June 2024

Hydrogen market in **Poland** and the **Baltics** until **2040**

01

Hydrogen landscape

Background and objectives

Background

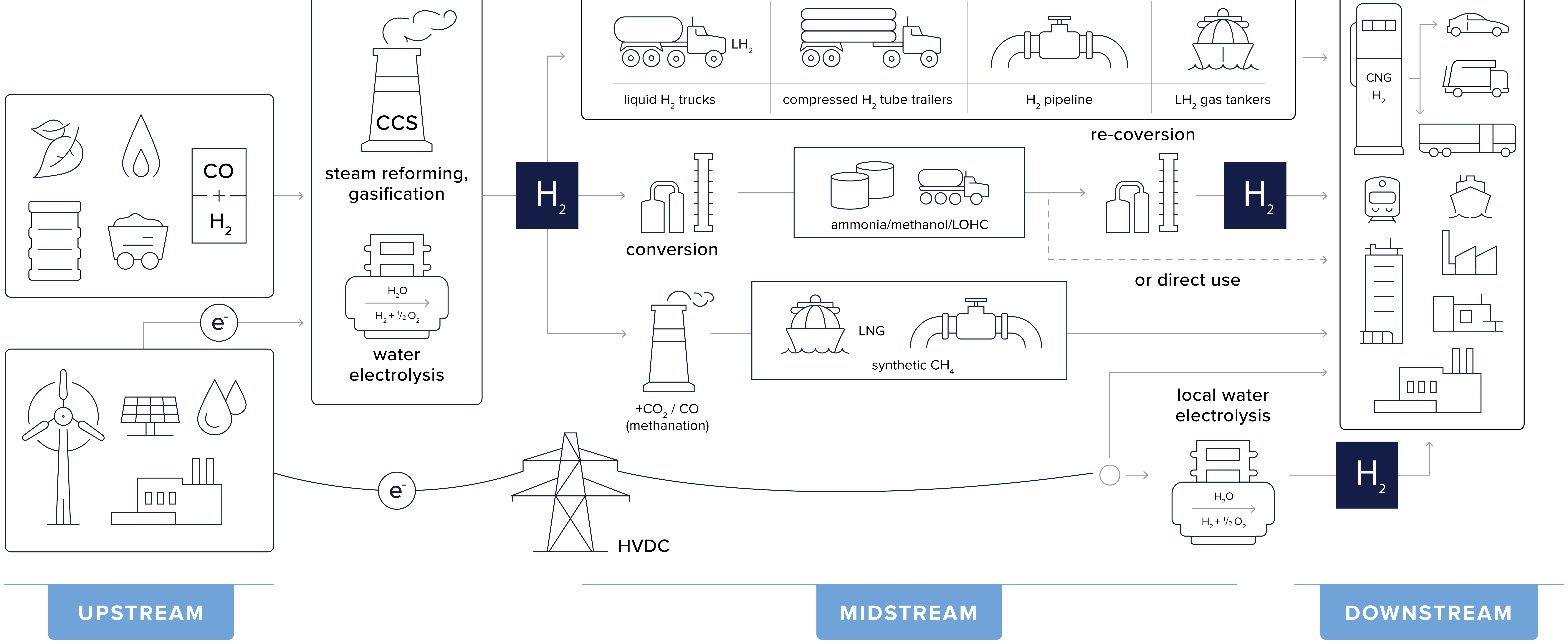
- Renewable/low carbon hydrogen is a significant opportunity for hard to abade sectors to meet the net-zero target
- Poland, Lithuania, Latvia and Estonia are the focus of the study given all hold significant renewable power potential and have seaborne import and export opportunities through the Baltic Sea. Poland and Lithuania are significant fossil-based hydrogen consumers
- RED III has placed challenging Renewable Fuels of Non-Biological Origin (RFNBO) targets to 2030 and 2035, leveraging the use of renewable hydrogen
- In this context, ORLEN and S&P Global worked together to assess hydrogen demand requirements by sector, the challenges to meeting targets, the supply sources to achieve targets and the opportunities renewable hydrogen presents to Poland and the Baltics

Objectives

- To assess the key policies and targets at the EU level and the implications for Poland, Lithuania, Latvia and Estonia
- To understand RFNBO demand requirements in the transportation and industrial sectors
- To assess the renewable hydrogen supply potential for the countries in scope and assess the gaps in supply
- To analyze the challenges to meeting supply and demand requirements and the infrastructure required
- To identify supply solutions for the analyzed countries inside and outside the EU to meet 2030-35 targets

Renewable and low carbon hydrogen are emerging as drivers of a new energy value chain

The hydrogen value chain



Upstream: includes hydrogen or hydrogen derivatives production technologies
Midstream: includes hydrogen, its derivatives and carbon dioxide storage and transportation
Downstream: includes hydrogen end uses, and links to related economic activities

Source: S&P Global

A colour-based hydrogen classification has been developed to describe the main hydrogen production routes, and is now evolving into different categories of hydrogen based on carbon footprint

Hydrogen production routes

- Grey
- Green
- Blue
- Yellow/Pink
- Turquoise

Hydrogen based on carbon footprint

Fossil-based H_2 (without CCS): Grey hydrogen (natural gas), brown hydrogen (brown coal) and black hydrogen (black coal)

Low carbon H_2: Can include nuclear and SMR/ATR with CCS but not all forms of low carbon hydrogen will be considered equal

Renewable H_2: Hydrogen produced through electrolysis of water through renewable sources or reforming of biogas or biochemical conversion of biomass

The latest Renewable Energy Directive (RED III) sets minimum targets for the use of renewable hydrogen across transportation and industry in 2030 and 2035

Transportation

min **1%**

2030

Of transportation energy consumption in 2030 must be based on RFNBOs*

Industrial

42%

2030

Of hydrogen consumption in industry in 2030 must be based on RFNBOs

60%

2035

Rising to 60% of hydrogen consumption in industry by 2035

Hydrogen can be considered as a Renewable Fuel of Non-Biological Origin (RFNBO) if it satisfies the conditions set out in the two Delegated Acts accompanying RED II, meeting conditions including additionality and temporal correlation

Source: S&P Global

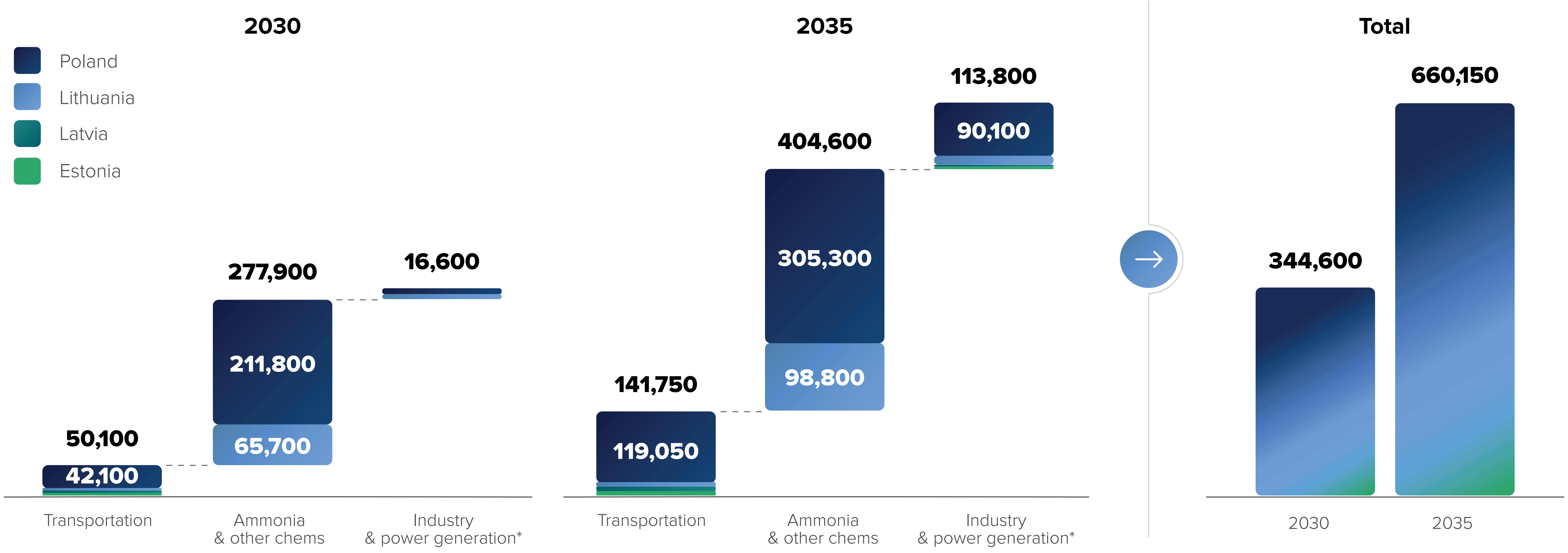
*This is part of a common 5.5% minimum advanced biofuels and RFNBO target

02

Hydrogen demand

At a minimum, ~344,600 tonnes of RFNBOs will be required across Poland, Lithuania, Latvia and Estonia in 2030, rising to ~660,150 tonnes in 2035

RFNBO required to meet the RED III targets | metric tonnes



Key assumptions 2030:
1% RFNBOs in transportation | 42% RFNBOs in industry | No ammonia imports

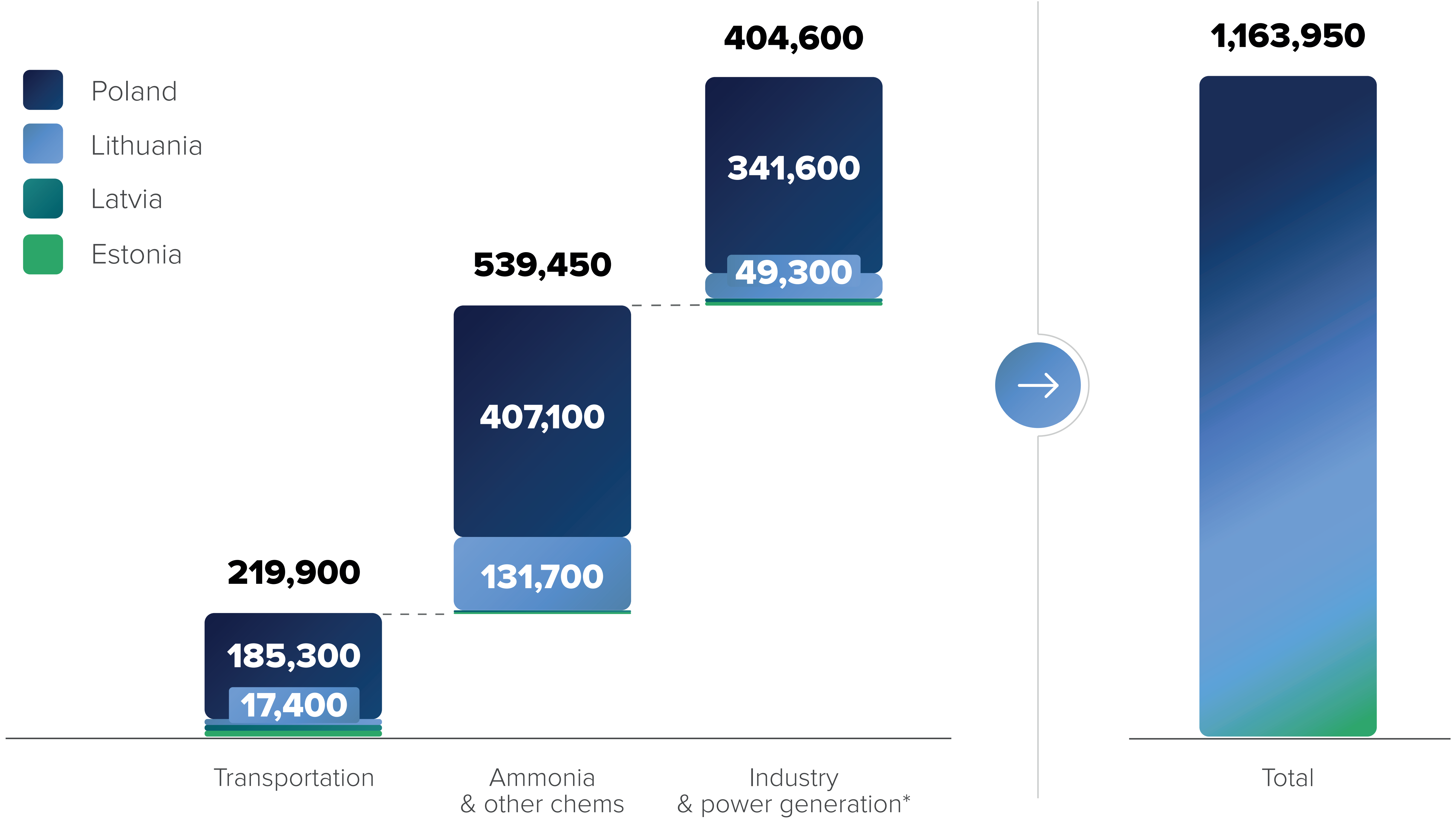
Key assumptions 2035:
3% RFNBOs in transportation | 60% RFNBOs in industry | No ammonia imports

*Includes applications such as heavy industry (steel, cement and power generation) and new sectors

Source: S&P Global

By 2040, 1.15 million tonnes+ of RFNBOs may be required across transportation and industry as pressure grows to decarbonize

RFNBO required to meet the 2040 RED III targets | metric tonnes



Key assumptions:
5% RFNBOs in transportation | 80% RFNBOs in industry | No ammonia imports

- Targets to 2040 are yet to be defined
- Taking an assumption that 5% of all transportation consumption is covered by RFNBO, 219,900 tonnes of renewable hydrogen would be required across Poland, Lithuania, Latvia and Estonia for transportation alone
- It is plausible that an 80% target for RFNBOs in industry could be derived to 2040
- To meet both targets, a minimum of 934,000 tonnes of renewable hydrogen, would have to be sourced in Poland, and at least 1,15 million across Poland, Lithuania, Latvia and Estonia

*Includes applications such as heavy industry (steel, cement and power generation) and new sectors
**In terms of ammonia & other chems the values are residual for Latvia and Estonia, and represent 300 and 350 t accordingly

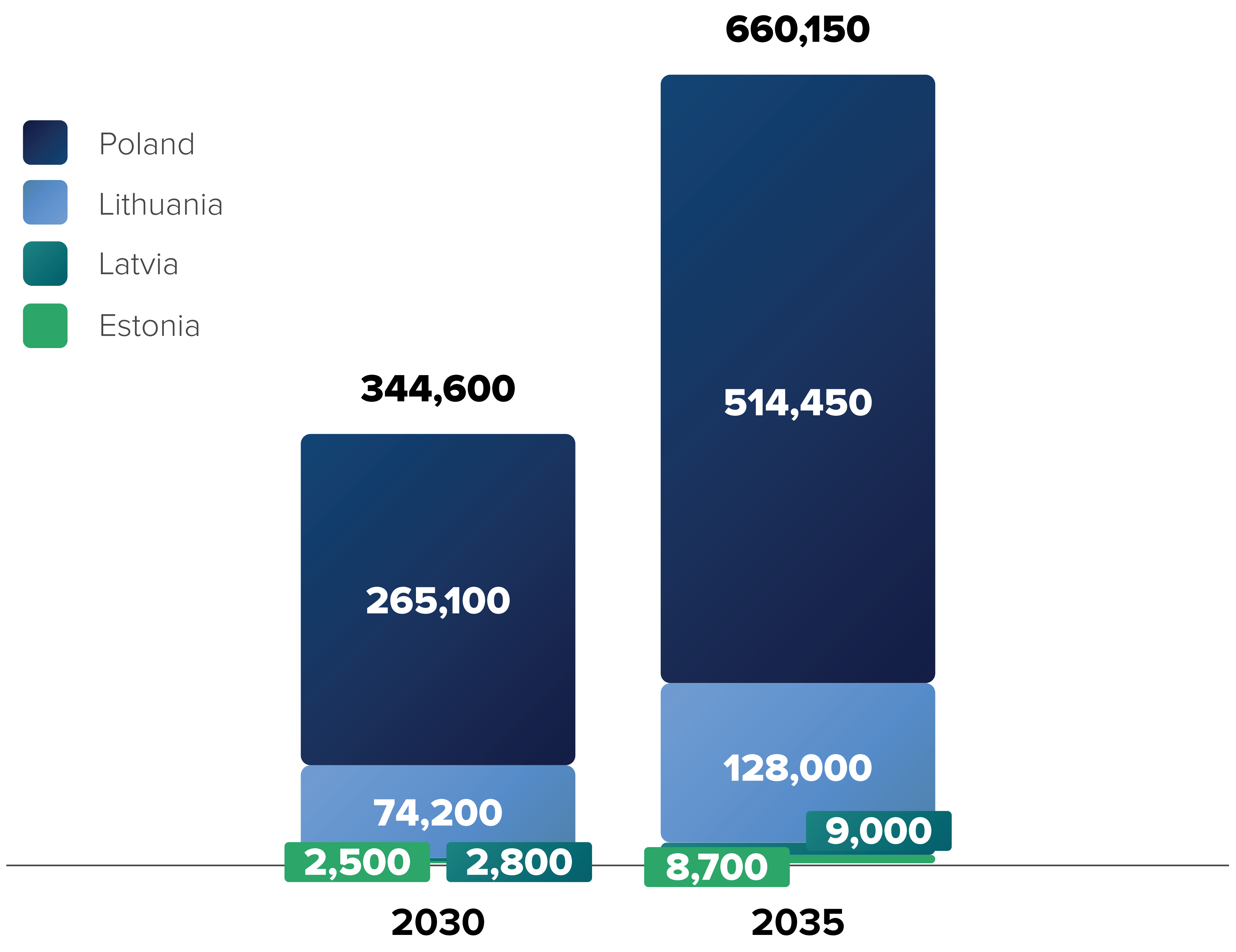
Source: S&P Global

03

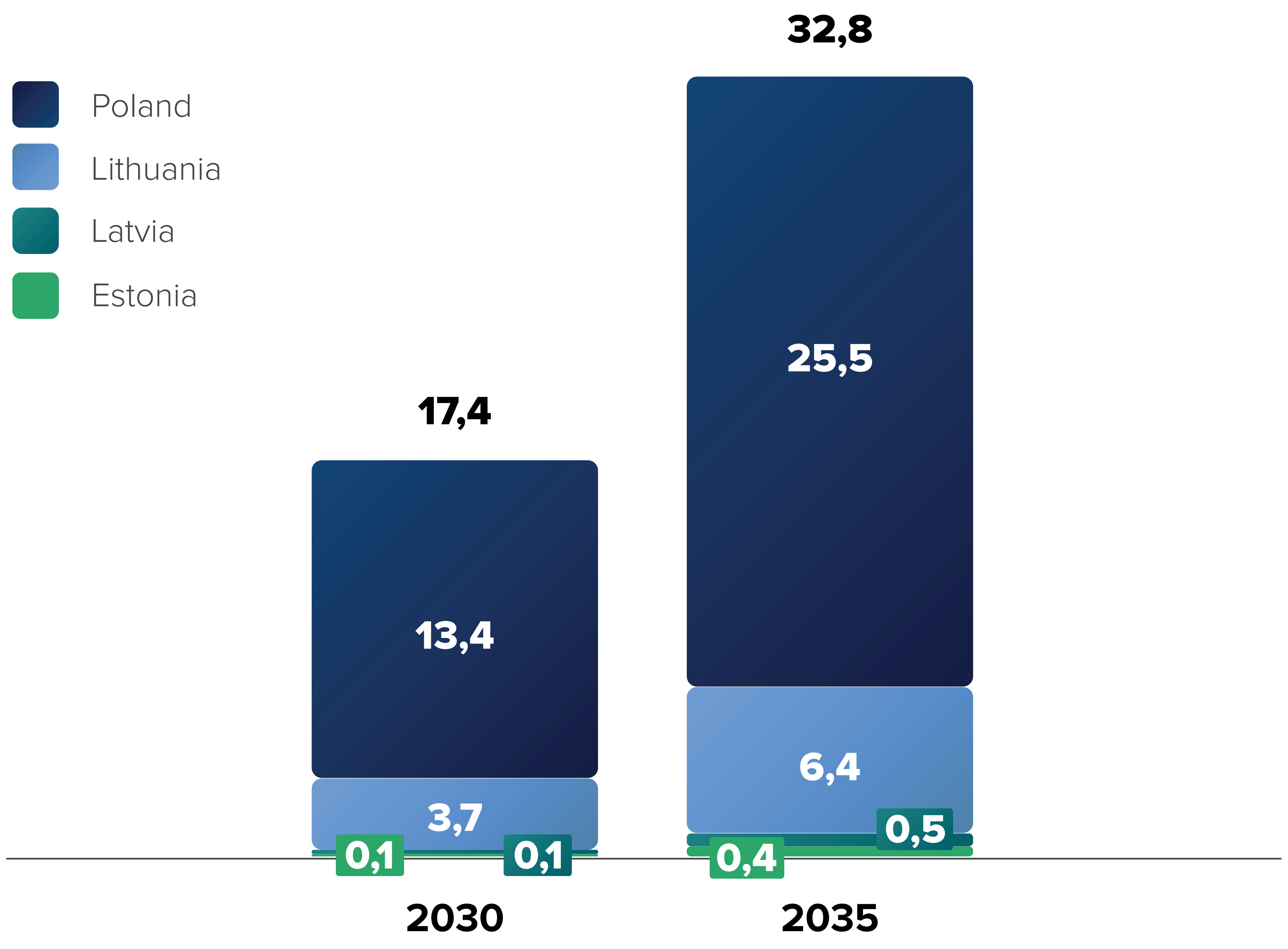
Power & infrastructure challenges

In 2030, 17,4 TWh of renewable electricity supply will be required to produce enough hydrogen to meet the RFNBO target across all analyzed countries, rising to ~32.8 TWh in 2035

RFNBO required to meet the RED III targets | metric tonnes



Renewable energy requirement | TWh

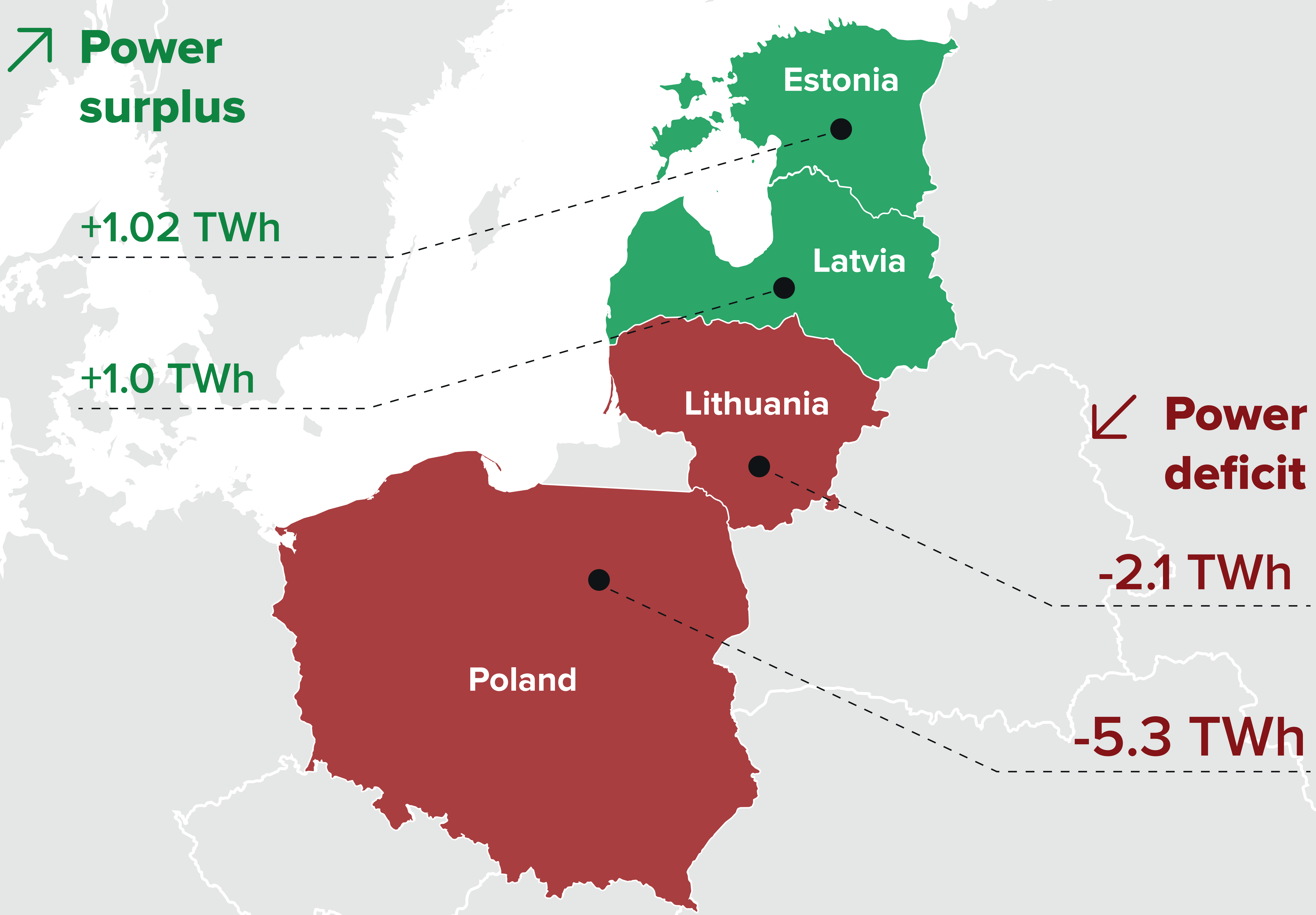


*Renewable electricity requirements refer specifically to the electricity required for the electrolysis process in hydrogen production. Electricity requirements for auxiliary applications are not included within the figures presented but can add 5-10% to electricity requirements

Source: S&P Global

Renewable energy supplies for hydrogen production are not anticipated to be available at the scale to meet targets in Poland and Lithuania

Deficits and surpluses of renewable energy for hydrogen production in 2023-2035

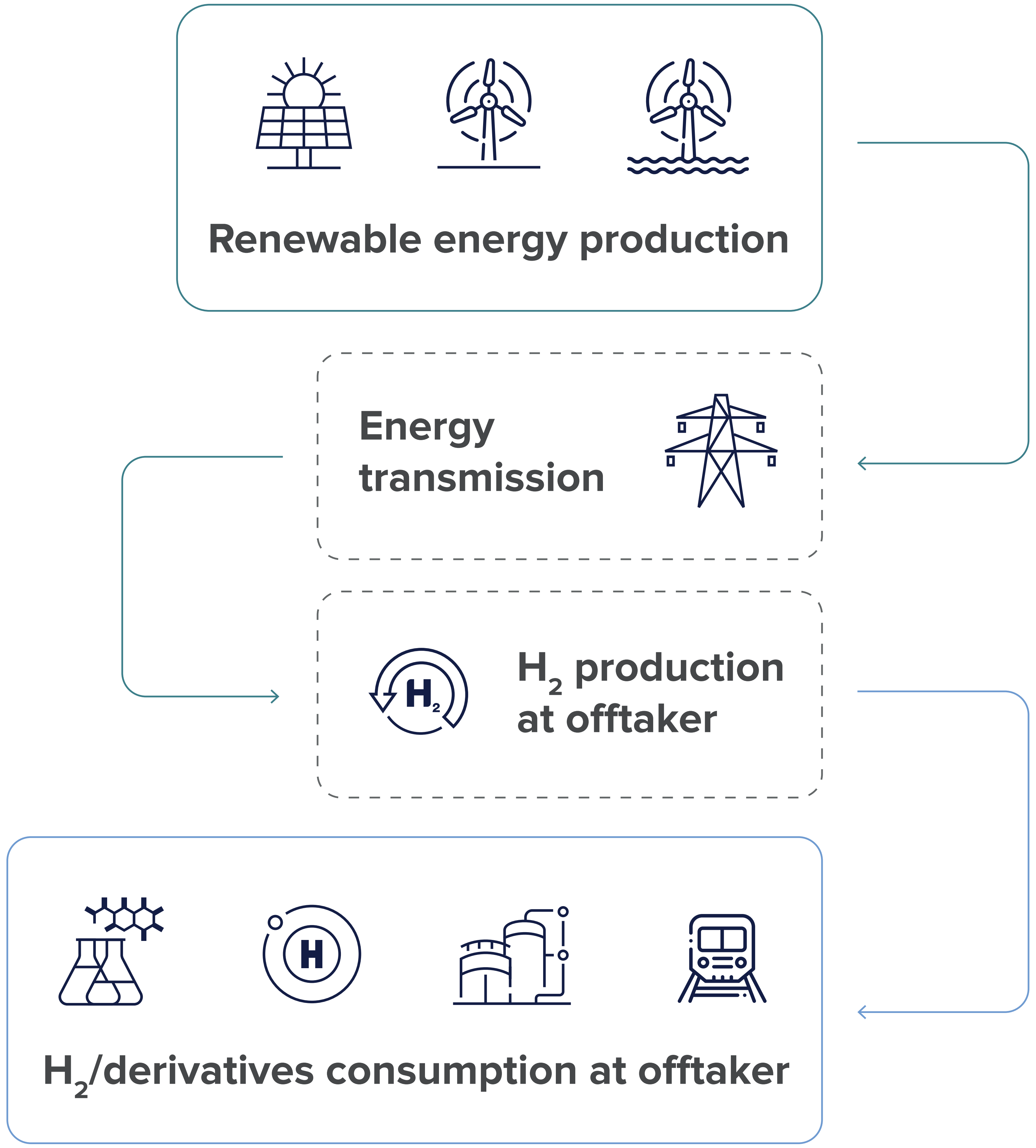


*Renewable electricity requirements refer specifically to the electricity required for the electrolysis process in hydrogen production. Electricity requirements for auxiliary applications are not included within the figures presented but can add 5-10% to electricity requirements

- Renewables for hydrogen at an EU level are projected to account for ~10% of all renewable additions for 2023-2030 rising to ~40% of additions from 2030-2035 in S&P's planning case
- Renewables additions for hydrogen across the analyzed countries are limited based upon:
  - Regulatory and infrastructure restrictions
  - Risks for developers in complying with additionality clauses
  - Other sector decarbonization goals
  - The costs of PPA's
- Greater availability of renewables for hydrogen production should be prioritized across all analyzed countries to avoid the need for imports of power and hydrogen derivatives

Energy transmission infrastructure at scale will be required to facilitate hydrogen production at offtaker sites, bringing renewable electrical energy from remote locations to the offtaker's production location

Co-location of hydrogen production with offtaker

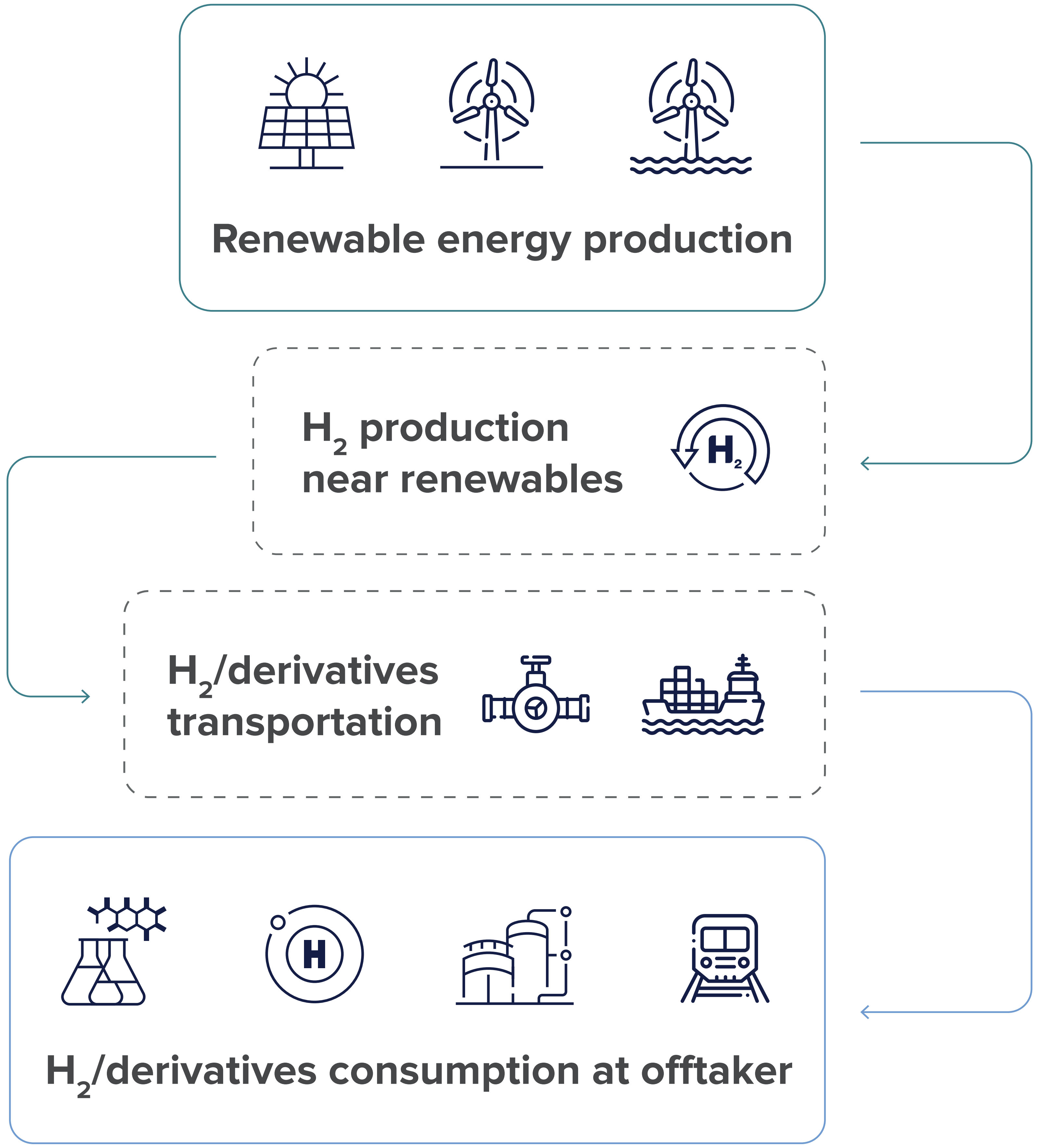


- Energy transmission infrastructure investment will be needed to accommodate the 17,4 TWh of renewable electrical energy generation required to 2030
  - Co-location with offtakers requires energy transmission to take offshore wind energy from the Baltic Sea to hydrogen demand centres inland
  - This would be a potential solution for renewable hydrogen and ammonia production at the likes of Plock and Wloclawek
- This would necessitate investments in new pieces of infrastructure including transmission towers, power lines, substations and transformers
- The development of this infrastructure would:
  - Avoid a reliance upon inland hydrogen transportation (not yet in place at scale)
  - Reduce grid congestion, enabling further integration of renewables into the grid
  - Enable the use of high capacity factor renewable sources, driving down hydrogen production costs

Source: S&P Global

Transportation infrastructure will be required to enable hydrogen supply to offtakers and move imports within/between countries

Co-location of hydrogen production with renewables



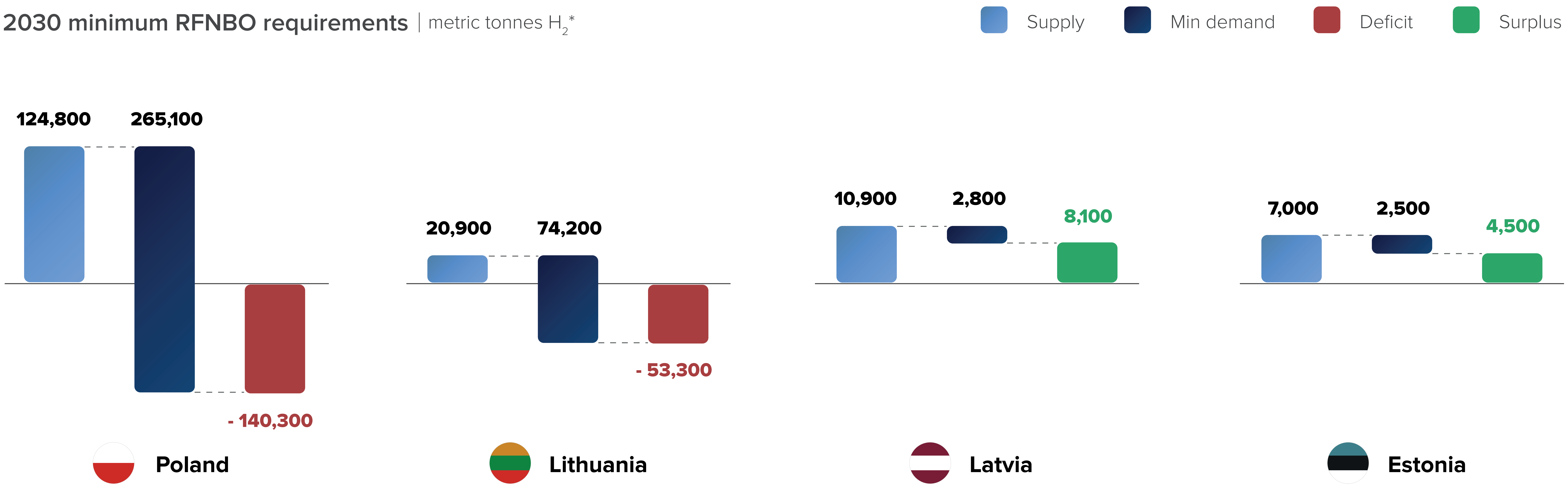
- Hydrogen transportation infrastructure investment will be required if hydrogen production is co-located with renewable energy, moving hydrogen to the end use location
- This would necessitate investments in new pieces of infrastructure including new or repurposed pipelines, compressor stations and road/rail links
- Poland and Latvia in particular have significant hydrogen storage potential in salt caverns, if developed
- The development of this infrastructure would:
  - Avoid the need for extensive buildouts of new energy transmission infrastructure
  - Facilitate a stable supply of hydrogen to refineries and ammonia plants, utilizing salt cavern storage
  - Enable imports of hydrogen and its derivatives to be moved at scale to end users

Source: S&P Global

04

Supply gap & supply options

By 2030, significant deficits are expected in Poland and Lithuania, Latvia and Estonia may have surpluses



- Deficits are based upon meeting the minimum transportation and industrial targets as set in RED III
- Significant additional quantities may be required if advanced biofuels are unavailable

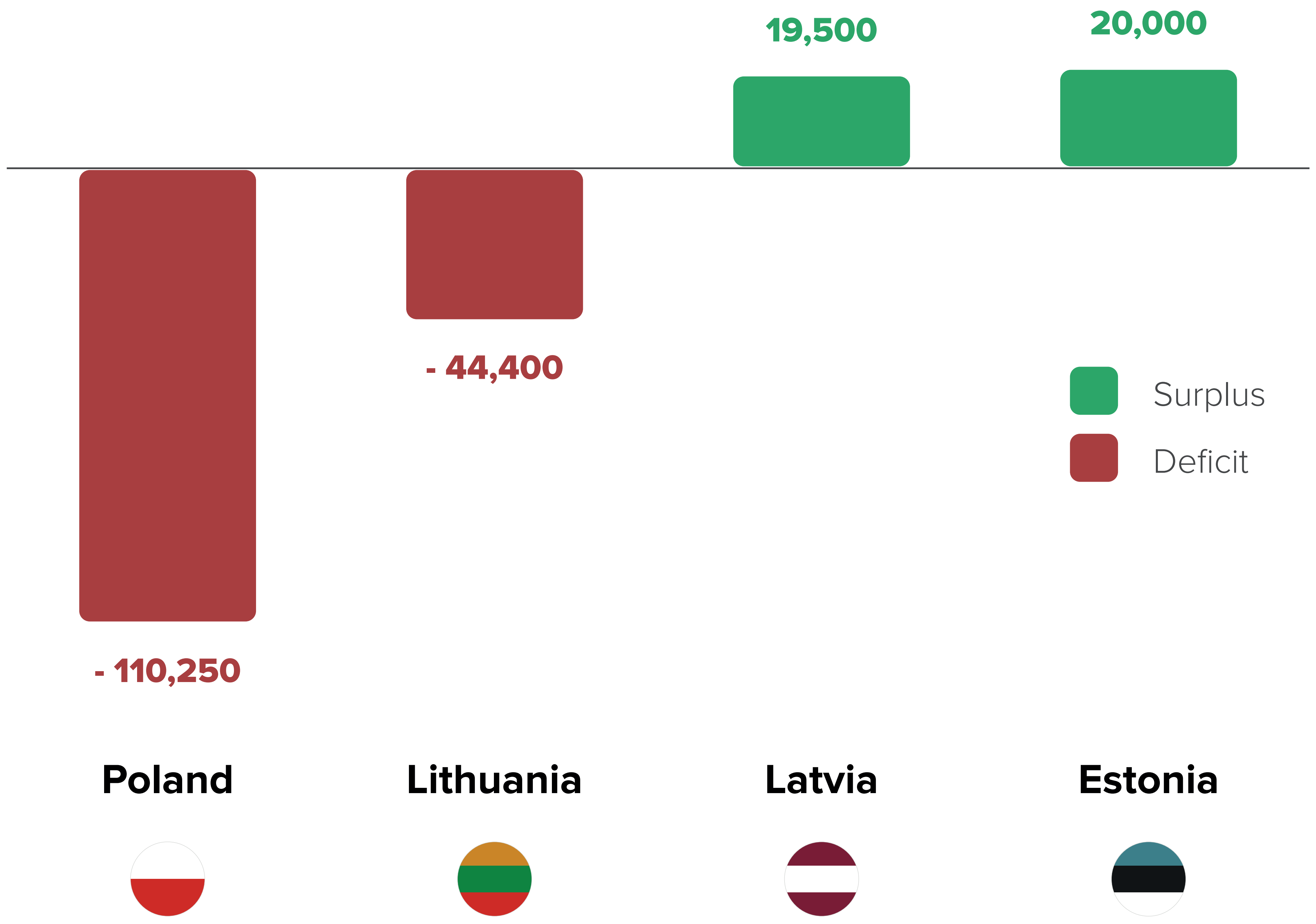
If RFNBOs are required to cover 3% of transportation demand in 2030 an extra ~89,300 tonnes of renewable hydrogen would be required in Poland alone**

*Key assumptions 2030: 1% RFNBOs in transportation | 42% RFNBOs in industry | No ammonia imports
**This assumes Aviation and Maritime demand is fixed at minimum requirements in 2030 under both 1% and 3% scenarios

Source: S&P Global

By 2035, deficits would remain in Poland and Lithuania driven by increasing targets

2035 RFNBO deficits and surpluses | metric tonnes H_2*



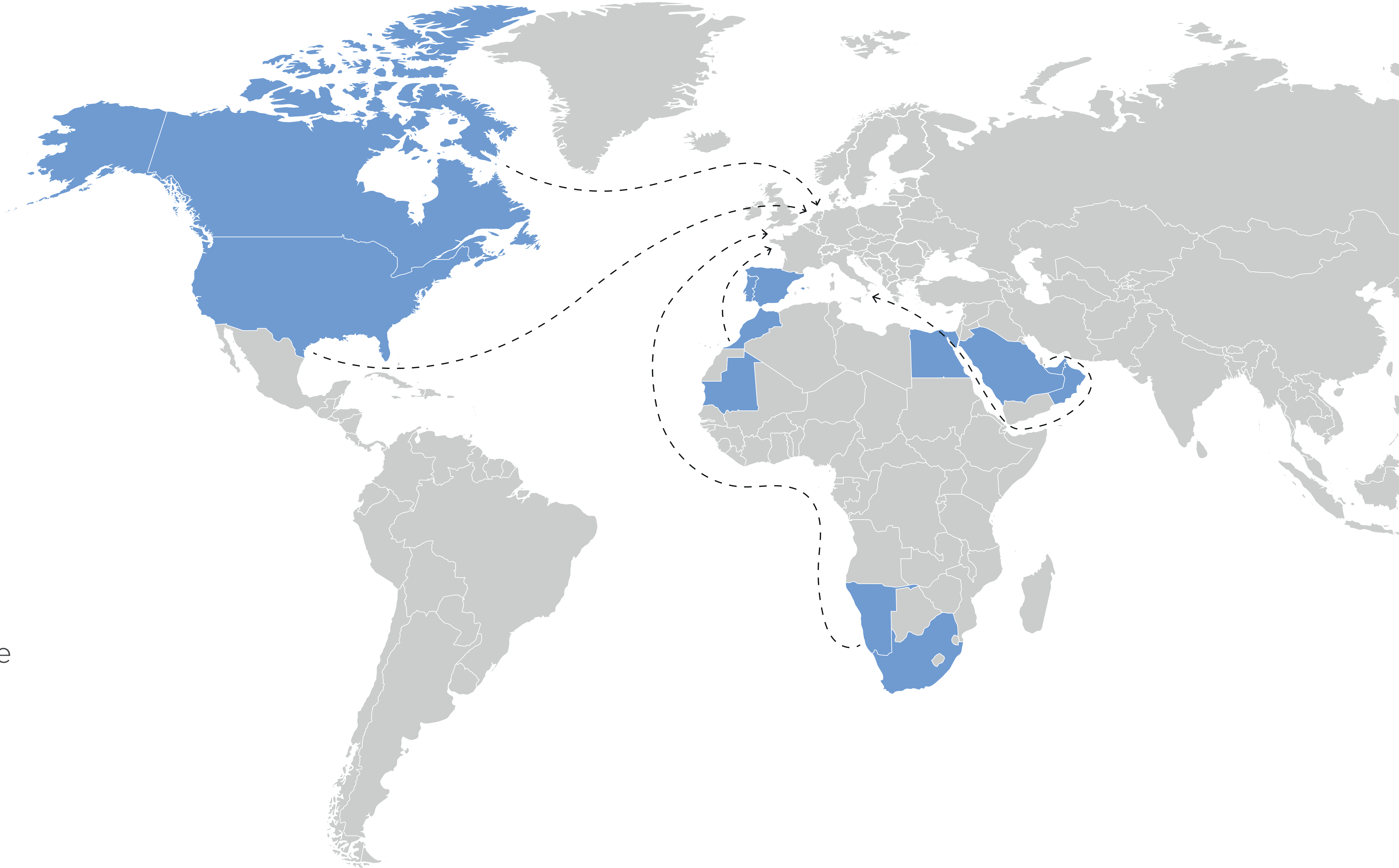
- A significant increase in the Industrial RFNBO target from 42% in 2030 to 60% in 2035 is the key driver behind expanding hydrogen requirements to 2035
- Renewables available for hydrogen production to 2035 are expected to grow but are not expected to be large enough to cover demand in Poland and Lithuania. The added renewables are however expected to reduce the deficits seen in 2030
- The absence of ammonia production at scale in Latvia and Estonia provides the opportunity for surpluses based upon renewable energy availability at scale
- Maximising renewable energy and hydrogen production domestically will be key to solving deficits alongside the use of imports

*Key assumptions 2035: 3% RFNBOs in transportation | 60% RFNBOs in industry | No ammonia imports

Source: S&P Global

To 2030, RFNBO supplies may need to be secured from the Middle East, Africa and the U.S. before European sources of RFNBO come online at scale…

- Supplies from outside the EU may be required to meet any RFNBO shortfalls to 2030, led by supplies from the Middle East, Africa and the United States
- There is however, no guarantee that supplies from outside the EU will be accepted at scale or accepted without tariffs applied given the desire to establish renewable hydrogen production at scale in Europe
- Moving towards 2030, more European supply is likely to come online but it is uncertain whether it will be available for exports before 2030
- Domestic production provides hydrogen with greater security of supply at a relatively comparable cost when transportation costs are taken into account. This requires the necessary infrastructure to be in place



Potential locations from which RFNBO supplies to Europe might come from

...and other EU countries are developing partnerships to facilitate trade and secure supplies, a step that could be considered to meet the supply gap

EU entity	Partner	Date	Details
Germany	Namibia	August 2021	Agreement that has facilitated collaboration on a $10 billion deal between Hyphen Energy and Namibia
	India	May 2022	Aims to establish a task force to promote the creation of a close network between the government, industry and research institutes of both countries
	Canada	August 2022	Development of the Canada-Germany Hydrogen alliance, committing the countries to developing supply chains and enabling a transatlantic supply corridor
	Norway	January 2023	Confirmation of intent to ensure large scale hydrogen supply with necessary infrastructure between Norway and Germany
Netherlands	Chile	March 2021	Agreement to facilitate trade links between Chilean production and supply into Rotterdam
	UAE	March 2023	Setting up export-import corridors for clean hydrogen between the two countries
	Australia	January 2023	Collaboration to support hydrogen trade between the two countries and port infrastructure at Rotterdam
Belgium	Oman	February 2022	Partnerships around Oman's Hyport Duqm project Partnerships on technology and certification development
EU	Marocco	October 2022	Collaboration on energy, climate and the environment, fostering joint projects, co-operation and job creation in green areas
	Egypt	November 2022	Collaboration on hydrogen production development within Egypt for supply to the EU

*The presented list of partnerships is not exhaustive

These have been followed by specific agreements between companies in these states, developing infrastructure and enabling offtake agreements

EU entity	Partner	Companies	Details
Germany	Namibia	Hyphen Energy, government, RWE	Development of a $10 billion hydrogen production project in Namibia MOU signed between RWE and Hyphen regarding offtakes of up to 300,000 tonnes of green ammonia
	Indie	Uniper, Greenko	MOU and Heads of Terms signed to negotiate a purchase agreement for 250,000 tonnes per year of green ammonia
	Norway	RWE, Equinor	Strategic partnership to facilitate pipeline transmission to Germany of up to 10GW of hydrogen by 2038
	Canada	Everwind Fuels, EON, Uniper	MOU's signed to negotiate offtake agreement for 500,000 tonnes of green ammonia between Everwind Fuels/EON and Everwind Fuels/Uniper
Netherlands	UAE	Port of Rotterdam, Masdar, others	MOU signed to develop a renewable hydrogen link between production in Abu Dhabi and supply into the Port of Rotterdam
	Australia	Port of Rotterdam, Fraunhofer, government	Confirmed intention for further partnership around the TrHyHub initiative
Belgium	Oman	Fluxys, OQGN	MOU on strategic development of Oman's hydrogen and CO_2 infrastructure, with a particular focus on the Hyport Duqm project

*The presented list of partnerships is not exhaustive

05

Opportunities & challenges

Challenges will exist in importing the hydrogen and its derivatives needed whilst remaining within the GHG emission limits required for RFNBO certification and being cost competitive

Opportunities

Ammonia shipping exists at scale

And is widely used as the predominant method for trading ammonia

Hydrogen pipeline may offer lower costs

With initiatives such as the European Hydrogen Backbone demonstrating the potential scale of pipeline infrastructure required in Europe

Salt cavern storage may be feasible

Notably in the likes of Poland and Latvia, offering significant cost advantages versus hydrogen tank storage

Low cost imports may be available by 2030

With countries such as Saudi Arabia, the United States, Morocco, and Brazil looking to supply the European market alongside European producers

Challenges

Ammonia reconversion adds to costs and emissions

Reconversion is not done at scale and can add significantly to costs, given losses of hydrogen in reconversion and the carbon intensity of electricity used in the process

Pipeline construction by 2030 is a challenge

With challenges around rights of way and the availability of gas pipelines to be repurposed to carry hydrogen

Existing capacity is used for gas storage

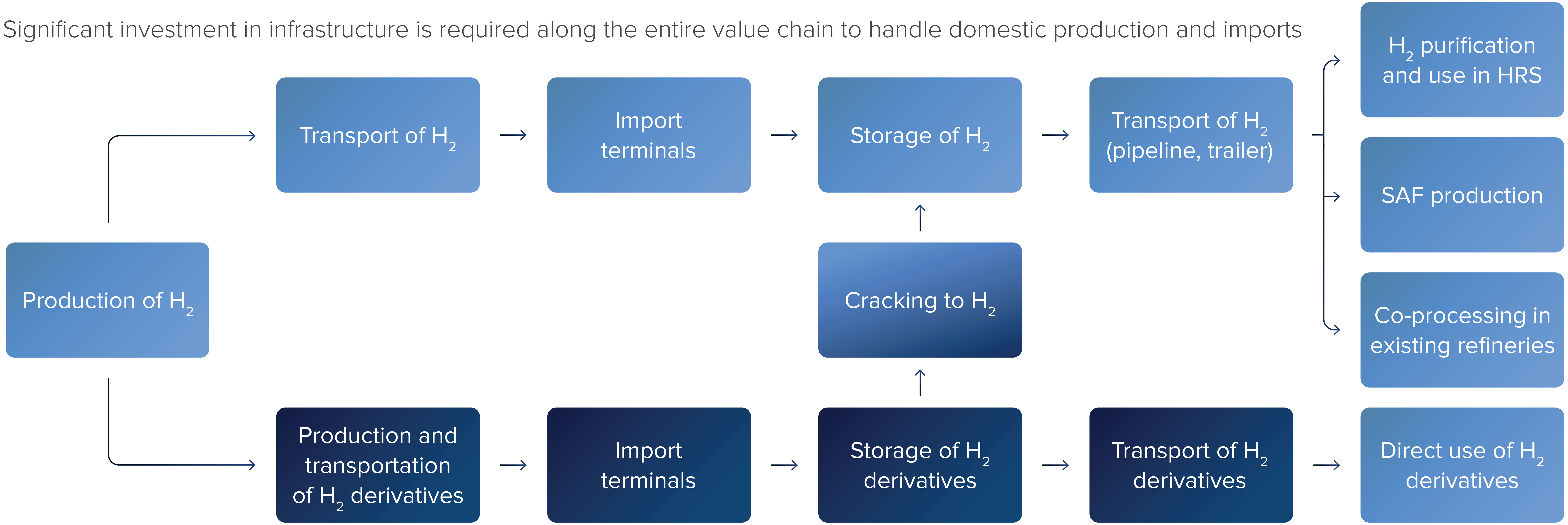
With gas expected to remain an important aspect of the energy mix, particularly in Poland. New salt cavern storage capacity will need to be developed

Carbon emissions from shipping are high

Transportation over large distances via ammonia can add significantly to the emission intensity of the delivered product, challenging the GHG emissions limits for RFNBOs

Infrastructure to meet the RED III targets will need to be focused on supporting large scale production and transportation of hydrogen for existing use cases

Significant investment in infrastructure is required along the entire value chain to handle domestic production and imports



RFNBO targets will support imports of hydrogen and its derivatives to key industrial and trasportation offtakers

- Direct use of ammonia avoids the costs and losses and CO_2 emissions from ammonia cracking and serves the key industrial target (ammonia use in fertiliser plants)
- Co-processing of hydrogen in existing refineries is likely to be the most cost effective way of meeting the transportation target

Infrastructure investments may therefore need to focus on ports and inland transportation of hydrogen rather than the production of automotive grade hydrogen and the buildout of refuelling stations. The development of electric vehicle technology may also limit the scale of hydrogen use in fuel cells in transportation

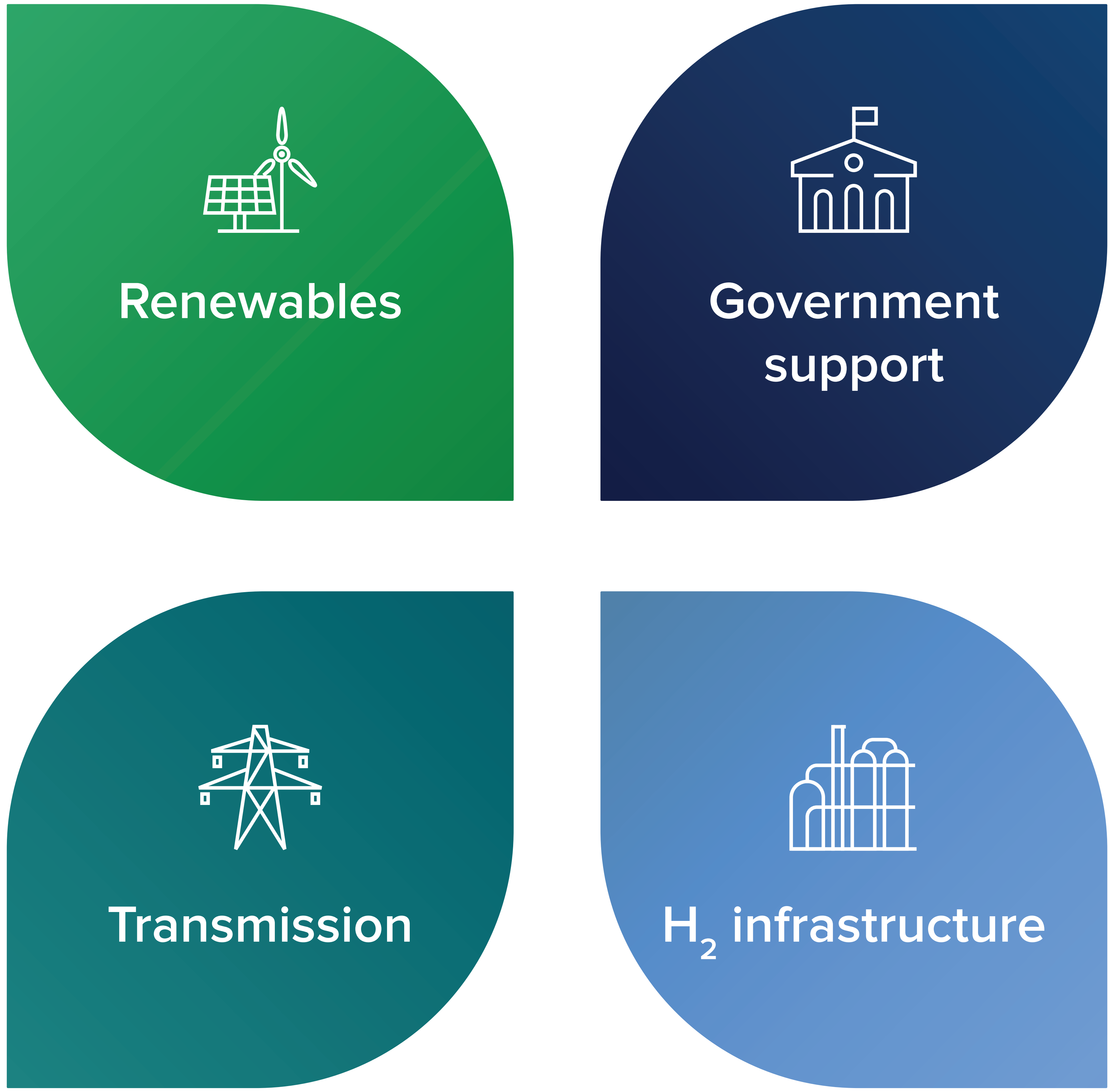
At a national level, enabling renewable power, developing infrastructure and providing government support are critical to meeting RED III targets by 2030 and 2035

Renewable energy sources development

The removal of barriers to renewables development is critical to provide enough renewables for electrolysis

Government support

Of the low emission hydrogen ecosystem to move away from fossil-based hydrogen production



Transmission infrastructure

Enabling the transfer of electricity from remote renewables locations to hydrogen production centres

Pipeline, port and rail infrastructure

To facilitate the movement of volumes within and into the analyzed countries

Source: S&P Global

The opportunities from developing this ecosystem are vast, from increasing export opportunities to meeting climate targets and future job creation

Trade relations

The ability to participate in international partnerships, trade agreements, and clean energy initiatives can be supported by decarbonising through hydrogen

Ability to meet climate targets

Access to renewable hydrogen will support emission reduction goals

Increasing export opportunities

Major export opportunities will be available for low CO_2 footprint products, needed for competitiveness in global markets

Energy security

Access to renewable hydrogen will increase independence from fossil fuel imports and support energy security

Avoidance of fines & sanctions

The ability to meet regulatory targets on RFNBO production will avoid the risk of sanctions and fines

Job creation & investment

Hydrogen and its derivatives are significant sources of employment and investment. Low emission sources will offer further opportunities

Source: S&P Global

06

Annex

Renewable power supplies for hydrogen production are not anticipated to be available at the scale to meet targets in Poland and Lithuania | TWh

2023-2030	Additions dedicated to hydrogen (planning case)	Electrical energy requirement for RFNBO in 2030	Surplus or deficit
Poland	6.3 (10%)	13.4	7.1
Lithuania	1.1 (10%)	3.7	2.6
Latvia	0.6 (10%)	0.14	0.46
Estonia	0.35 (10%)	0.13	0.22

2030-2035	Additions dedicated to hydrogen (planning case)	Electrical energy requirement for RFNBO in 2035	Surplus or deficit
Poland	13.9 (40%)	12.1	1.8
Lithuania	3.1 (40%)	2.6	0.5
Latvia	0.9 (40%)	0.31	0.59
Estonia	1.1 (40%)	0.3	0.8

2023-2035	Poland	Lithuania	Latvia	Estonia
TWh Gap	5.3	2.1	1.0	1.02

Summary of key terms

Advanced Biofuels – Biofuels derived from feedstocks listed under annex IXA of RED II

Annex IX A Feedstocks – Feedstocks listed under annex IXA of RED II that qualify for the production of advanced biofuels. Feedstocks include palm oil mill effluent and empty palm fruit bunches, biomass waste from feedstocks and biomass from industrial waste amongst other feedstocks

Co-processing in Refineries – The use of renewable hydrogen as a replacement for fossil-based hydrogen within refining applications

European Hydrogen Backbone – An initiative combining 33 energy infrastructure operators to develop hydrogen infrastructure in Europe based upon existing and new pipelines

FuelEU Maritime – An initiative to increase the demand for renewable and low carbon fuels and reduce greenhouse gas emissions from the shipping sector

Low Carbon Hydrogen – Defined within this report as hydrogen produced using fossil fuel-based methods with carbon capture technology deployed and hydrogen produced via electrolysis using nuclear power

PPA – A Power Purchase Agreement, an agreement to buy electricity between a producer and a consumer of power

RED II/III – The 2nd and 3rd Renewable Energy Directives, These are the legal framework for the development of clean energy across the EU economy.

Renewable Hydrogen – Defined within this report as hydrogen produced through electrolysis of water through renewable sources or reforming of biogas or biochemical conversion of biomass

ReFuelEU Aviation – An initiative as part of the EU's Fit for 55 package, to increase both demand for and supply of sustainable aviation fuels (SAF)

RFNBO – Renewable Fuels of Non-Biological Origin means renewable liquid and gaseous fuels of non-biological origin. It is a product group of renewable fuels defined in the Renewable Energy Directive. These fuels are produced from renewable energy sources other than biomass. Gaseous renewable hydrogen produced by feeding renewables-based electricity into an electrolyser is therefore considered a RFNBO

TWh – Tera-watt hour

SMR – Steam Methane Reforming

ATR – Autothermal Reforming

CCS – Carbon Capture & Storage

HRS – Hydrogen Refuelling Stations

SAF – Sustainable Aviation Fuel

Source: EU Commission/S&P Global

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