 - **Intensify energy partnerships** with exporting, non-EHB countries like Morocco and Algeria.

Southwest Europe & North Africa

Agenda

1. Corridor Summary
- 2. Hydrogen Demand & Supply**
3. Supply Costs & Cost-Competitiveness
4. National Strategies & Regulation
5. Actions Needed

This section explores the development of hydrogen demand, supply and transport infrastructure across the corridor



Hydrogen Demand

By 2030, the corridor connects **all major industrial clusters** from Spain to Germany. **From 2030 to 2040**, the corridor expands to **all demand centers along its route**, increasing demand from 200 to ~720 TWh.

Hydrogen supply

By 2030, the corridor enables access to low-cost supply from **parts of the Iberian peninsula**. By 2040, the corridor gains access to **supply from most of the peninsula and low-cost imports from Morocco**.

In 2030, hydrogen supply is **~160 TWh**, of which 65% of supply is from dedicated green hydrogen. Hydrogen supply increases significantly by 2040, reaching 570 TWh.

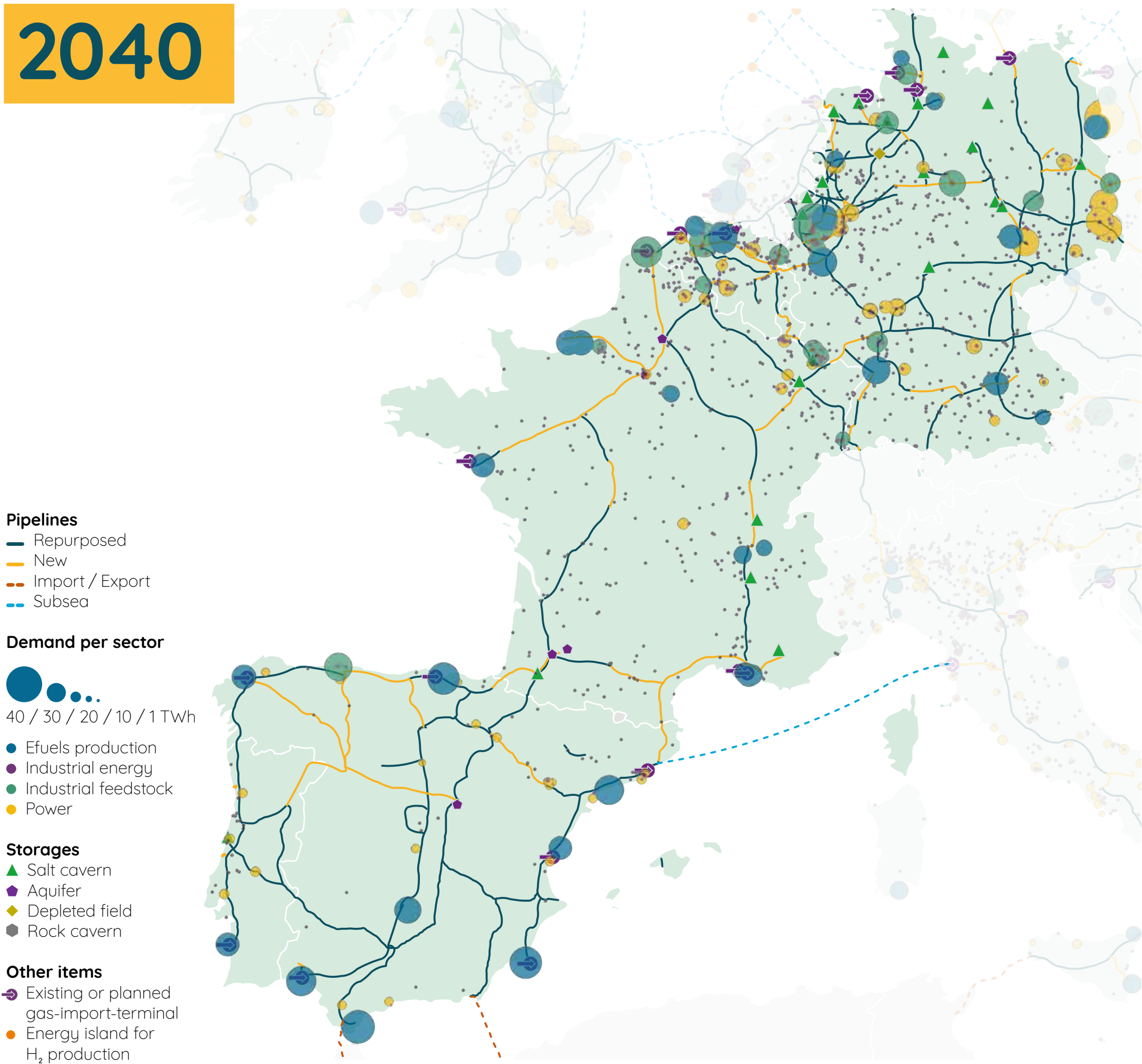
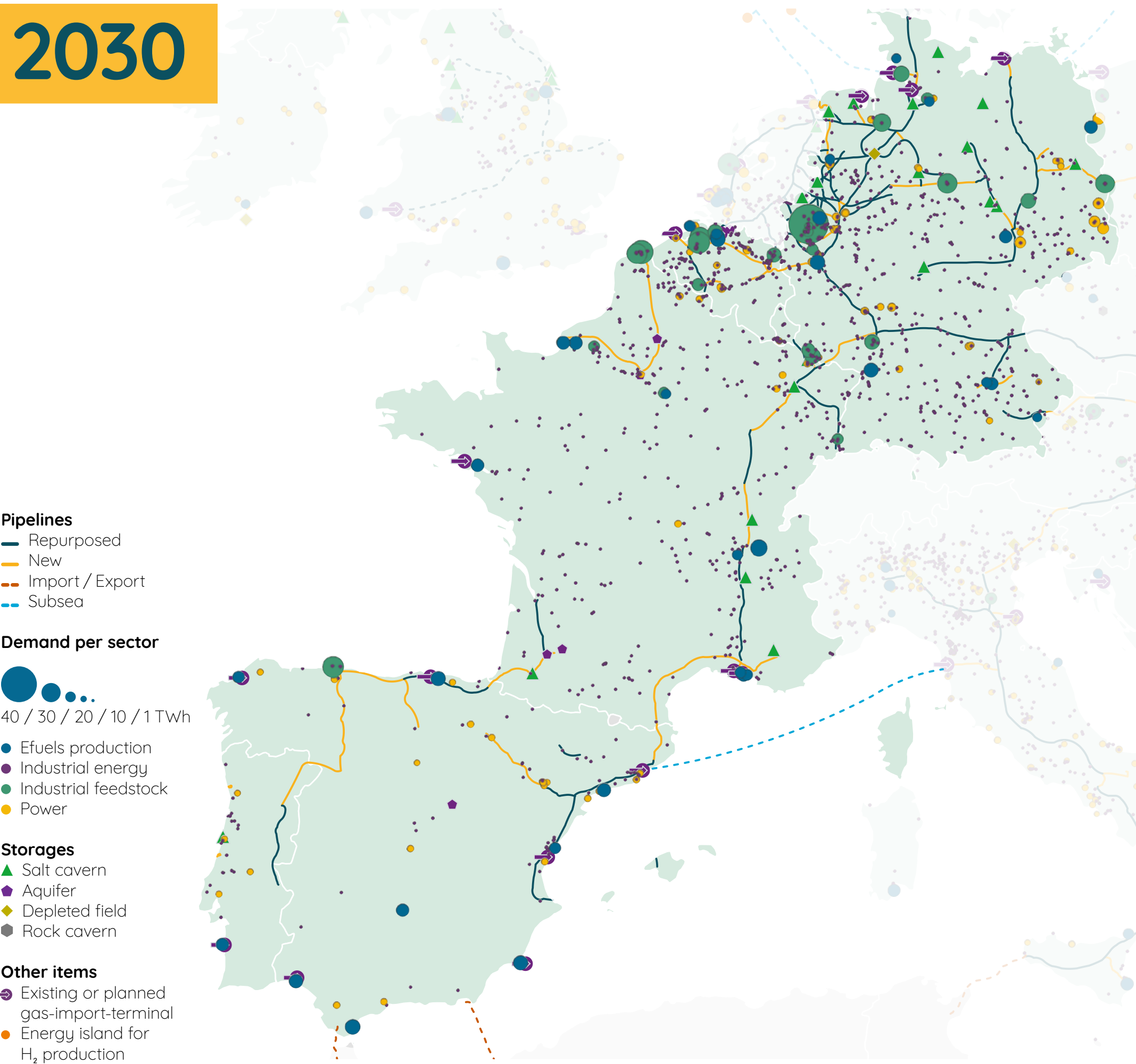


Hydrogen Infrastructure

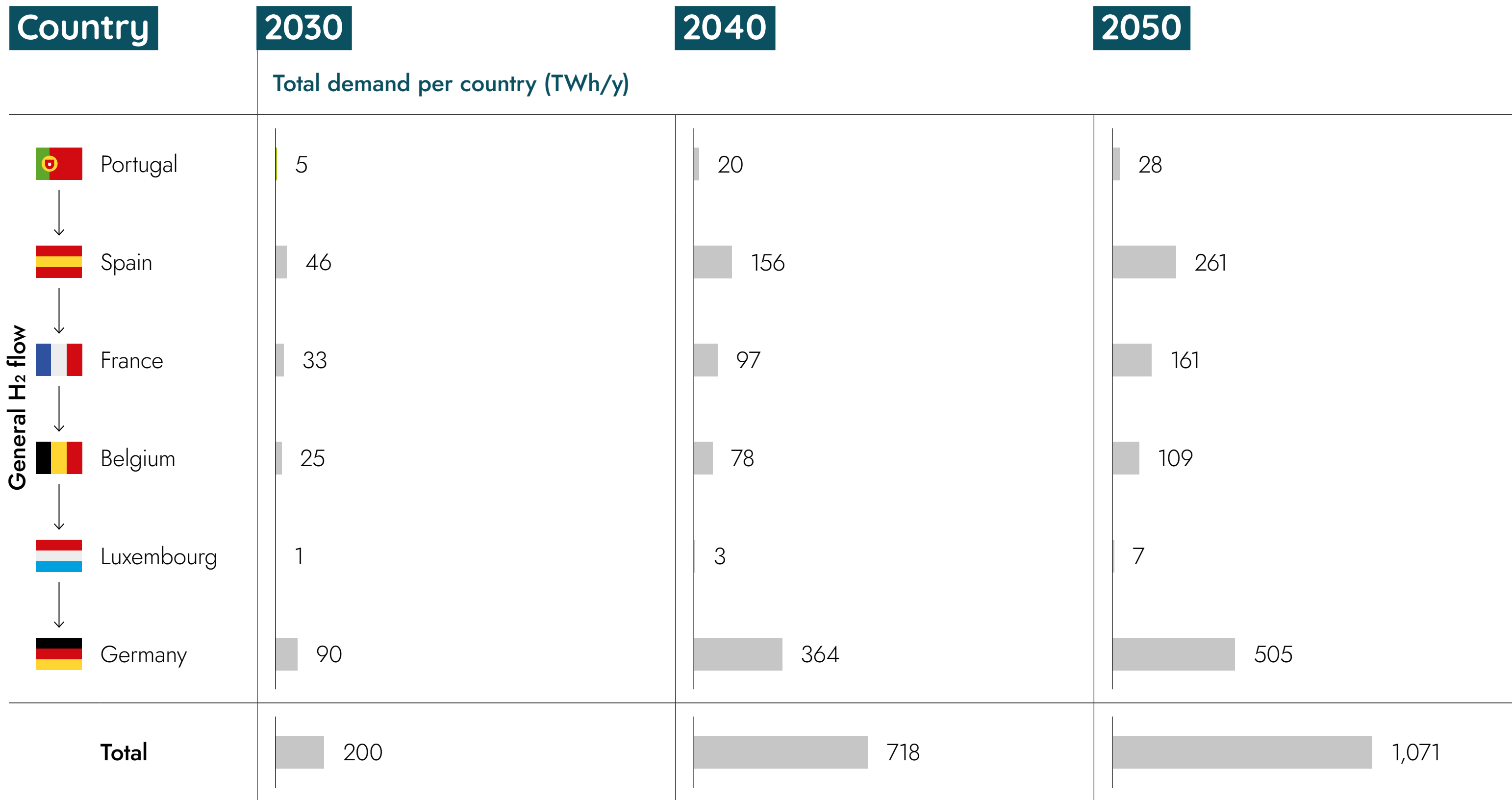
By 2030, the **buildout of pipeline infrastructure** across all countries of the corridor reaches **10,000 km** of large-scale pipelines. Corridor benefits from a **large share of repurposed infrastructure**.



Corridor connects substantial hydrogen demand by 2030,
expanding to all major demand centers by 2040



Hydrogen demand increases rapidly from 2030 to 2040, with most demand from Germany and Spain



Hydrogen demand – across all countries of the corridor – increases significantly from 2030 to 2050. Demand reaches 200 TWh by 2030, increasing to roughly 1,100 TWh by 2050.

Hydrogen demand may accelerate and increase further than forecasted as a result of additional regulatory measures adopted in response to the RePowerEU plan.

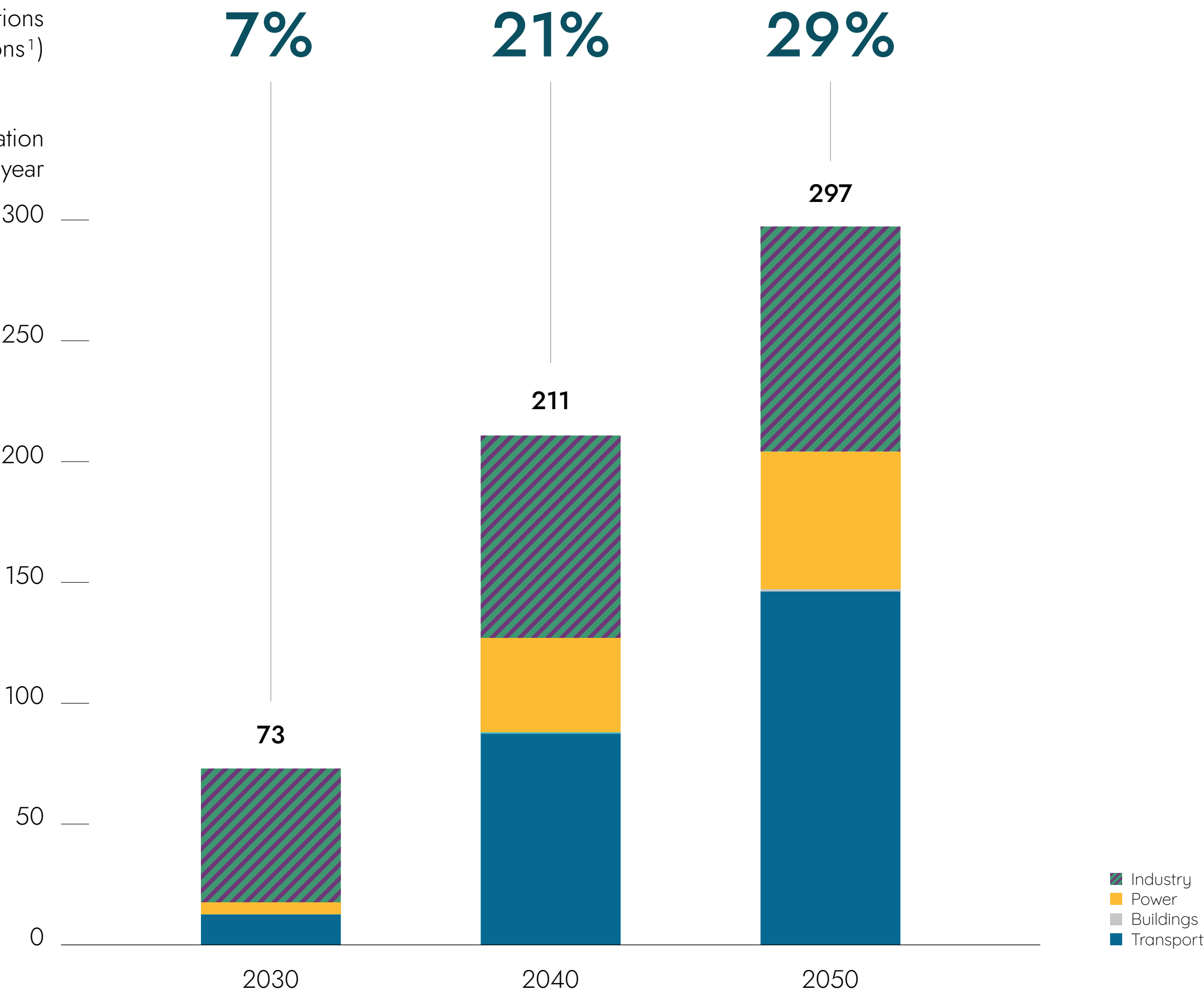
- Up to 2030, most hydrogen demand is driven by the industrial sector in Spain, France and Germany with hydrogen being used as feedstock and for energy needs.
- From 2040 to 2050, most new hydrogen demand is for e-fuels production and for power generation.

Note: Does not include grey hydrogen demand. Numbers represent total demand by country, even if only parts of the country are included in the corridor.

Hydrogen adoption in all countries of the corridor enables an emissions reduction of 29% by 2050

Emissions reductions
(vs. 2019 emissions¹)

Decarbonisation
in MtCO₂ / year



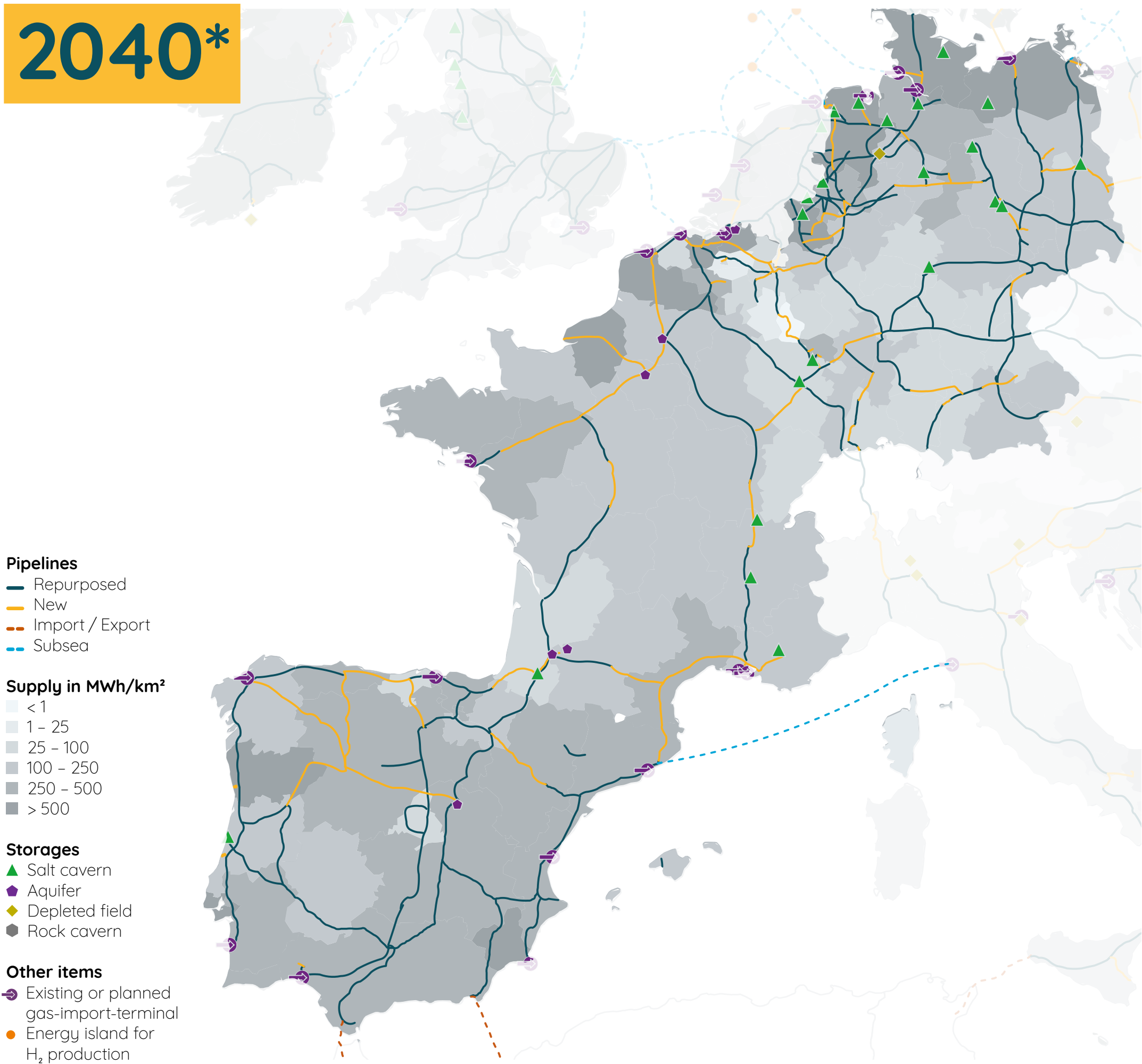
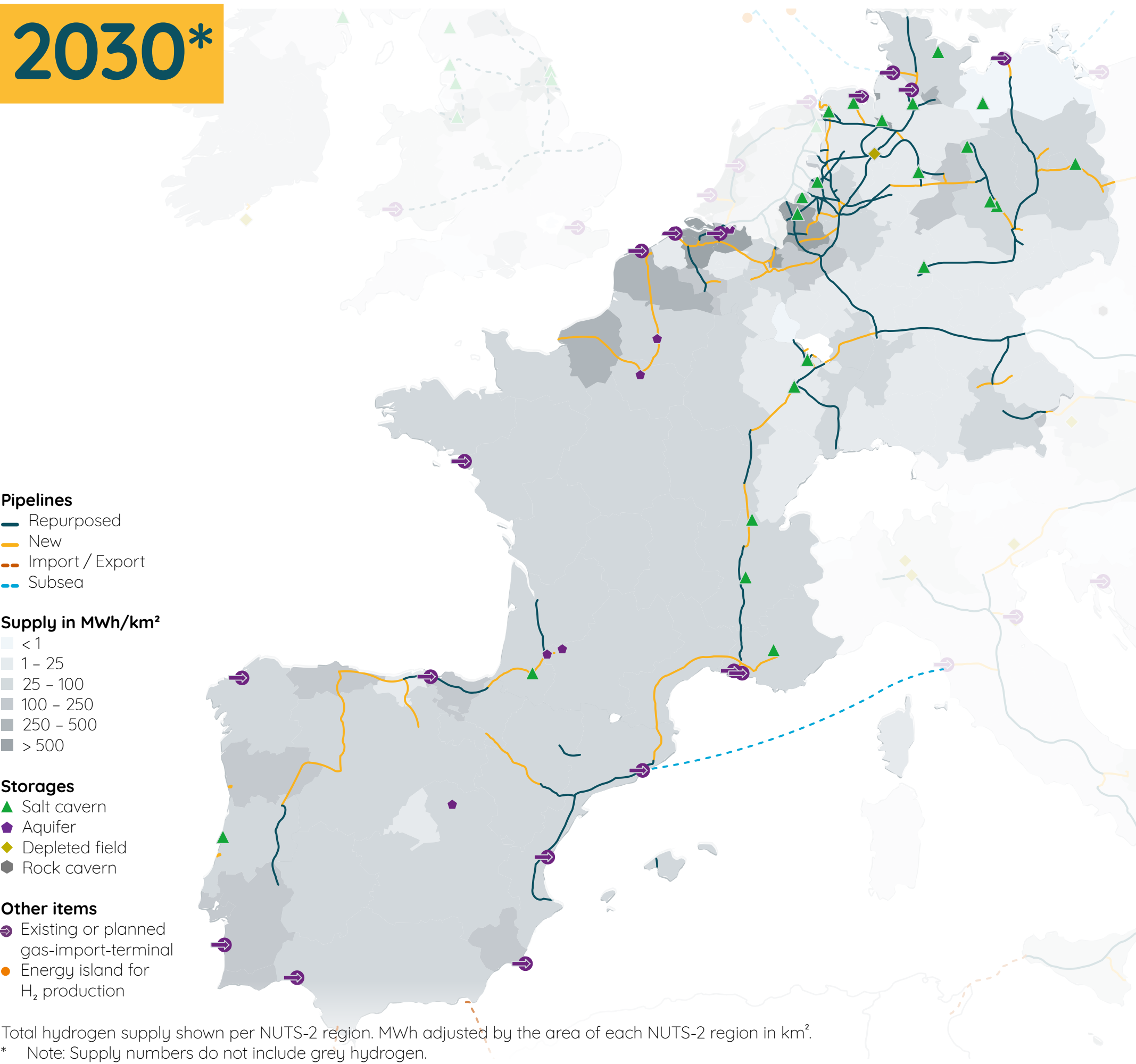
Hydrogen adoption across all demand sectors enables an **emissions reduction of ~300 MtCO₂/yr. by 2050**, equivalent to a **29% reduction²**.

- **Up to 2030**, the industrial sector contributes 75% of the total emissions reductions, largely driven by the decarbonisation of the steel sector.
- **By 2040**, emissions reductions from transport (road, shipping and aviation) increase substantially and combined with industry, account for 80% of emissions reductions. The power sector account for the remaining 20% of reductions.
- **By 2050**, the transport sector alone accounts for over 50% of emissions reductions.

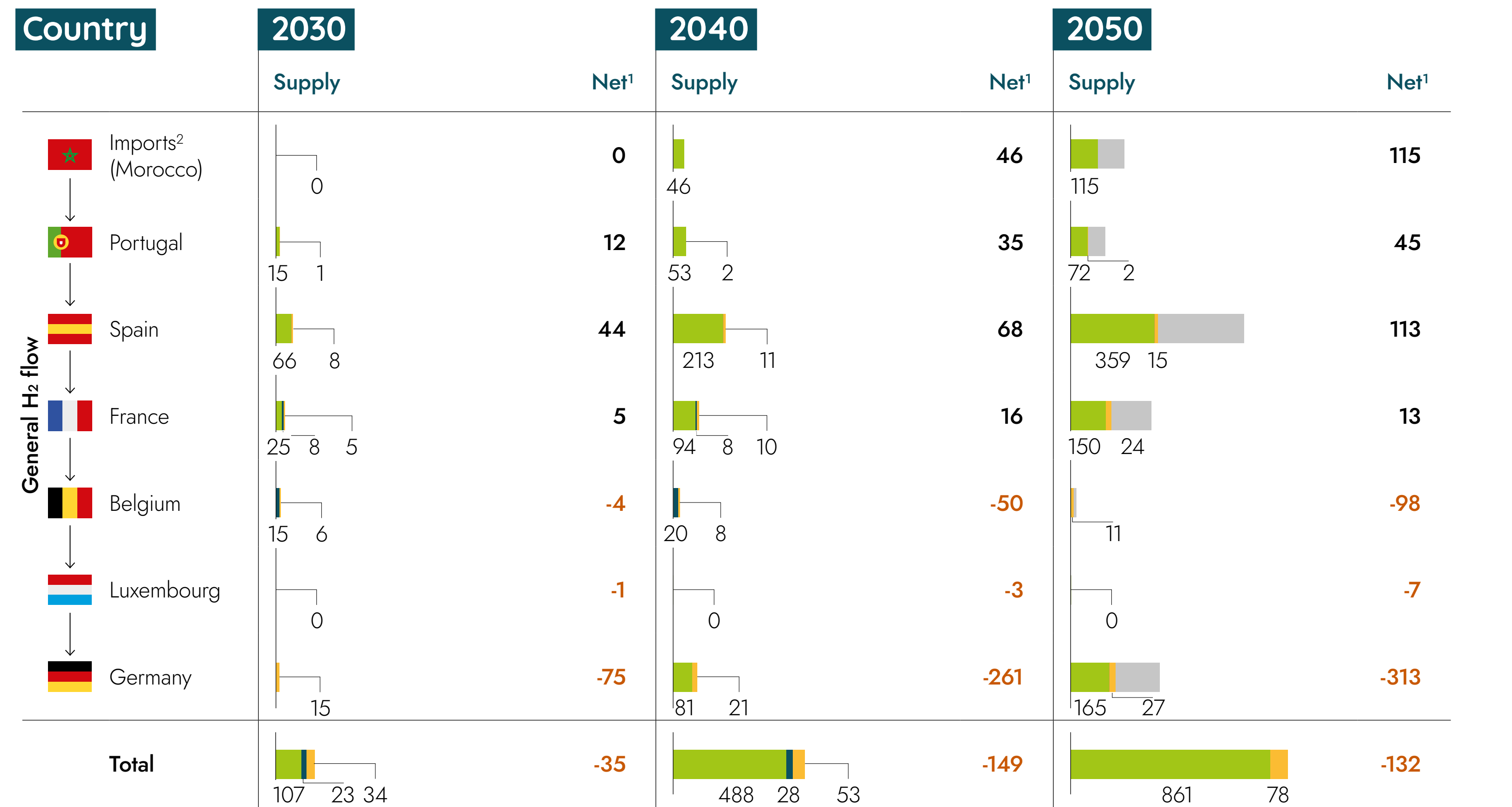
¹ CO₂-Emissions from countries and sectors included in corridor (1.02 bn t CO₂ / year), Source: EEA

² Emissions reductions are calculated compared to the baseline fossil fuel used in each sectors. For example, emissions reductions associated with the adoption of hydrogen by the primary steel sector are relative to the use of coal. Similarly, emissions reductions , for e-fuels production are relative to the use of fossil fuels in shipping, aviation and other uses.

Corridor enables access to supply from parts of the Iberian peninsula by 2030, and potentially from North Africa, by 2040



Hydrogen supply increases significantly from 2030 to 2040, largely driven by green hydrogen supply from Spain



Hydrogen supply includes a mix of supply options including **grid-based green hydrogen³, dedicated green hydrogen, and blue hydrogen⁴.**

By 2030, hydrogen supply reaches ~160 TWh, largely from dedicated green hydrogen and grid-based hydrogen.

By 2040, hydrogen supply increases substantially to ~570 TWh, of which roughly 85% is from dedicated green hydrogen. The remaining 15% is from grid-based and blue hydrogen supply. Grid-based supply increases slightly from 2030 due to the increasing decarbonization of the electricity grid mix.

By 2050, hydrogen supply increases further to ~1,000 TWh. Dedicated green supply continues to account for the largest share at roughly 90%. Blue hydrogen supply is not included in 2050 due to assumed target of zero emissions and de-fossilisation of Europe by 2050.

1 Net represents excess supply after subtracting demand

2 No imports are reported for Morocco in 2030 as the interconnection with Morocco would likely not be available until after 2030.

3 Blue hydrogen supply volumes will be subject to the evolution of gas markets and the development of low carbon hydrogen regulation in different country. As a result, some countries may have additional blue hydrogen supply which could be used to satisfy local demand.

4 Grid-based green hydrogen is estimated based on the oversupply of electricity (demand less supply) in each country of the corridor from 2030 to 2050.

Dedicated green

Blue

Grid-based

2050 technical potential

Note: Hydrogen supply volumes do not include hydrogen imports by ship.

Morocco may become a potential source of hydrogen imports to Europe by 2040, and potentially Algeria

State of Gas Infra-structure

- North Africa connects to Spain through Morocco via the **Maghred-Europe offshore pipeline**, currently used for natural gas exports to Europe. Morocco’s national hydrogen roadmap identified the potential to **repurpose the Maghreb-Europe pipeline** for hydrogen export¹.
- Morocco is currently in preparatory stages ahead of **upgrades to its existing port infrastructure for LNG imports**.
- Hydrogen export potential via this corridor focuses primarily on **hydrogen supply from Morocco**, however, there is also potential for hydrogen exports from Algeria to contribute to this corridor.

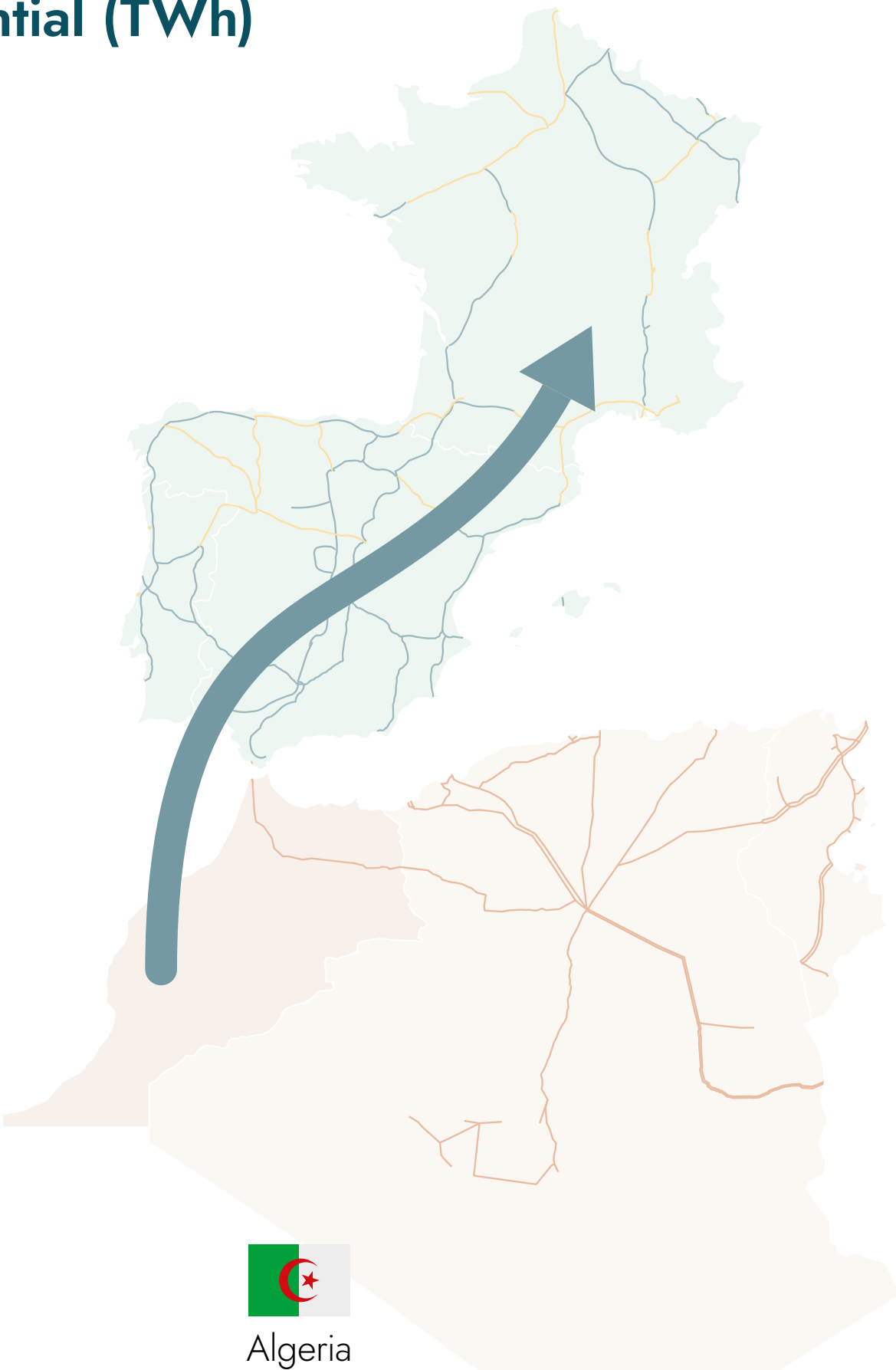
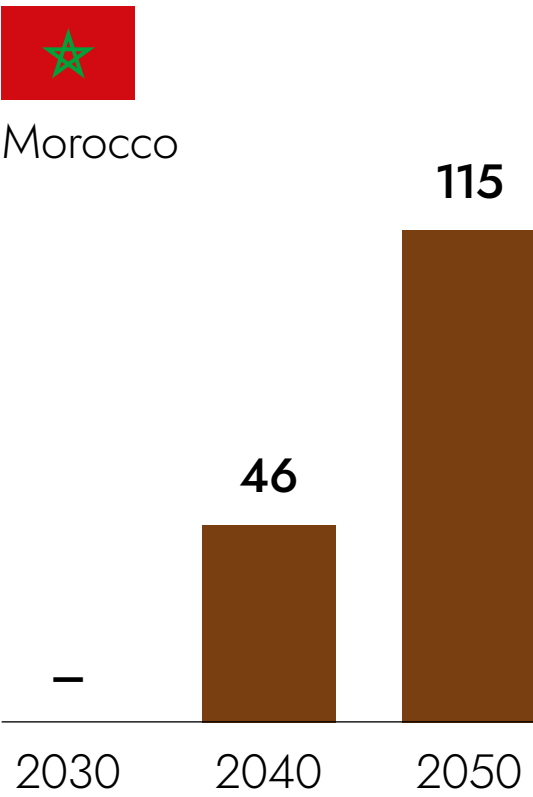
Market Attractive-ness

- **Abundant renewable energy potential, particularly solar PV**
- **Partnerships:** Hydrogen cooperation agreement with Germany (June 2020) to develop the hydrogen sector in Morocco².
- **Market developments:**
 - HEVO Ammonia: 183k t/yr. of green ammonia by 2026 (Vitol, Fusion Fuel)³
 - Cluster Maroc Hydrogen: Organization aiming to mediate between the different market actors to create a hydrogen cluster in Morocco.

Market Barriers

- **Limited transparency** and **slow decision-making and procedures** when dealing with Government entities
- **Recent political disputes** with neighboring countries (Algeria) and international partners (Germany)

Hydrogen supply potential (TWh) Morocco only



Note:
Supply potential based on Reference scenario from National Green Hydrogen Roadmap for Morocco¹

Note:
Hydrogen supply from Algeria has not been incorporate into the supply figures of this corridor. Rather, it is reported under Corridor A.

1 MEM – Green Hydrogen Roadmap (2021)
2 HEVO Ammonia (<https://energy-utilities.com/fusion-fuel-and-ccc-to-develop-850m-morocco-green-news113290.html>; and stakeholder interviews)
3 Due to political tension as a result of the Western Sahara sovereignty, Morocco halted the agreement in 2021, however, it is currently looking to restore ties as of 2022.

Southwest Europe & North Africa

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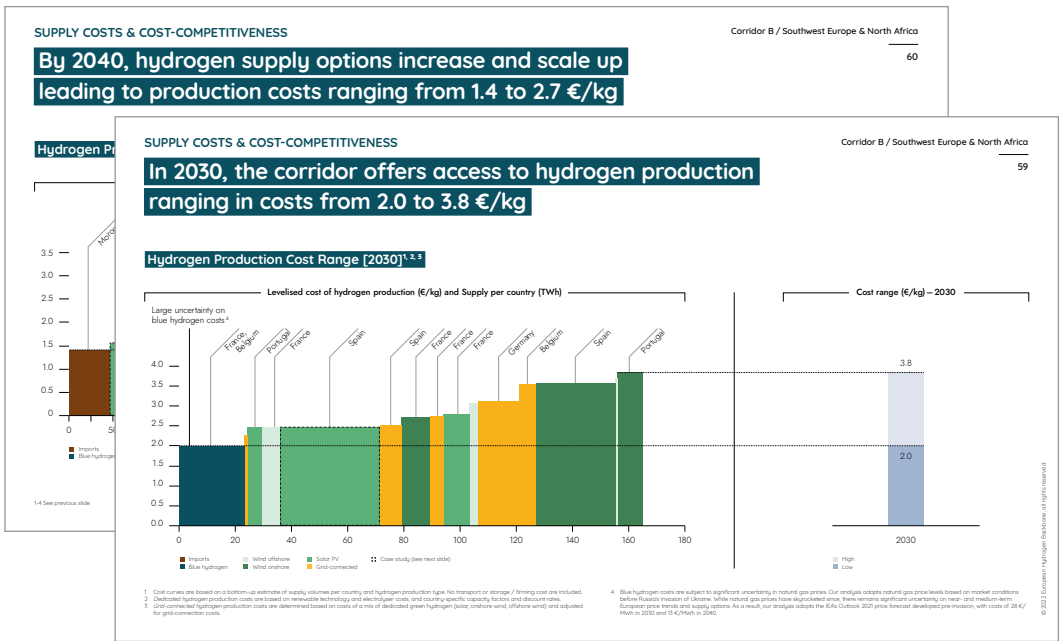
This section explores corridor’s hydrogen production and delivery costs and their cost-competitiveness with fossil-fuel alternatives

Hydrogen production cost

Key Questions Answered

Content Material

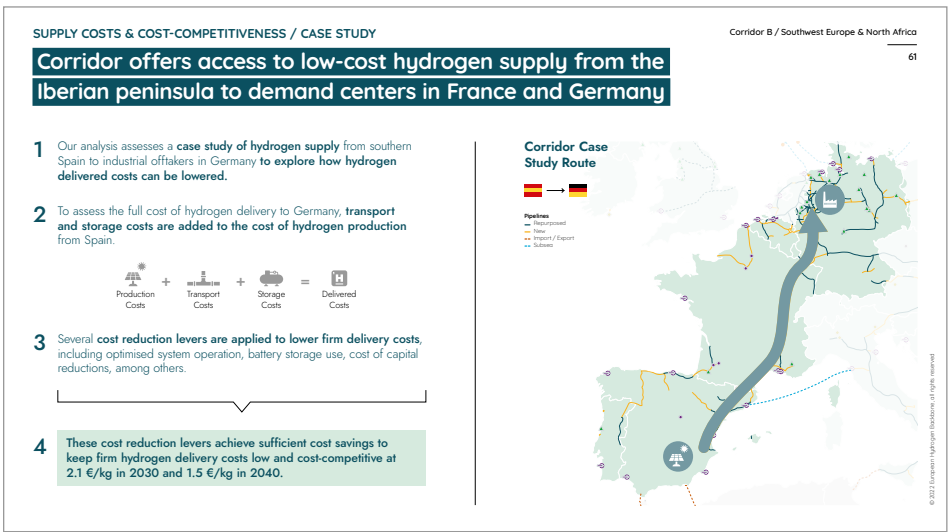
What **hydrogen production costs** does the corridor provide access to **by 2030 and by 2040**?



- Corridor provides access to hydrogen production costs of **2.0–3.8 €/kg by 2030**
- The scale-up of hydrogen supply leads to reductions to **1.4–2.7 €/kg in 2040**

Hydrogen delivered costs

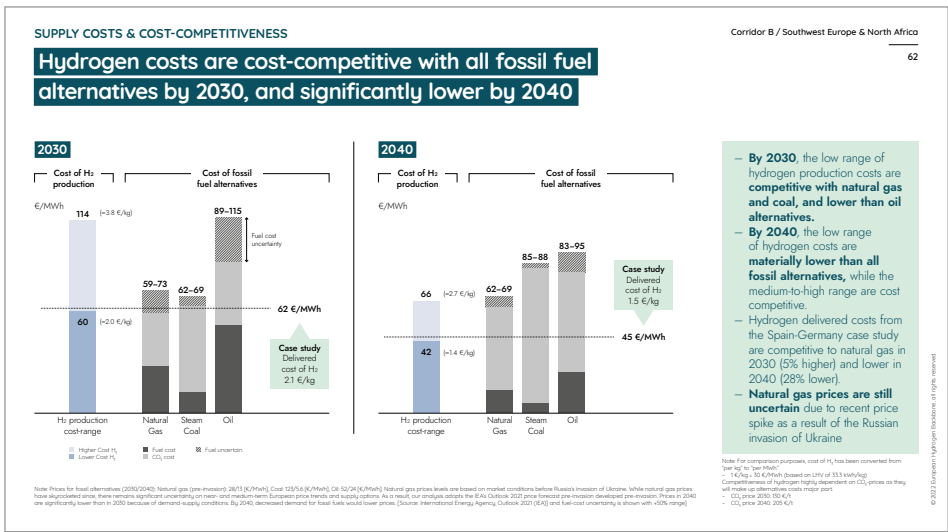
What are the **full costs of delivered hydrogen** accounting for **transport and storage** costs?
What **cost levers** are available to lower the cost of delivery costs?



- Several **cost reduction levers** can be applied to **lower the costs of hydrogen delivery**.
- For the Spain-to-Germany case study, **these levers achieve delivery costs that are low and cost-competitive**.

Comparison with fossil alternatives

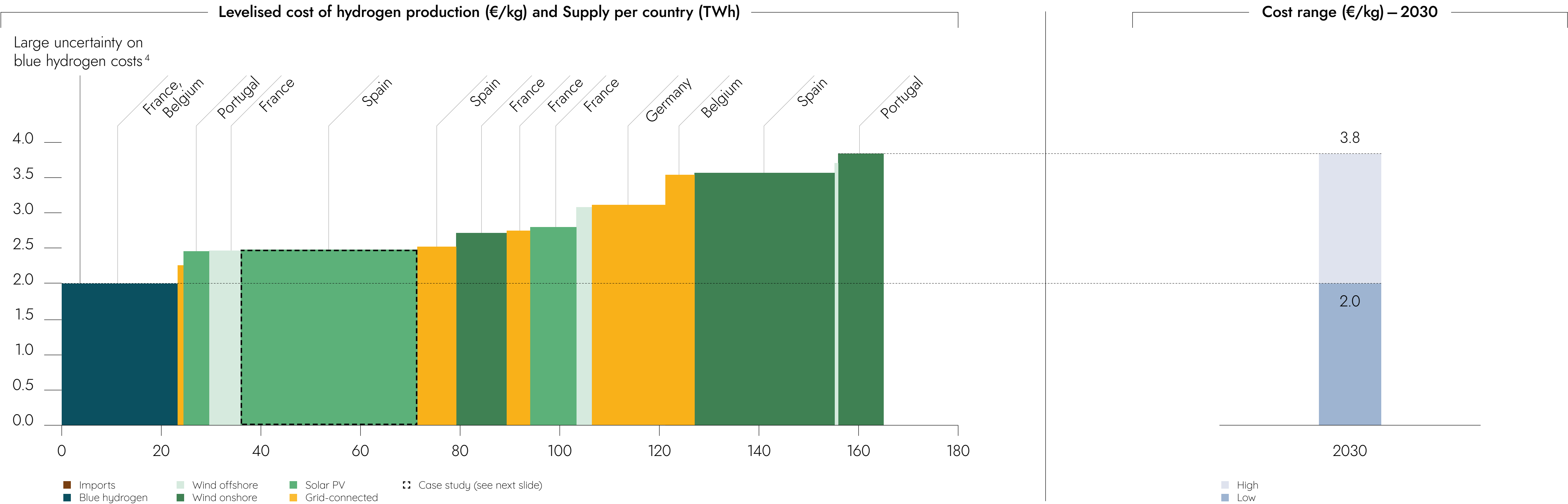
How **cost-competitive** are hydrogen costs compare to fossil fuel alternatives?



- **Hydrogen costs are competitive with fossil fuel alternatives by 2030**, and lower by 2040.
- Fossil fuel costs are subject to **significant uncertainty**.

In 2030, the corridor offers access to hydrogen production ranging in costs from 2.0 to 3.8 €/kg

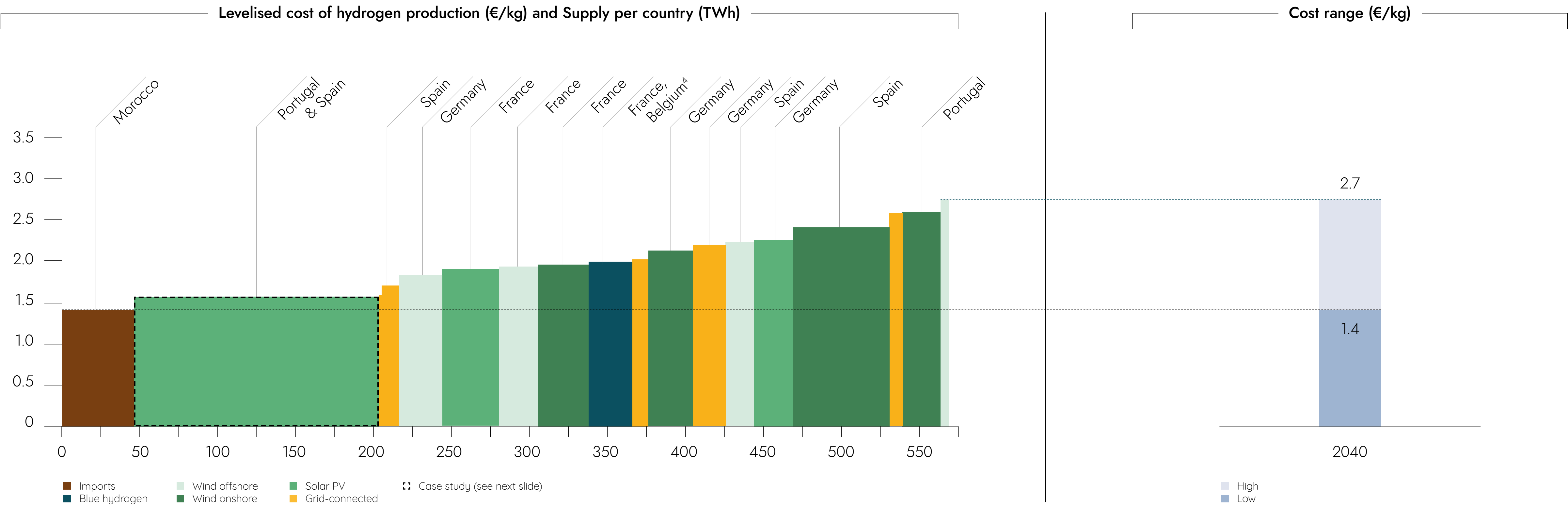
Hydrogen Production Cost Range [2030]^{1, 2, 3}



1 Cost curves are based on a bottom-up estimate of supply volumes per country and hydrogen production type. No transport or storage / firming cost are included.
2 Dedicated hydrogen production costs are based on renewable technology and electrolyser costs, and country-specific capacity factors and discount rates.
3 Grid-connected hydrogen production costs are determined based on costs of a mix of dedicated green hydrogen (solar, onshore wind, offshore wind) and adjusted for grid-connection costs.
4 Blue hydrogen costs are subject to significant uncertainty in natural gas prices. Our analysis adopts natural gas price levels based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast developed pre-invasion, with costs of 28 €/MWh in 2030 and 13 €/MWh in 2040.

By 2040, hydrogen supply options increase and scale up leading to production costs ranging from 1.4 to 2.7 €/kg

Hydrogen Production Cost Range [2040]^{1, 2, 3}

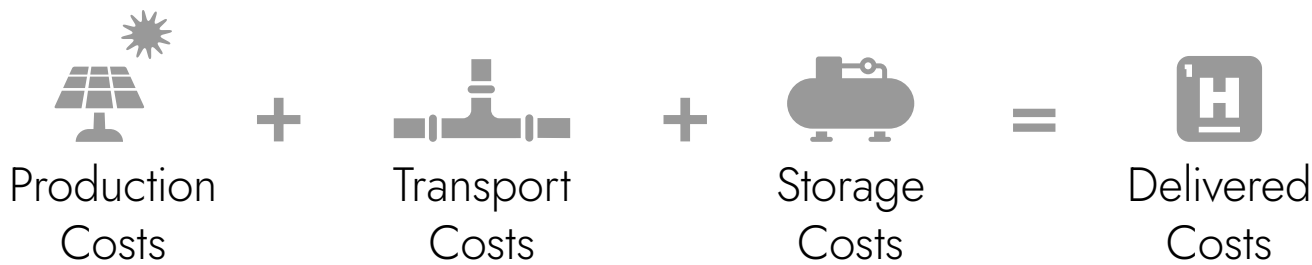


1-4 See previous slide

Corridor offers access to low-cost hydrogen supply from the Iberian peninsula to demand centers in France and Germany

1 Our analysis assesses a **case study of hydrogen supply** from southern Spain to industrial offtakers in Germany **to explore how hydrogen delivered costs can be lowered.**

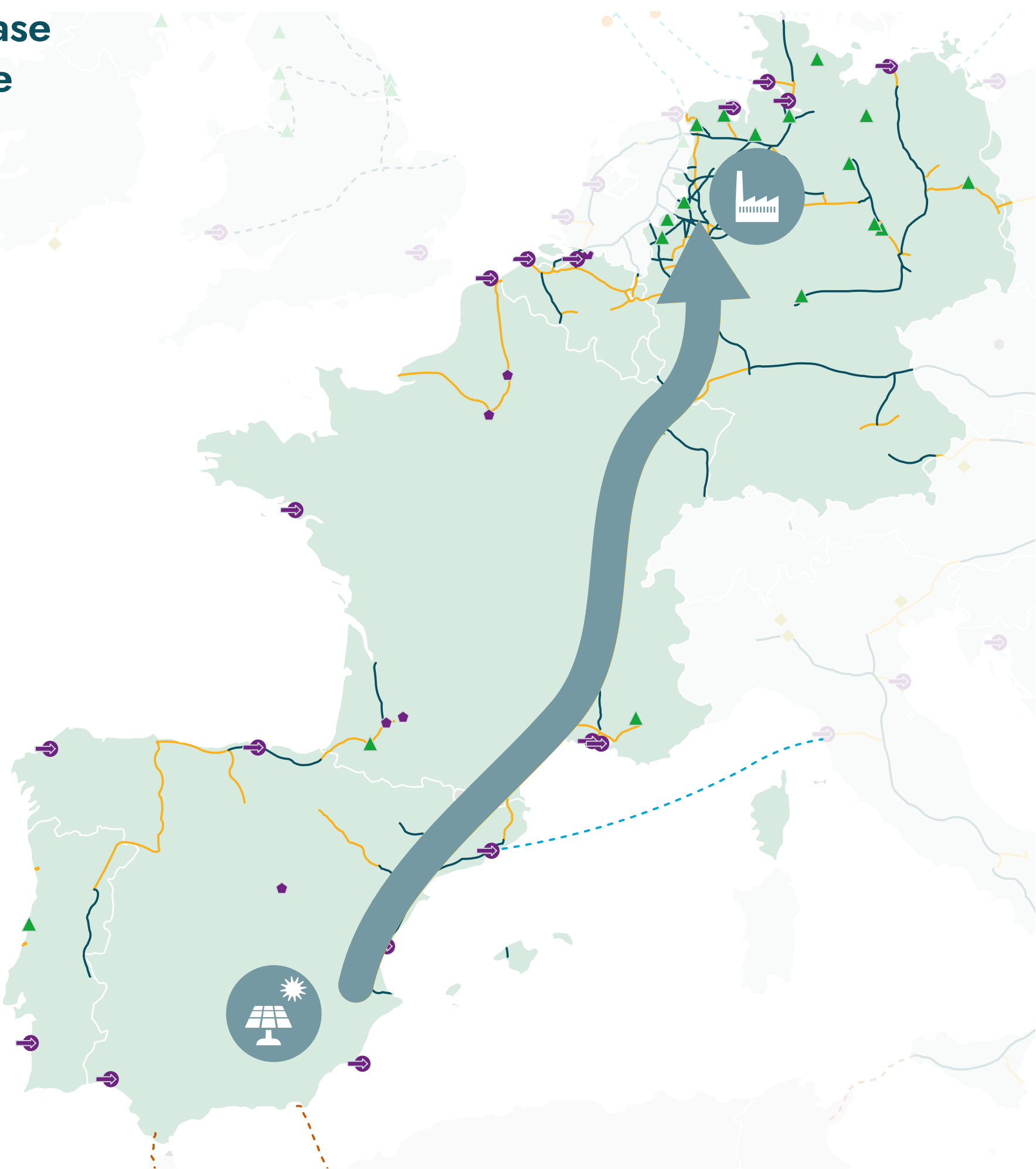
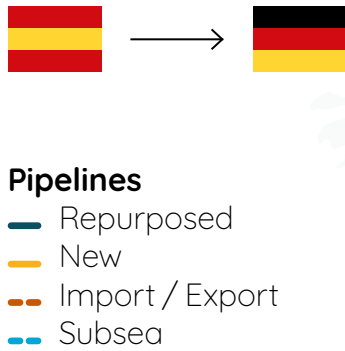
2 To assess the full cost of hydrogen delivery to Germany, **transport and storage costs are added to the cost of hydrogen production** from Spain.



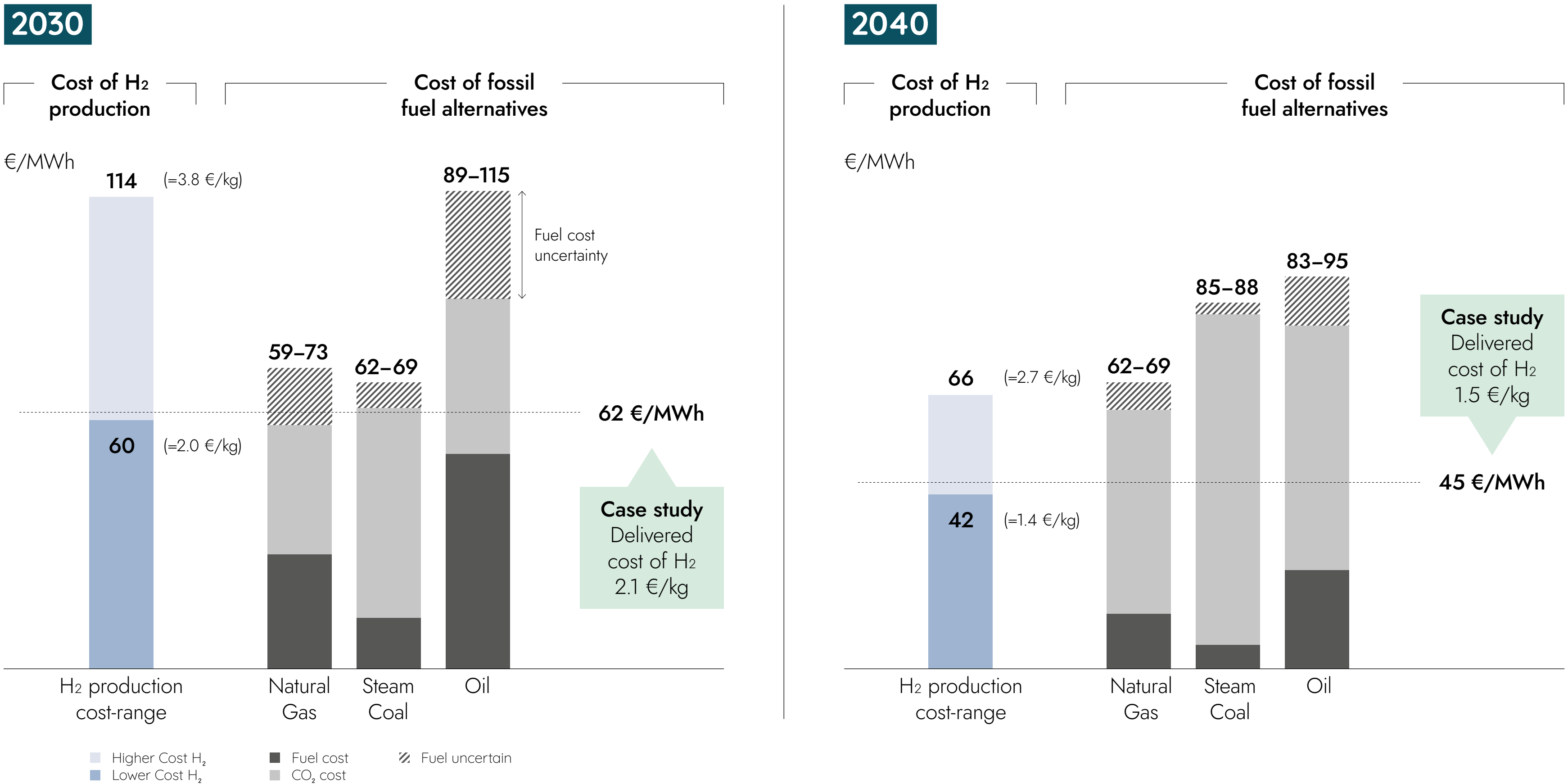
3 Several **cost reduction levers** are applied to **lower firm delivery costs**, including optimised system operation, battery storage use, cost of capital reductions, among others.

4 These cost reduction levers achieve sufficient cost savings to keep firm hydrogen delivery costs low and cost-competitive at 2.1 €/kg in 2030 and 1.5 €/kg in 2040.

Corridor Case Study Route



Hydrogen costs are cost-competitive with all fossil fuel alternatives by 2030, and significantly lower by 2040



- By 2030, the low range of hydrogen production costs are competitive with natural gas and coal, and lower than oil alternatives.
- By 2040, the low range of hydrogen costs are materially lower than all fossil alternatives, while the medium-to-high range are cost competitive.
- Hydrogen delivered costs from the Spain-Germany case study are competitive to natural gas in 2030 (5% higher) and lower in 2040 (28% lower).
- Natural gas prices are still uncertain due to recent price spike as a result of the Russian invasion of Ukraine

Note: Prices for fossil alternatives (2030/2040): Natural gas (pre-invasion): 28/13 [€/MWh], Coal: 123/5.6 [€/MWh], Oil: 52/24 [€/MWh]. Natural gas prices levels are based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast pre-invasion developed pre-invasion. Prices in 2040 are significantly lower than in 2030 because of demand-supply conditions. By 2040, decreased demand for fossil fuels would lower prices. [Source: International Energy Agency, Outlook 2021 (IEA)] and fuel-cost uncertainty is shown with +50% range]

Note: For comparison purposes, cost of H₂ has been converted from "per kg" to "per MWh"
- 1 €/kg = 30 €/MWh (based on LHV of 33.3 kWh/kg)
Competitiveness of hydrogen highly dependent on CO₂-prices as they will make up alternatives costs major part.
- CO₂ price 2030: 130 €/t
- CO₂ price 2040: 205 €/t

Southwest Europe & North Africa

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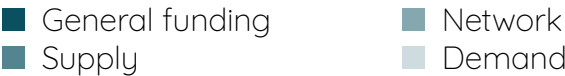
All countries have developed national strategies and targets. Moving forward, the development of regulation is key to enable infrastructure investment.

Pre-
RePowerEU
targets²



	National Hydrogen strategy	Network regulation & policy	Funding ¹ (bn €)	Highlights
Portugal	<ul style="list-style-type: none">5% share of hydrogen at final energy consumption, 2 GW electrolyser 203010 – 15% H₂ injection to gas grid by 2030	<ul style="list-style-type: none">Expected to come with EU regulations	<div><div></div>1.1</div>	<ul style="list-style-type: none">Mixed focus on national consumption and export to central EuropeProduction for export with 1 GW in Sines planned
Spain	<ul style="list-style-type: none">Replacing 25% of industrial grey hydrogenInstallation of 4 GW electrolyser capacitySetting up H₂ refuelling stations across Spain	<ul style="list-style-type: none">Expected to come with EU regulations	<div><div></div>1.6</div>	<ul style="list-style-type: none">Decarbonisation of grey hydrogen use by industryH₂ in heavy transport (fuelling stations)
France	<ul style="list-style-type: none">Implementation of local hydrogen hubs pre 2030Focus on demand (e.g. heavy transport) and generation (6.5 GW electrolyser in 2030)No strategy on H₂ infrastructure yet	<ul style="list-style-type: none">Hydrogen injections to gas grid are possible, below threshold of technical restrictions	<div><div></div><div></div><div></div>7.2</div>	<ul style="list-style-type: none">Strong investments in transport sector (heavy duty) and hydrogen production for industryNeed to accelerate strategy and policy around exports and imports
Belgium	<ul style="list-style-type: none">Focus: Industry, (freight) transport, electricity storage150 MW for electrolysis production by 2026Import and transit of H₂ and its derivatives via existing network and additional infrastructure	<ul style="list-style-type: none">2026: 100-160 new km pipelinesOpen access H₂ backbone by 2030 connecting ports, industrial clusters, and neighboring countries	<div><div></div>0.1</div>	<ul style="list-style-type: none">The NHS sees Belgium as an import hub of renewable molecules for EuropeStrong focus on national and cross-country hydrogen network infrastructure
Luxembourg	<ul style="list-style-type: none">Focus on renewable hydrogenPrioritized use in industry, sector coupling & transportDedicated H₂ network explicitly mentioned	<ul style="list-style-type: none">Goal to regulate transmission, storage & distribution infrastructure in line with ambitions of the EU		<ul style="list-style-type: none">Strong need for imports, hence cross border H₂ infrastructure & national networks to meet industry & transport demand
Germany	<ul style="list-style-type: none">National production & import focus due to supply gapIn place since 2020, currently reviewed towards increasing its ambition10 GW (2030) electrolyser in coalition plans	<ul style="list-style-type: none">H₂ network potentially opt-in regulated and vertically unbundledFirst rules and standards for high pressure pipelines are formulated	<div><div></div><div></div><div></div>9</div>	<ul style="list-style-type: none">Strong focus on international cooperation to ensure sufficient supplyNational funding

Note: Sequencing of countries follows the general corridor direction but does not represent the hydrogen flows.
1 Cumulative public funding amount by the respective state until 2030
2 Strategies and funding is under evaluation of meeting latest targets



Southwest Europe & North Africa

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This corridor plays a fundamental role in achieving a European backbone by 2040

The need for this corridor

- The development of **this corridor ensures access to abundant, low-cost hydrogen supply from Spain and Portugal** by 2030, and by 2040 additional supply from Morocco and potentially Algeria.
- The **decarbonisation of the largest hydrogen demand centers along this corridor** — in **Spain, France, and Germany** — is dependent on the buildout of this corridor by 2030, and its expansion towards 2040.

Actions required

- The buildout of this corridor by 2030 **requires national governments to take clear and concrete actions across.**
- This includes actions associated with **infrastructure development and planning, the development of cross-national initiatives** and **securing access to early funding and long-term, low-cost financing.**

2040

Pipelines

- Repurposed
- New
- Import / Export
- Subsea

Demand per sector

- 40 / 30 / 20 / 10 / 1 TWh
- Efuels production
 - Industrial energy
 - Industrial feedstock
 - Power

Supply in MWh/km²

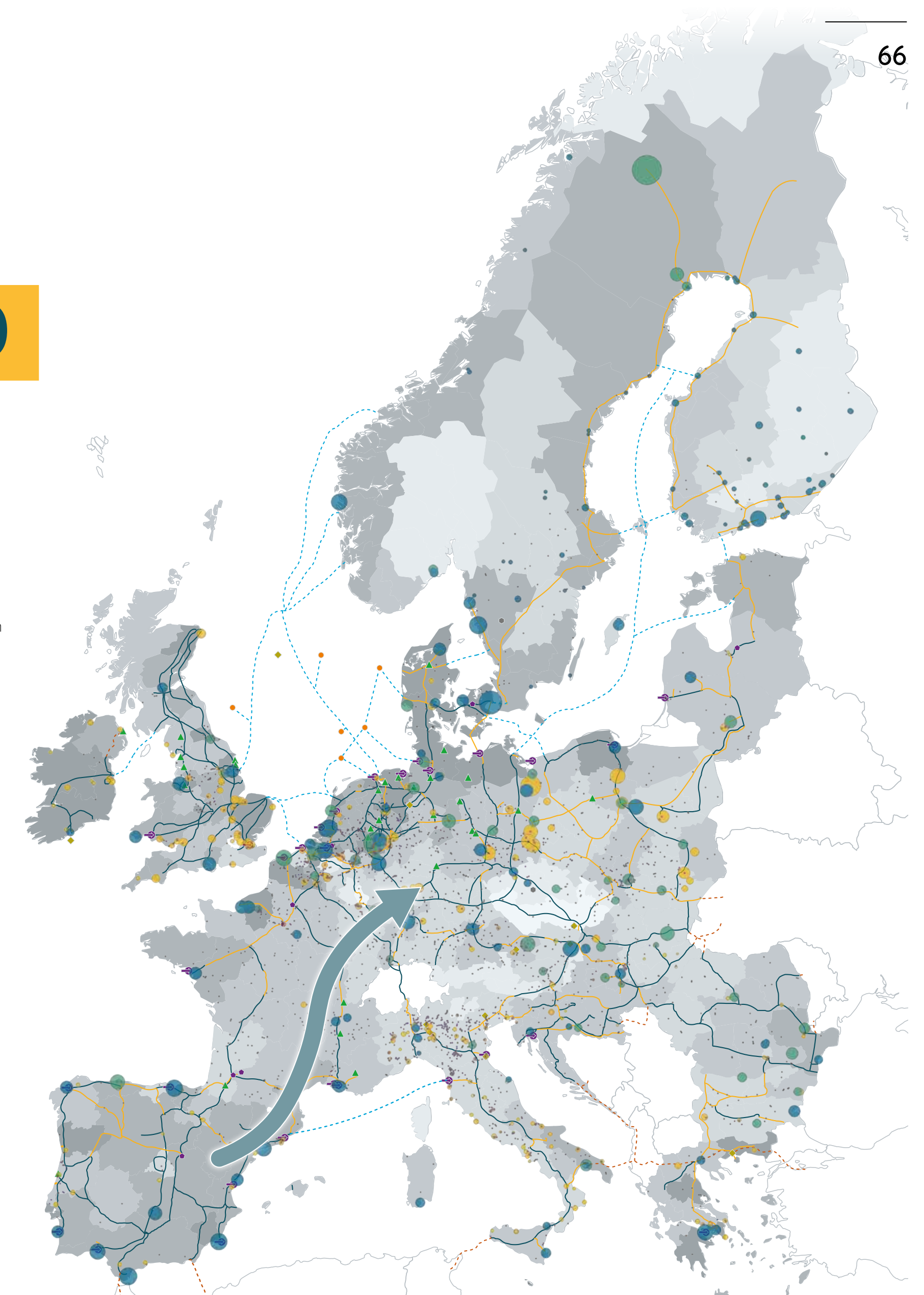
- < 1
- 1 – 25
- 25 – 100
- 100 – 250
- 250 – 500
- > 500

Storages

- ▲ Salt cavern
- ▲ Aquifer
- ▲ Depleted field
- ▲ Rock cavern

Other items

- Existing or planned gas-import-terminal
- Energy island for H₂ production



**To ensure the development of this corridor by 2030,
there is a need for clear and concrete actions**

Fostering development of new and repurposed **hydrogen infrastructure**, for example, by unbundling rules facilitating the efficient use of TSO expertise and services and by allowing the adoption of different vertical unbundling models in the EU, as is the case with natural gas

+

Unlock financing to fast-track **hydrogen infrastructure deployment** by applying regional regulatory flexibility and other pragmatic financing solutions (including incentivizing the adoption of hydrogen by demand sectors)

+

Simplify and shorten **planning and permitting procedures** for renewable energy and hydrogen infrastructure projects.

+

Intensify energy **partnerships with exporting, non-EHB countries** like Morocco, and other countries in North Africa, and providing financing support to reduce their cost of capital

+

Facilitate integrated **energy system planning of hydrogen, natural gas, and electricity infrastructure** supporting the accelerated deployment and integration of renewable energy resources

→ However, speed will be of essence!

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Corridor D: Nordic and Baltic regions

Corridor E: East and South-East Europe

3. Detailed methodology

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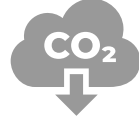

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North
Sea

- Norway
- Ireland
- Netherlands
- Denmark
- United Kingdom
- Luxembourg
- Belgium
- France
- Germany



Corridor emerges in the North Sea providing access to low-cost, blue and green hydrogen supply to demand clusters in northwestern Europe

Drivers & Opportunities	Major driver of development is the need to meet demand from large industrial & transport clusters in the UK, Netherlands, Belgium, France and Germany. Key opportunities include the repurposing potential of onshore/offshore infrastructure, integration of North Sea wind resources and the portfolio of planned import terminals		
Hydrogen Supply & Decarbonization Potential	H2 supply potential¹ (TWh/year)  <div><div>249 TWh</div><div>852 TWh</div><div>20302040</div></div>	Emissions Reductions (MtCO ₂ /year vs. 2019; % reduction)  <div><div>20302040</div><div>-94 Mt (8%)</div><div>-254 Mt (21%)</div></div>	
Supply Costs & Cost-Competitiveness	Cost of H2 production¹ (€/kg of H ₂)  <div><div>1.6–3.5</div><div>1.5–2.6</div><div>20302040</div></div>	Cost competitiveness² — Hydrogen delivered price vs. — natural gas price high/low, (€/MWh) <div><div>66735969</div><div>20302040</div><div>54</div></div>	
Actions Needed	<ul style="list-style-type: none">— Fostering development of new and repurposed hydrogen infrastructure— Unlock financing to fast-track hydrogen infrastructure deployment— Simplify and shorten planning and permitting procedures— Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure		

1 Figures reported reflect outputs for all countries included in the corridor. Even if a country is only partially in the corridor, results for the full country are included (e.g., supply potential and costs, demand, transmission network length).

2 Savings are based on the corridor's case study of hydrogen delivered in 2030 and 2040. The cost of natural gas includes CO₂ prices. Refer to Subsection 3 (Supply Costs & Cost-Competitiveness)

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Corridor offers access to low-cost, North Sea blue & green hydrogen supply to demand clusters in the UK and northwestern Europe

Drivers & Opportunities

- **The major driver** behind the development of this corridor is hydrogen adoption associated with the **decarbonisation of industry**, transport and power in the UK and northwestern Europe. The speed of hydrogen adoption in these regions may be even faster than anticipated driven by increasing CO₂ prices in the EU and the RePowerEU ambitions to replace natural gas consumption.
- In the near term, the corridor offers **access to abundant, low-cost blue hydrogen supply from the North Sea**. In the longer term, this corridor also provide access to significant green hydrogen potential leveraging **strong onshore and offshore wind resources in the North Sea**, offering an opportunity to integrate even higher capacities of offshore wind.
- A **major opportunity** for this corridor relates to the **large portfolio of ongoing and planned hydrogen infrastructure projects** in the region – including large-scale offshore wind developments, large-scale integrated hydrogen projects, and a growing list of planned **import terminals for hydrogen and hydrogen-derivatives** – in the Netherlands, Belgium, Germany and France.
- This corridor emerges as a **highly-integrated supply corridor** that can leverage **extensive offshore gas infrastructure in the North Sea**, planned **national and regional hydrogen backbones** in the Netherlands (by 2027), and in Belgium and Germany by 2030 – connecting all major demand clusters in north-western Europe – as well as **potential hydrogen storage** at salt cavern locations northwest Europe.
- The corridor would be stood up by 2030, covering **12,000 km** of large-scale hydrogen pipelines across all countries of the corridor, of which approximately **70% will be repurposed pipelines**. The corridor’s high repurposing potential of existing infrastructure offers an opportunity to keep the cost of hydrogen transport relatively low.

Hydrogen Demand & Supply

- **Total hydrogen demand** in the corridor reaches **~260 TWh by 2030**, increasing substantially to **~900 TWh by 2040**. Up to 2030, most hydrogen demand is driven by large industrial clusters in the UK and northwestern Europe. Hydrogen use in the transport sector also contributes a significant share of hydrogen demand. From 2040 to 2050, hydrogen demand increases substantially in the transport and power sectors and continues to ramp up in industry.
- Hydrogen adoption across all countries of the corridors enables an emissions reduction of ~360 MtCO₂/yr. by 2050, **equivalent to a 29% emissions reduction**.
- The corridor enables access to **hydrogen supply potential of ~250 TWh by 2030, increasing to roughly 850 TWh by 2040**. Major sources of supply include North Sea blue hydrogen potential in 2030, expanding to green hydrogen from onshore and offshore wind resources in the North Sea.

To successfully stand up this corridor by 2030, actions are needed to support infrastructure planning, financing and development

Costs & Cost-Competitiveness

- By 2030, the corridor provides access to hydrogen ranging in production cost from **1.6 to 3.5 €/kg**. By 2040, as supply options increase and technology costs decrease, hydrogen production costs decrease to **1.5 to 2.6 €/kg**.
- In the long term, this corridor’s lowest-cost hydrogen supply options are onshore and offshore wind resources from the North Sea.
- Based on a case-study of green hydrogen supply and transport from the North Sea to North Rhine Westphalia (Germany), **the cost of delivered hydrogen** – inclusive of transport and firming costs – **can be lowered to achieve cost levels comparable to production costs** both in 2030 and 2040. Lowering delivery costs can be achieved through various cost levers including optimized operation of the system and cost of capital reductions.

National Strategies & Regulation

- **Most countries have developed** – or are in the process of developing – **national strategies**. Further, in most high-demand countries, hydrogen regulation is also already in place, if not currently under development. The **development of hydrogen regulation** in all other countries will accelerate investment in infrastructure.
- In select countries, **substantial funding has been allocated** to support the development of the hydrogen market including funding for gas network infrastructure.

Actions Needed

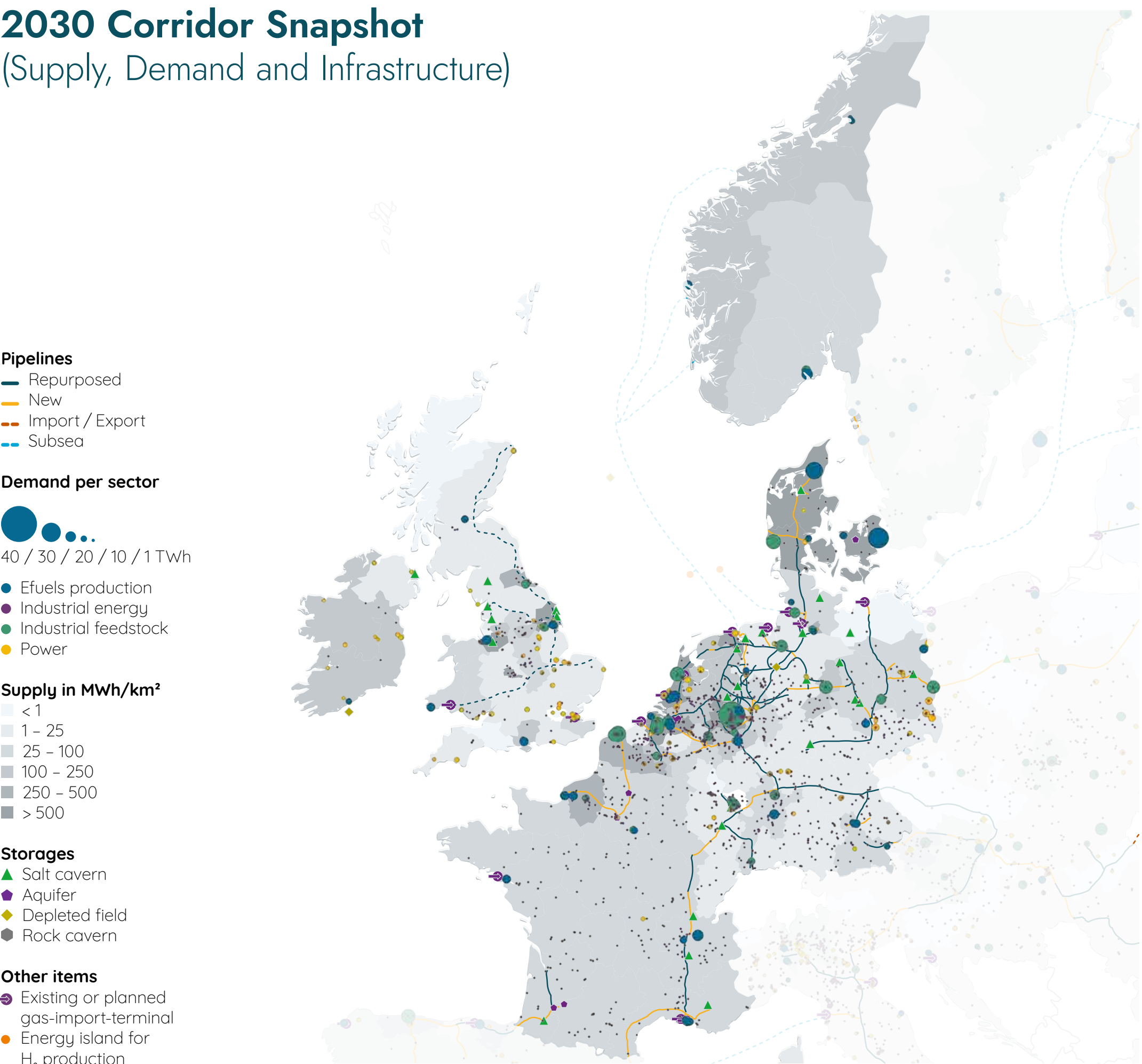
- To support the buildout of this corridor by 2030, clear and concrete actions related to infrastructure planning, financing and development have been identified:
- Fostering development of **new and repurposed hydrogen infrastructure**.
 - Unlock financing to **fast-track hydrogen infrastructure deployment** by applying regional regulatory flexibility and other pragmatic financing solutions.
 - Simplify and shorten **planning and permitting procedures** for the full value chain of renewable energies and hydrogen infrastructure projects.
 - Establish **integrated energy system planning** of hydrogen, natural gas, and electricity infrastructure.

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This section explores the development of demand, supply and transport infrastructure in the corridor from 2030 to 2050

2030 Corridor Snapshot
(Supply, Demand and Infrastructure)



Hydrogen demand

By 2030, the corridor connects **all major industrial clusters** in the UK and northwest Europe. **From 2030 to 2040**, the corridor expands to **all demand centers along its route**, increasing demand from 260 to ~900 TWh.

Hydrogen supply¹

By 2030, the corridor enables access to low-cost, blue hydrogen supply from the **North Sea**. By 2040, the corridor diversifies its supply with green hydrogen from offshore wind resources in the North Sea.

In 2030, hydrogen supply is **~250 TWh**, of which over 40% is blue hydrogen. Hydrogen supply increases significantly by 2040, reaching 850 TWh.



Hydrogen Infrastructure

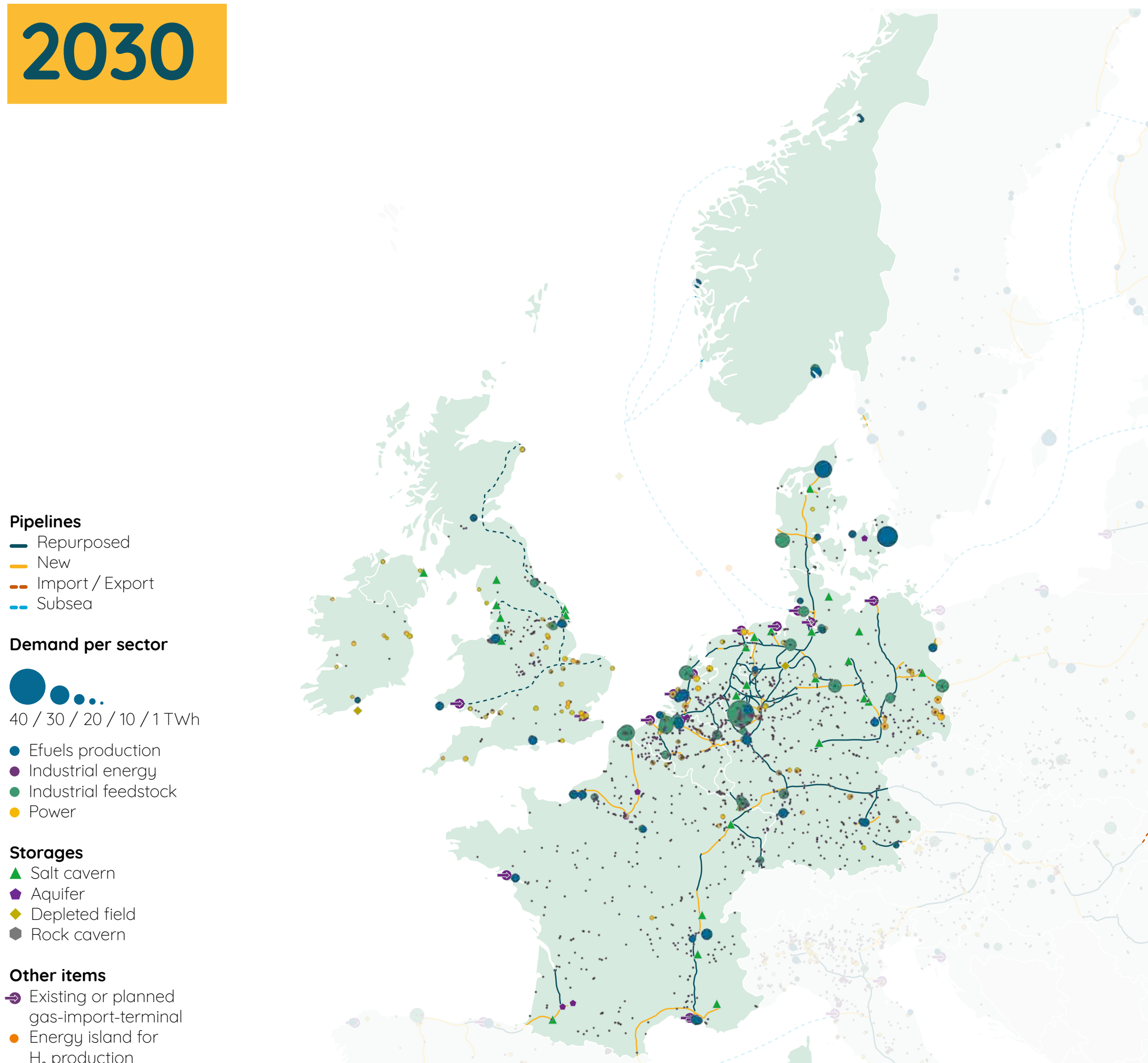
By 2030, the buildout of pipeline infrastructure across all countries of the corridor reaches 12,000 km of large-scale pipelines. Corridor benefits from a very large share of repurposed infrastructure.



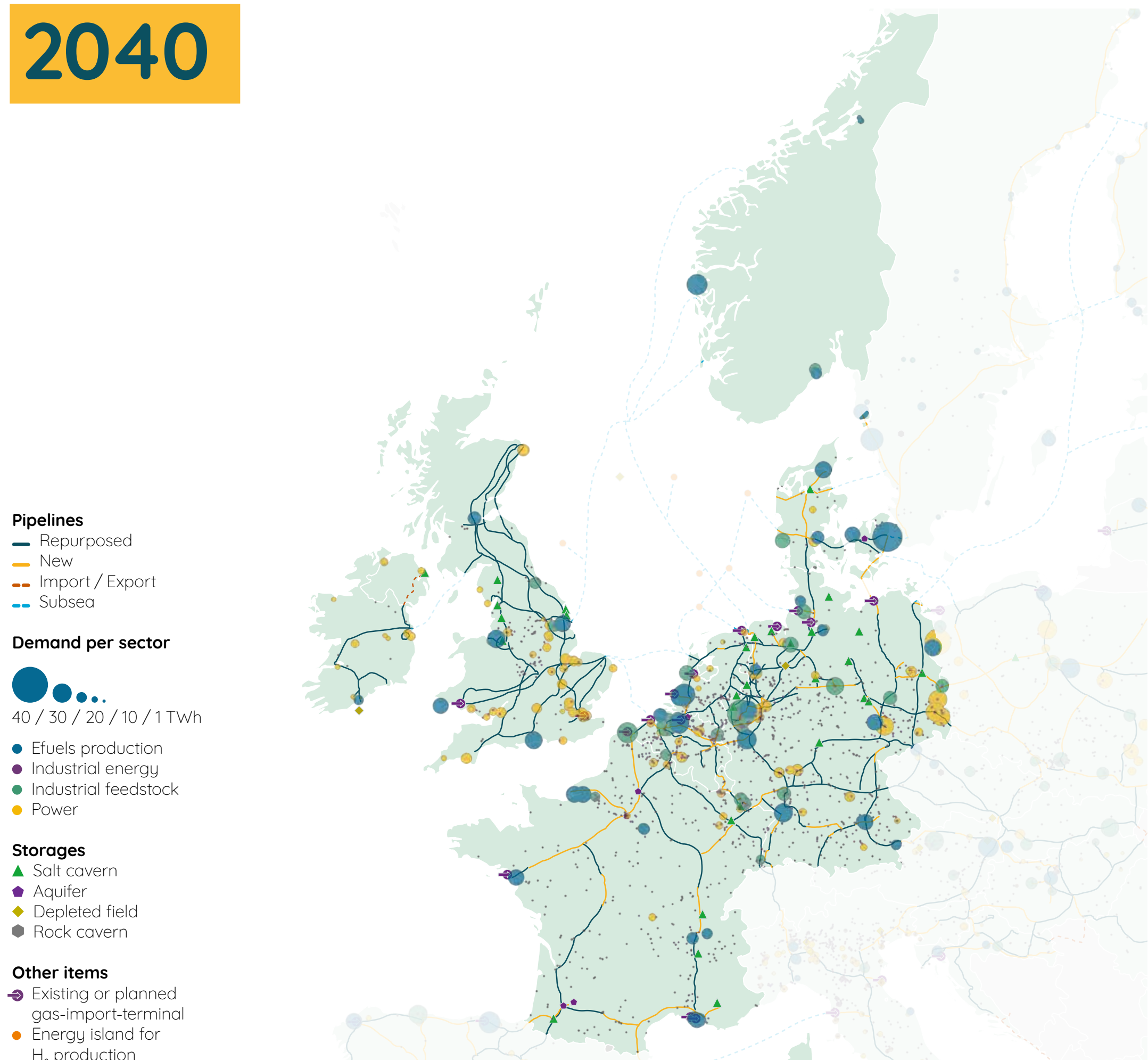
¹ Ship imports of hydrogen and hydrogen-derivatives are not included.

Corridor connects major industrial clusters in the UK and northwest Europe by 2030, expanding to all demand centers by 2040

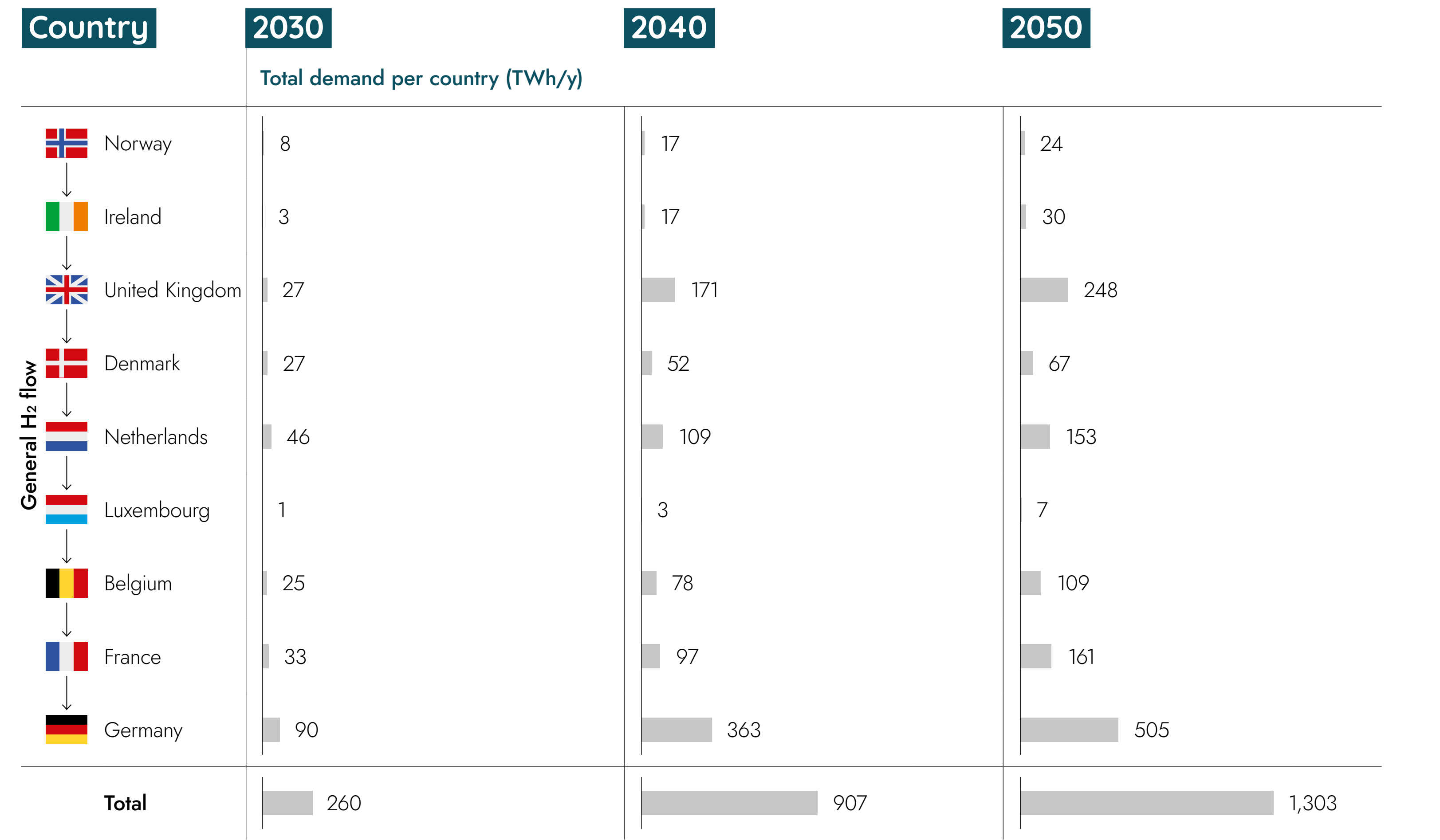
2030



2040



Hydrogen demand increases rapidly from 2030 to 2040, largely driven by the UK, Belgium, the Netherlands, France and Germany



Hydrogen demand – across all countries of the corridor – increases significantly from 2030 to 2050. Demand reaches 260 TWh by 2030, increasing to roughly ~900 TWh by 2050.

Hydrogen demand may accelerate and increase further than forecasted as a result of additional regulatory measures adopted in response to the RePowerEU plan.

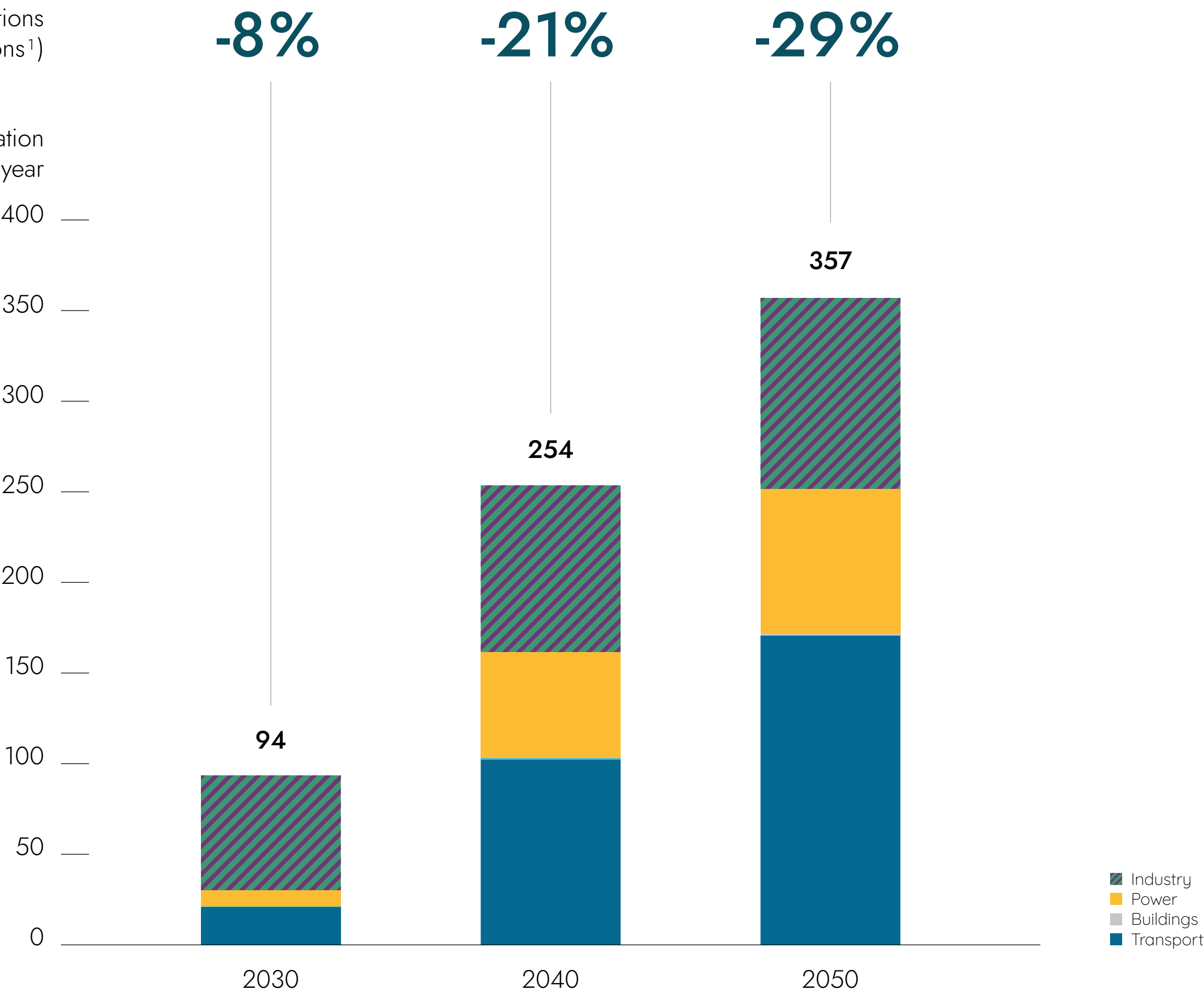
- Up to 2030, most hydrogen demand is driven by large industrial clusters in the UK, Belgium, the Netherlands, France and Germany. Hydrogen use in power generation also accounts for a significant share of demand.
- From 2040 to 2050, hydrogen demand expands into the transport sector and continues to ramp up in industry and power generation.

Note: Does not include grey hydrogen demand. Numbers represent total demand by country, even if only parts of the country are included in the corridor.

Hydrogen adoption enables a reduction in emissions of 29% by 2050 across all countries of the corridor

Emissions reductions (vs. 2019 emissions¹)

Decarbonisation in MtCO₂ / year



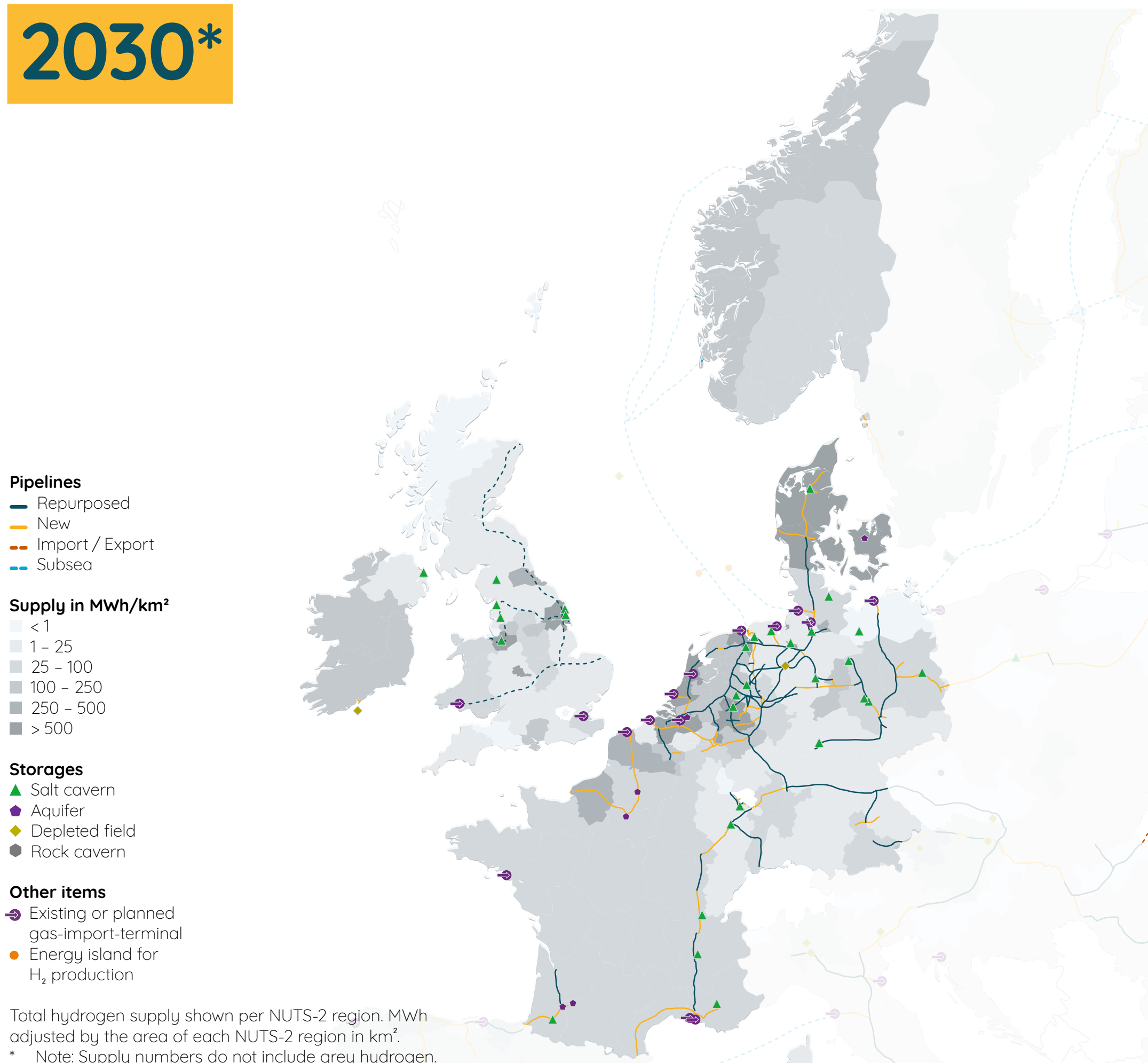
Hydrogen adoption across all demand sectors enables an **emissions reduction of ~360 MtCO₂/yr. by 2050**, equivalent to a 29% reduction².

- **Up to 2030**, the industrial sector contributes just under 70% of the total emissions reductions, largely driven by the decarbonisation of the steel sector. Notably, roughly 20% of emissions reductions are from the transport sector.
- **By 2040**, emissions reductions from transport (road, shipping and aviation) increase substantially and combined with industry, account for 80% of emissions reductions. The power sector account for the remaining 20% of reductions.
- **By 2050**, the transport sector alone accounts for over 50% of emissions reductions.

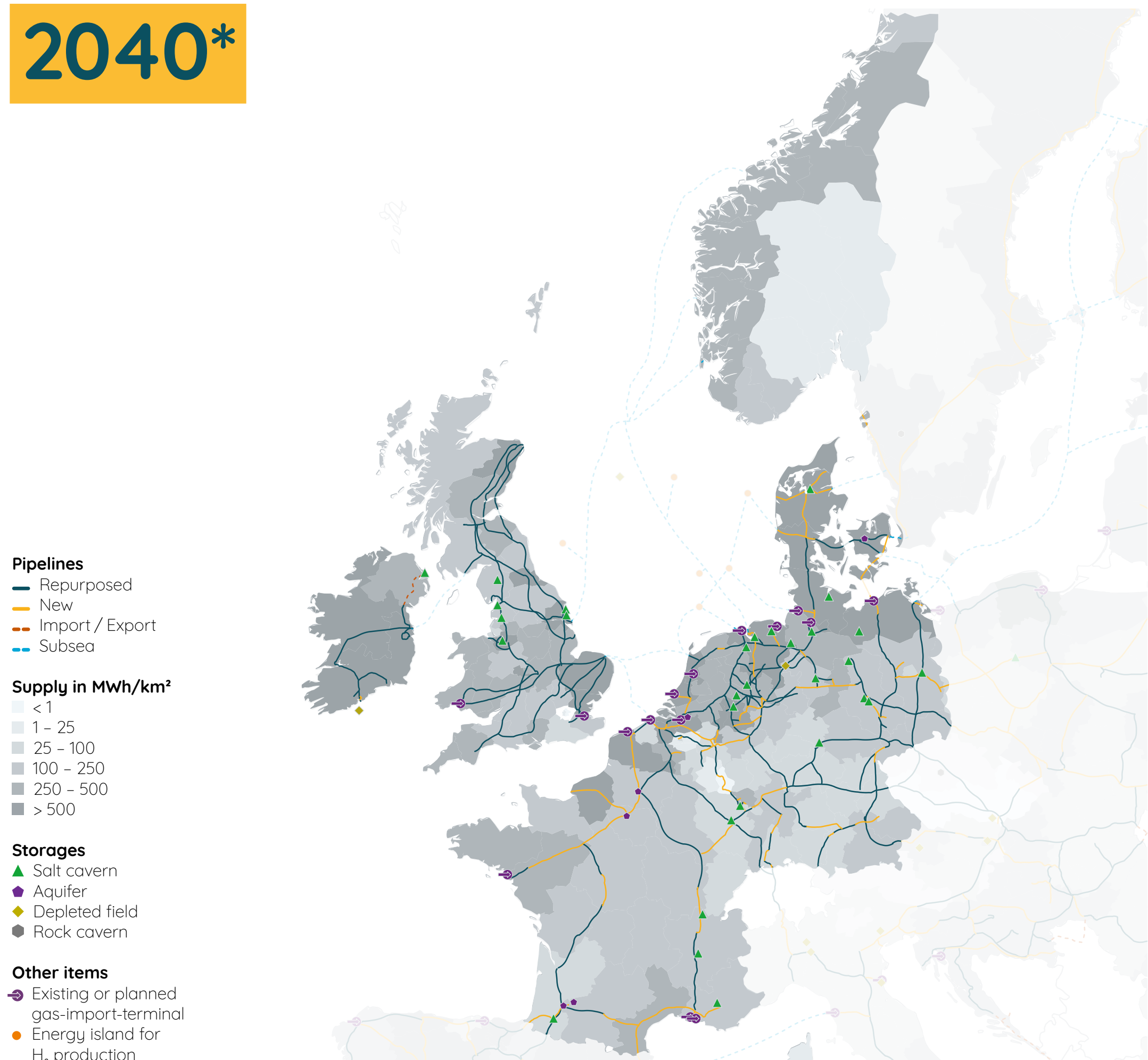
¹ CO₂-Emissions from countries and sectors included in corridor (1.24 bn t CO₂ / year), Source: EEA
² Emissions reductions are calculated compared to the baseline fossil fuel used in each sectors. For example, emissions reductions associated with the adoption of hydrogen by the primary steel sector are relative to the use of coal. Similarly, emissions reductions, for e-fuels production are relative to the use of fossil fuels in domestic transport, shipping and other uses.

Corridor enables access to North Sea blue hydrogen by 2030,
expanding to hydrogen supply from abundant offshore wind by 2040

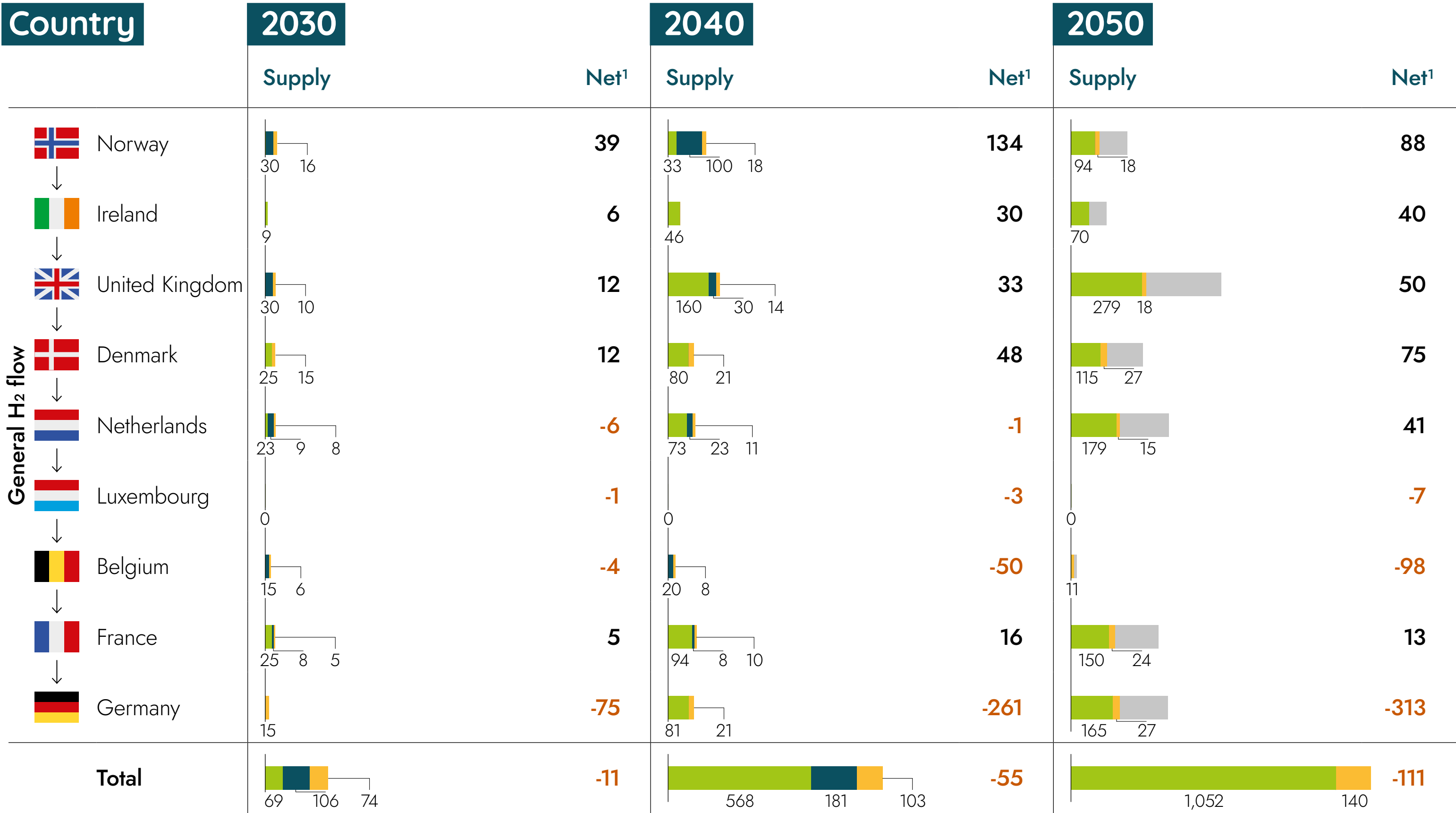
2030*



2040*



Hydrogen supply increases significantly from 2030 to 2040, driven by a scale up in supply across multiple countries in the corridor



1 Net represents excess supply after subtracting demand;
2 Grid-based is estimated using national 2030 electrolyser targets which, by 2030, are assumed to be largely grid-connected rather than dedicated. Grid-based increases over 2030-2050 with increasing RES;
3 Blue hydrogen supply volumes will be subject to the evolution of gas markets and the development of low carbon hydrogen regulation in different country. As a result, some countries may have additional blue hydrogen supply which could be used to satisfy local demand.

Dedicated green
Blue
Grid-based
2050 technical potential

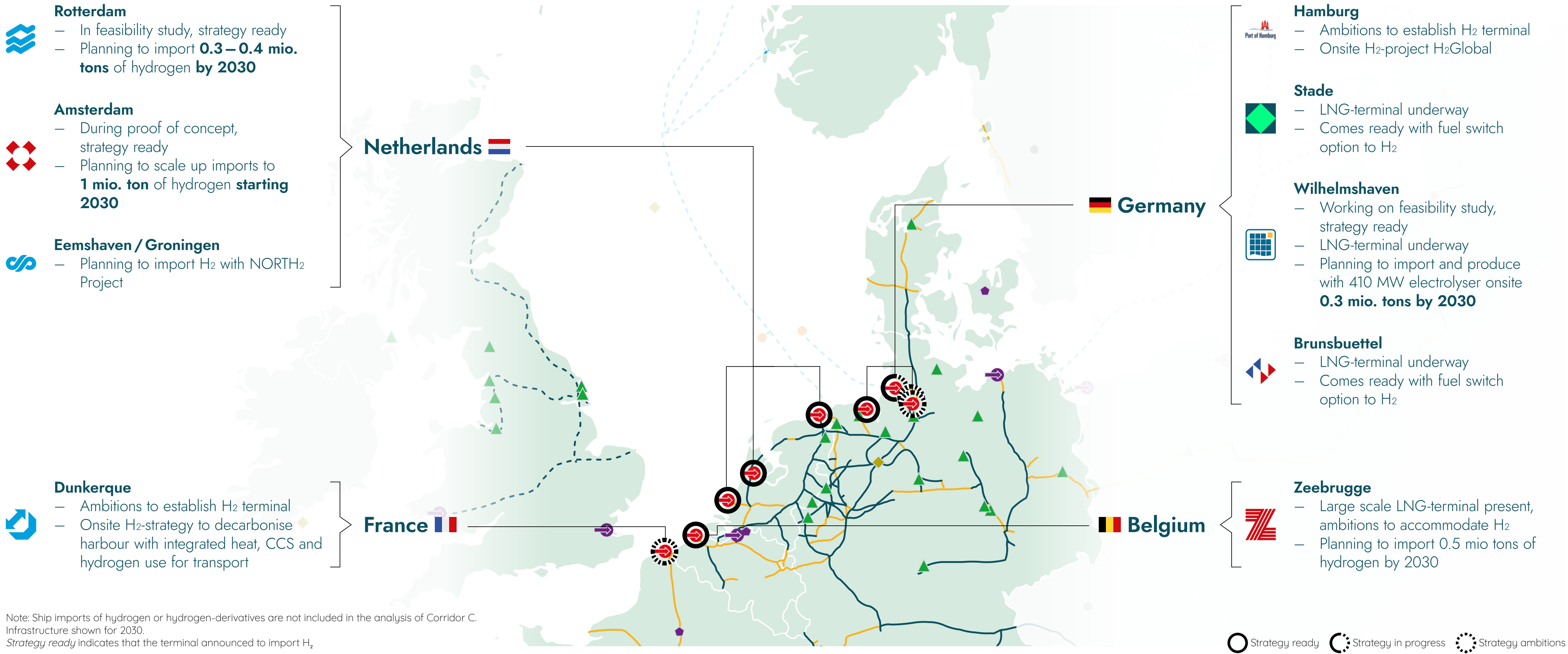
Hydrogen supply includes a mix of supply options including **grid-based green hydrogen², dedicated green hydrogen, and blue hydrogen³.**

- **By 2030, hydrogen supply reaches ~250 TWh**, roughly 40% blue hydrogen and 30% each for dedicated green and grid-based hydrogen.
- **By 2040, hydrogen supply increases substantially to ~850 TWh**, of which 70% is from dedicated green hydrogen. Blue hydrogen accounts for just under 20%, while grid-based hydrogen for the remaining 10%.
- **By 2050, hydrogen supply increases further to ~1,190 TWh**. Dedicated green supply account for the largest share at 90%, while grid-based hydrogen account for the remaining 10%. Blue hydrogen supply is not included in 2050 due to assumed target of zero emissions and de-fossilisation of Europe by 2050.

Hydrogen supply may accelerate and increase further as a result of additional regulatory measures adopted in response to the RePowerEU plan.

Note: Hydrogen supply volumes do not include hydrogen imports by ship.

The scale up in supply is supported by the development of several hydrogen import terminals in the North Sea



Agenda

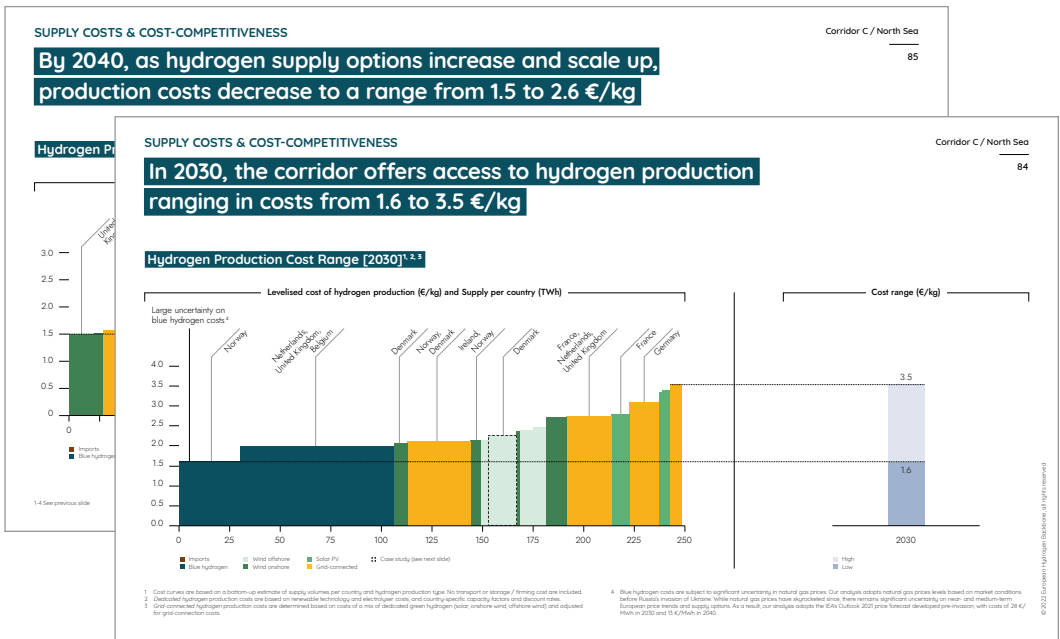
1. Corridor Summary
2. Hydrogen Demand & Supply
- 3. Supply Costs & Cost-Competitiveness**
4. National Strategies & Regulation
5. Actions Needed

This section explores the costs of hydrogen production and delivery for this corridor and their competitiveness

Hydrogen production cost

Key Questions Answered

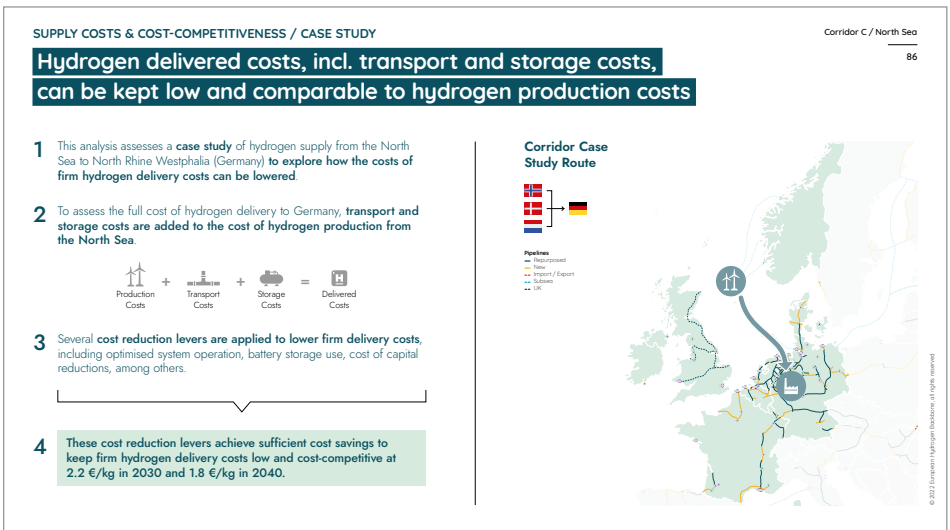
What is the range of production costs achieved by the corridor in 2030 and 2040?



- By 2030, the corridor provides access to hydrogen production costs of **1.6 to 3.5 €/kg**.
- By 2040, hydrogen production costs decrease to the range of **1.5 to 2.6 €/kg**.

Hydrogen delivered costs

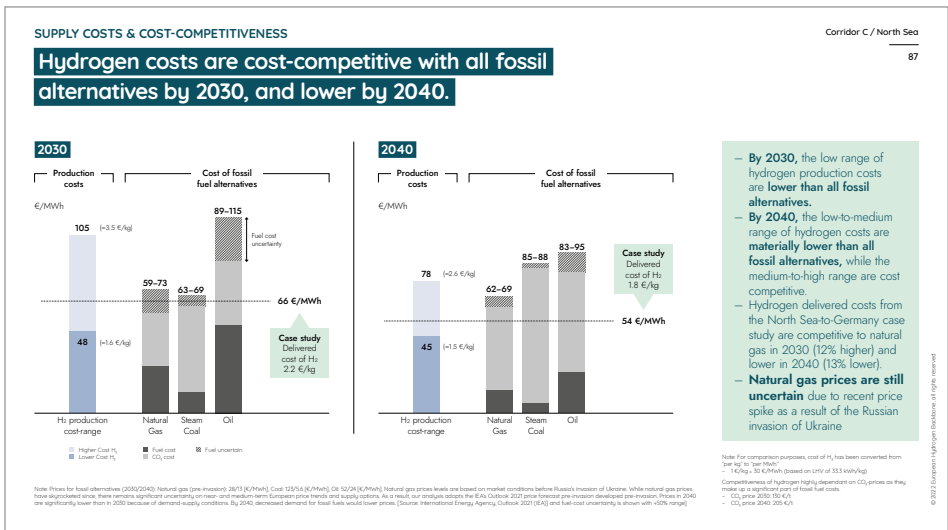
- Based on a **case-study of hydrogen supply** from the North Sea to Germany:
- What are the **full costs of firm hydrogen delivery** after accounting for **transport** and **storage** costs?
 - What **cost levers** are available to lower the cost of hydrogen delivery?



- Several **cost reduction levers** can be applied to **lower the costs of hydrogen delivery**.
- For the North Sea-to-Germany case study, **these levers achieve delivery costs that are low and cost-competitive**.

Comparison with fossil alternatives

How **competitive** is hydrogen supply from this corridor compared to fossil fuel alternatives?



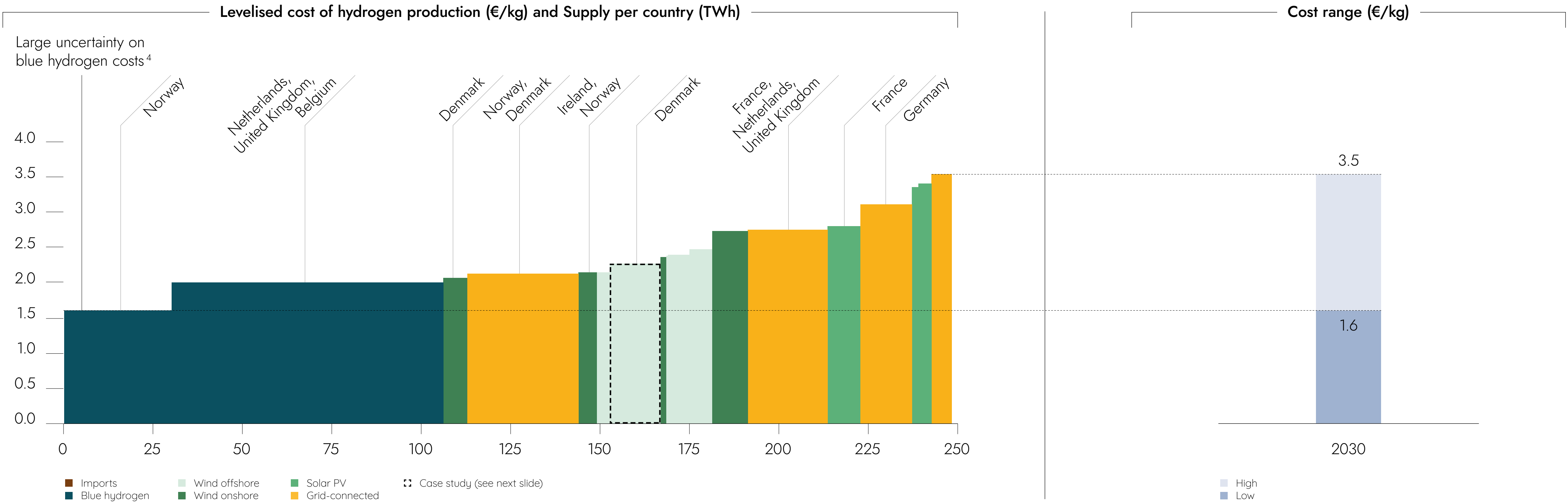
- Hydrogen costs are competitive with fossil fuel alternatives by 2030**, and lower by 2040.
- Fossil fuel costs are subject to **significant uncertainty**.

Content Material

Key Findings & Results

In 2030, the corridor offers access to hydrogen production ranging in costs from 1.6 to 3.5 €/kg

Hydrogen Production Cost Range [2030]^{1, 2, 3}



1 Cost curves are based on a bottom-up estimate of supply volumes per country and hydrogen production type. No transport or storage / firming cost are included.

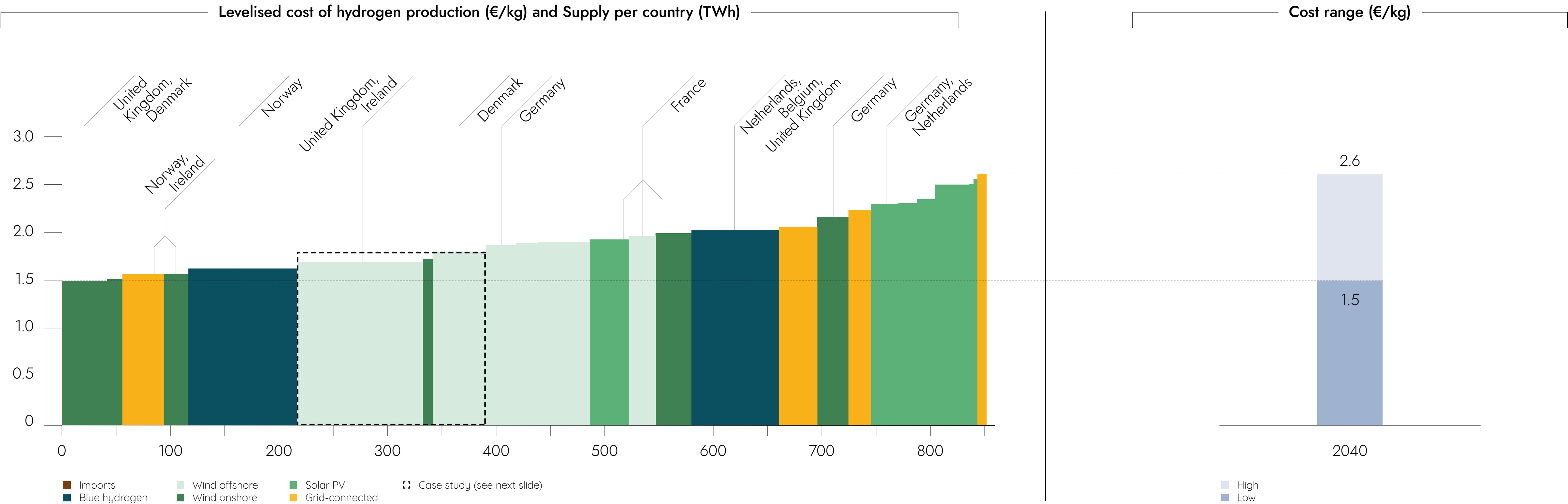
2 Dedicated hydrogen production costs are based on renewable technology and electrolyser costs, and country-specific capacity factors and discount rates.

3 Grid-connected hydrogen production costs are determined based on costs of a mix of dedicated green hydrogen (solar, onshore wind, offshore wind) and adjusted for grid-connection costs.

4 Blue hydrogen costs are subject to significant uncertainty in natural gas prices. Our analysis adopts natural gas prices levels based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast developed pre-invasion, with costs of 28 €/MWh in 2030 and 13 €/MWh in 2040.

By 2040, as hydrogen supply options increase and scale up, production costs decrease to a range from 1.5 to 2.6 €/kg

Hydrogen Production Cost Range [2040]^{1, 2, 3}

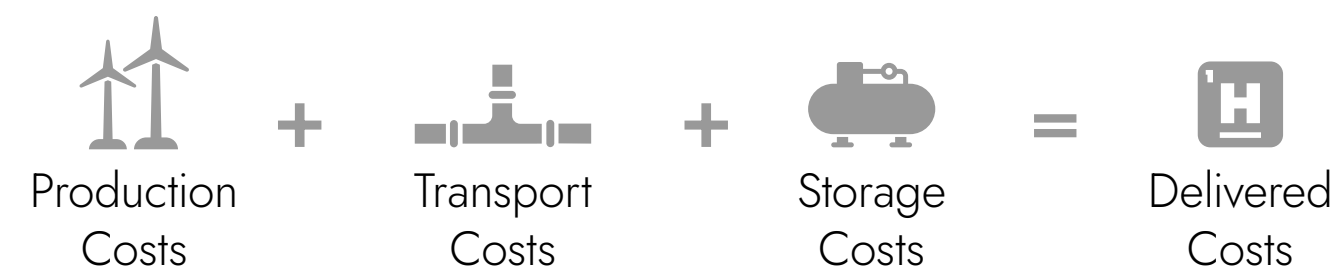


1-4 See previous slide

Hydrogen delivered costs, incl. transport and storage costs, can be kept low and comparable to hydrogen production costs

1 This analysis assesses a **case study** of hydrogen supply from the North Sea to North Rhine Westphalia (Germany) **to explore how the costs of firm hydrogen delivery costs can be lowered.**

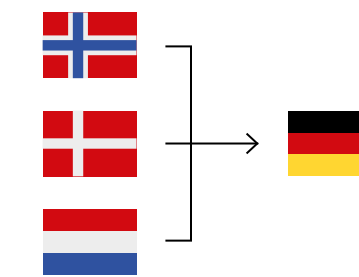
2 To assess the full cost of hydrogen delivery to Germany, **transport and storage costs are added to the cost of hydrogen production from the North Sea.**



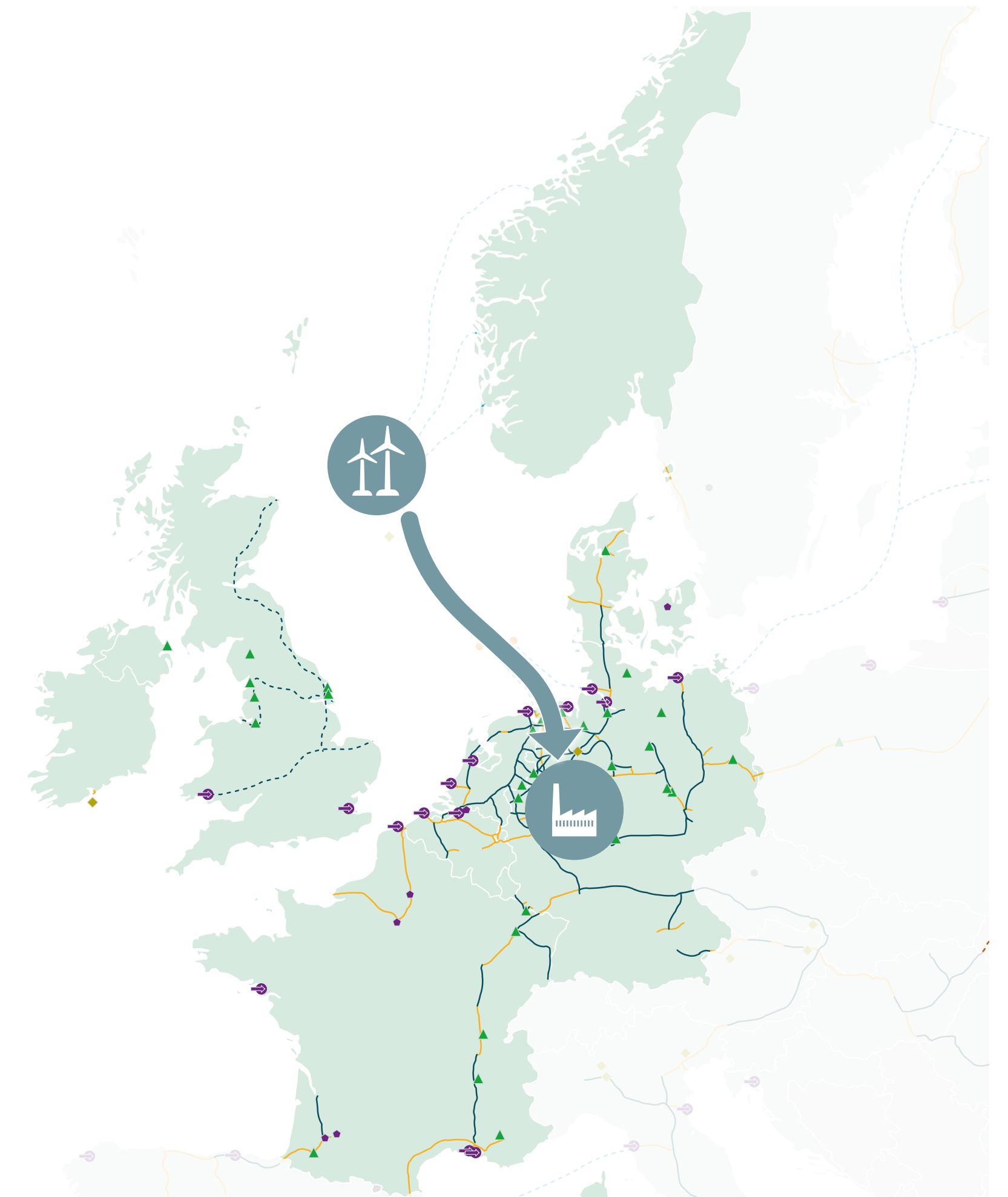
3 Several **cost reduction levers** are applied to lower firm delivery costs, including optimised system operation, battery storage use, cost of capital reductions, among others.

4 These cost reduction levers achieve sufficient cost savings to keep firm hydrogen delivery costs low and cost-competitive at 2.2 €/kg in 2030 and 1.8 €/kg in 2040.

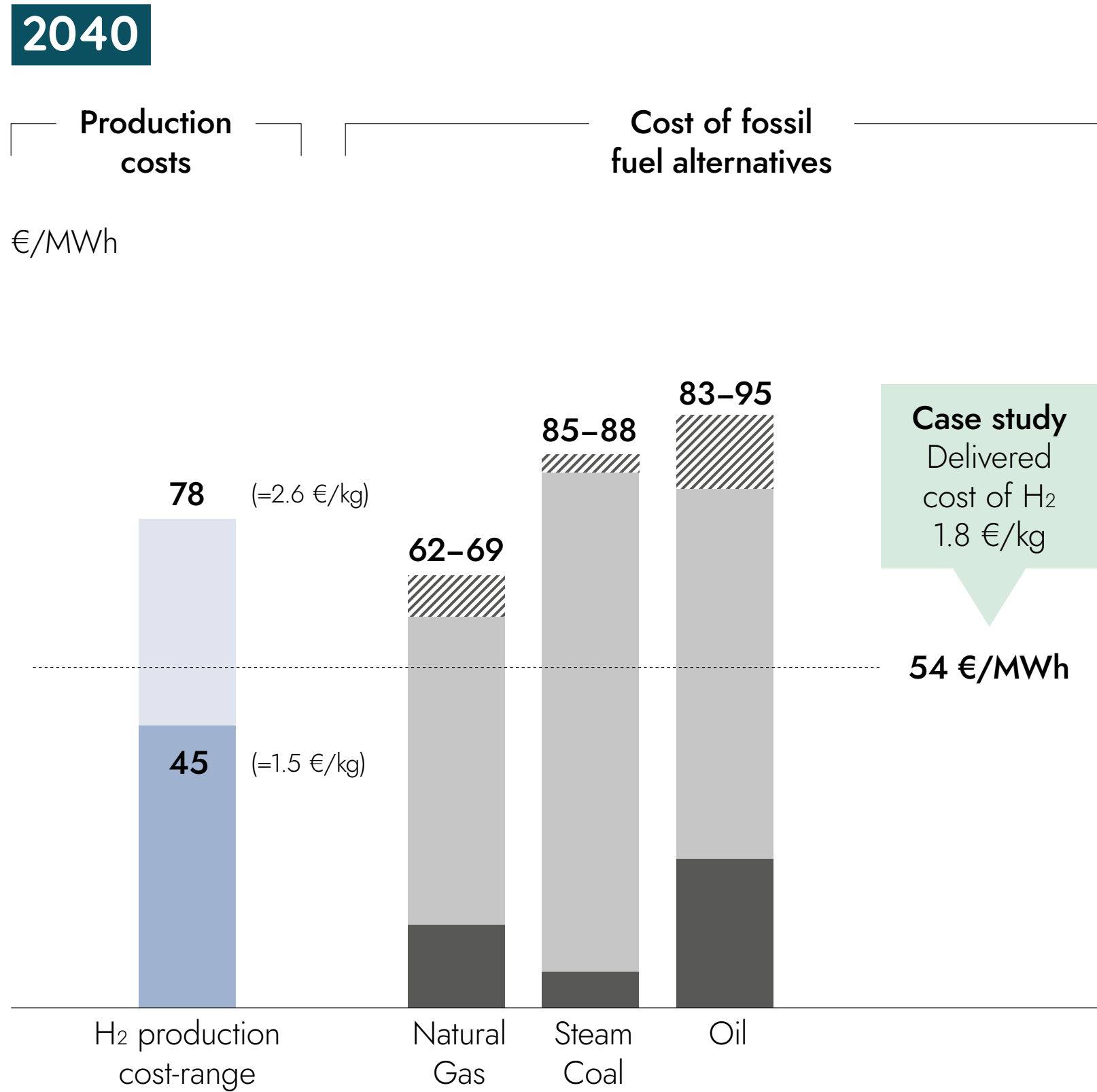
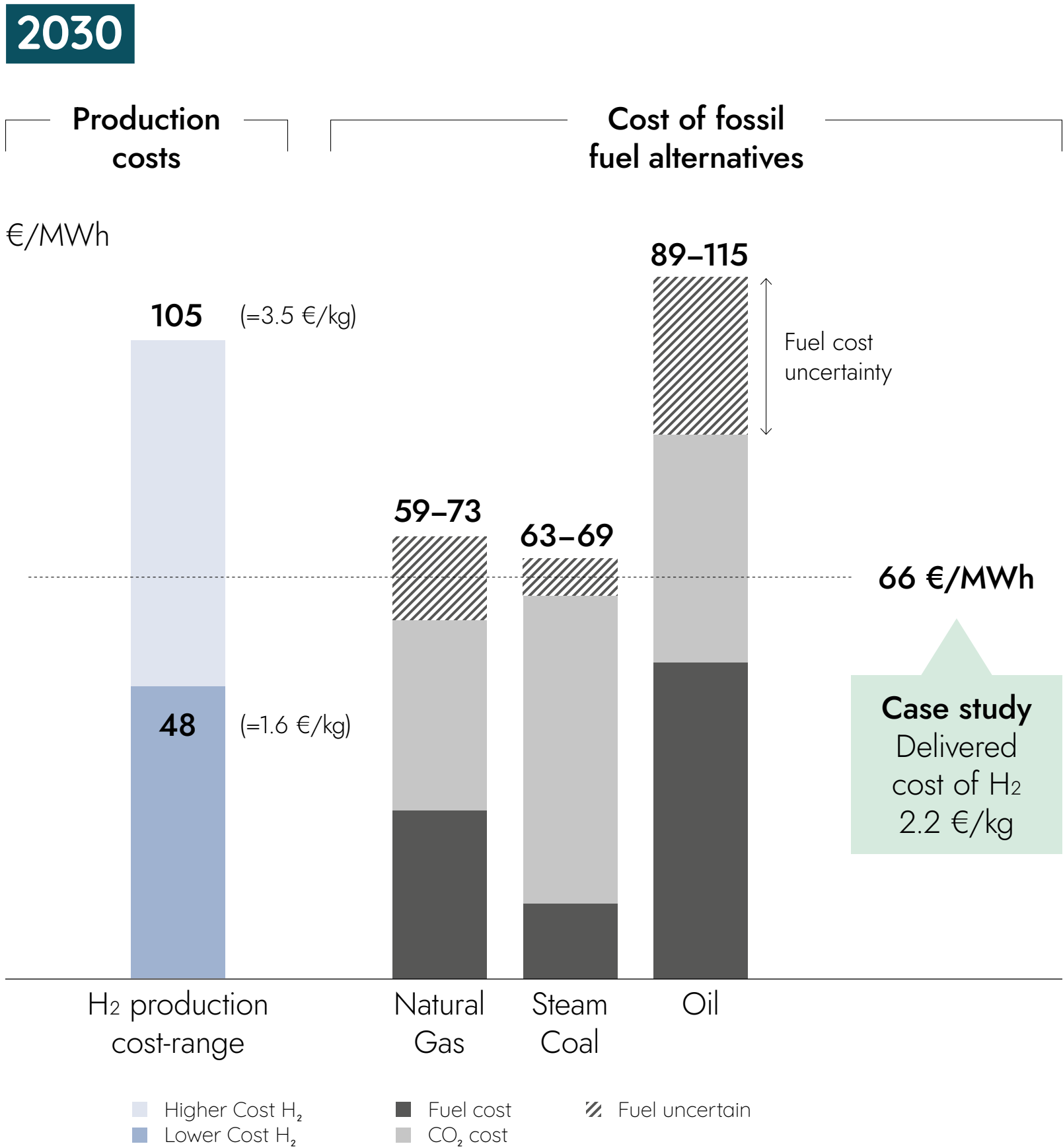
Corridor Case Study Route



Pipelines
— Repurposed
— New
— Import / Export
— Subsea
— UK



Hydrogen costs are cost-competitive with all fossil alternatives by 2030, and lower by 2040.



- By 2030, the low range of hydrogen production costs are **lower than all fossil alternatives**.
- By 2040, the low-to-medium range of hydrogen costs are **materially lower than all fossil alternatives**, while the medium-to-high range are cost competitive.
- Hydrogen delivered costs from the North Sea-to-Germany case study are competitive to natural gas in 2030 (12% higher) and lower in 2040 (13% lower).
- Natural gas prices are still uncertain** due to recent price spike as a result of the Russian invasion of Ukraine

Note: Prices for fossil alternatives (2030/2040): Natural gas (pre-invasion): 28/13 [€/MWh], Coal: 123/5.6 [€/MWh], Oil: 52/24 [€/MWh]. Natural gas prices levels are based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast pre-invasion developed pre-invasion. Prices in 2040 are significantly lower than in 2030 because of demand-supply conditions. By 2040, decreased demand for fossil fuels would lower prices. [Source: International Energy Agency, Outlook 2021 (IEA)] and fuel-cost uncertainty is shown with +50% range]










Note: For comparison purposes, cost of H₂ has been converted from "per kg" to "per MWh"
- 1 €/kg = 30 €/MWh (based on LHV of 33.3 kWh/kg)
Competitiveness of hydrogen highly dependant on CO₂-prices as they make up a significant part of fossil fuel costs.
- CO₂ price 2030: 130 €/t
- CO₂ price 2040: 205 €/t

Agenda

1. Corridor Summary
2. Hydrogen Demand & Supply
3. Supply Costs & Cost-Competitiveness
- 4. National Strategies & Regulation**
5. Actions Needed

Most countries have developed national strategies and targets. Moving forward, the development of regulation is key to enable infrastructure investment.

Pre-
RePowerEU
targets²

	National Hydrogen strategy (NHS)	Network regulation & policy	Funding ¹ (bn €)	Highlights
	Norway <ul style="list-style-type: none">2025: H2 hubs for maritime, industrial & product.2030: Network of spread hydrogen hubs	<ul style="list-style-type: none">N/A	<div><div></div>0.1</div>	<ul style="list-style-type: none">Focus on maritime applications and H2 hubsAssessment of CCFDs for industrial projects
	Ireland <ul style="list-style-type: none">Government plans NHS in July, 2022	<ul style="list-style-type: none">N/A		<ul style="list-style-type: none">Early stage policy developments only
	United Kingdom <ul style="list-style-type: none">2030: 10 GW of low-carbon hydrogen productionMix of green and blue hydrogen incl. fundingBlending of 20% vol. to gas network foreseen	<ul style="list-style-type: none">Initial network regulatory and legal framework not expected before 2025	<div><div></div>2.3</div>	<ul style="list-style-type: none">More clarity on H2 funding & strategy for ind. cluster application & H2 productionPolicy decision on heat due in 2026
	Denmark <ul style="list-style-type: none">Focus on green H2 (4-6 GW) and Efuels, and export of Efuels and PtX technologies to demand hubs (DE, NL, etc.)	<ul style="list-style-type: none">Proposition: Allow TSO & DSO to own and operate H2 infrastructure	<div><div></div>0.2</div>	<ul style="list-style-type: none">Transport infrastructure is seen as key to enable role as PtX producer and exporter
	Netherlands <ul style="list-style-type: none">Focus: Production & network to supply industryBuild dedicated national hydrogen grid3 – 4 GW electrolyser capacity in 2030	<ul style="list-style-type: none">Unbundling of natural gas and H2 grid operation and productionIntegrated network planning	<div><div></div>1.5</div>	<ul style="list-style-type: none">Production and transport infrastructure€750 m funding for national hydrogen transmission network.
	Luxembourg <ul style="list-style-type: none">Focus on renewable hydrogenPrioritized use in industry, sector coupling & transportDedicated H2 network explicitly mentioned	<ul style="list-style-type: none">Goal to regulate transmission and distribution infrastructure in line with ambitions of the EU		<ul style="list-style-type: none">Strong need for imports, hence cross border H2 infrastructure & national networks to meet industry & transport demand
	Belgium <ul style="list-style-type: none">Focus: Industry, (freight) transport, electricity storage150 MW for electrolysis production by 2026Import and transit of H2 and its derivatives via existing network and additional infrastructure	<ul style="list-style-type: none">2026: 100-160 new km pipelinesOpen access H2 backbone by 2030 connecting ports, industrial clusters, and neighboring countries	<div><div></div>0.1</div>	<ul style="list-style-type: none">The NHS sees Belgium as an import hub of renewable molecules for EuropeStrong focus on national and cross-country hydrogen network infrastructure
	France <ul style="list-style-type: none">Implementation of local hydrogen hubs pre 2030Focus on demand (e.g. heavy transport) and generation (6.5 GW electrolyser in 2030)No strategy on H2 infrastructure yet	<ul style="list-style-type: none">Hydrogen injections to gas grid are possible, below threshold of technical restrictions	<div><div></div>7.2</div>	<ul style="list-style-type: none">Strong investments in transport sector (heavy duty) and hydrogen production for industryNeed to accelerate strategy and policy around exports and imports
	Germany <ul style="list-style-type: none">National production & import focus due to supply gapIn place since 2020, currently reviewed towards increasing its ambition10 GW (2030) electrolyser in coalition plans	<ul style="list-style-type: none">H2 network potentially opt-in regulated and vertically unbundledFirst rules and standards for high pressure pipelines are formulated	<div><div></div>9</div>	<ul style="list-style-type: none">Strong focus on international cooperation to ensure sufficient supplyNational funding

Note: Sequencing of countries follows the general corridor direction but does not represent the hydrogen flows.
1 Cumulative public funding amount by the respective state until 2030
2 Strategies and funding is under evaluation of meeting latest targets



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This corridor plays a fundamental role in achieving a European backbone by 2040

The need for this corridor

- The development of **this corridor ensures access to abundant, low-cost blue hydrogen supply from the North Sea** by 2030, and by 2040 diversifying its supply with green hydrogen from offshore wind resources in the North Sea.
- The **decarbonisation of the largest hydrogen demand centers along this corridor** — in the **UK, the Netherlands, Belgium, northern France and western Germany** — is dependent on the buildout of this corridor by 2030, and its expansion towards 2040.

Actions required

- The buildout of this corridor by 2030 **requires national governments to take clear and concrete actions across.**
- This includes actions associated with **infrastructure development and planning, the development of cross-national initiatives** and **securing access to early funding and long-term, low-cost financing.**

2040

Pipelines

- Repurposed
- New
- Import / Export
- Subsea

Demand per sector

- 40 / 30 / 20 / 10 / 1 TWh
- Efuels production
 - Industrial energy
 - Industrial feedstock
 - Power

Supply in MWh/km²

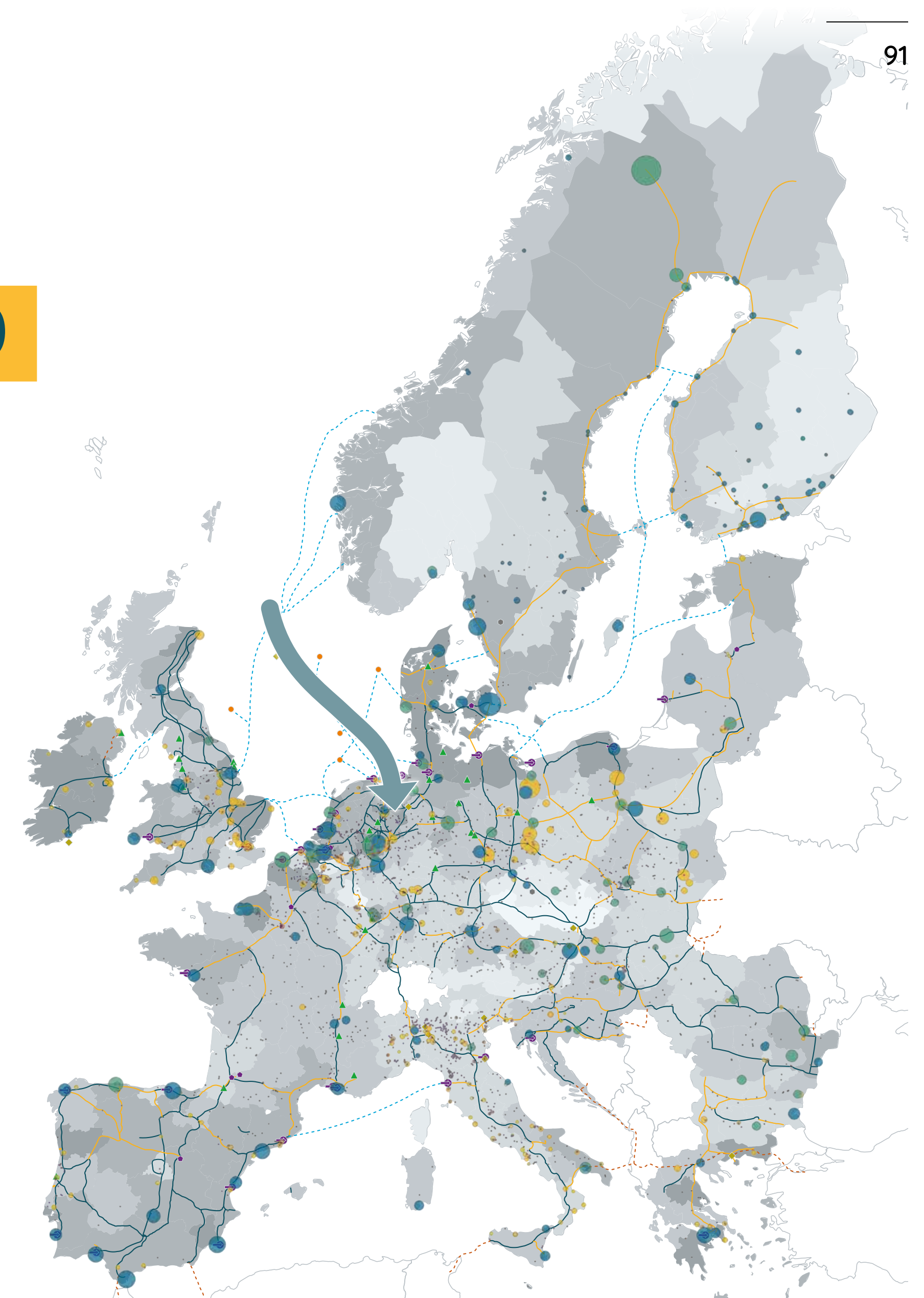
- < 1
- 1 – 25
- 25 – 100
- 100 – 250
- 250 – 500
- > 500

Storages

- ▲ Salt cavern
- ▲ Aquifer
- ▲ Depleted field
- ▲ Rock cavern

Other items

- Existing or planned gas-import-terminal
- Energy island for H₂ production



**To ensure the development of this corridor by 2030,
there is a need for clear and concrete actions**

Fostering development of new and repurposed hydrogen infrastructure, for example, by un-bundling rules facilitating the efficient use of TSO expertise and services and by allowing the adoption of different vertical un-bundling models in the EU, as is the case with natural gas

+

Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions (including incentivizing the adoption of hydrogen by demand sectors)

+

Simplify and shorten planning and permitting procedures for renewable energy and hydrogen infrastructure projects.

+

Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure supporting the accelerated deployment and integration of renewable energy resources

→ However, speed will be of essence!

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Corridor A: North Africa & Southern Europe

Corridor B: Southwest Europe & North Africa

Corridor C: North Sea

Corridor D: Nordic and Baltic regions

Corridor E: East and South-East Europe

3. Detailed methodology

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Nordics
& Baltics

- Finland
- Sweden
- Estonia
- Lithuania
- Latvia
- Denmark
- Poland
- Germany
- Czechia



Corridor emerges in the Nordics and Baltics providing access to low-cost hydrogen supply from vast onshore and offshore wind resources

<div>Drivers & Opportunities</div>	Major drivers of development are early national decarbonisation targets of Nordic countries and hydrogen adoption in heavy industry and transport . Key opportunities include the early development of new H₂ infrastructure in the Bothnian Bay, and regional opportunities for offshore pipelines and salt cavern storage .		
<div>Hydrogen Supply & Decarbonization Potential</div>	<div><div>H₂ supply potential¹</div><div>(TWh/year)</div><div></div><div><div><div>184 TWh</div><div>501 TWh</div></div><div><div>2030</div><div>2040</div></div></div></div>	<div><div>Emissions Reductions</div><div>(MtCO₂/year vs. 2019; % reduction)</div><div></div><div><div><div>2030</div><div>2040</div></div><div><div>-91 Mt (12%)</div><div>-228 Mt (30%)</div></div></div></div>	
<div>Supply Costs & Cost-Competitiveness</div>	<div><div>Cost of H₂ production¹</div><div>(€/kg of H₂)</div><div></div><div><div><div>2.1–3.8</div><div>1.5–2.7</div></div><div><div>2030</div><div>2040</div></div></div></div>	<div><div>Cost competitiveness²</div><div>— Hydrogen delivered price vs.</div><div> natural gas price high/low, (€/MWh)</div><div><div><div>75</div><div>73</div><div>69</div><div>59</div><div>63</div></div><div><div>2030</div><div>2040</div></div></div></div>	
<div>Actions Needed</div>	<div><div>— Fostering development of new and repurposed hydrogen infrastructure</div><div>— Unlock financing to fast-track hydrogen infrastructure deployment</div><div>— Simplify and shorten planning and permitting procedures</div><div>— Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure</div></div>		

1 Figures reported reflect outputs for all countries included in the corridor. Even if a country is only partially in the corridor, results for the full country are included (e.g., supply potential and costs, demand, transmission network length).

2 Savings are based on the corridor's case study of hydrogen delivered in 2030 and 2040. The cost of natural gas includes CO₂ prices. Refer to Subsection 3 (Supply Costs & Cost-Competitiveness)

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Corridor offers access to low-cost supply from the Nordics to demand centers along the corridor to Poland and Germany

Drivers & Opportunities

- **The major driver** behind the development of this corridor is the adoption of hydrogen associated with the **decarbonisation of industry, transport and power** in the Nordics, the Baltics, Poland and Germany. Initially, the development of the corridor will be driven by new green steel and e-fuel projects and early national decarbonisation targets in Sweden and Finland. The speed of hydrogen adoption in these regions may be even faster than anticipated driven by increasing CO₂ prices in the EU and the RePowerEU ambitions to replace natural gas consumption.
- In the near term, the corridor offers **access to abundant low-cost, onshore wind and grid-based hydrogen supply from the Nordics**. In the longer term, the corridor also provides access to hydrogen supply from offshore wind in the Nordics and the Baltics.
- A major opportunity of this corridor is the **early and accelerated development of new hydrogen infrastructure in the Bothnian Bay**, one of the earliest, greenfield hydrogen infrastructure projects in Europe. The early buildout of hydrogen infrastructure also offers an **opportunity to pilot and operationalise new regulatory, planning and permitting processes** aiming to accelerate and streamline the rollout of hydrogen infrastructure.
- Another set of opportunities includes the **development of offshore pipelines** connecting Nordic offshore wind resources to demand centers in Germany and Central Europe, as well as the **potential development of salt cavern hydrogen storage**.
- The corridor would be stood up by 2030, covering **13,500 km** of large-scale hydrogen pipelines across all countries of the corridor, of which approximately **45% will be repurposed pipelines**.

Hydrogen Demand & Supply

- **Total hydrogen demand** in the corridor reaches **~220 TWh by 2030**, increasing substantially to **~725 TWh by 2040**. Up to 2030, most hydrogen demand is driven by the steel sector in Germany and the Nordics, along with some hydrogen adoption in transport. From 2040 to 2050, hydrogen demand expands further in industry and transport and plays a more meaningful role in power generation.
- Hydrogen adoption across all countries of the corridors enables an emissions reduction of ~290 MtCO₂/yr. by 2050, equivalent to a **39% emissions reduction**. Emissions reductions are notoriously higher than other corridors due to the high emissions reduction potential in the steel sector.
- The corridor enables access to **hydrogen supply potential of ~185 TWh by 2030, increasing to roughly 500 TWh by 2040**. Major sources of supply include hydrogen from onshore and offshore wind in the Nordics, along with grid-based green hydrogen, leveraging the vast, low-cost hydropower potential of the Nordics.

To successfully stand up this corridor by 2030, actions are needed to support infrastructure planning, financing and development.

Costs & Cost-Competitiveness

- By 2030, the corridor provides access to hydrogen ranging in production costs from 2.1 to 3.8 €/kg. By 2040, as supply options increase and technology costs decrease, hydrogen production costs decrease to 1.5 to 2.7 €/kg.
- In the long term, this corridor’s lowest-cost hydrogen supply options are onshore and offshore wind from the Nordics.
- Based on a case-study of hydrogen supply and transport from the Bothnia Bay region of Finland to Germany, the cost of delivered hydrogen – inclusive of transport and storage costs – can be lowered significantly and be cost-competitive with fossil fuel alternatives. Lowering delivery costs can be achieved through various cost levers including optimised operation of the system and cost of capital reductions.

National Strategies & Regulation

- Most countries have developed – or are in the process of developing – national strategies. Moving forward, the development of hydrogen regulation in all countries will be key in enabling investment in infrastructure.
- In select countries, substantial funding has been allocated to support the development of the hydrogen market including funding for gas network infrastructure.

Actions Needed

- To support the buildout of this corridor by 2030, clear and concrete actions related to infrastructure planning, financing and development have been identified:
- Fostering development of new and repurposed hydrogen infrastructure.
 - Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions.
 - Simplify and shorten planning and permitting procedures for the full value chain of renewable energies and hydrogen infrastructure projects.
 - Establish integrated energy system planning of hydrogen, natural gas, and electricity infrastructure.

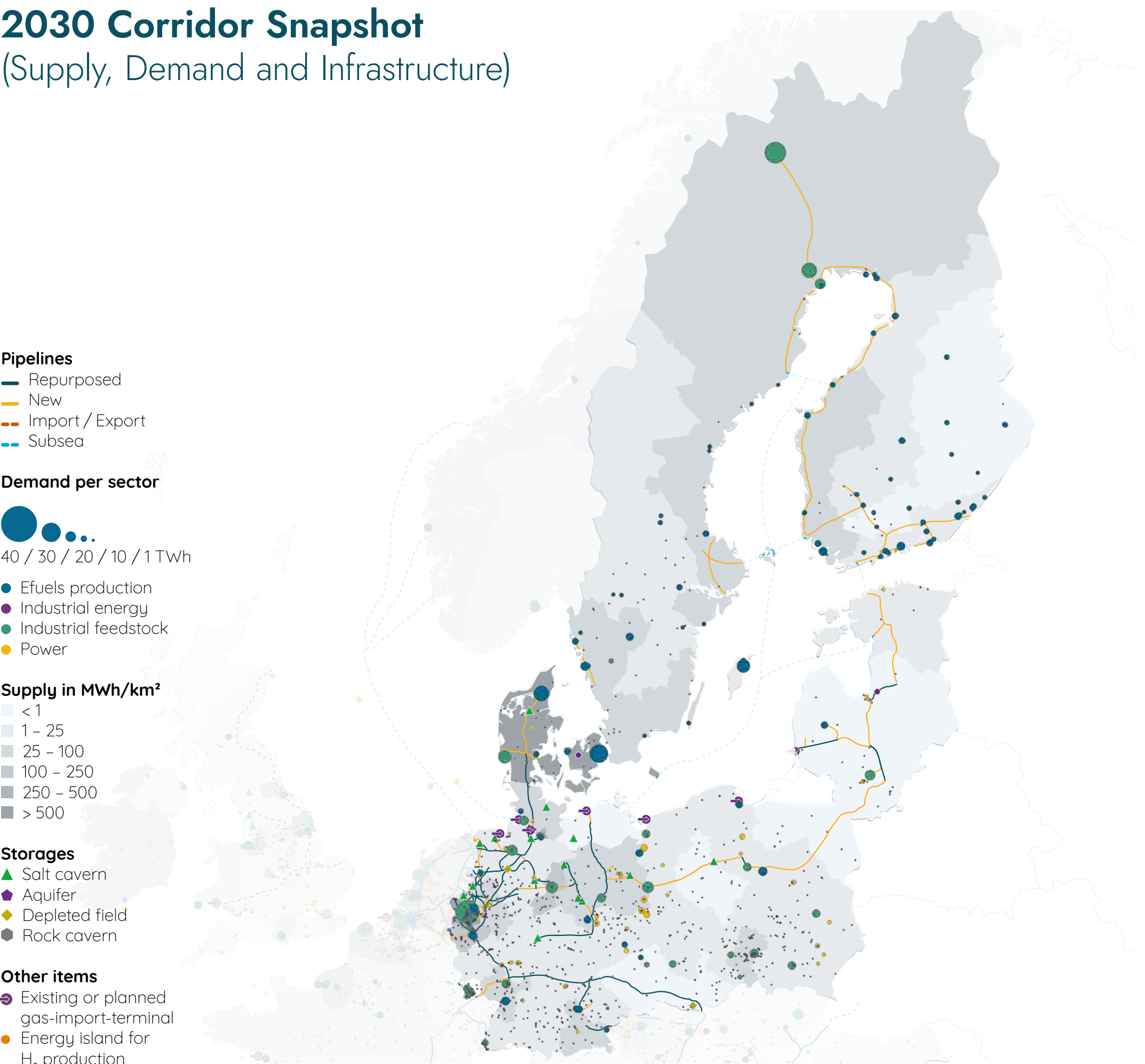
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This section explores the development of demand, supply and transport infrastructure in the corridor from 2030 to 2050

2030 Corridor Snapshot
(Supply, Demand and Infrastructure)



Hydrogen demand

By 2030, the corridor connects **all major industrial clusters** from the Nordics to Germany. By 2040, the corridor expands to **all demand centers along its route**, increasing demand from 220 to 725 TWh.

Hydrogen supply

By 2030, the corridor enables access to low-cost, hydrogen supply from **parts of the Nordics**. By 2040, the corridor expands access to supply across the Nordics and into the Baltics.

In 2030, hydrogen supply is **~185 TWh**, of which nearly 70% is dedicated green hydrogen. Hydrogen supply increases significantly by 2040, reaching 500 TWh.



Hydrogen Infrastructure

By 2030, the buildout of **pipeline infrastructure** across all countries of the corridor reaches **13,500 km** of large-scale pipelines. Notably, this corridor includes a **large share of new pipeline infrastructure**.

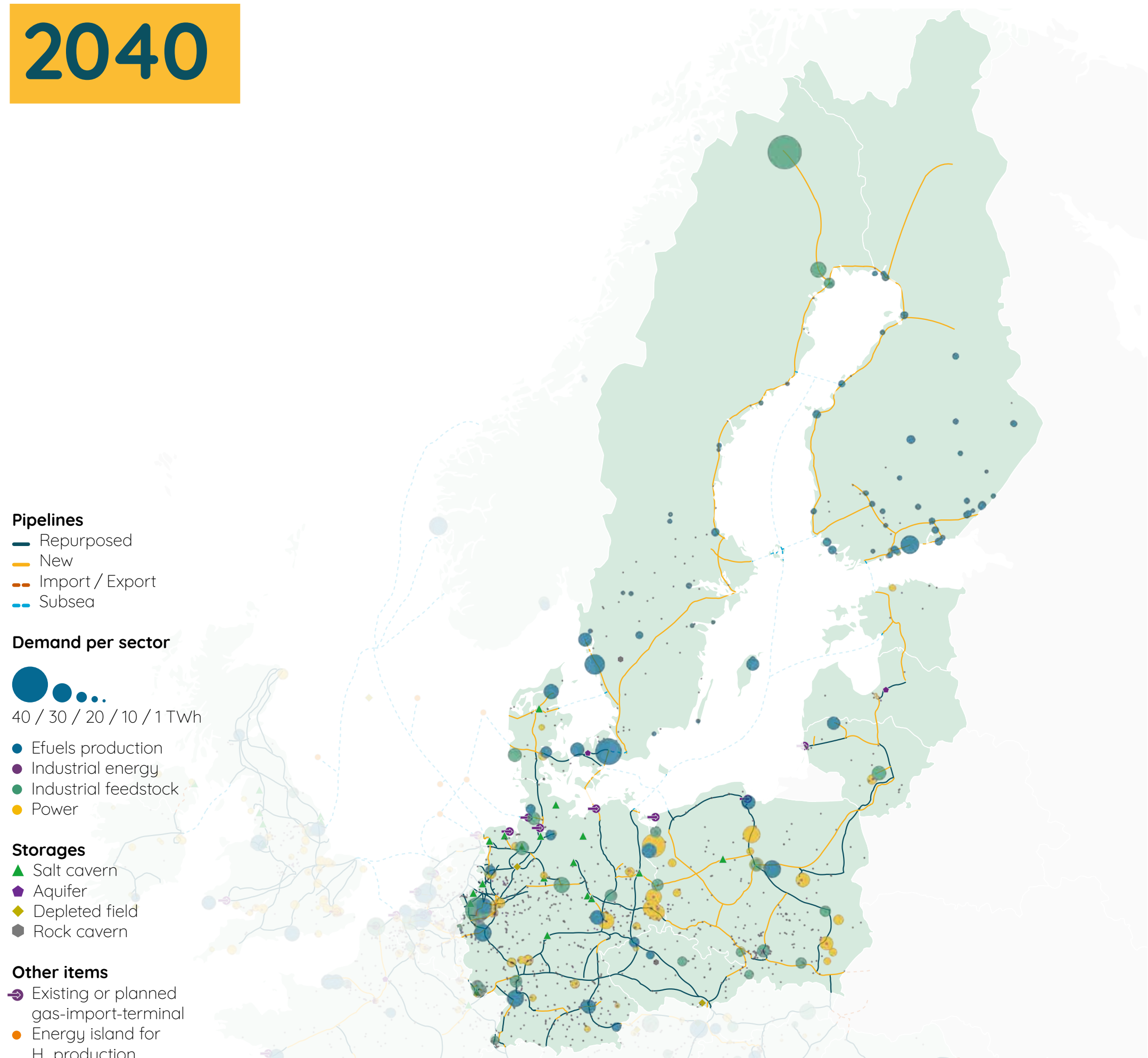


Corridor connects major hydrogen clusters from the Nordics to Germany by 2030, expanding to all major demand centers by 2040

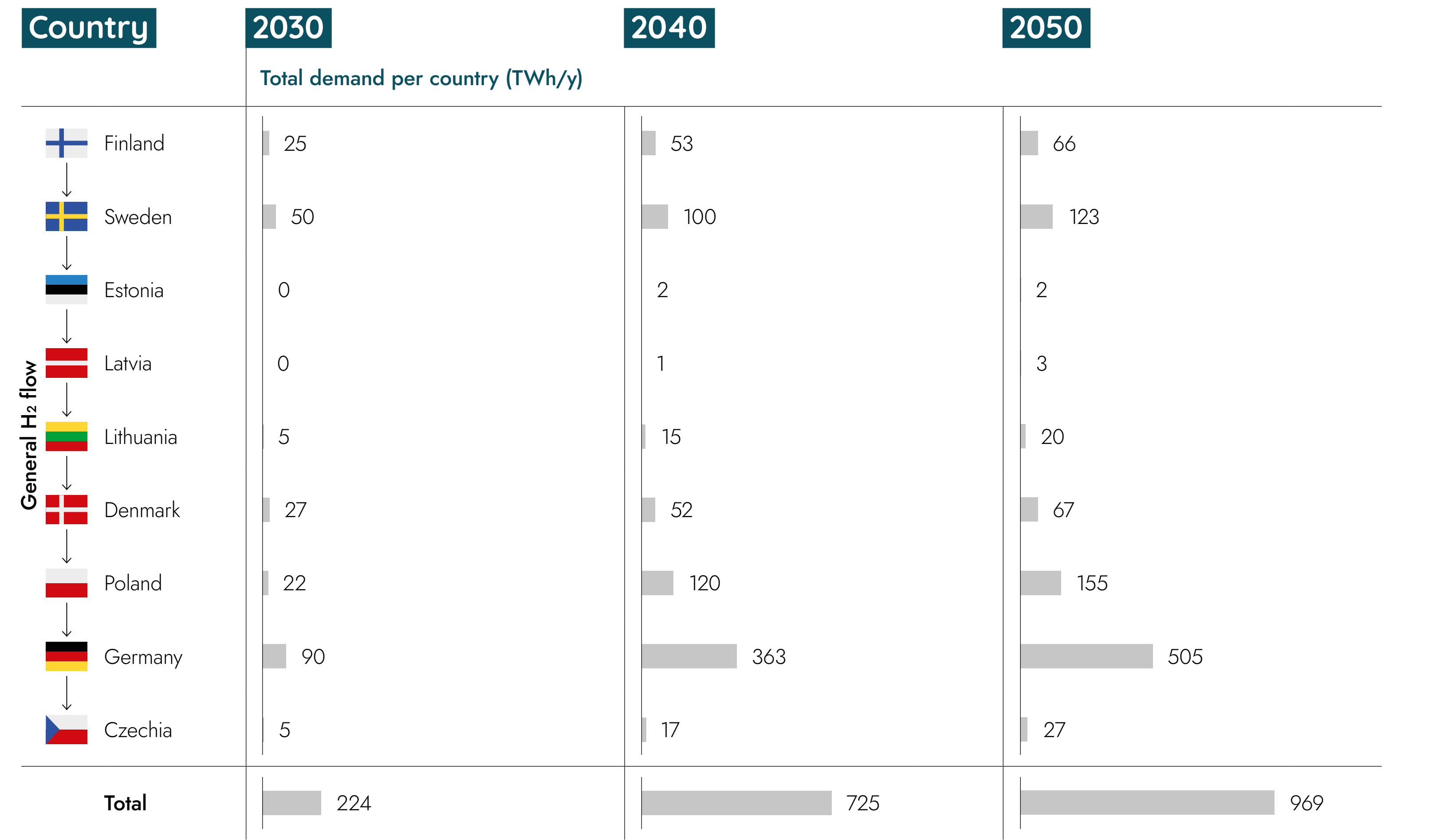
2030



2040



Hydrogen demand increases rapidly from 2030 to 2040, largely driven by Germany, Poland and the Nordics



Note: Does not include grey hydrogen demand. Numbers represent total demand by country, even if only parts of the country are included in the corridor.

Hydrogen demand – across all countries of the corridor – increases significantly from 2030 to 2050. Demand reaches ~220 TWh by 2030, increasing to roughly 970 TWh by 2050.

Early national decarbonisation targets in Sweden (2045) and Finland (2035) also contribute to early adoption.

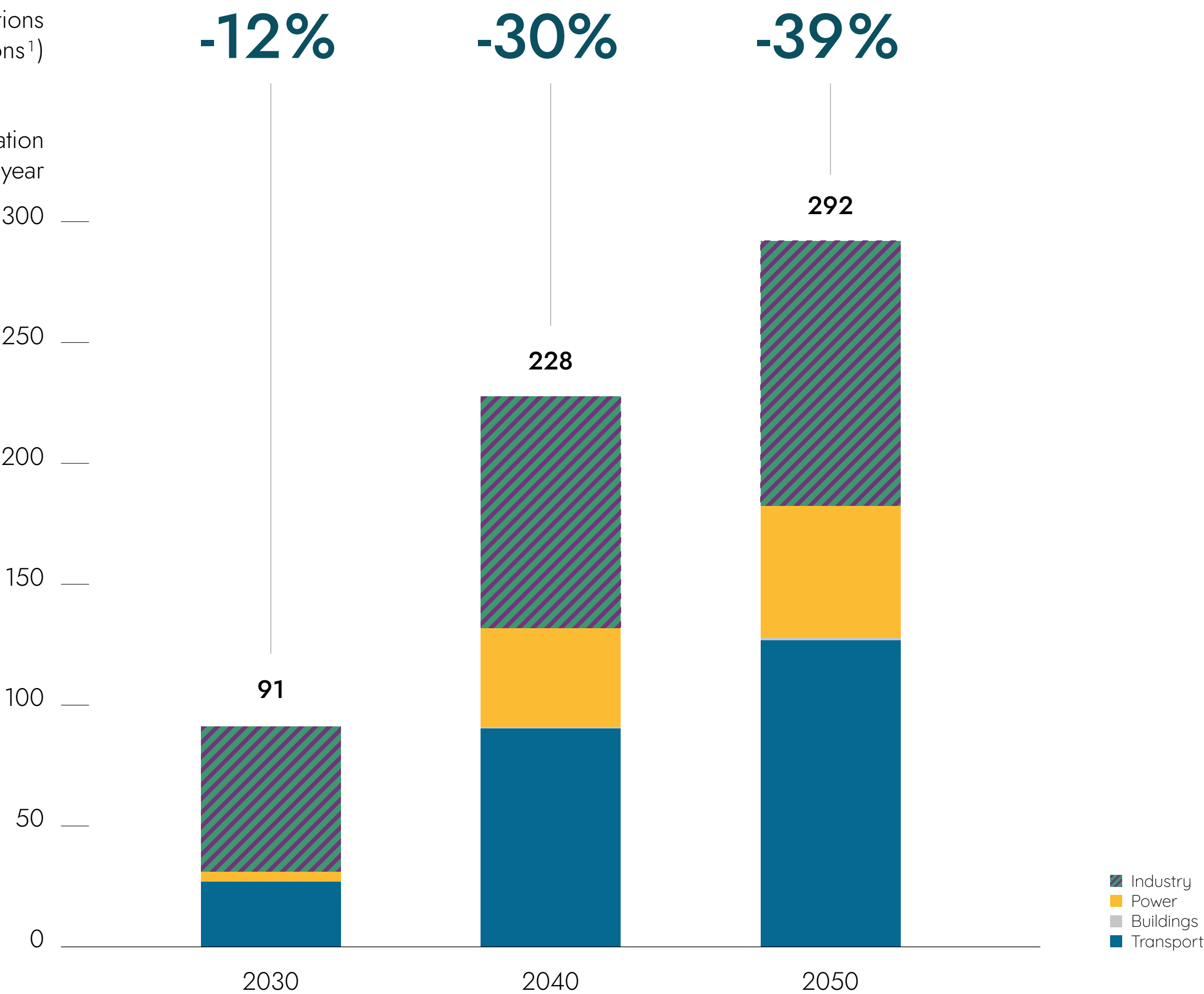
Hydrogen demand may accelerate and increase further than forecasted as a result of additional regulatory measures adopted in response to the RePowerEU plan.

- Up to 2030, most hydrogen demand is driven by the industrial sector in Sweden and Germany – primarily related to the adoption of hydrogen in the steel sector.
- From 2040 to 2050, most new hydrogen demand is for e-fuels production and for power generation, with demand in Finland, Denmark and Poland contributing an increasing share.

Hydrogen adoption in all countries of the corridor enables an emissions reduction of 39% by 2050

Emissions reductions
(vs. 2019 emissions¹)

Decarbonisation
in MtCO₂ / year



Hydrogen adoption across all demand sectors enables an **emissions reduction of ~290 MtCO₂/yr. by 2050**, equivalent to a **39% reduction²**.

Emissions reductions are notoriously higher than other corridors due to the high emissions reduction potential in the steel sector.

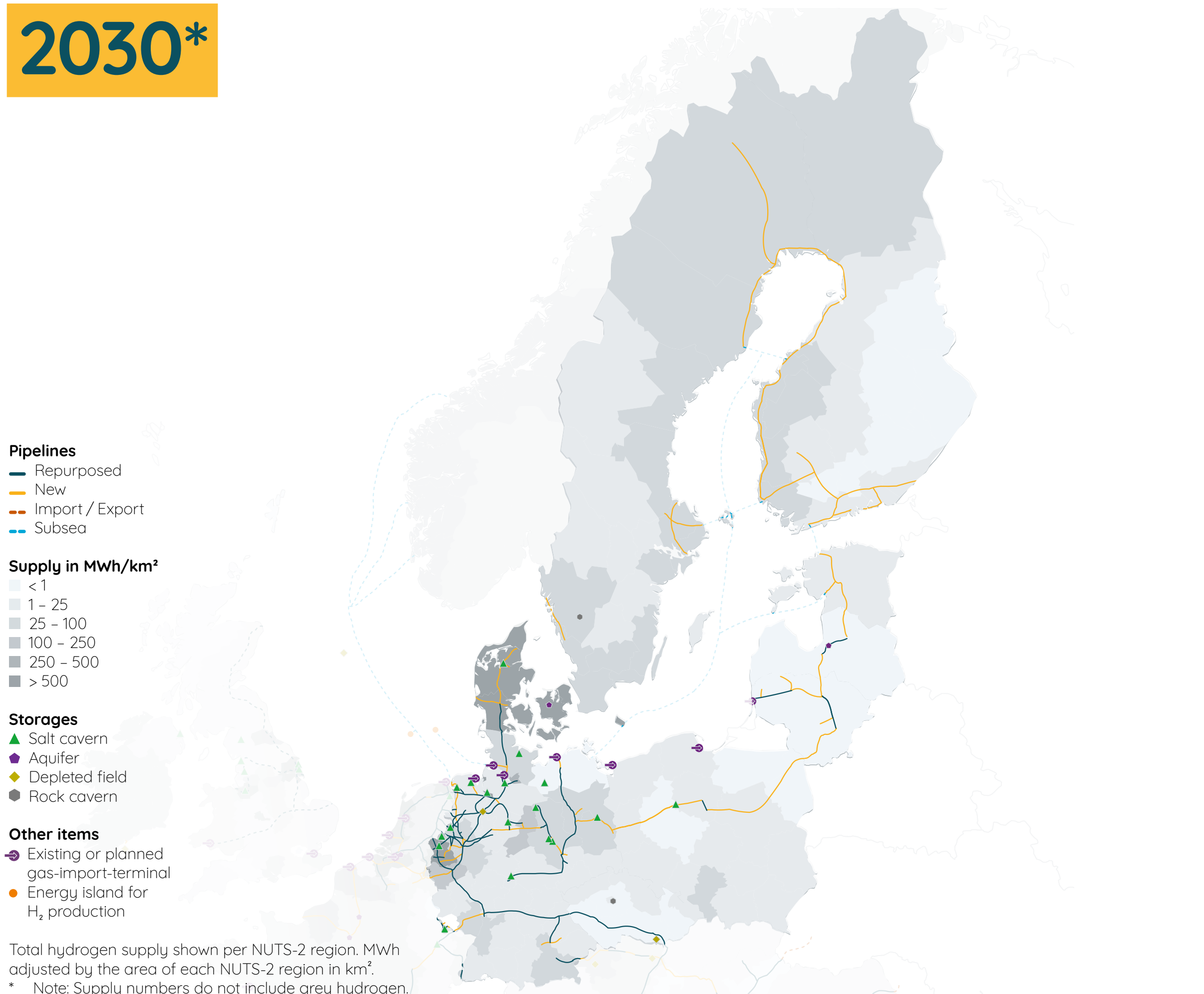
- **Up to 2030**, the industrial sector contributes 70% of the total emissions reductions, largely driven by the steel sector in Sweden and Germany.
- **By 2040**, emissions reductions from transport (road, shipping and aviation) increase substantially and combined with industry, account for 80% of emissions reductions. The power sector account for the remaining 20% of reductions.
- **By 2050**, emissions reductions from the transport and power sector continue rising.

¹ CO₂-Emissions from countries and sectors included in corridor (0.75 bn t CO₂ / year), Source: EEA

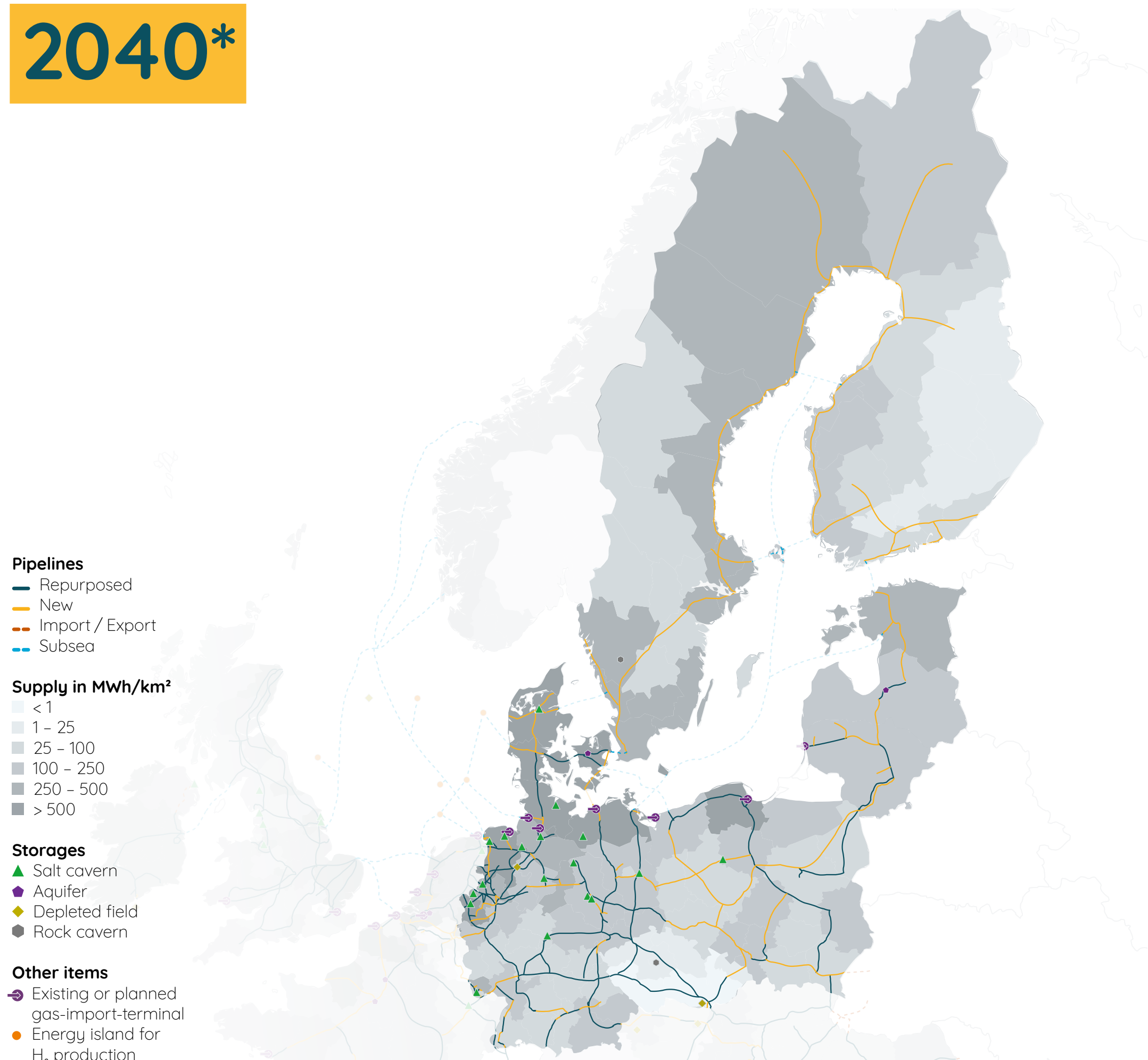
² Emissions reductions are calculated compared to the baseline fossil fuel used in each sectors. For example, emissions reductions associated with the adoption of hydrogen by the primary steel sector are relative to the use of coal. Similarly, emissions reductions, for e-fuels production are relative to the use of fossil fuels in shipping, aviation and other uses.

Corridor enables access to supply from parts of the Nordics
by 2030, expanding to supply from the Baltics by 2040

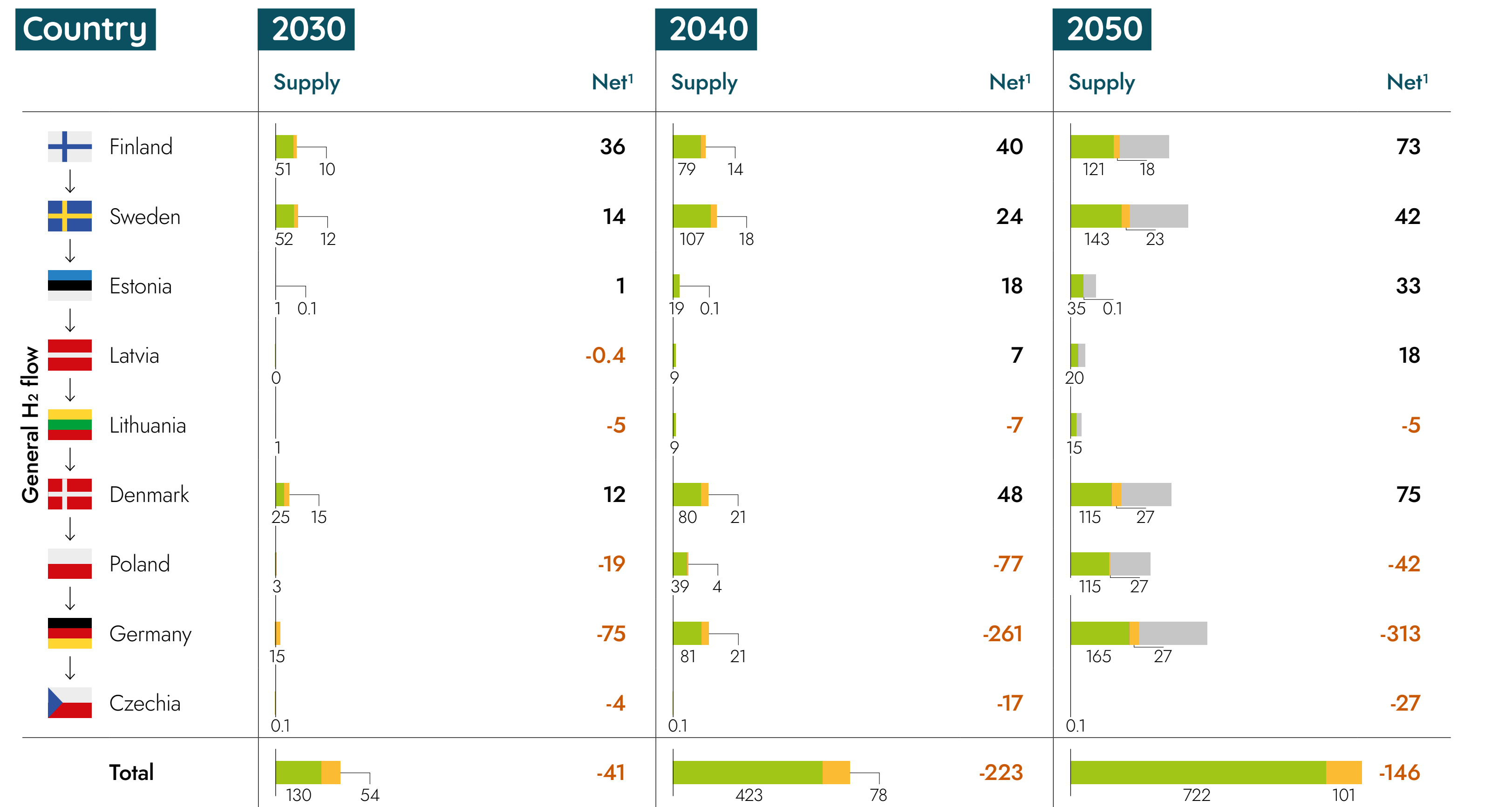
2030*



2040*



Hydrogen supply increases significantly from 2030 to 2040, largely driven by green hydrogen supply from the Nordics



The hydrogen supply mix includes **grid-based green hydrogen²** and **dedicated green hydrogen**.

- By 2030, hydrogen supply reaches ~185 TWh, largely from dedicated green hydrogen and grid-based hydrogen.
- By 2040, hydrogen supply increases substantially to ~500 TWh, of which roughly 85% is from dedicated green hydrogen. The remaining 15% is from grid-based hydrogen supply. Grid-based supply increases slightly from 2030 due to the increasing decarbonization of the electricity grid mix.
- By 2050, hydrogen supply increases further to ~820 TWh. Dedicated green supply continues to account for the largest share at roughly 90%.

Hydrogen supply may accelerate and increase further as a result of additional regulatory measures adopted in response to the RePowerEU plan.

¹ Net represents excess supply after subtracting demand.
² Grid-based is estimated using national 2030 electrolyser targets which, by 2030, are assumed to be largely grid-connected rather than dedicated. Grid-based increases over 2030-2050 with increasing RES.

Dedicated green
Blue
Grid-based
2050 technical potential

Note: Hydrogen supply volumes do not include hydrogen imports by ship.

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1. Corridor Summary
2. Hydrogen Demand & Supply
- 3. Supply Costs & Cost-Competitiveness**
4. National Strategies & Regulation
5. Actions Needed

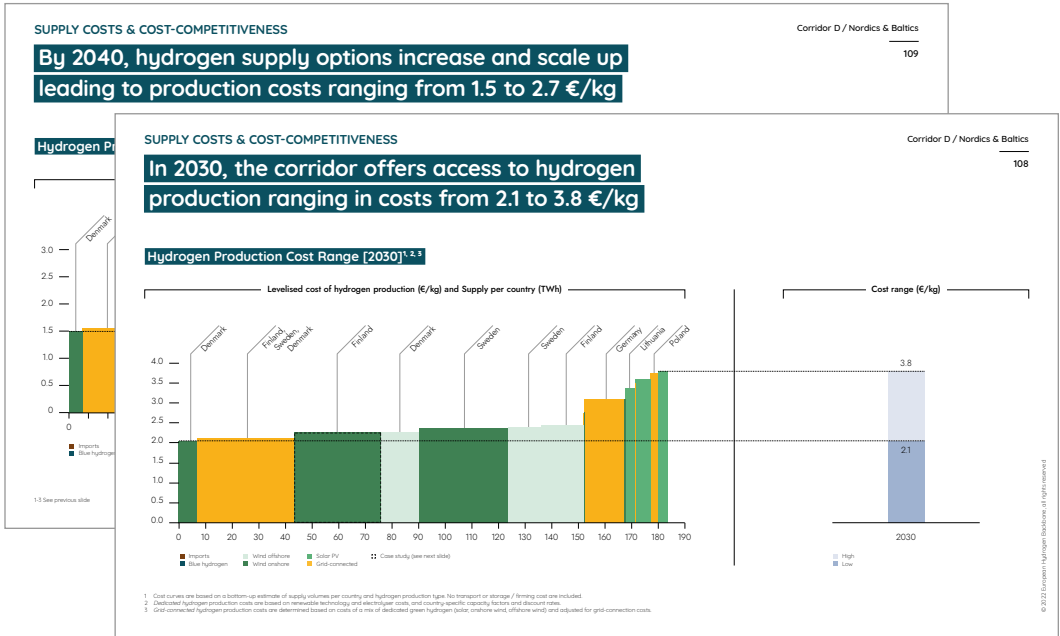


This section explores the costs of hydrogen production and delivery for this corridor and their competitiveness with fossil fuels

Hydrogen production cost

Key Questions Answered

What is the range of production costs achieved by the corridor in 2030 and 2040?

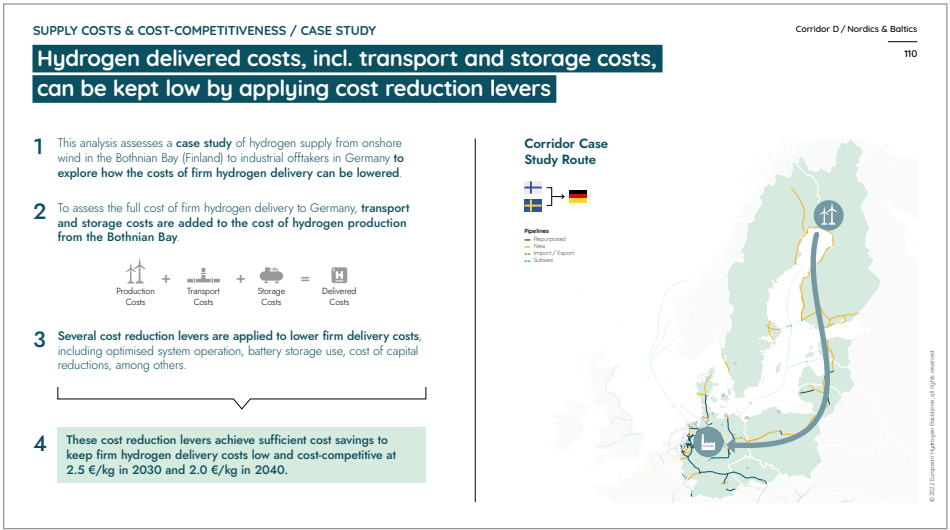


- By 2030, the corridor provides access to hydrogen production costs of 2.1 to 3.8 €/kg.
- By 2040, hydrogen production costs decrease to the range of 1.5 to 2.7 €/kg.

Hydrogen delivered costs

Based on a case-study of hydrogen supply from the Bothnian Bay (Finland) to Germany:

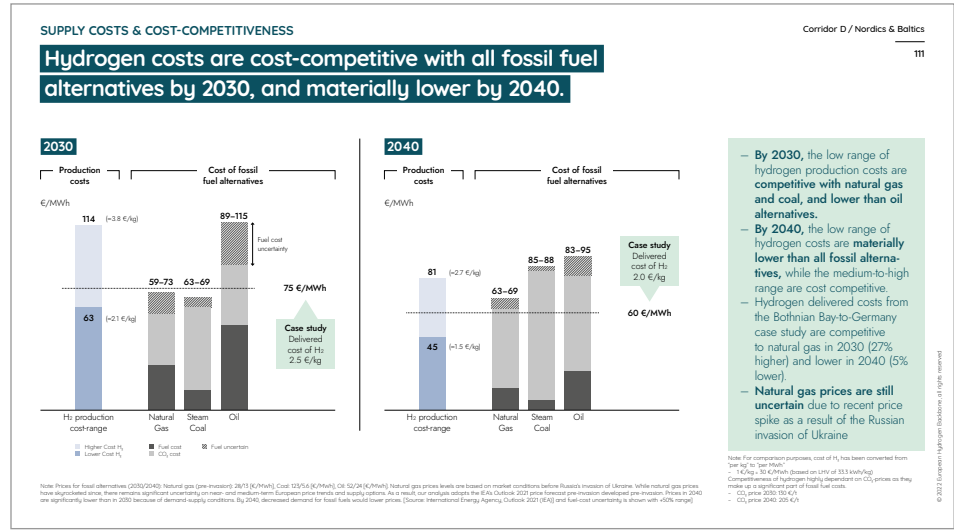
- What are the full costs of firm hydrogen delivery after accounting for transport and storage costs?
- What cost levers are available to lower the cost of hydrogen delivery?



- Several cost reduction levers can be applied to lower the costs of hydrogen delivery.
- For the Bothnian Bay-to-Germany case study, these levers achieve delivery costs that are low and cost-competitive.

Comparison with fossil alternatives

How competitive is hydrogen supply from this corridor compared to fossil fuel alternatives?



- Hydrogen costs are competitive with fossil fuel alternatives by 2030, and lower by 2040.
- Fossil fuel costs are subject to significant uncertainty.

Content Material

Key Findings & Results

In 2030, the corridor offers access to hydrogen production ranging in costs from 2.1 to 3.8 €/kg

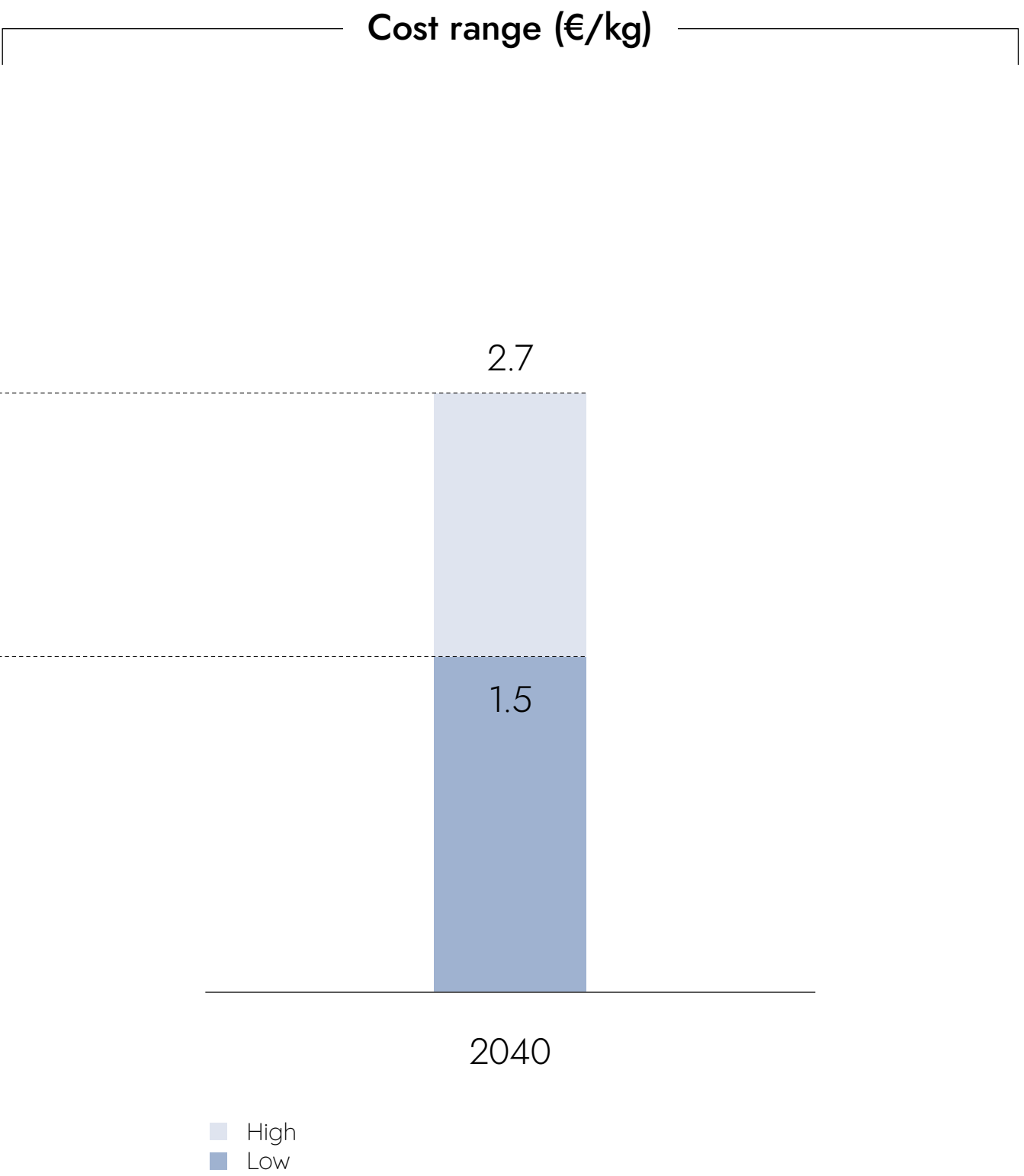
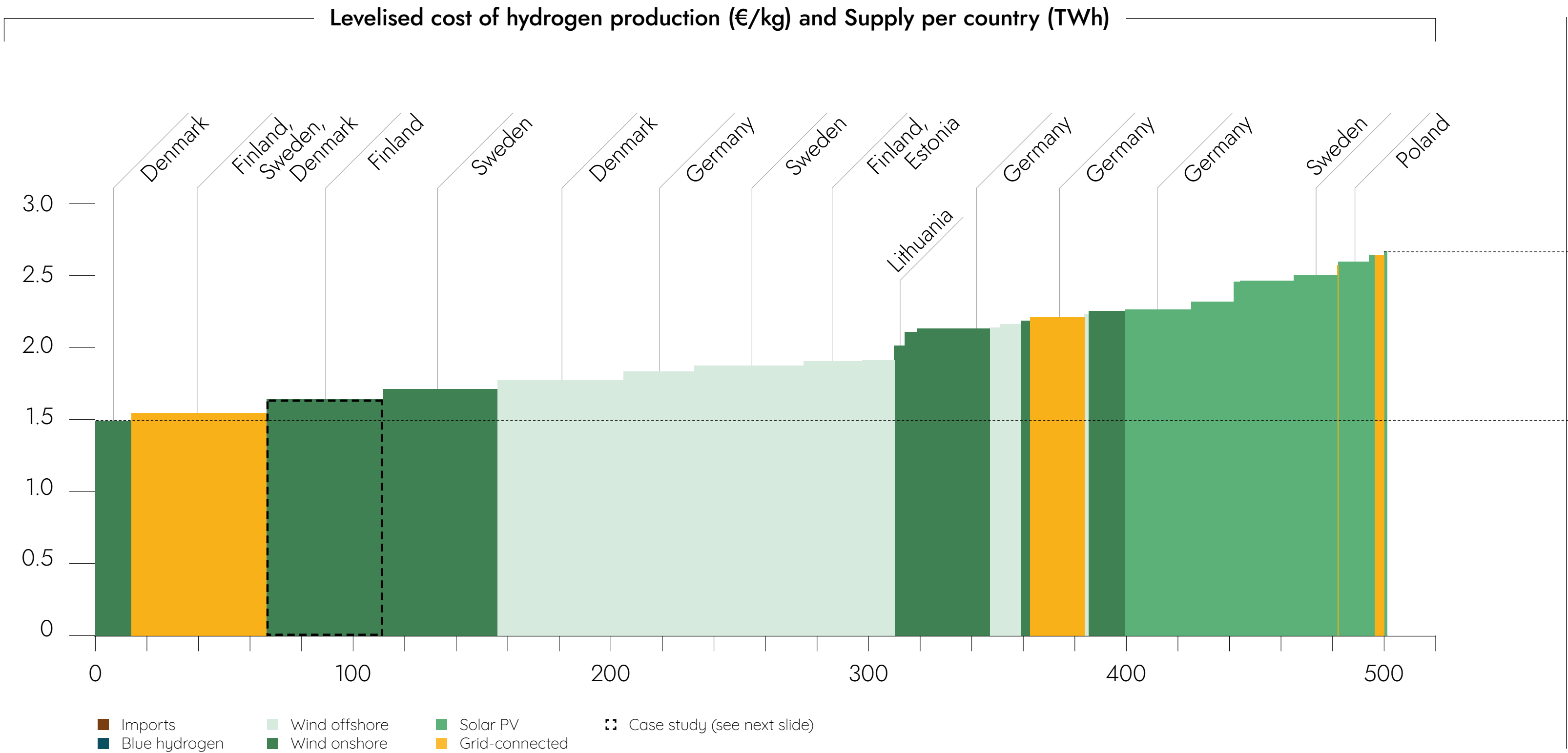
Hydrogen Production Cost Range [2030]^{1, 2, 3}



1 Cost curves are based on a bottom-up estimate of supply volumes per country and hydrogen production type. No transport or storage / firming cost are included.
2 Dedicated hydrogen production costs are based on renewable technology and electrolyser costs, and country-specific capacity factors and discount rates.
3 Grid-connected hydrogen production costs are determined based on costs of a mix of dedicated green hydrogen (solar, onshore wind, offshore wind) and adjusted for grid-connection costs.

By 2040, hydrogen supply options increase and scale up leading to production costs ranging from 1.5 to 2.7 €/kg

Hydrogen Production Cost Range [2040]^{1, 2, 3}

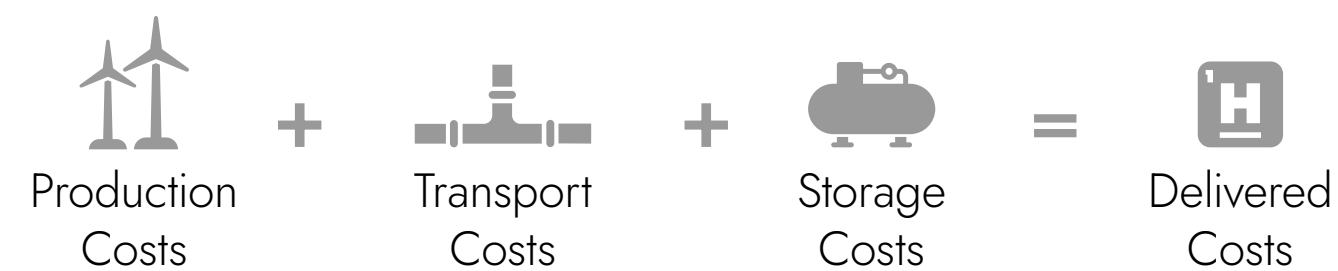


1-3 See previous slide

Hydrogen delivered costs, incl. transport and storage costs, can be kept low by applying cost reduction levers

1 This analysis assesses a **case study** of hydrogen supply from onshore wind in the Bothnian Bay (Finland) to industrial off-takers in Germany **to explore how the costs of firm hydrogen delivery can be lowered.**

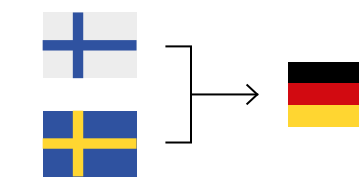
2 To assess the full cost of firm hydrogen delivery to Germany, **transport and storage costs are added to the cost of hydrogen production from the Bothnian Bay.**



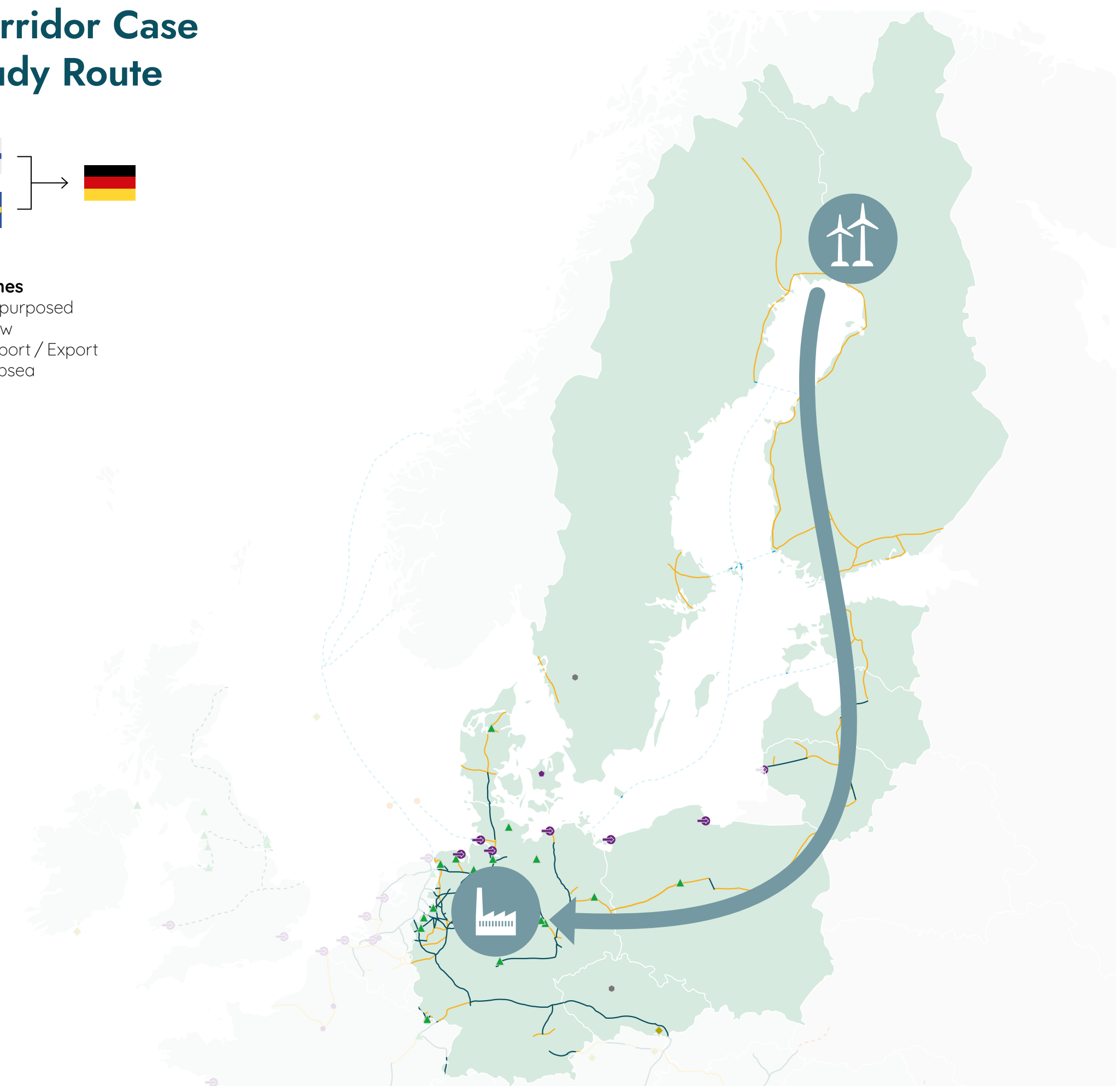
3 Several cost reduction levers are applied to lower firm delivery costs, including optimised system operation, battery storage use, cost of capital reductions, among others.

4 These cost reduction levers achieve sufficient cost savings to keep firm hydrogen delivery costs low and cost-competitive at 2.5 €/kg in 2030 and 2.0 €/kg in 2040.

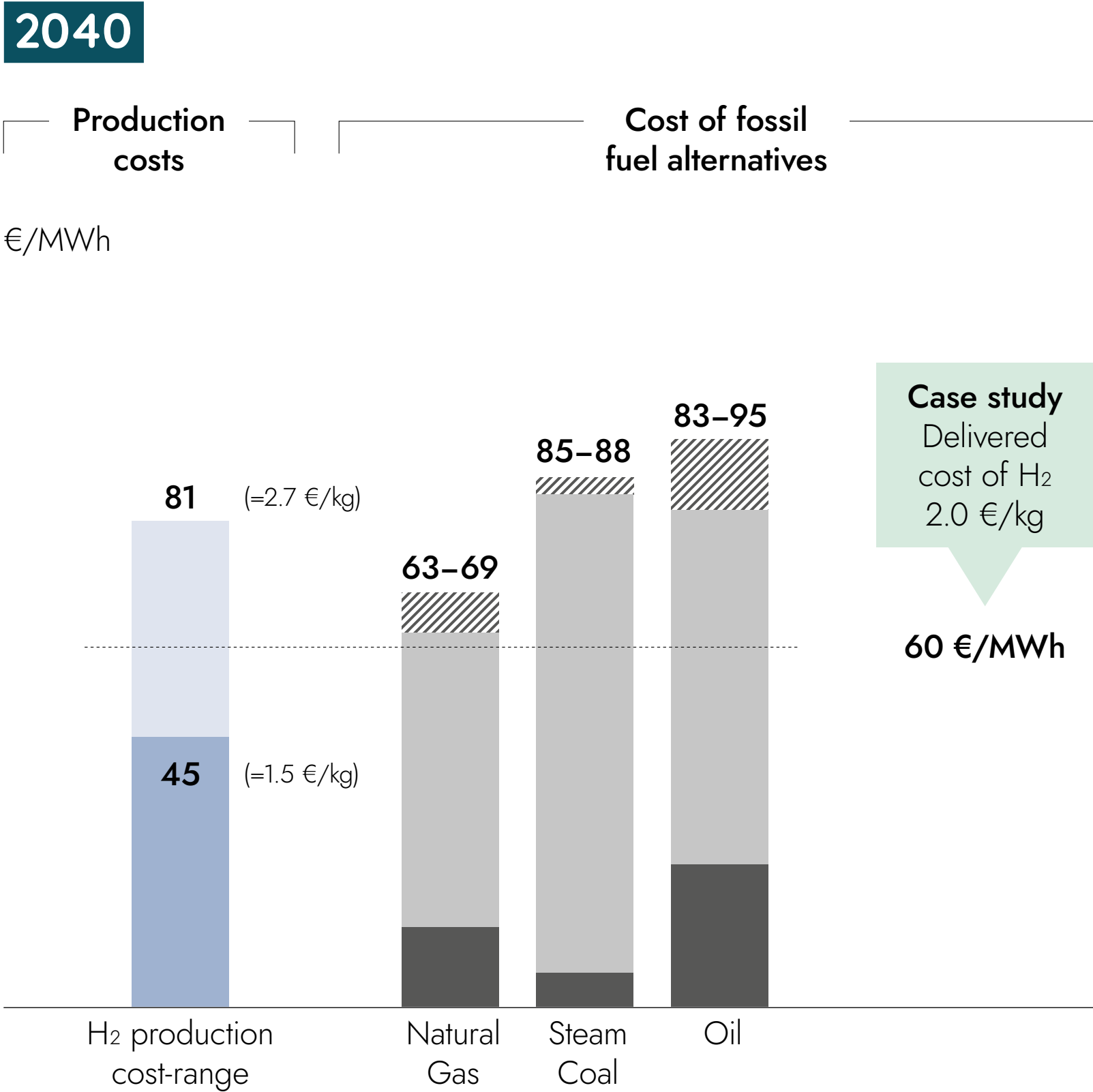
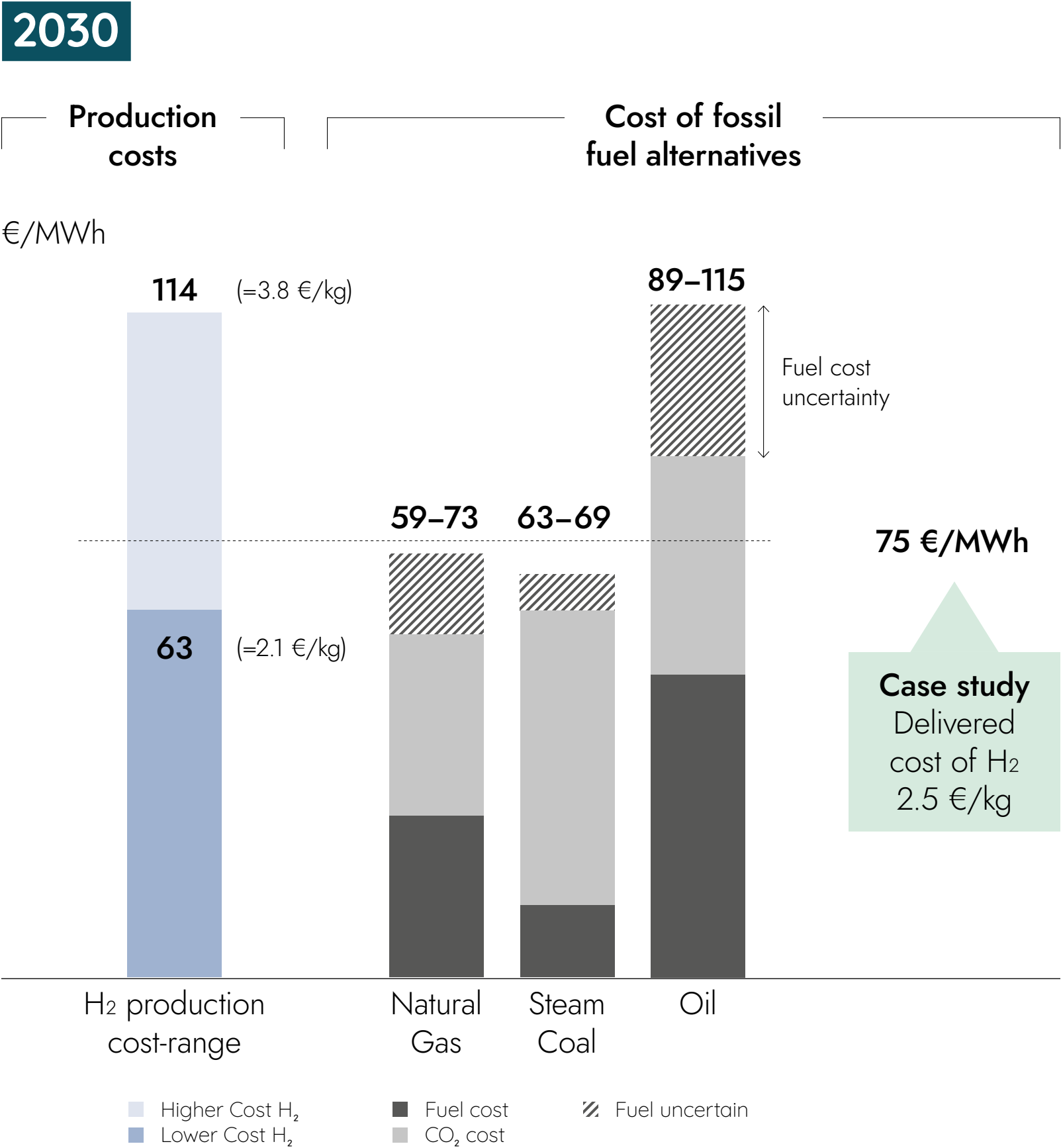
Corridor Case Study Route



Pipelines
— Repurposed
— New
— Import / Export
— Subsea



Hydrogen costs are cost-competitive with all fossil fuel alternatives by 2030, and materially lower by 2040.



- By 2030, the low range of hydrogen production costs are competitive with natural gas and coal, and lower than oil alternatives.
- By 2040, the low range of hydrogen costs are materially lower than all fossil alternatives, while the medium-to-high range are cost competitive.
- Hydrogen delivered costs from the Bothnian Bay-to-Germany case study are competitive to natural gas in 2030 (27% higher) and lower in 2040 (5% lower).
- Natural gas prices are still uncertain due to recent price spike as a result of the Russian invasion of Ukraine

Note: Prices for fossil alternatives (2030/2040): Natural gas (pre-invasion): 28/13 [€/MWh], Coal: 123/5.6 [€/MWh], Oil: 52/24 [€/MWh]. Natural gas prices levels are based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast pre-invasion developed pre-invasion. Prices in 2040 are significantly lower than in 2030 because of demand-supply conditions. By 2040, decreased demand for fossil fuels would lower prices. [Source: International Energy Agency, Outlook 2021 (IEA)] and fuel-cost uncertainty is shown with +50% range]

Note: For comparison purposes, cost of H₂ has been converted from "per kg" to "per MWh"

- 1 €/kg = 30 €/MWh (based on LHV of 33.3 kWh/kg)

Competitiveness of hydrogen highly dependant on CO₂-prices as they make up a significant part of fossil fuel costs.

- CO₂ price 2030: 130 €/t
- CO₂ price 2040: 205 €/t

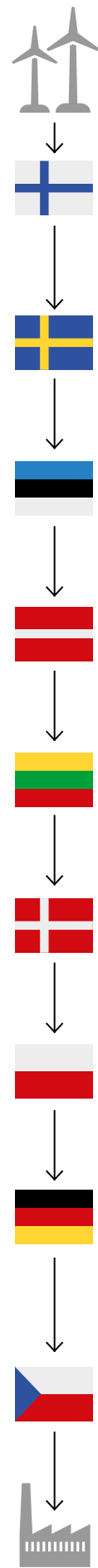
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- 4. National Strategies & Regulation**
5. Actions Needed



Most countries have developed, or are developing, national strategies. Moving forward, the development of regulation is key to enable infrastructure investment.

Pre-RePowerEU targets²



	National Hydrogen strategy (NHS)	Network regulation & policy	Funding ¹ (bn €)	Highlights
Finland	<ul style="list-style-type: none">– H₂ strategy part of National Climate & Energy Plan, with focus on production (via wind resources) and industrial use of green H₂	<ul style="list-style-type: none">– Act on Guarantees of Origin for Energy extended to gas & H₂	<div><div></div>0.2</div>	<ul style="list-style-type: none">– Recommended to build 1st dedicated H₂ pipelines– Significant additional potential for wind power and e-fuels production, chemicals and fertilisers.
Sweden	<ul style="list-style-type: none">– Focus on industry & heavy-duty vehicles– Electrolyser capacity 5 GW (2030) & 15 GW (2045)	<ul style="list-style-type: none">– National H₂ strategy requests regulator to have commissioned revenue framework by 2023	<div><div></div>0.1</div>	<ul style="list-style-type: none">– Funding is provided to various hydrogen projects for demand and supply by the Swedish Energy Agency
Estonia	<ul style="list-style-type: none">– Intention to create national hydrogen strategy	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– Potential for local production and export
Latvia	<ul style="list-style-type: none">– No specific national hydrogen strategy	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– Most potential is seen in transport sector
Lithuania	<ul style="list-style-type: none">– National hydrogen strategy is in progress	<ul style="list-style-type: none">– Legal framework allows issue guarantees of origin for hydrogen	<div><div></div>0.16</div>	<ul style="list-style-type: none">– Potential for production, transit and export
Denmark	<ul style="list-style-type: none">– Focus on green H₂ and export of PtX technologies to demand hubs (GER, NL, etc.)	<ul style="list-style-type: none">– Proposition: Allow TSO & DSO to own and operate H₂ infrastructure	<div><div></div>0.2</div>	<ul style="list-style-type: none">– Transport infrastructure is seen as key to enable role as PtX producer and exporter
Poland	<ul style="list-style-type: none">– Focus: Power/heat sector, transport, industry, production, network, creating regulatory framework	<ul style="list-style-type: none">– Creation of regulatory framework mentioned in H₂ strategy		<ul style="list-style-type: none">– Gas network to be adapted & new build: “Hydrogen Highway” (North-South)
Germany	<ul style="list-style-type: none">– National production & import focus due to supply gap– In place since 2020, currently reviewed towards increasing its ambition– 10 GW (2030) electrolyser in coalition plans	<ul style="list-style-type: none">– H₂ network potentially opt-in regulated and vertically unbundled– First rules and standards for high pressure pipelines are formulated	<div><div></div><div></div><div></div>9</div>	<ul style="list-style-type: none">– Strong focus on international cooperation to ensure sufficient supply– National funding
Czech Republic	<ul style="list-style-type: none">– Focus Transport, then energy & chemical industry– Production also CCS and nuclear– Import and transit country for H₂ from the south	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– H₂-Readiness of gas transmission system is urged, due to potential role in H₂ transport from south to north and from east to west

Note: Sequencing of countries follows the general corridor direction but does not represent the hydrogen flows.
1 Cumulative public funding amount by the respective state until 2030
2 Strategies and funding is under evaluation of meeting latest targets



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This corridor plays a fundamental role in achieving a European backbone by 2040

The need for this corridor

- The development of **this corridor ensures access to abundant, low-cost supply from parts of the Nordics by 2030**, expanding to supply from the Baltics by 2040.
- The **decarbonisation of the largest hydrogen demand centers along this corridor – in the Nordics, Baltics, Poland and Germany –** is dependent on the buildout of this corridor by 2030, and its expansion towards 2040.

Actions required

- The buildout of this corridor by 2030 **requires national governments to take clear and concrete actions across.**
- This includes actions associated with **infrastructure development and planning, the development of cross-national initiatives and securing access to early funding and long-term, low-cost financing.**

2040

Pipelines

- Repurposed
- New
- Import / Export
- Subsea

Demand per sector

- 40 / 30 / 20 / 10 / 1 TWh
- Efuels production
 - Industrial energy
 - Industrial feedstock
 - Power

Supply in MWh/km²

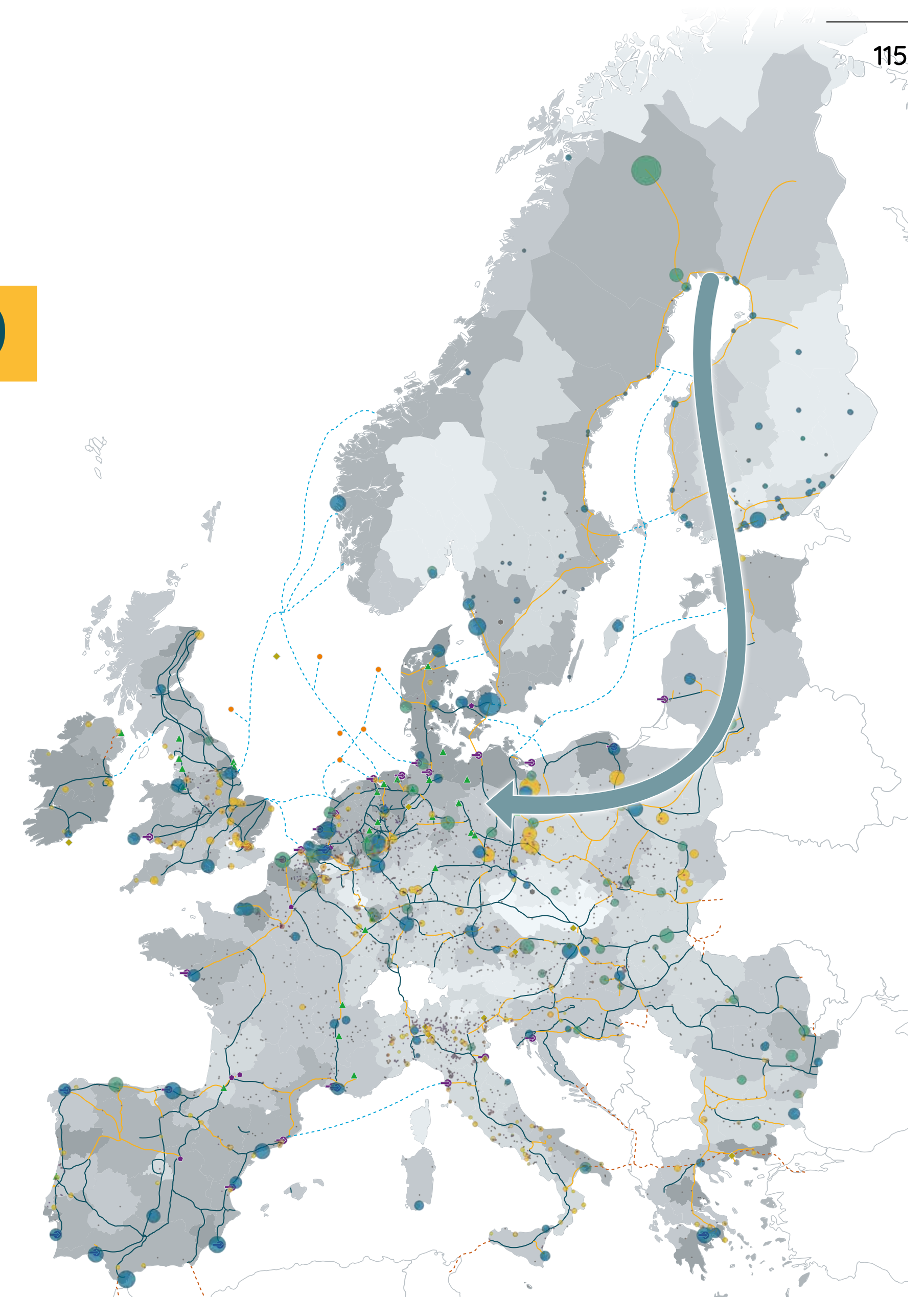
- < 1
- 1 – 25
- 25 – 100
- 100 – 250
- 250 – 500
- > 500

Storages

- ▲ Salt cavern
- ▲ Aquifer
- ▲ Depleted field
- ▲ Rock cavern

Other items

- Existing or planned gas-import-terminal
- Energy island for H₂ production



**To ensure the development of this corridor by 2030,
there is a need for clear and concrete actions**

Fostering development of new and repurposed hydrogen infrastructure, for example, by unbundling rules facilitating the efficient use of TSO expertise and services and by allowing the adoption of different vertical unbundling models in the EU, as is the case with natural gas

+

Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions (including incentivizing the adoption of hydrogen by demand sectors)

+

Simplify and shorten planning and permitting procedures for renewable energy and hydrogen infrastructure projects.

+

Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure supporting the accelerated deployment and integration of renewable energy resources

→ However, speed will be of essence!

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Corridor B: Southwest Europe & North Africa

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3. Detailed methodology

East and South-East Europe

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East and South-East Europe

-  Greece

 Bulgaria

 Romania

 Hungary
-  Slovenia

 Croatia

 Slovakia


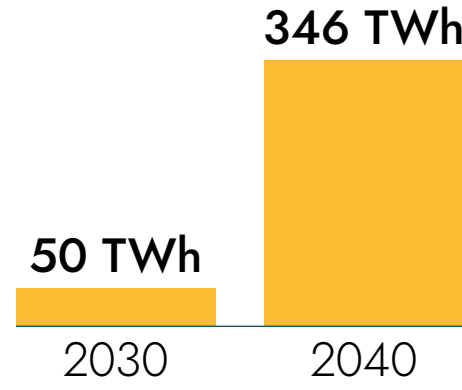

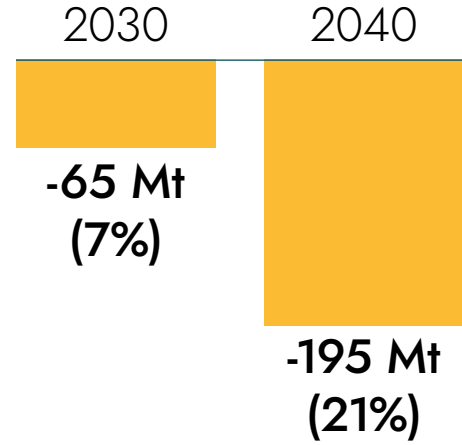

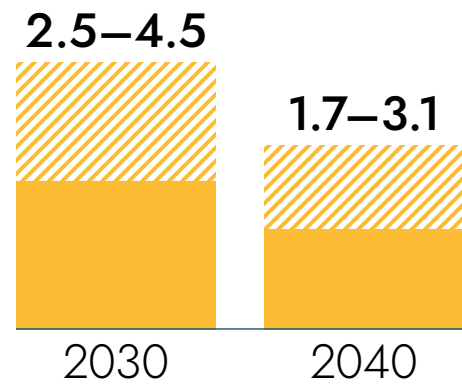
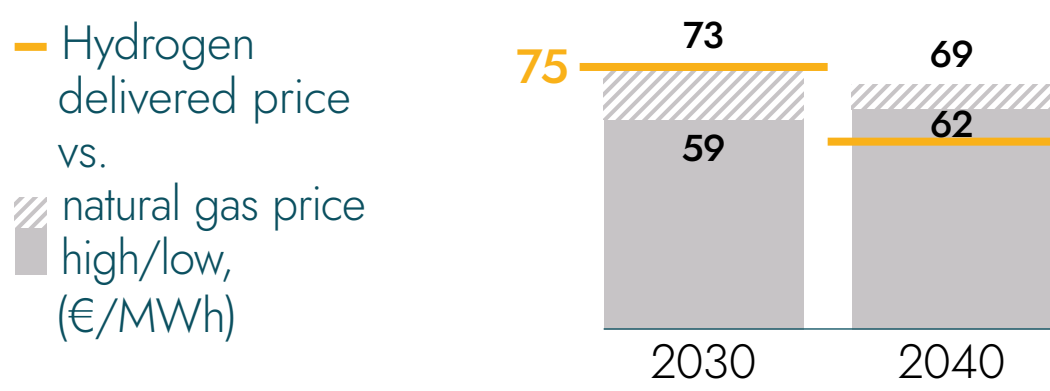
 Czechia
-  Austria

 Germany

 Poland



Corridor emerges in Eastern & South-Eastern Europe providing access to low-cost hydrogen supply to demand centers along the corridor

Drivers & Opportunities	Major driver of development is the need to meet hydrogen demand from industry, transport and power across Eastern and South-Eastern Europe. Key opportunities include leveraging the abundant renewables potential in Eastern Europe and gaining access to hydrogen imports from Ukraine		
Hydrogen Supply & Decarbonization Potential	H₂ supply potential¹ (TWh/year)  	Emissions Reductions (MtCO ₂ /year vs. 2019; % reduction)  	
Supply Costs & Cost-Competitiveness	Cost of H₂ production¹ (€/kg of H ₂)  	Cost competitiveness²  <p>— Hydrogen delivered price vs. natural gas price high/low, (€/MWh)</p>	
Actions Needed	<ul style="list-style-type: none">— Fostering development of new and repurposed hydrogen infrastructure— Unlock financing to fast-track hydrogen infrastructure deployment— Simplify and shorten planning and permitting procedures— Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure— Intensify energy partnerships with exporting, non-EHB countries like Ukraine		

1 Figures reported reflect outputs for all countries included in the corridor. Even if a country is only partially in the corridor, results for the full country are included (e.g., supply potential and costs, demand, transmission network length).
2 Savings are based on the corridor's case study of hydrogen delivered in 2030 and 2040. The cost of natural gas includes CO₂ prices. Refer to Subsection 3 (Supply Costs & Cost-Competitiveness)

East and South-East Europe

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Corridor offers access to low-cost hydrogen supply from Eastern and South-Eastern Europe to demand centers along the corridor

Drivers & Opportunities

- **The major driver** behind the development of this corridor is the adoption of hydrogen associated with the **decarbonisation of industry, transport and power** across Eastern and South-Eastern Europe, particularly new green steel projects and existing industry along the corridor through Greece, Romania, Hungary, Austria and Germany. The speed of hydrogen adoption in these regions may be even faster than anticipated driven by increasing CO₂ prices in the EU and the RePowerEU ambitions to replace natural gas consumption.
- In the near term, the corridor offers **access to low-cost, hydrogen supply from Eastern and South-Eastern Europe** – including hydrogen imports from Ukraine, Poland, Greece, and Romania among the larger sources of supply. In the longer term, this corridor gains further access to hydrogen supply across the entire region.
- A major opportunity of the corridor is to **leverage the abundant renewables potential in Eastern Europe** with its vast land availability and high-capacity factors for solar and onshore wind, particularly in relation to the high **hydrogen export potential of Ukraine. Another major opportunity relates to the potential for hydrogen storage provided by depleted fields along the corridor in Greece, Czechia, Austria and Germany.**
- The corridor would be stood up by 2030, covering **10,000 km** of large-scale hydrogen pipelines across all countries of the corridor, of which approximately **60% will be repurposed pipelines.**

Hydrogen Demand & Supply

- **Total hydrogen demand** in the corridor reaches **~165 TWh by 2030**, increasing substantially to **~660 TWh by 2040**. Up to 2030, the major driver of hydrogen adoption is the industrial sector, with hydrogen being used as feedstock. From 2040 onwards, most new hydrogen demand is for the transport and the power sectors.
- Hydrogen adoption across all countries of the corridors enables an emissions reduction of ~260 MtCO₂/yr. by 2050, equivalent to a **28% emissions reduction.**
- The corridor enables access to **hydrogen supply potential of ~50 TWh by 2030, increasing to roughly 350 TWh by 2040.** Major sources of supply include grid-connected hydrogen production by 2030, with a **huge potential** role for **Ukrainian imports** by 2040.

To successfully stand up this corridor by 2030, actions are needed to support infrastructure planning, financing and development

Costs & Cost-Competitiveness

- By 2030, the corridor provides access to hydrogen ranging in production costs from 2.5 to 4.5 €/kg. By 2040, as supply options increase, technology costs decrease, and imports from Ukraine scale up, hydrogen production costs decrease to 1.7 to 3.1 €/kg.
- In the long term, this corridor’s largest amounts of low-cost supply options are hydrogen imports from Ukraine.
- Based on a case-study of hydrogen supply and transport from South-Eastern Romania to Germany, the cost of delivered hydrogen – inclusive of transport and storage costs – can be lowered significantly and be cost-competitive with fossil fuel alternatives. Lowering delivery costs can be achieved through various cost levers including optimised operation of the system and cost of capital reductions.

National Strategies & Regulation

- Some countries have developed national strategies, while in others they are under development. Moving forward, the development of hydrogen regulation in all countries will be key in enabling investment in infrastructure.
- In select countries, substantial funding has been allocated to support the development of the hydrogen market including funding for gas network infrastructure. However, most countries are yet to define and earmarked funds.

Actions Needed

- To support the buildout of this corridor by 2030, clear and concrete actions related to infrastructure planning, financing and development have been identified:
- Fostering development of new and repurposed hydrogen infrastructure.
 - Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions.
 - Simplify and shorten planning and permitting procedures for the full value chain of renewable energies and hydrogen infrastructure projects.
 - Establish integrated energy system planning of hydrogen, natural gas, and electricity infrastructure
 - Intensify energy partnerships with exporting, non-EHB countries like Ukraine.

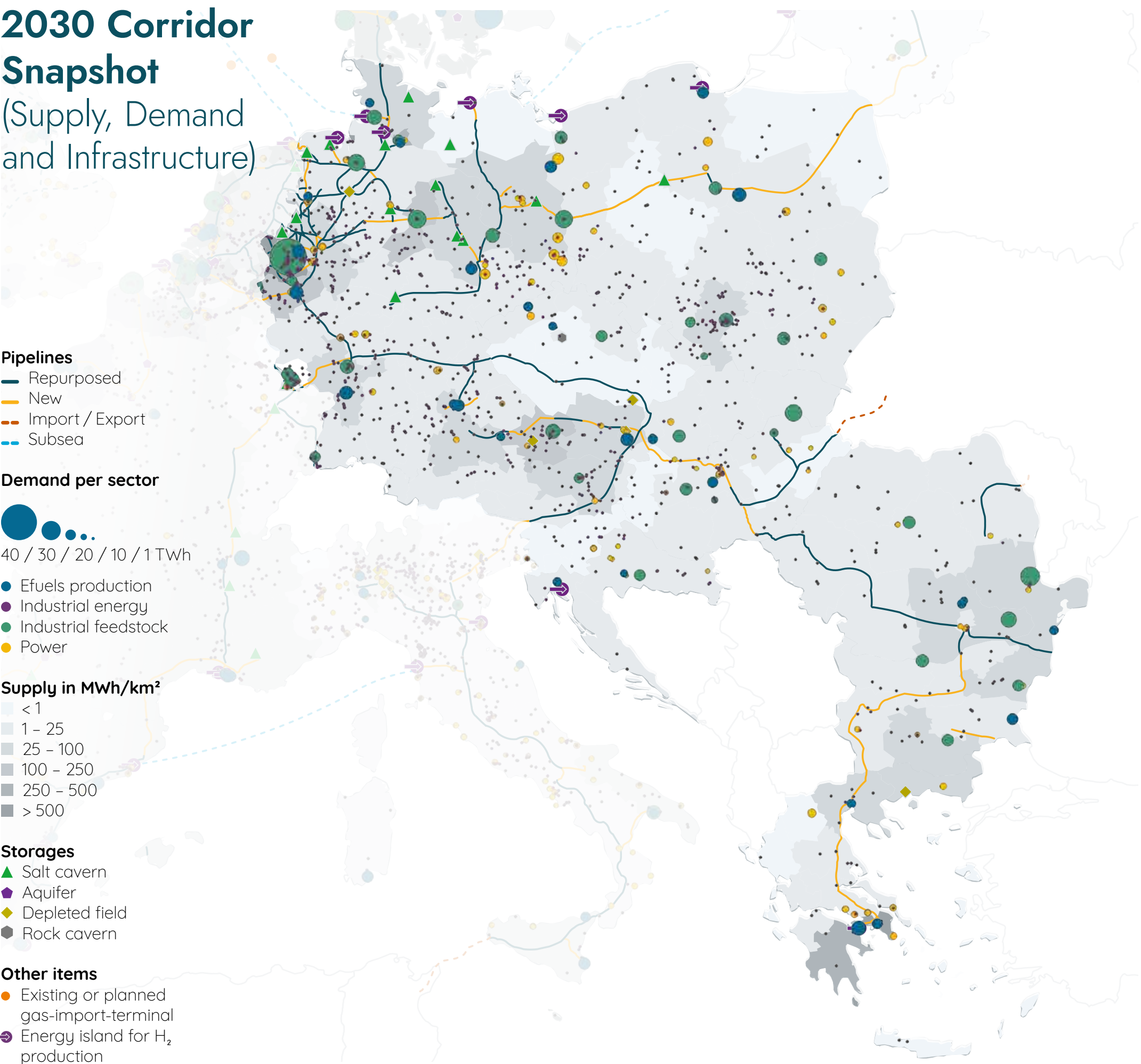
East and South-East Europe

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This section explores the development of demand, supply and transport infrastructure in the corridor from 2030 to 2050

2030 Corridor Snapshot
(Supply, Demand and Infrastructure)



Hydrogen demand

By 2030, the corridor connects **major demand clusters** across Eastern and South-Eastern Europe. **From 2030 to 2040**, the corridor expands to **all demand centers along its route**, increasing demand from 165 to ~660 TWh.

Hydrogen supply

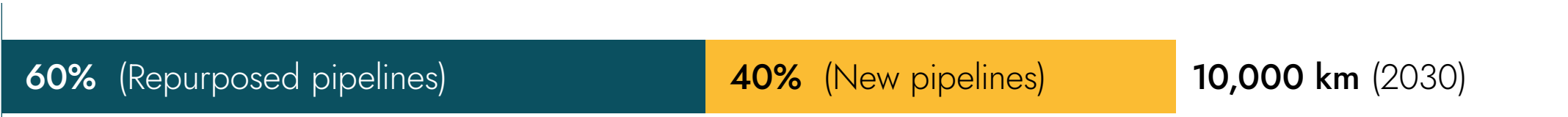
By 2030, the corridor enables access to low-cost supply from **parts of Eastern and South-Eastern Europe and Ukraine**. By 2040, the corridor gains additional access expanding across the region.

In 2030, hydrogen supply is ~50 TWh, of which 65% of supply is from grid-based hydrogen. Hydrogen supply increases significantly by 2040, reaching ~350 TWh.

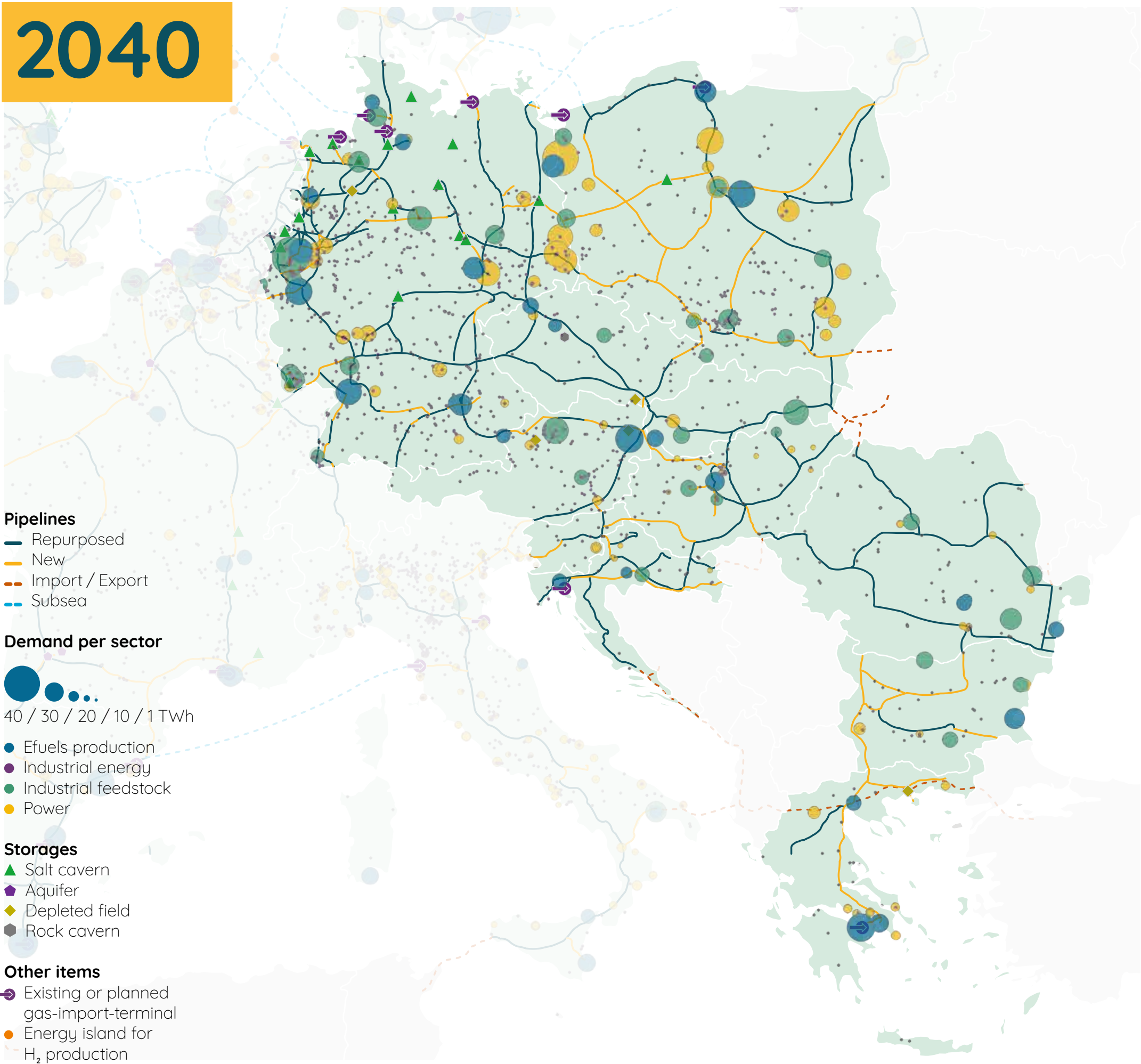
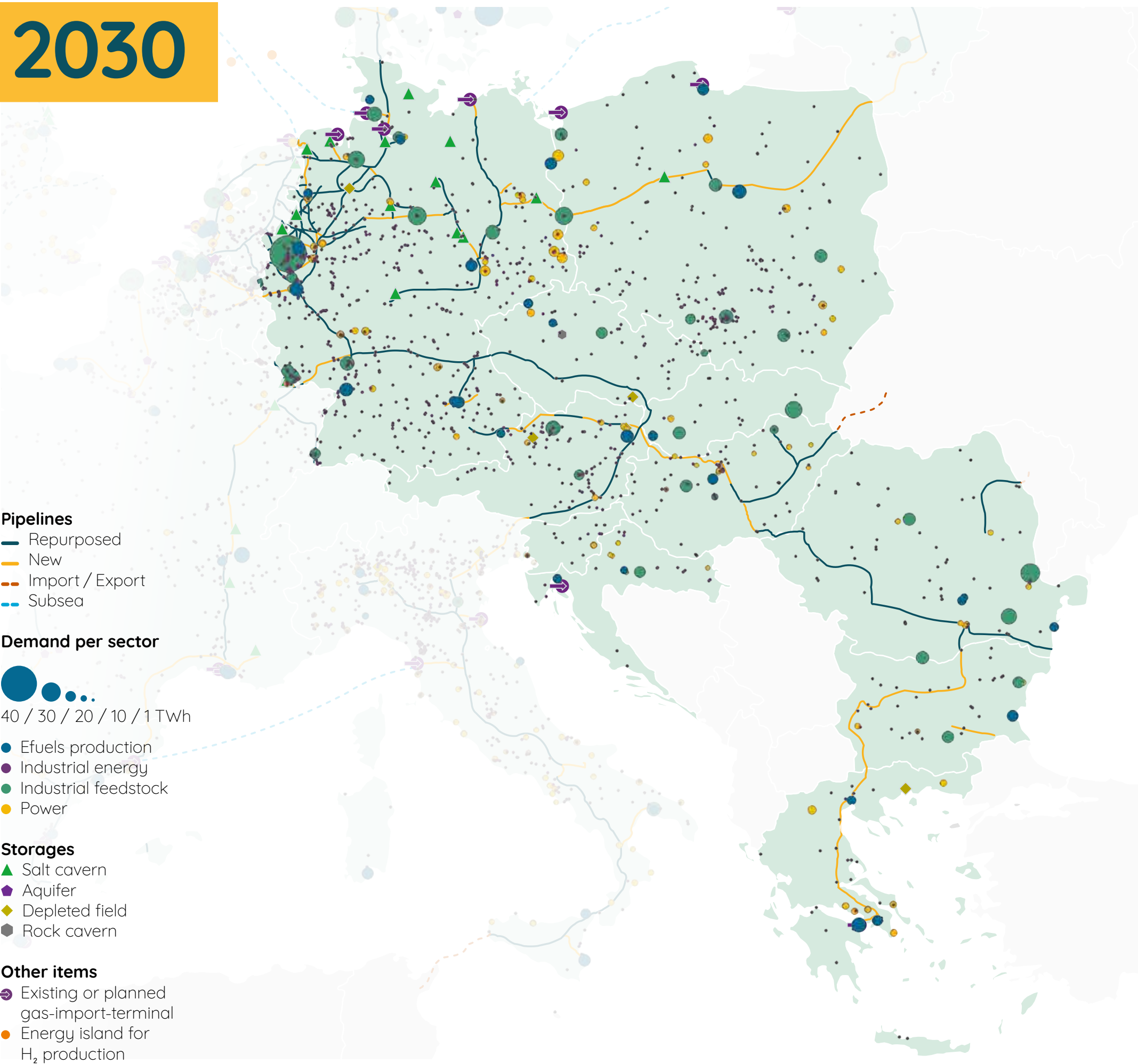


Hydrogen Infrastructure

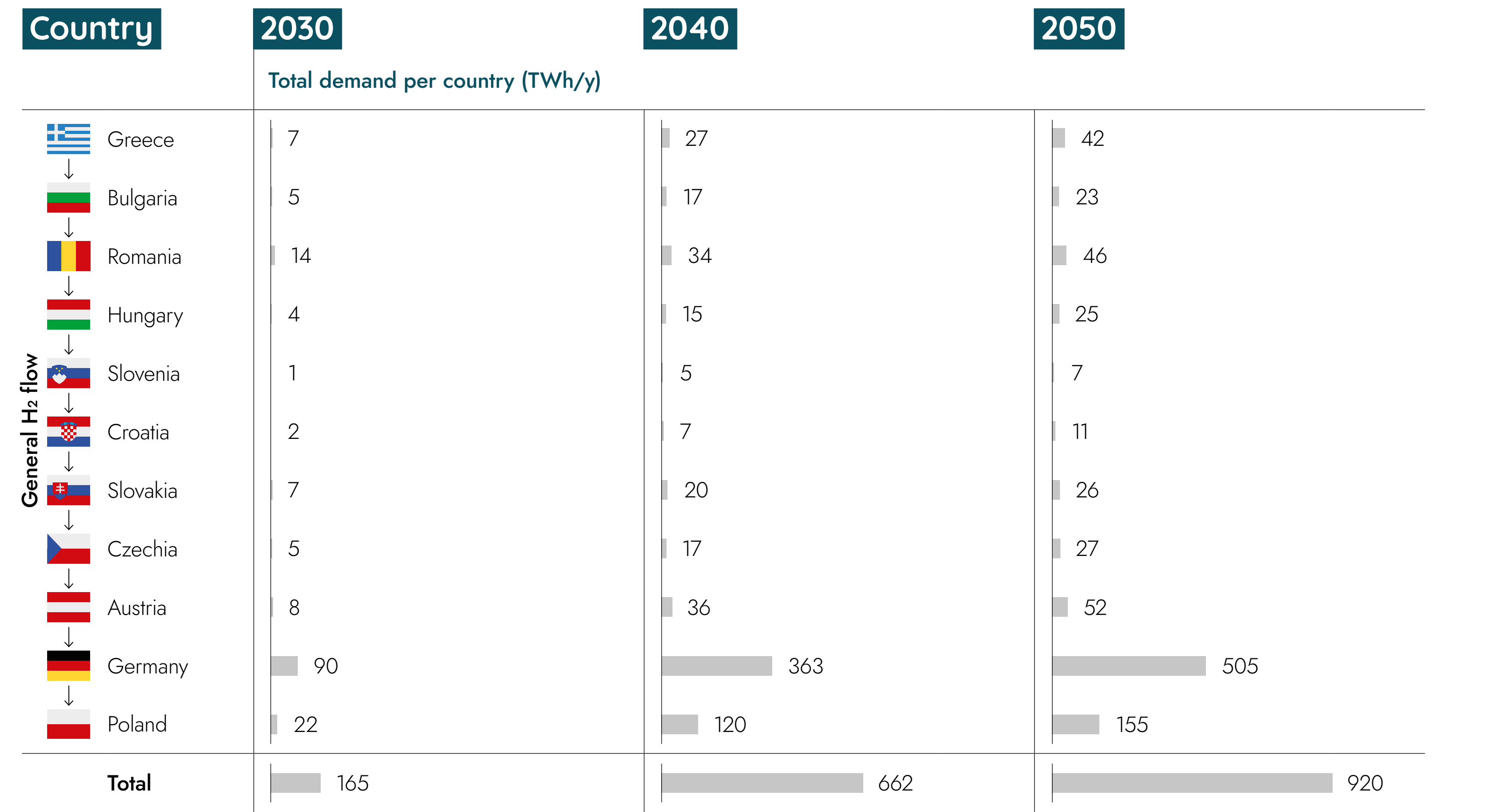
By 2030, the buildout of **pipeline infrastructure** across all countries of the corridor reaches **10,000 km** of large-scale pipelines. Corridor benefits from a **large share of repurposed infrastructure**.



Corridor connects hydrogen clusters from South-Eastern Europe to Germany by 2030, expanding to major demand centers by 2040



Hydrogen demand increases rapidly from 2030 to 2040, largely driven by Germany and Poland



Hydrogen demand – across all countries of the corridor – increases significantly from 2030 to 2050. Demand reaches 165 TWh by 2030, increasing to roughly 920 TWh by 2050.

Hydrogen demand may accelerate and increase further than forecasted as a result of additional regulatory measures adopted in response to the RePowerEU plan.

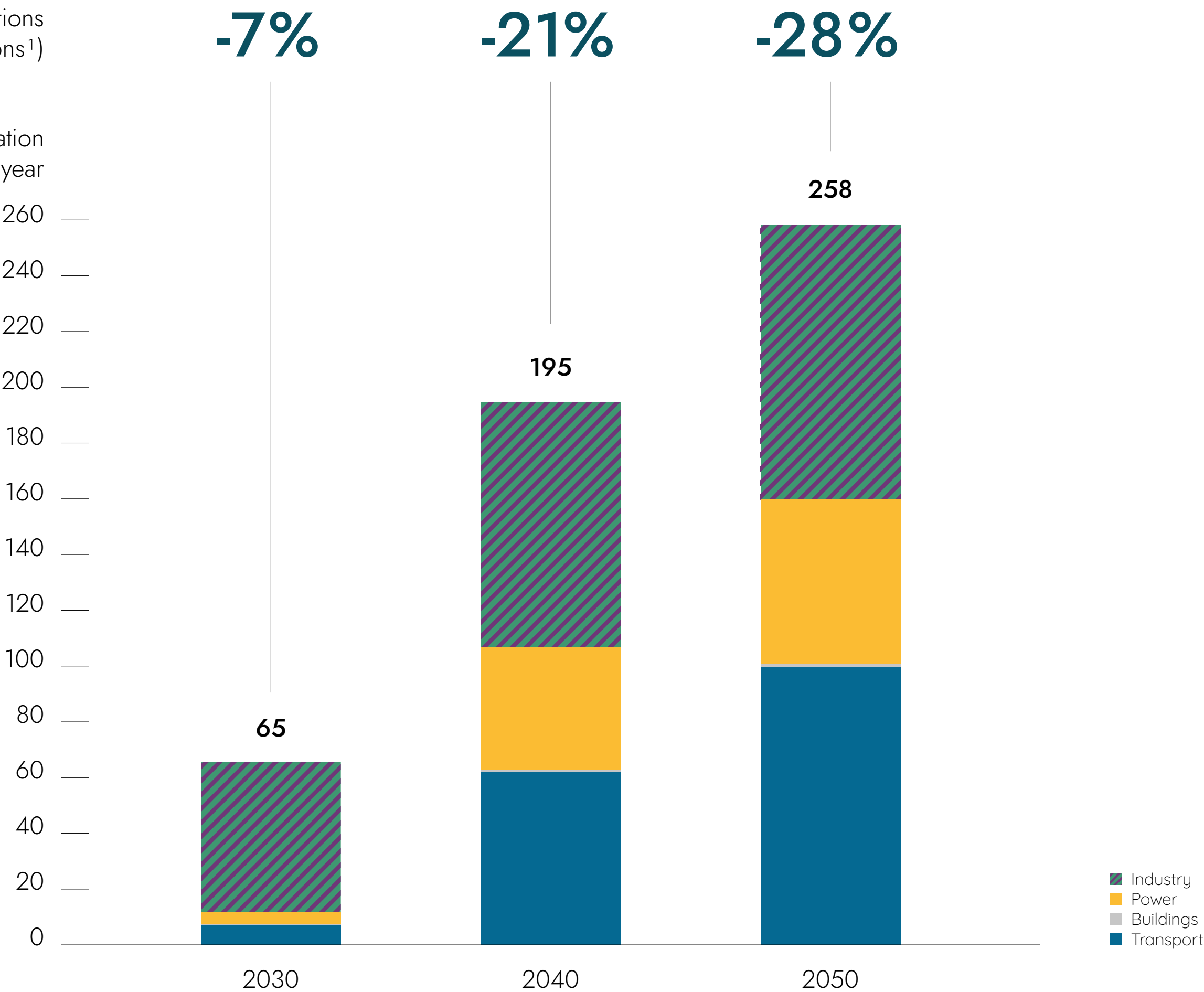
- Up to 2030, most hydrogen demand is driven by the industrial sector in the destination countries – Germany and Poland.
- From 2040 to 2050, most new hydrogen demand is for e-fuels production and for power generation.

Note: Does not include grey hydrogen demand. Numbers represent total demand by country, even if only parts of the country are included in the corridor.

Hydrogen adoption enables a reduction in emissions of 28% by 2050 across all countries of the corridor

Emissions reductions (vs. 2019 emissions¹)

Decarbonisation in MtCO₂ / year

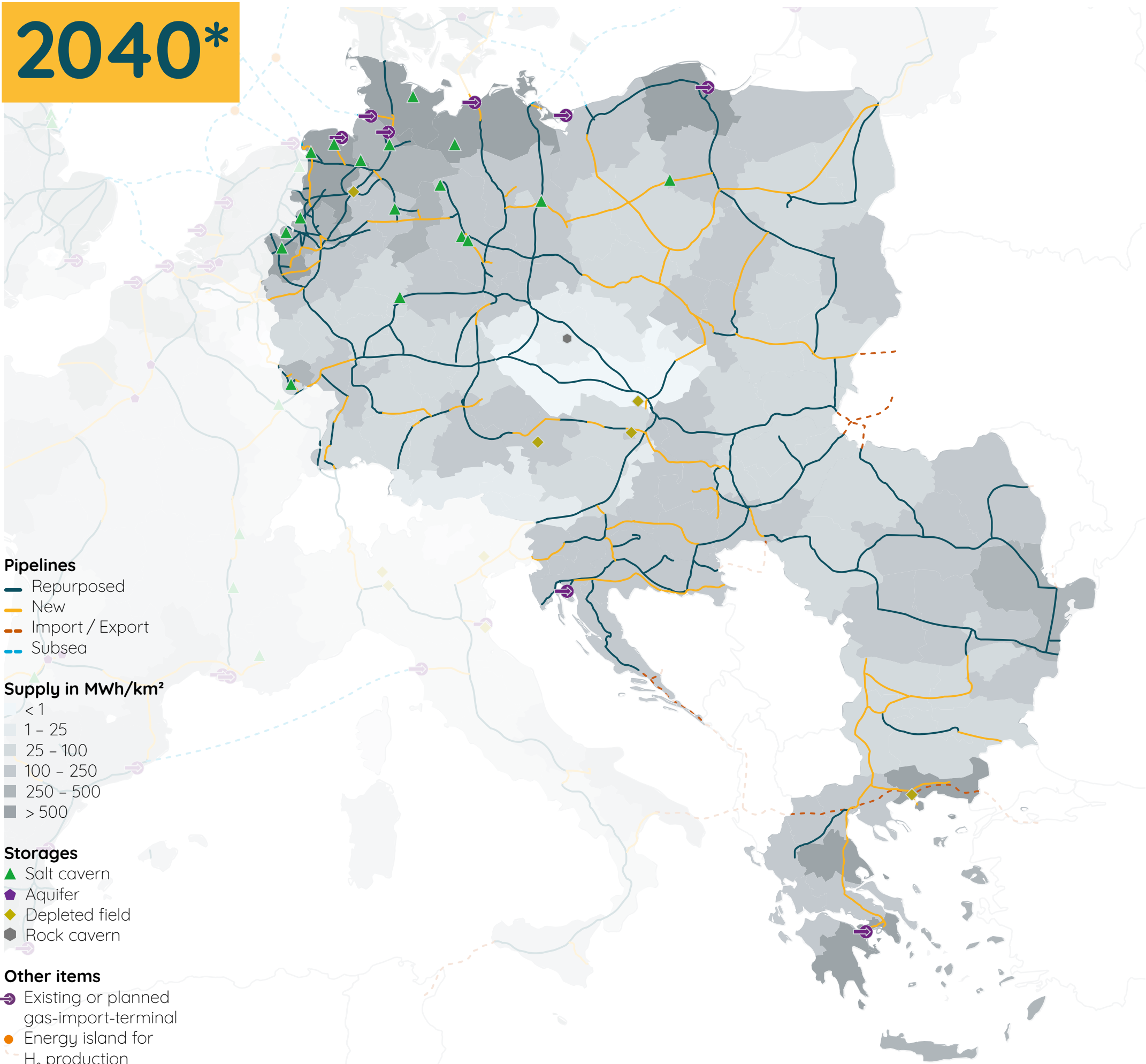
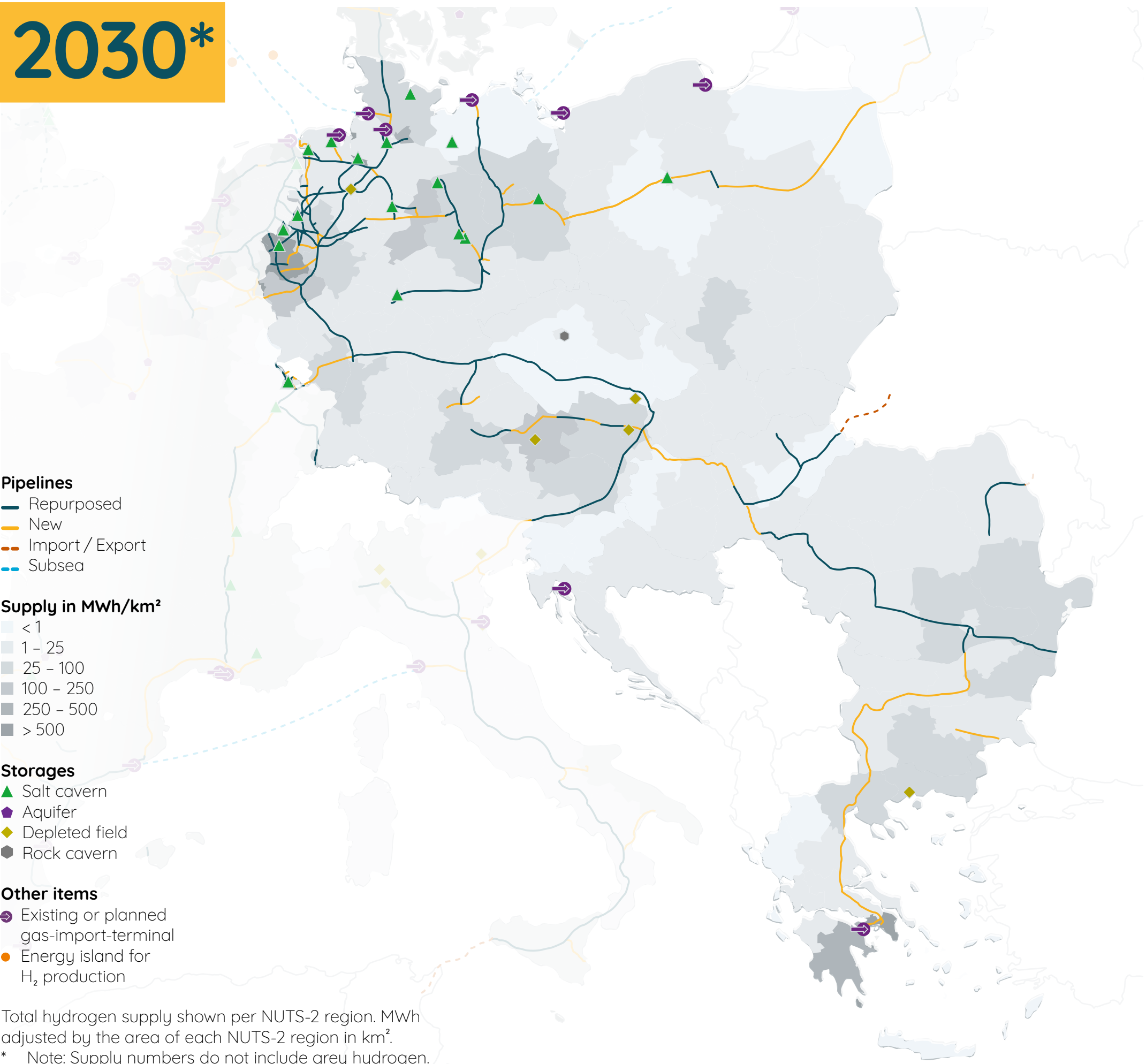


Hydrogen adoption across all demand sectors enables an **emissions reduction of ~260 MtCO₂/yr. by 2050**, equivalent to a **28% reduction²**.

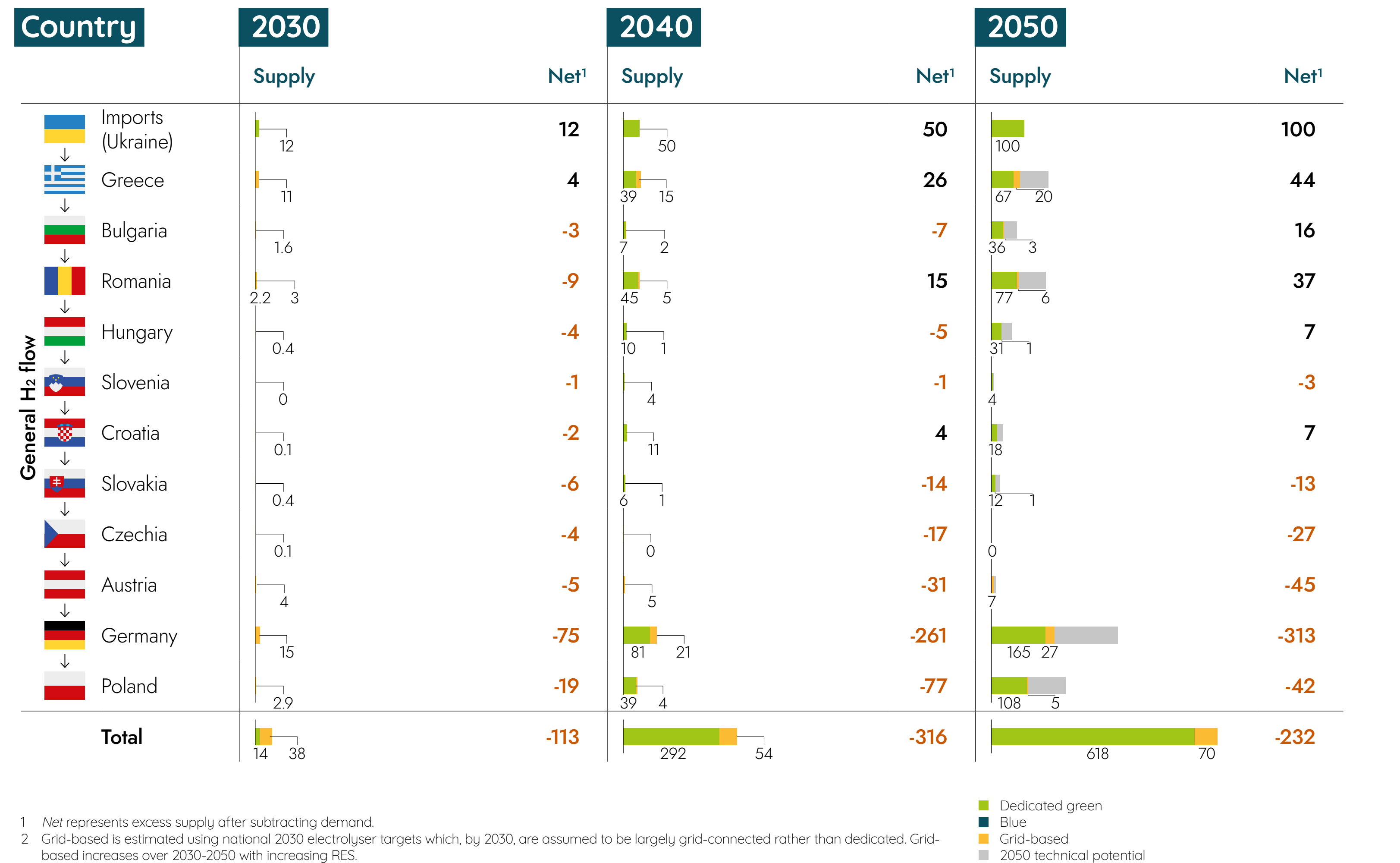
- **Up to 2030**, the industrial sector contributes 85% of the total emissions reductions.
- **By 2040**, emissions reductions from transport (road, shipping and aviation) increase substantially and combined with industry, account for 75% of emissions reductions. The power sector account for the remaining 25% of reductions.
- **By 2050**, most incremental emissions reductions are associated with hydrogen adoption in the power and transport sectors.

¹ CO₂-Emissions from countries and sectors included in corridor (0.91 bn t CO₂ / year), Source: EEA
² Emissions reductions are calculated compared to the baseline fossil fuel used in each sectors. For example, emissions reductions associated with the adoption of hydrogen by the primary steel sector are relative to the use of coal. Similarly, emissions reductions , for e-fuels production are relative to the use of fossil fuels in shipping, aviation and other uses.

Corridor enables access to supply from Eastern & South-Eastern Europe and Ukraine by 2030, expanding across the region by 2040



Hydrogen supply increases significantly from 2030 to 2040, largely driven by imports from Ukraine and South-Eastern Europe



The hydrogen supply mix includes **grid-based green hydrogen²** and **dedicated green hydrogen**.

- By 2030, hydrogen supply reaches **50 TWh**, largely from grid-based green hydrogen.
- By 2040, hydrogen supply increases substantially to **~350 TWh**, of which roughly 85% is from dedicated green hydrogen. The remaining 15% is from grid-based hydrogen supply.
- By 2050, hydrogen supply increases further to **~690 TWh**. Dedicated green supply continues to account for the largest share at roughly 90%, while grid-based hydrogen increases only slightly.

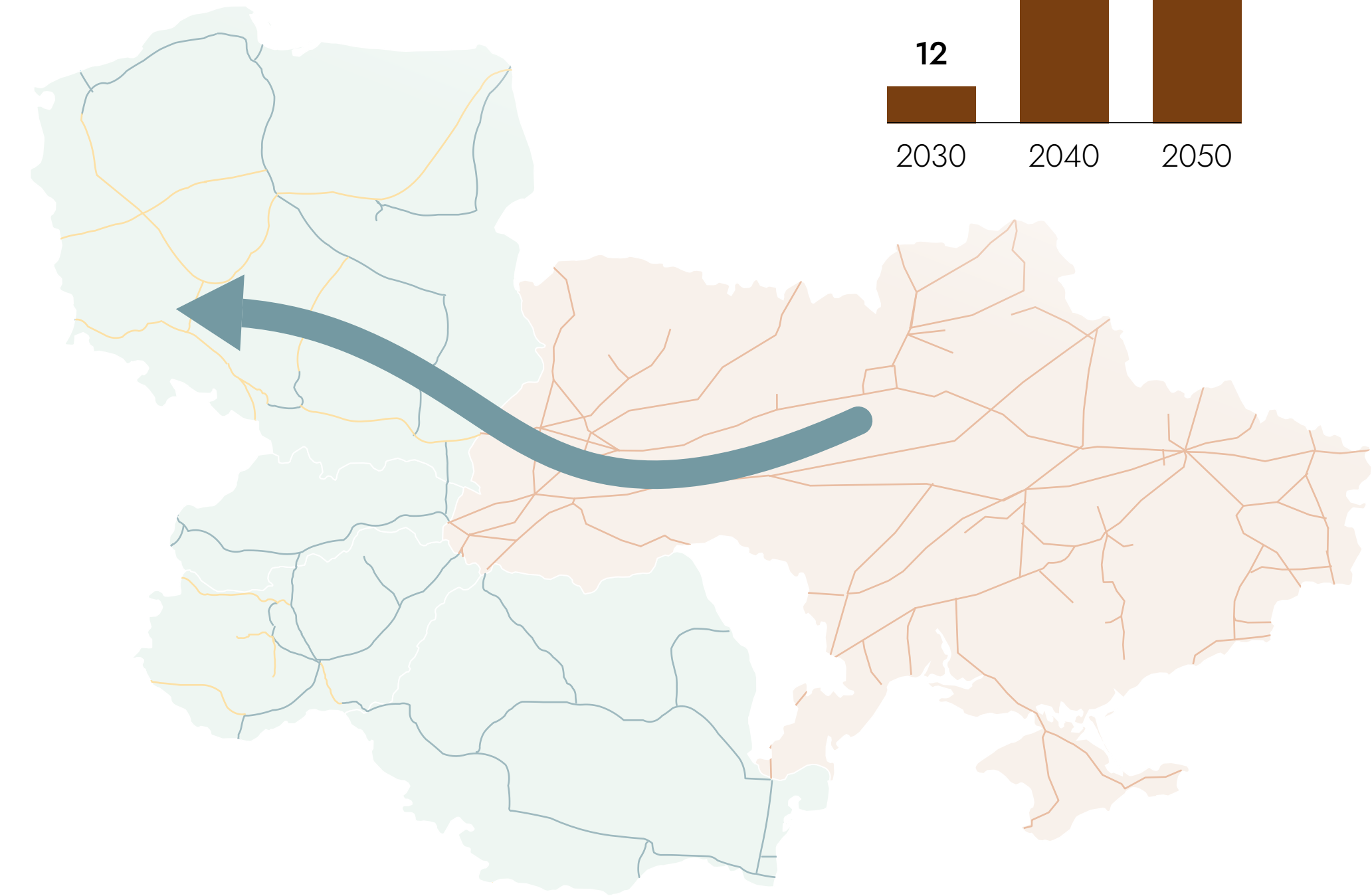
Hydrogen supply may accelerate and increase further as a result of additional regulatory measures adopted in response to the RePowerEU plan.

Note: Hydrogen supply volumes do not include hydrogen imports by ship.

Ukraine may become a potential source of imports by 2030

Supply potential	<ul style="list-style-type: none">Supply potential estimated based on Hydrogen Europe’s 2x40 GW Green Hydrogen Initiative report¹.This analysis assumes a delay compared to the 2x40 GW report – due to the war in Ukraine – resulting in more moderate hydrogen export volumes².
State of Gas Infra-structure	<ul style="list-style-type: none">Ukraine is approaching H₂ as an export opportunity and is actively investigating retrofitting existing gas pipelines to hydrogen.The Ukrainian Ministry of Energy highlighted the potential of using existing gas pipelines for the domestic use and for exports to Romania, Slovakia, Hungary and Poland³.
Market Attractive-ness	<ul style="list-style-type: none">Technical green hydrogen potential is substantial. Based on an estimated technical potential of ~500-800 GW of renewable energy capacity, the supply potential ranges between ~1,000-1500 TWh.Ukraine has a well-developed ammonia and steel production industries (applicable for green hydrogen).Ukraine’s Naftogaz joined the European Clean Hydrogen Alliance with the ambition of becoming a leader in hydrogen export to EU countries.Partnerships:<ul style="list-style-type: none">TSO’s of Slovakia, Austria and Germany—as part of an international consortium—are investigating the establishment of necessary capacities for transporting hydrogen from Ukraine via Slovakia and Austria to Germany for accessing storage facilities in Central EuropeUkraine’s, Czech Republic, Slovakia and Germany’s gas TSOs collaborate to investigate the technical feasibility of establishing a 120GWh/day corridor from Ukraine to Germany
Market Barriers	<p>Mayor uncertainties relate to the current war</p> <ul style="list-style-type: none">The operational state of Ukraine’s natural gas infrastructureThe speed of economic recovery and infrastructure investmentThe development of a hydrogen market and related supply chains in Ukraine.

Hydrogen supply potential (TWh)¹



1 Hydrogen Europe (2021). 2x40 GW Green Hydrogen Initiative. https://hydrogeneurope.eu/wp-content/uploads/2021/11/Hydrogen-Europe_2x40-GW-Green-H2-Initiative-Paper.pdf

2 This report estimates 12 TWh of exports in 2030 based on of 5.5 GW of export capacity (vs. 8 GW in Hydrogen Europe’s estimations). Export volumes assume an onshore wind capacity factor of 35% and an electrolyser efficiency of 70%.

3 UNECE – Draft Roadmap for Production & Use of Hydrogen in Ukraine (2021)

Note: Export projections to Europe from 2030 to 2040-2050 are based on an assumed four-fold increase in exports by 2040 and two-fold increase from 2040 to 2050. These assumptions are informed by scale up projections from other export countries of this study and Hydrogen Europe’s 2x40 GW report.

East and South-East Europe

Agenda

1. Corridor Summary
2. Hydrogen Demand & Supply
- 3. Supply Costs & Cost-Competitiveness**
4. National Strategies & Regulation
5. Actions Needed

This section explores the costs of hydrogen production and delivery for this corridor and their competitiveness with fossil fuels

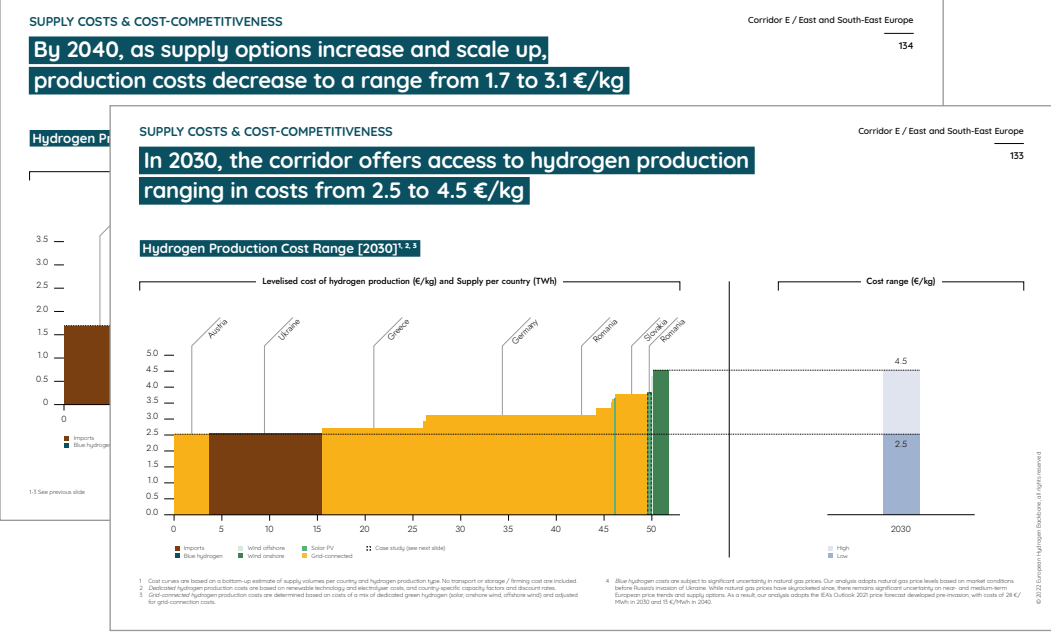
Hydrogen production cost

Key Questions Answered

Content Material

Key Findings & Results

What is the range of production costs achieved by the corridor in 2030 and 2040?



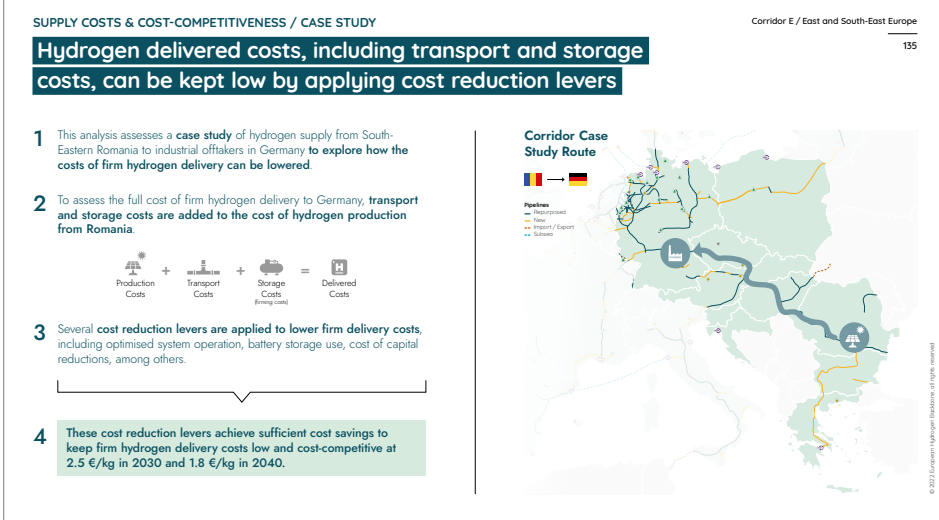
By 2040, as supply options increase and scale up, production costs decrease to a range from 1.7 to 3.1 €/kg

- By 2030, the corridor offers access to hydrogen production ranging in costs from 2.5 to 4.5 €/kg
- By 2040, hydrogen production costs decrease to the range of 1.7 to 3.1 €/kg.

Hydrogen delivered costs

Based on a case-study of hydrogen supply from South-Eastern Romania to Germany:

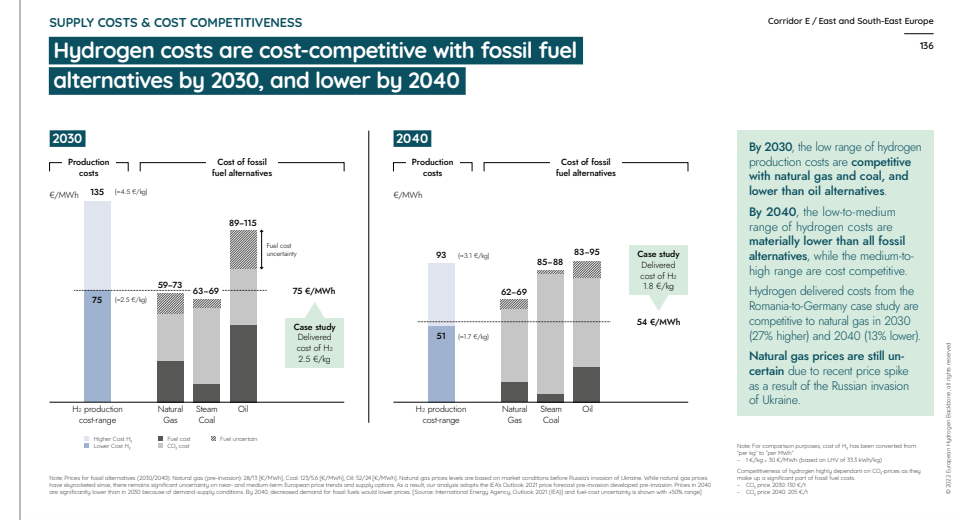
- What are the full costs of firm hydrogen delivery after accounting for transport and storage costs?
- What cost levers are available to lower the cost of hydrogen delivery?



- Several cost reduction levers can be applied to lower the costs of hydrogen delivery.
- For the Romania-to-Germany case study, these levers achieve delivery costs that are low and cost-competitive.

Comparison with fossil alternatives

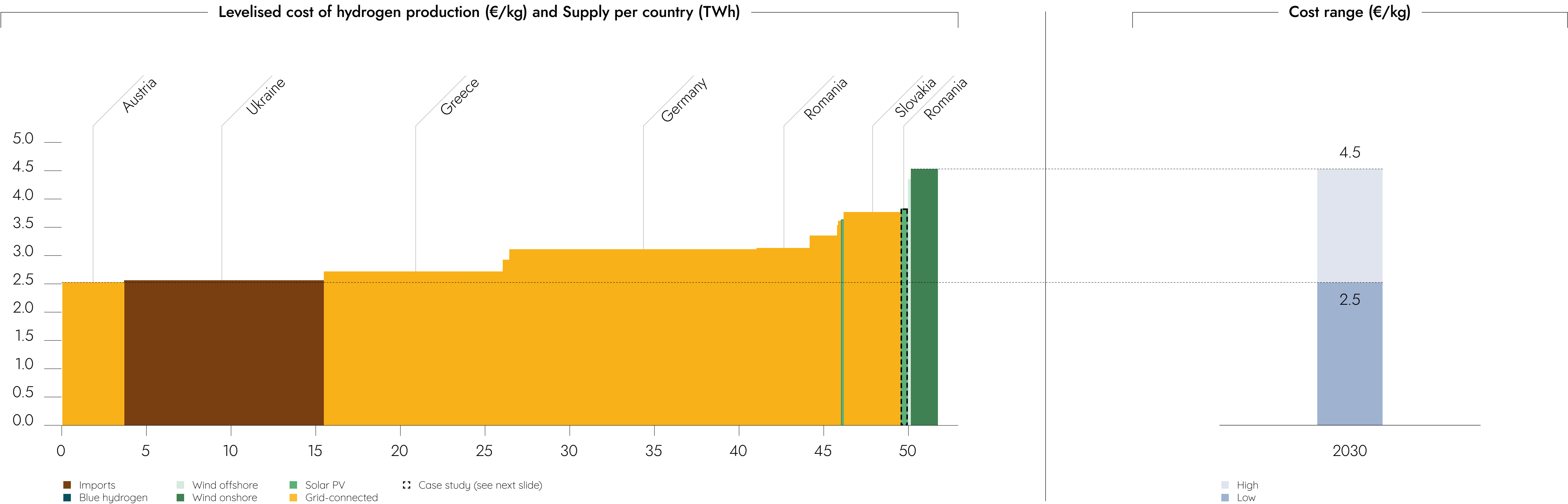
How competitive is hydrogen supply from this corridor compared to fossil fuel alternatives?



- Hydrogen costs are competitive with fossil fuel alternatives both in 2030 and 2040.
- Fossil fuel costs are subject to significant uncertainty.

In 2030, the corridor offers access to hydrogen production ranging in costs from 2.5 to 4.5 €/kg

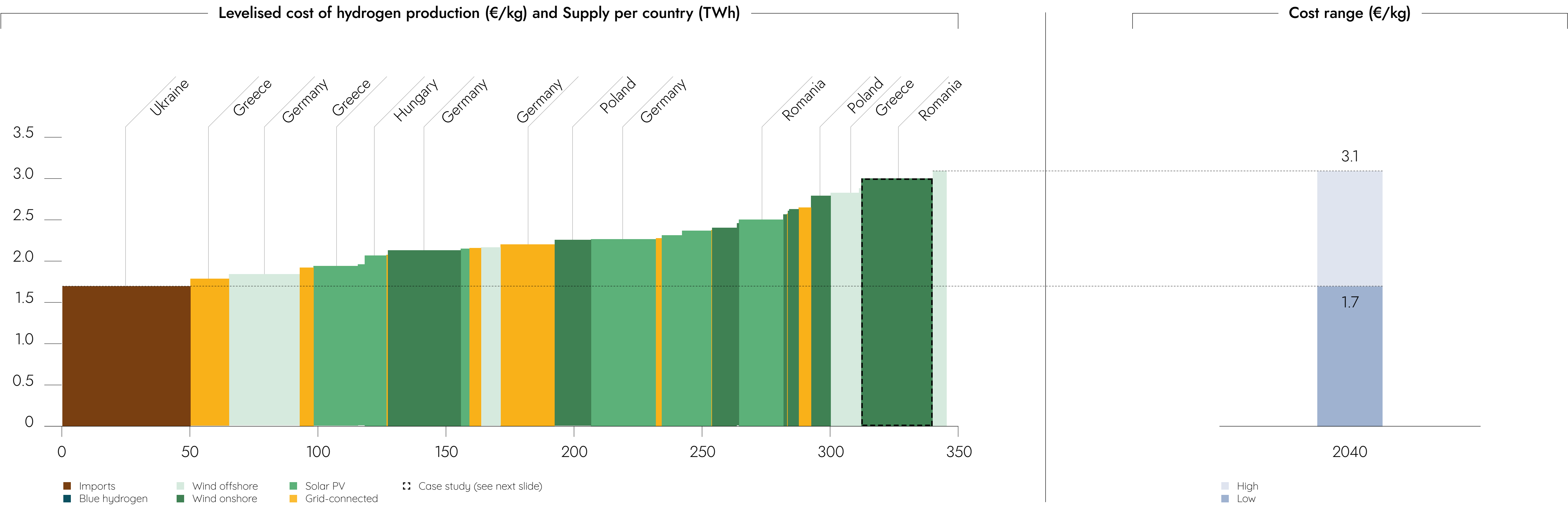
Hydrogen Production Cost Range [2030]^{1, 2, 3}



1 Cost curves are based on a bottom-up estimate of supply volumes per country and hydrogen production type. No transport or storage / firming cost are included.
2 Dedicated hydrogen production costs are based on renewable technology and electrolyser costs, and country-specific capacity factors and discount rates.
3 Grid-connected hydrogen production costs are determined based on costs of a mix of dedicated green hydrogen (solar, onshore wind, offshore wind) and adjusted for grid-connection costs.
4 Blue hydrogen costs are subject to significant uncertainty in natural gas prices. Our analysis adopts natural gas price levels based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast developed pre-invasion, with costs of 28 €/MWh in 2030 and 13 €/MWh in 2040.

By 2040, as supply options increase and scale up,
production costs decrease to a range from 1.7 to 3.1 €/kg

Hydrogen Production Cost Range [2040]^{1, 2, 3}



1-3 See previous slide

Hydrogen delivered costs, including transport and storage costs, can be kept low by applying cost reduction levers

1 This analysis assesses a **case study** of hydrogen supply from South-Eastern Romania to industrial offtakers in Germany **to explore how the costs of firm hydrogen delivery can be lowered.**

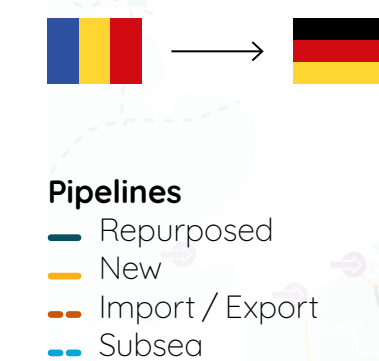
2 To assess the full cost of firm hydrogen delivery to Germany, **transport and storage costs are added to the cost of hydrogen production from Romania.**



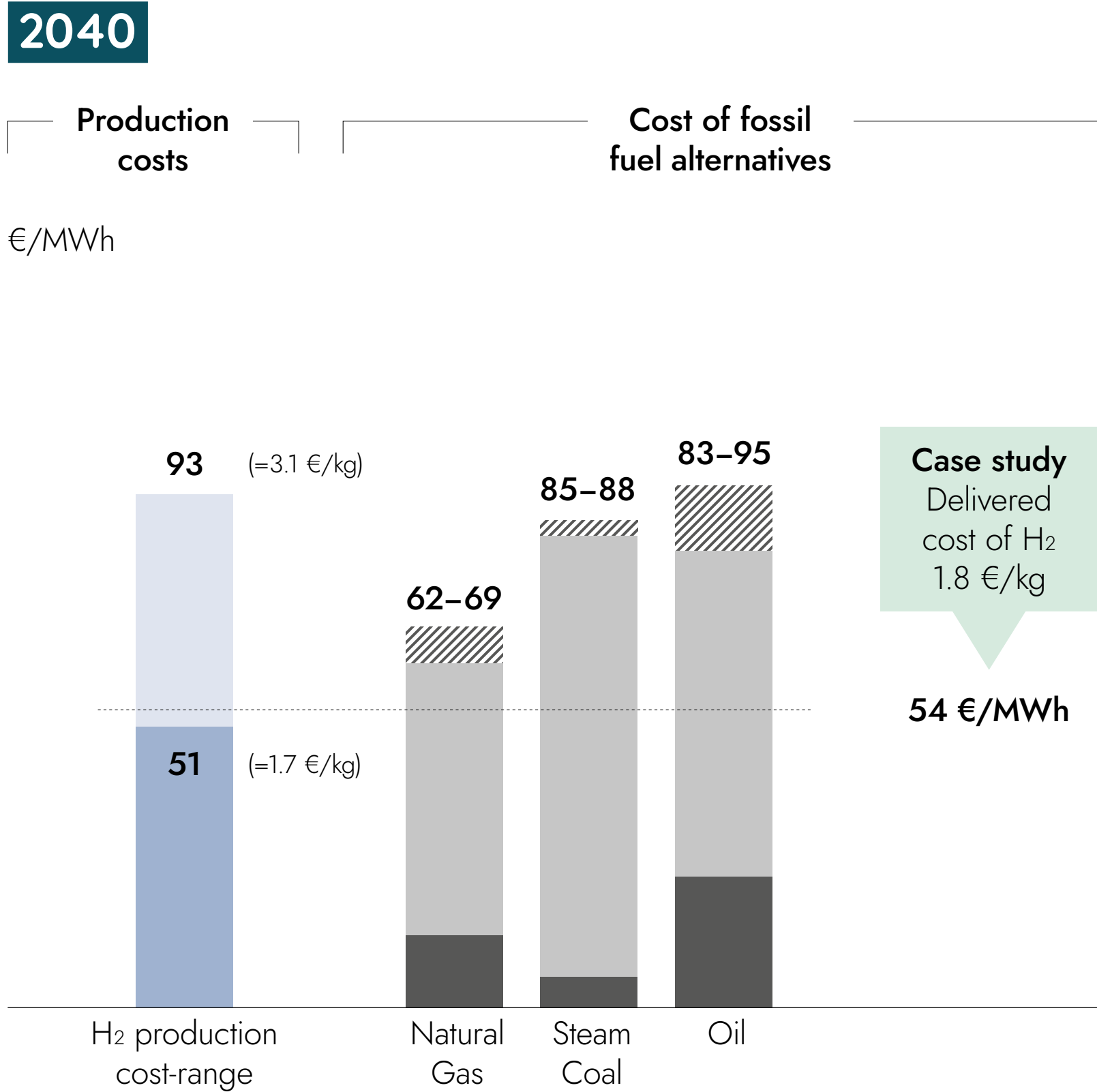
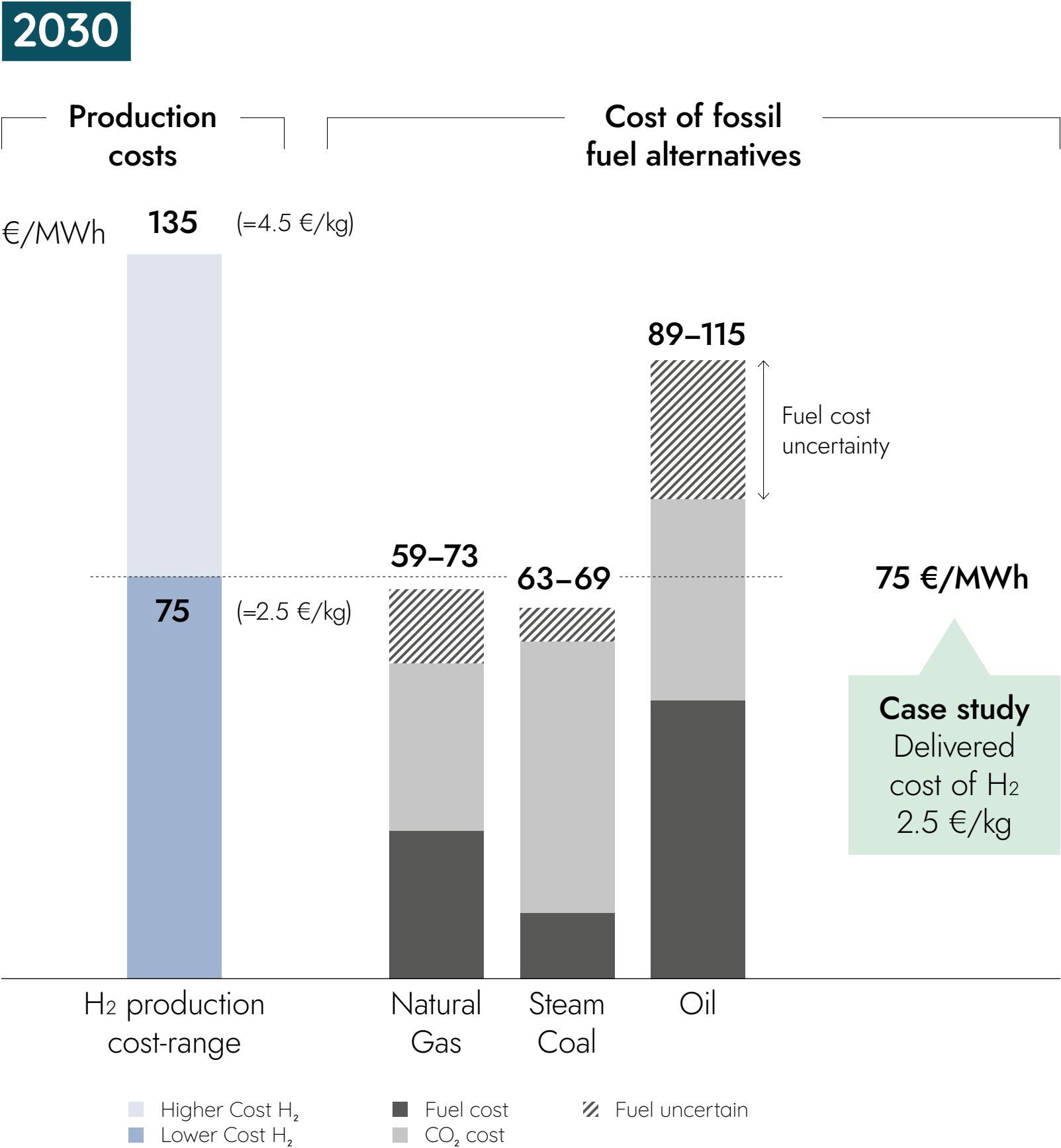
3 Several **cost reduction levers** are applied to lower firm delivery costs, including optimised system operation, battery storage use, cost of capital reductions, among others.

4 These cost reduction levers achieve sufficient cost savings to keep firm hydrogen delivery costs low and cost-competitive at 2.5 €/kg in 2030 and 1.8 €/kg in 2040.

Corridor Case Study Route



Hydrogen costs are cost-competitive with fossil fuel alternatives by 2030, and lower by 2040



By 2030, the low range of hydrogen production costs are **competitive with natural gas and coal, and lower than oil alternatives**.

By 2040, the low-to-medium range of hydrogen costs are **materially lower than all fossil alternatives**, while the medium-to-high range are cost competitive.

Hydrogen delivered costs from the Romania-to-Germany case study are competitive to natural gas in 2030 (27% higher) and 2040 (13% lower).

Natural gas prices are still uncertain due to recent price spike as a result of the Russian invasion of Ukraine.

Note: Prices for fossil alternatives (2030/2040): Natural gas (pre-invasion): 28/13 [€/MWh], Coal: 123/5.6 [€/MWh], Oil: 52/24 [€/MWh]. Natural gas prices levels are based on market conditions before Russia's invasion of Ukraine. While natural gas prices have skyrocketed since, there remains significant uncertainty on near- and medium-term European price trends and supply options. As a result, our analysis adopts the IEA's Outlook 2021 price forecast pre-invasion developed pre-invasion. Prices in 2040 are significantly lower than in 2030 because of demand-supply conditions. By 2040, decreased demand for fossil fuels would lower prices. [Source: International Energy Agency, Outlook 2021 (IEA)] and fuel-cost uncertainty is shown with +50% range]

Note: For comparison purposes, cost of H₂ has been converted from "per kg" to "per MWh"
– 1 €/kg = 30 €/MWh (based on LHV of 33.3 kWh/kg)
Competitiveness of hydrogen highly dependant on CO₂-prices as they make up a significant part of fossil fuel costs.
– CO₂ price 2030: 130 €/t
– CO₂ price 2040: 205 €/t

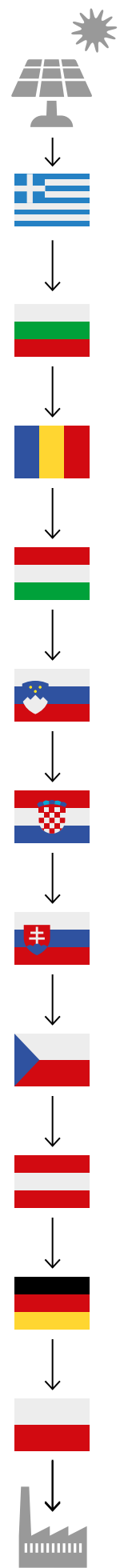
East and South-East Europe

Agenda

1. Corridor Summary
2. Hydrogen Demand & Supply
3. Supply Costs & Cost-Competitiveness
- 4. National Strategies & Regulation**
5. Actions Needed

A selection of countries have developed national strategies. Moving forward, the development of regulation is key to enable infrastructure investment.

Pre-RePowerEU targets²



	National Hydrogen strategy (NHS)	Network regulation & policy	Funding ¹ (bn €)	Highlights
Greece	<ul style="list-style-type: none">– In 2020, the government formed a Committee to work on NHS. The final draft of the NHS is expected in Q2 2022.	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– H2 in shipping, power, production from renewable electricity and H2 related R&D
Bulgaria	<ul style="list-style-type: none">– No specific national hydrogen strategy, but consideration of role for hydrogen in NECP	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– 20 MW H2 refuelling stations are planned and a demand of 32 GWh in transport by 2030
Romania	<ul style="list-style-type: none">– Hydrogen strategy to be published in 2022	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– Project with 2 x 20 MW electrolyzers powered by solar-PV parks is under development
Hungary	<ul style="list-style-type: none">– 240MW of electrolyser capacity– Demand seen in industry and transport sector	<ul style="list-style-type: none">– Min. 2% volume blending to natural gas grid		<ul style="list-style-type: none">– Low carbon and renewable H2 planned– €5.3 m for project to store H2 underground
Slovenia	<ul style="list-style-type: none">– In NECP is set indicative target to have 10 % of renewable methane or hydrogen in the network (2030)	<ul style="list-style-type: none">– TSO is obliged to prepare the plan for acceptance of H2		<ul style="list-style-type: none">– Foreseen H2 demand sectors: Transport (2030), buildings, industry (NECP)
Croatia	<ul style="list-style-type: none">– Foresees demand in industry, buildings, transport and power, with a supply potential of 1.3 GW electrolyzers	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– First production site by 2025
Slovakia	<ul style="list-style-type: none">– H2 used in the chemicals, petrochemicals, steel and heating industries as well as in transport	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– Use H2 in industries/areas impossible or not cost-effective to directly engage electricity
Czech Republic	<ul style="list-style-type: none">– Focus Transport, then energy & chemical industry– Production also CCS and nuclear– Import and transit country for H2 from the south	<ul style="list-style-type: none">– N/A		<ul style="list-style-type: none">– H2-Readiness of gas transmission system is urged, due to potential role in H2 transport from south to north and from east to west
Austria	<ul style="list-style-type: none">– NHS is still in discussion; known elements are: 1 – 2 GW electrolyser capacity (2030), use in industry	<ul style="list-style-type: none">– H2 mixtures of up to 10 % within Austria and 4-5 % on entry/exit points are allowed	<div><div></div>0.5</div>	<ul style="list-style-type: none">– Production of green H2 is subsidised– Preferred use to decarbonise industry– Focus: Transport sector and underground H2 storage
Germany	<ul style="list-style-type: none">– National production & import focus due to supply gap– In place since 2020, currently reviewed towards increasing its ambition– 10 GW (2030) electrolyser in coalition plans	<ul style="list-style-type: none">– H2 network potentially opt-in regulated and vertically unbundled– First rules and standards for high pressure pipelines are formulated	<div><div></div>9</div>	<ul style="list-style-type: none">– Strong focus on international cooperation to ensure sufficient supply– National funding
Poland	<ul style="list-style-type: none">– Focus: Power/heat sector, transport, industry, production, network, creating regulatory framework	<ul style="list-style-type: none">– Creation of regulatory framework mentioned in H2 strategy		<ul style="list-style-type: none">– Gas network to be adapted & new build: “Hydrogen Highway” (North-South)

Note: Sequencing of countries follows the general corridor direction but does not represent the hydrogen flows.
1 Cumulative public funding amount by the respective state until 2030
2 Strategies and funding is under evaluation of meeting latest targets



East and South-East Europe

Agenda

1. Corridor Summary
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This corridor plays a fundamental role in achieving a European backbone by 2040

The need for this corridor

- The development of **this corridor ensures access to abundant, low-cost hydrogen supply from parts of Eastern and South-Eastern Europe and Ukraine by 2030**, and by 2040 expanding access to additional supply from the region.
- The **decarbonisation of the largest hydrogen demand centers along this corridor** – in **Greece, Romania, Bulgaria, Hungary, Austria and further towards Germany and Poland** – is dependent on the buildout of this corridor by 2030, and its expansion towards 2040.

Actions required

- The buildout of this corridor by 2030 **requires national governments to take clear and concrete actions across**.
- This includes actions associated with **infrastructure development and planning, the development of cross-national initiatives** and **securing access to early funding and long-term, low-cost financing**.

2040

Pipelines

- Repurposed
- New
- Import / Export
- Subsea

Demand per sector

- 40 / 30 / 20 / 10 / 1 TWh
- Efuels production
 - Industrial energy
 - Industrial feedstock
 - Power

Supply in MWh/km²

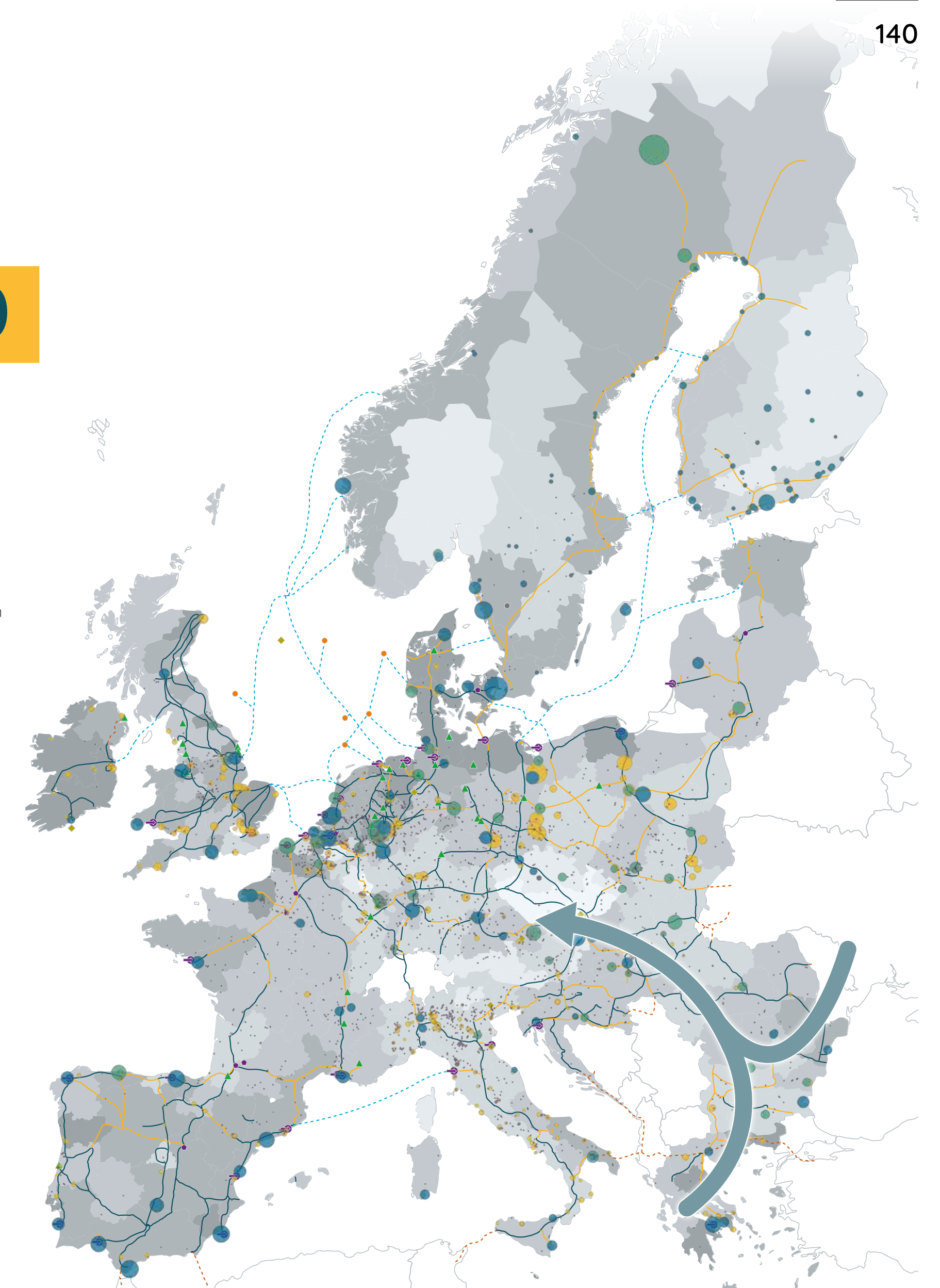
- < 1
- 1 – 25
- 25 – 100
- 100 – 250
- 250 – 500
- > 500

Storages

- ▲ Salt cavern
- Aquifer
- ◆ Depleted field
- Rock cavern

Other items

- Existing or planned gas-import-terminal
- Energy island for H₂ production



**To ensure the development of this corridor by 2030,
there is a need for clear and concrete actions**

Fostering development of new and repurposed hydrogen infrastructure, for example, by unbundling rules facilitating the efficient use of TSO expertise and services and by allowing the adoption of different vertical unbundling models in the EU, as is the case with natural gas

+

Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility and other pragmatic financing solutions (including incentivizing the adoption of hydrogen by demand sectors)

+

Simplify and shorten planning and permitting procedures for renewable energy and hydrogen infrastructure projects

+

Intensify energy partnerships with exporting, non-EHB countries like Ukraine, and providing financing support to reduce their cost of capital

+

Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure supporting the accelerated deployment and integration of renewable energy resources

→ However, speed will be of essence!

TABLE OF CONTENTS

1. Executive Summary

2. Five emerging supply corridors

Corridor A: North Africa & Southern Europe

Corridor B: Southwest Europe & North Africa

Corridor C: North Sea

Corridor D: Nordic and Baltic regions

Corridor E: East and South-East Europe

3. Detailed methodology

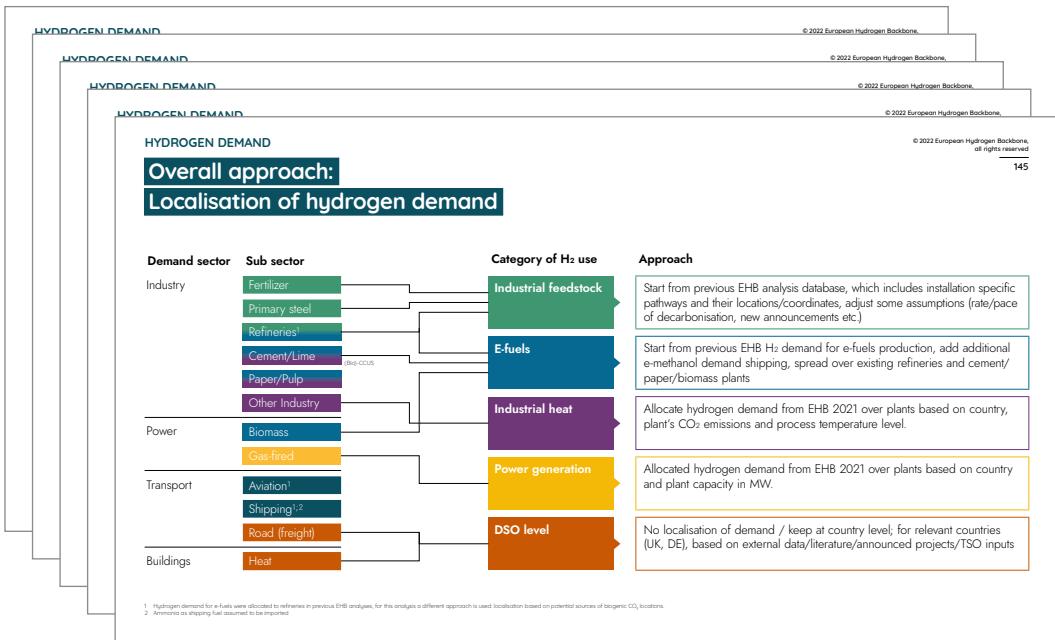
This section describes the methodology used to define hydrogen demand, supply, decarbonisation potential and cost competitiveness

H₂ demand

Objective

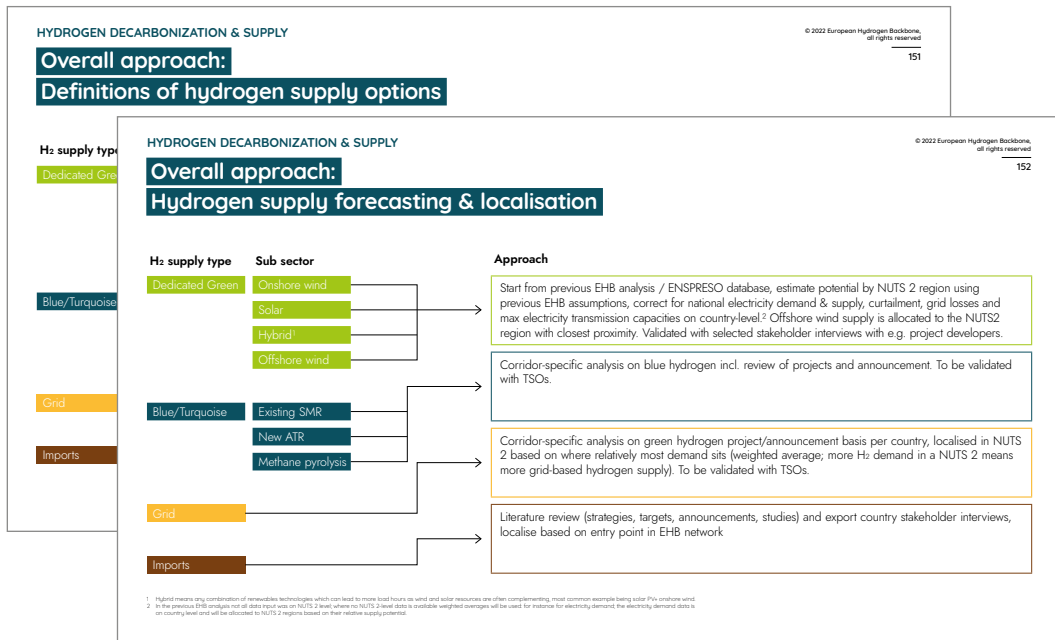
Forecast and localise future hydrogen demand.

Content
Material



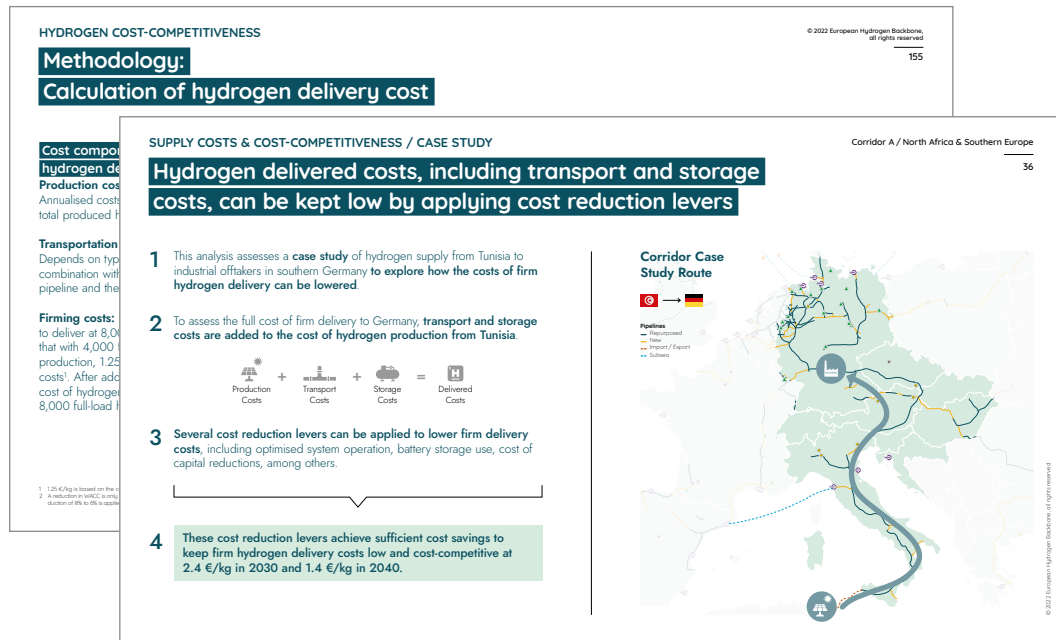
H₂ supply & decarbonisation

Forecast and localise future hydrogen supply and determine the emissions reductions impact of hydrogen adoption



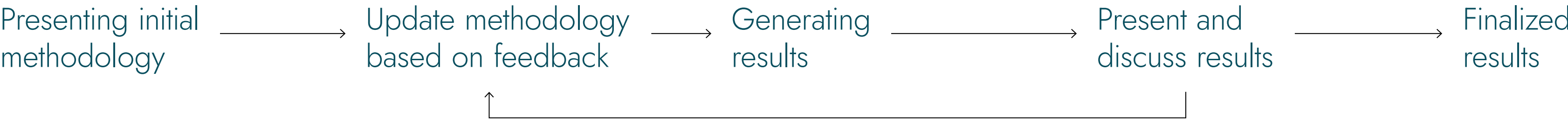
H₂ cost competitiveness

Calculate the cost of delivered hydrogen for different corridor case studies



Using the iterative process the working groups provided

Overall
Process

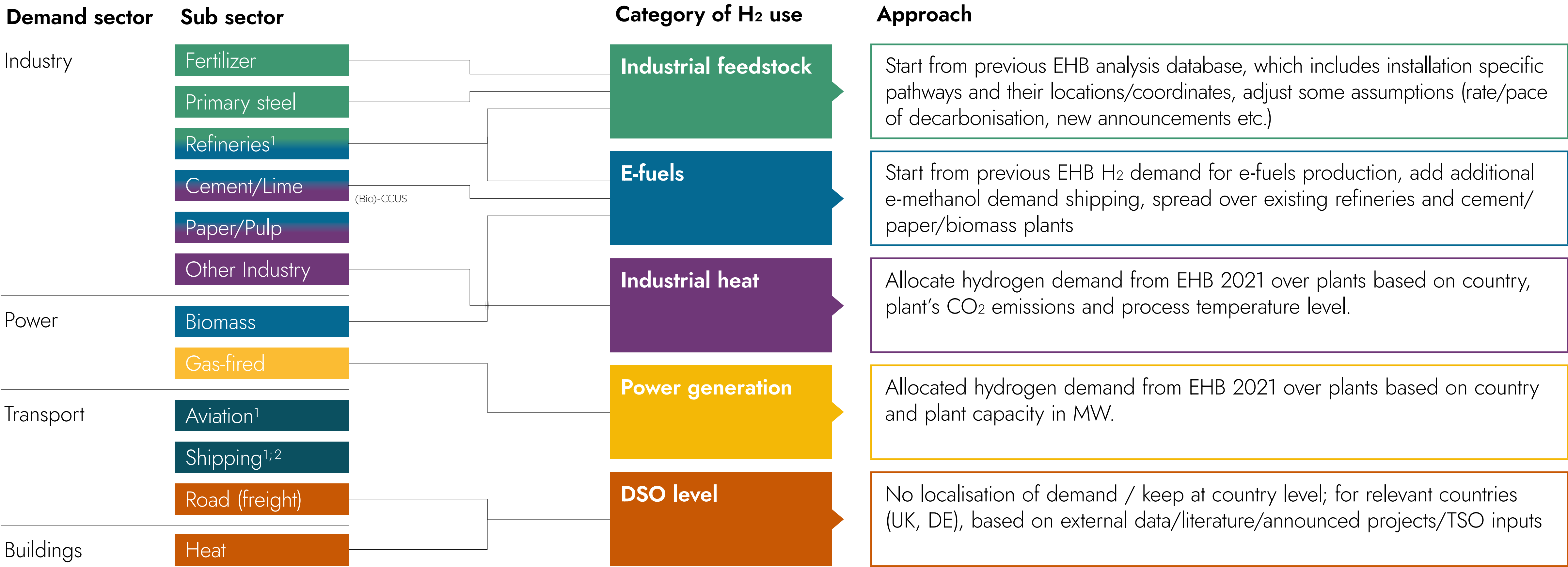


Detailed methodology

1. **Hydrogen demand**
2. Hydrogen supply & decarbonisation
3. Hydrogen cost-competitiveness

Overall approach:

Localisation of hydrogen demand

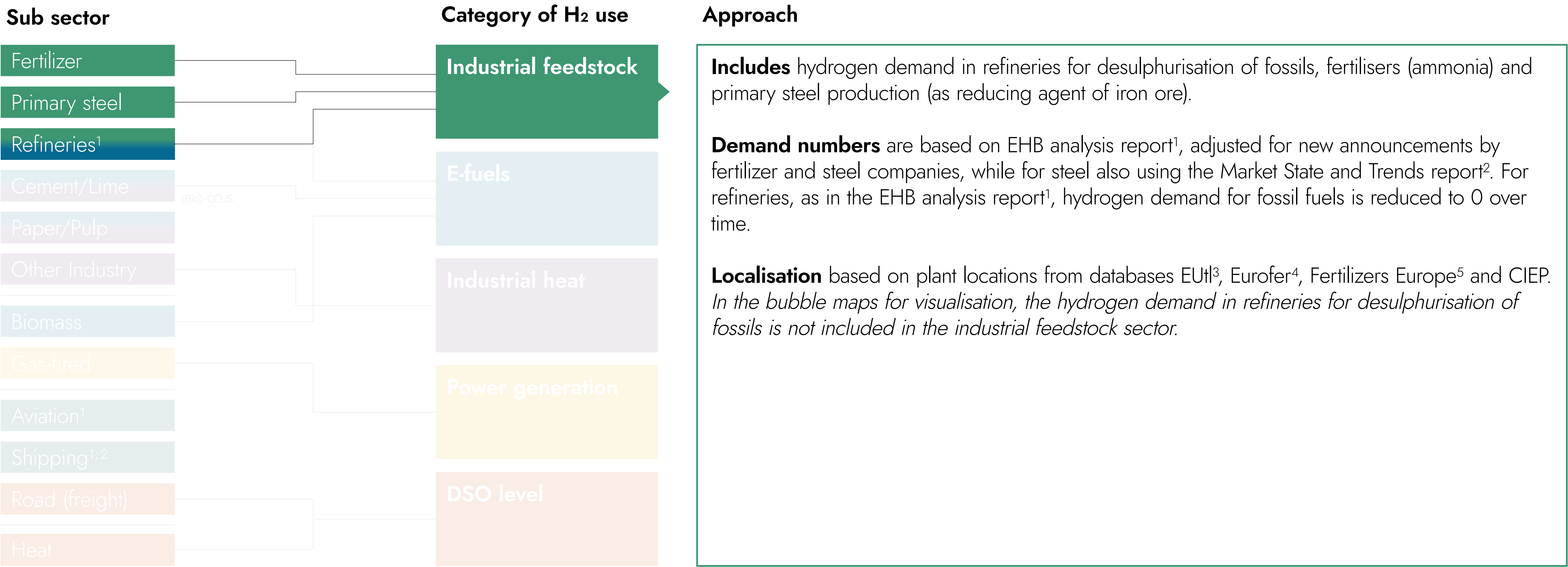


1 Hydrogen demand for e-fuels were allocated to refineries in previous EHB analyses, for this analysis a different approach is used: localisation based on potential sources of biogenic CO₂ locations.

2 Ammonia as shipping fuel assumed to be imported

Detailed approach:

Demand for industrial feedstock



Sources:

1 EHB analysis report (June 2021);

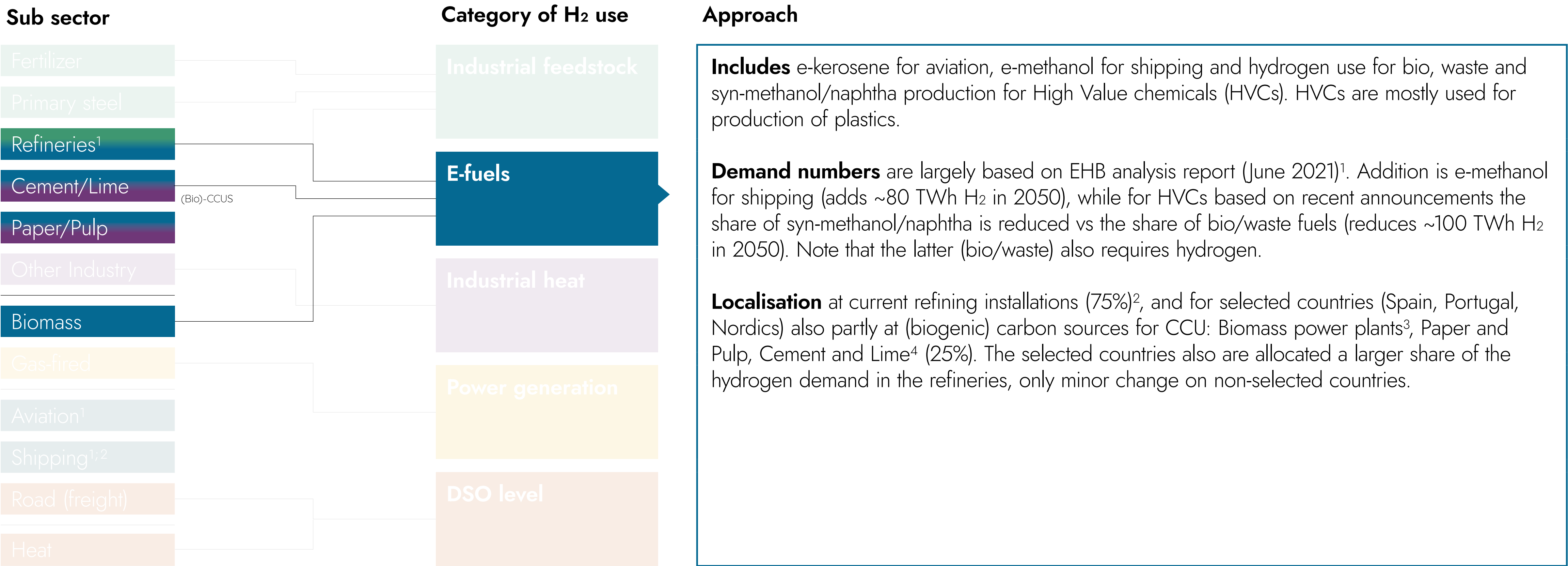
2 GfC Market state and trends report (2021) EUtl database (2019);

3 JRC power plant database (2019);

4 Eurofer;

5 Fertilizers Europe; Company announcements, Stakeholder interviews.

Detailed approach:
Demand for e-fuels

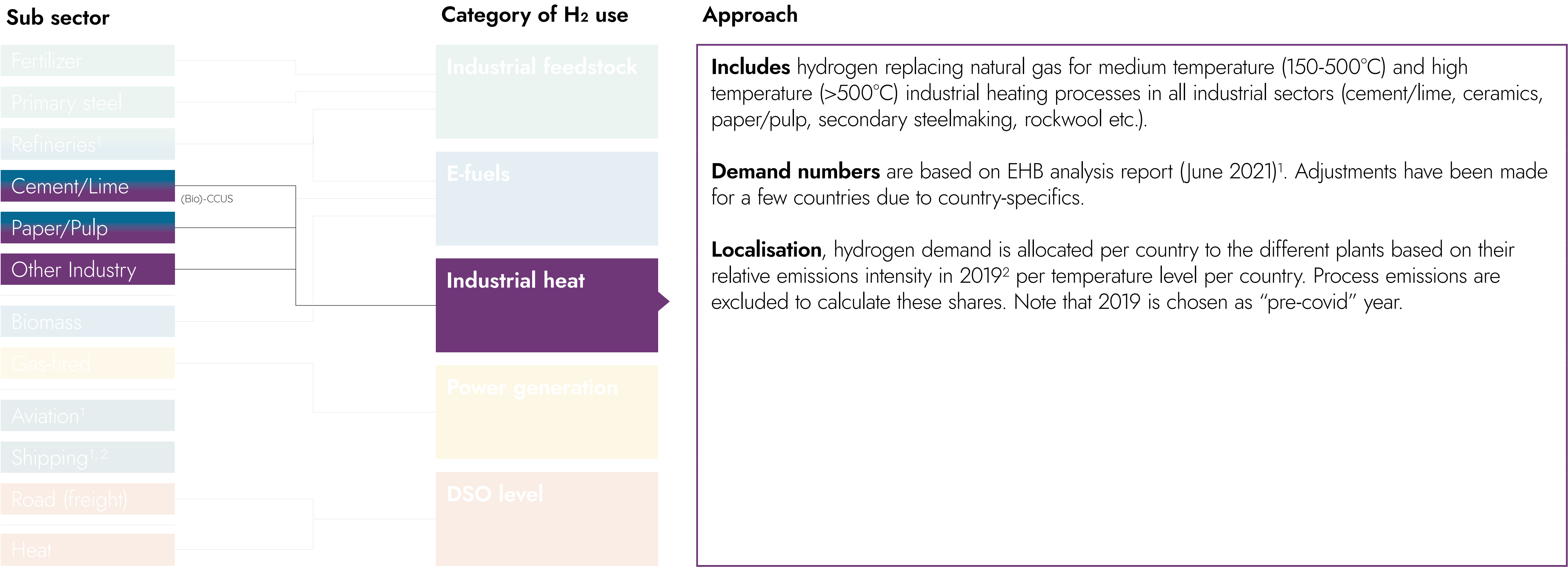


Sources:
1 EHB analysis report (June 2021),
2 Clingendael International Energy Program (CIEP) (2017);

3 JRC power plant database (2019);
4 EUtl database (2019), company announcements, stakeholder interviews.

Note:
In the bubble maps for visualisation, the efuels category also includes hydrogen demand in refineries for desulphurisation of fossils. For Paper and Pulp, Cement and lime, if a location is selected as e-fuel production location no hydrogen demand is included for industrial heat – as efuels will provide for significant demand numbers already

Detailed approach: Demand for industrial heat

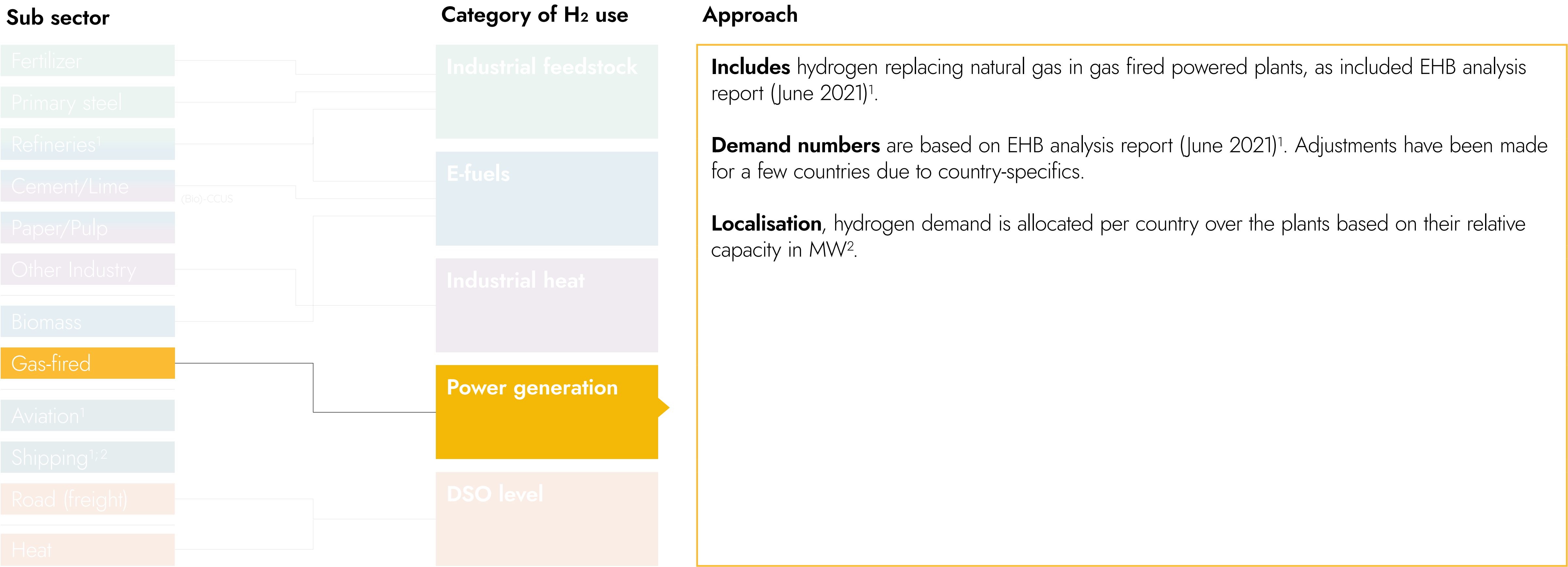


Sources:
1 EHB analysis report (June 2021),

2 EUtl database (2019);

Note:
For Paper and Pulp, Cement and lime, if a location is selected as e-fuel production location no hydrogen demand is included for industrial heat – as efuels will provide for significant demand numbers already.

Detailed approach: Demand for power generation



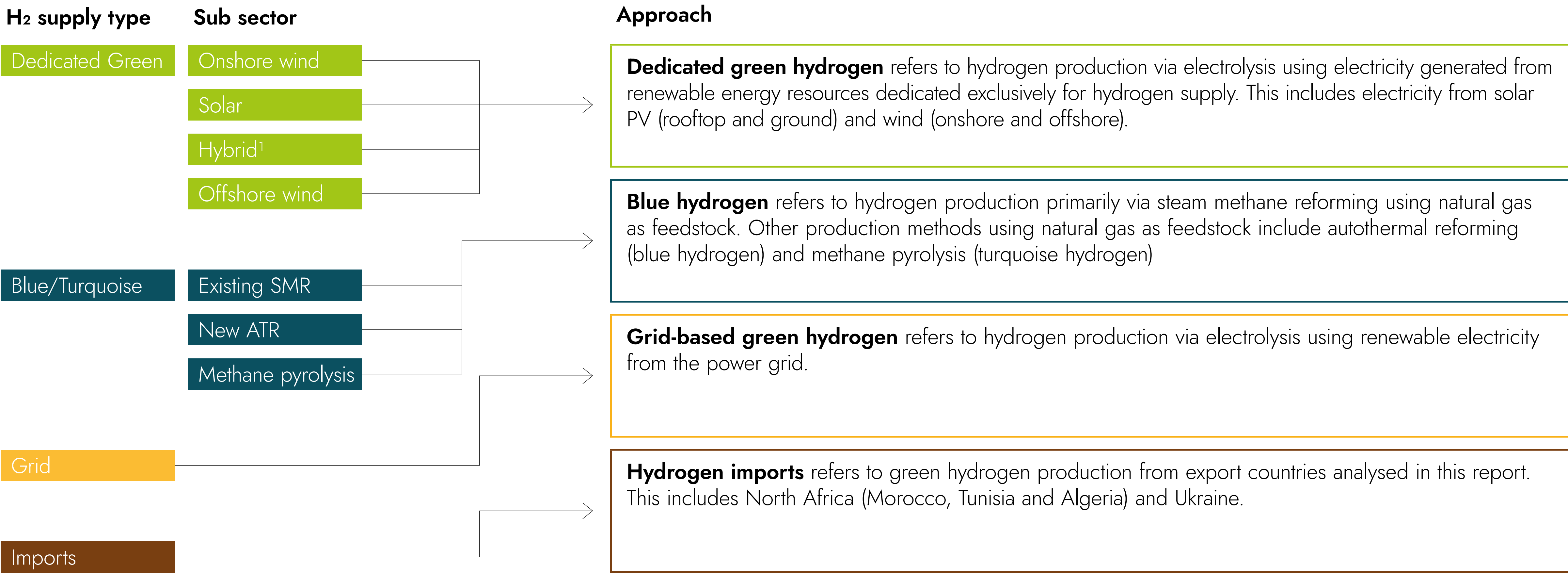
Sources:
1 EHB analysis report (June 2021),
2 JRC power plant database (2019)

Detailed methodology

1. Hydrogen demand
- 2. Hydrogen supply & decarbonisation**
3. Hydrogen cost-competitiveness

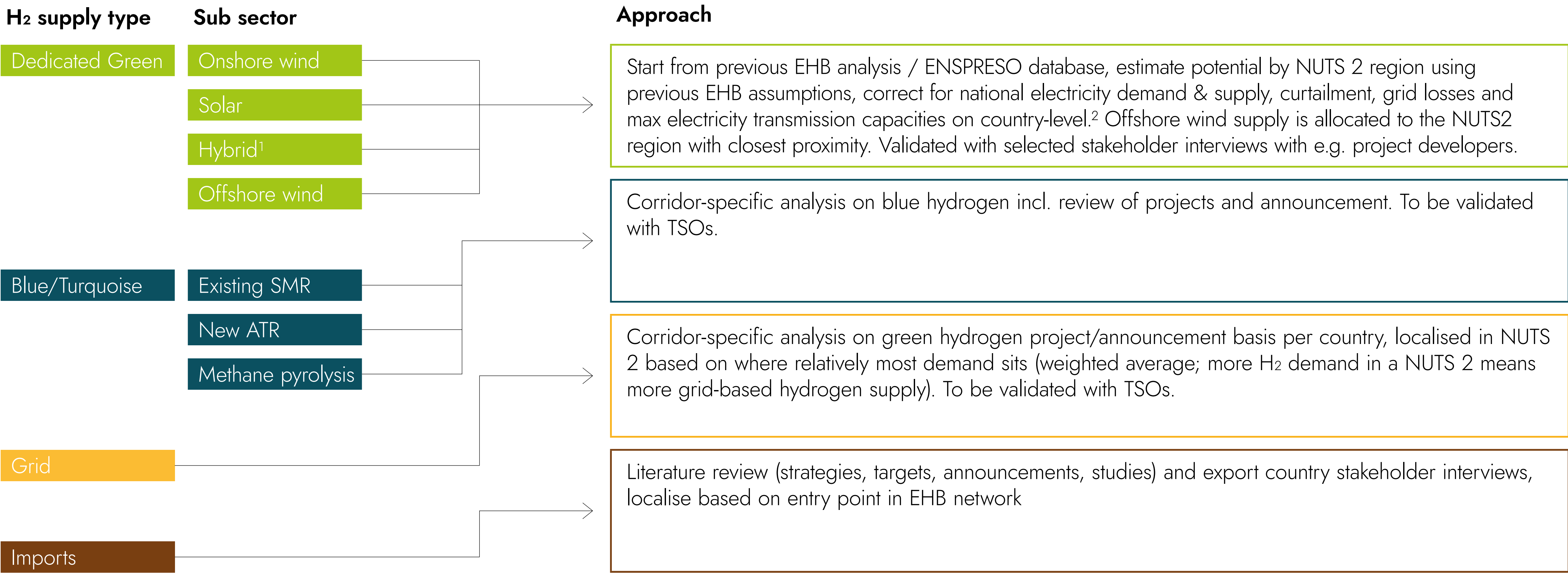
Overall approach:

Definitions of hydrogen supply options



Overall approach:

Hydrogen supply forecasting & localisation



1 Hybrid means any combination of renewables technologies which can lead to more load hours as wind and solar resources are often complementing, most common example being solar PV+ onshore wind.
2 In the previous EHB analysis not all data input was on NUTS 2 level; where no NUTS 2-level data is available weighted averages will be used: for instance for electricity demand; the electricity demand data is on country level and will be allocated to NUTS 2 regions based on their relative supply potential.

Overall approach:

Emissions reductions calculation

Demand sector	Sub sector	Approach
Industry	Fertilizer	CO ₂ -Emission by transforming methane (80% market share) and coal (20%) to hydrogen for ammonia production, resulting in 13.10 tons CO ₂ saved by using 1 ton of green hydrogen.
	Primary steel	Using direct-reduction-plants instead of common blast-furnaces 26 tons of CO ₂ can be saved by 1 ton of green hydrogen.
	Refineries	By using 1 ton green hydrogen for Hydrocracking or Hydrotreating, Steam-Methane-Reforming is not longer necessary which concludes in 10.92 tons CO ₂ saved.
	Energy	A 2.4 times higher calorific value of hydrogen in comparison with methane, which emits 182 g CO ₂ / kWh by burning, conclude to 0.43 t CO ₂ saved using one ton of hydrogen.
Power	Gas-fired	One ton of hydrogen saves 0.74 ton CO ₂ in 2030, 0.46 ton CO ₂ in 2040 and 0.27 ton CO ₂ in 2050, depending on the total emissions of the electricity mix in that year.
Transport	Mobility	Direct hydrogen use for heavy transport (e.g. 25 t truck) saves 4.375 litres diesel per kg hydrogen, which equals to 11.55 tons CO ₂ saved by 1 ton of hydrogen.
	Efuels	Depending on the FLH of synthesis plant (e.g. 4000 h/year) 10.89 tons CO ₂ can be saved by using 1 ton of hydrogen considering a diesel engine with 2.64 kg CO ₂ / litre diesel as status-quo.
Buildings	Heat	A 2.4 times higher calorific value of hydrogen in comparison with methane, which emits 182 g CO ₂ / kWh by burning, conclude to 0.43 t CO ₂ saved using one ton of hydrogen.

Detailed methodology

1. Hydrogen demand
2. Hydrogen supply & decarbonisation
- 3. Hydrogen cost-competitiveness**

Methodology:

Calculation of hydrogen delivery cost

Cost components of
hydrogen delivered

Production costs per kg of hydrogen:
Annualised costs of system setup, divided by total produced hydrogen per year.

Transportation costs per kg of hydrogen:
Depends on type of pipelines used in combination with full load hours on that pipeline and the length of the pipeline.

Firming costs: Reflecting the additional cost to deliver at 8,000 full-load hours. It is assumed that with 4,000 full load hours of hydrogen production, 1.25 €/kg is added to the total costs¹. After adding the firming costs, the total cost of hydrogen reflect hydrogen delivered at 8,000 full-load hours to offtakers.

Potential cost reduction levers

Cost factor

Power electronics: Removing the inverter of the solar PV modules, enabling a reduction of 11% in CAPEX, which reduces the production costs.	→	CAPEX
Leveraging foreign investment: Foreign investment will reduce the Weighted Average Cost of Capital. This reduces annualised CAPEX and total production costs ² .	→	
Using integrated electrolysis: Increasing total energy efficiency due to reduction of conversion inefficiencies (DC/AC and AC/DC steps) ³ . Also enabling to replace electrical infrastructure for H ₂ pipeline, also reducing the peak capacity cost component of the infrastructure ⁴	→	
Battery energy storage: Including battery energy storage increases full load hours, and with that reduces the transport and firming costs.	→	Full Load Hours
System optimisation: Optimising electrolyser size and installed capacity of solar and wind to increase full load hours, which reduces transport and firming costs. System optimisation also reduces production costs.	→	
Optimise generator capacity off offshore wind turbine based on hydrogen production: Increasing total energy output, leveraging flexibility in transmission capacity of H ₂ infrastructure ⁵	→	Energy output

1 1.25 €/kg is based on the cost of 5 € to store 1kg of hydrogen for a year, assuming an average of 2 storage cycles. Source: U.S. Department of Energy (2019).

2 A reduction in WACC is only applied to select corridors; for example, a reduction of 10% to 8% is applied to imports from Tunisia in Corridor A and supply from Romania in Corridor E, while a reduction of 8% to 6% is applied to imports from Spain in Corridor B. No cost reductions are applied to Corridors C and D because the credit rating of its supply countries are already relatively high.

3 Resulting in 2% more energy output due to reduction of conversion inefficiencies and 3% CAPEX reduction due to avoiding of electrical infrastructure.

4 Resulting in a 12.4% reduction of offshore infrastructure costs in comparison with full-electric infrastructure.

5 Resulting in a 5% higher energy yield, based on increasing the generator capacity from 15GW to 16GW.