2023 PORTUGAL RENEWABLE ENERGY SUMMIT

The Delegated Act for Hydrogen and Iberia's competitive advantage

Ana Barillas, Head of Iberia and LATAM

AURORA ENERGY RESEARCH

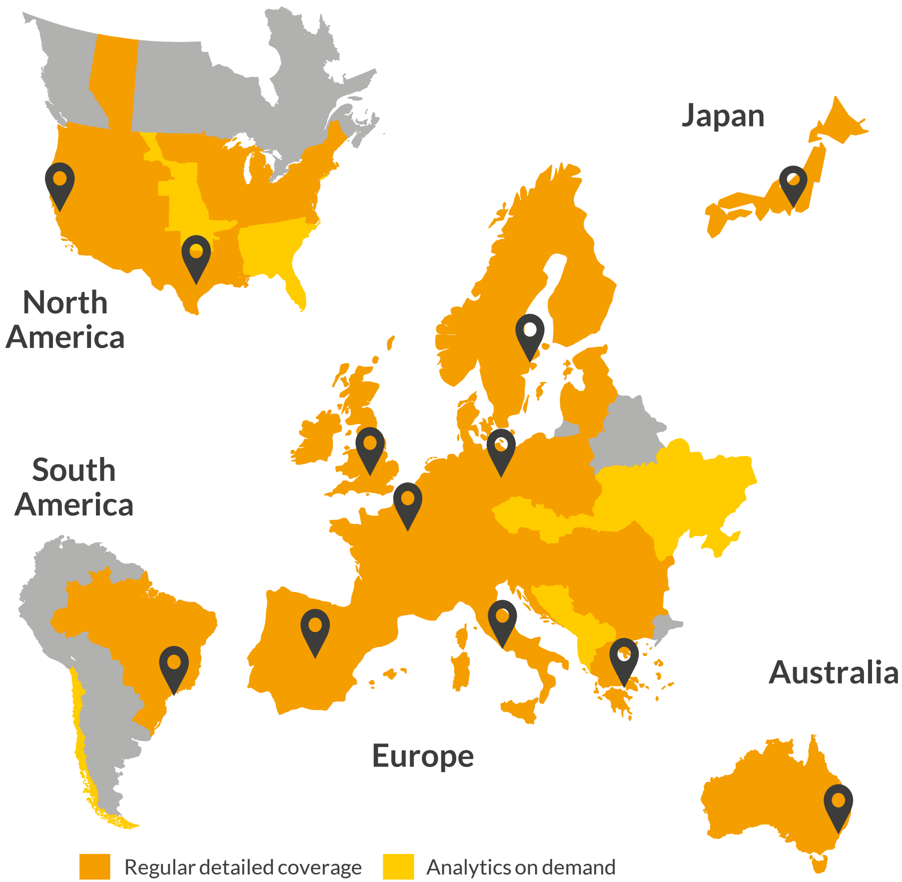
29 November 2023

APREN Associação de Energias Renováveis

2023 PORTUGAL RENEWABLE ENERGY SUMMIT

Aurora provides market leading forecasts & data-driven intelligence for the global energy transition

- Power markets
- Renewables
- Storage
- Electric vehicles
- Hydrogen (H_2)
- Carbon (CO_2)
- Natural gas



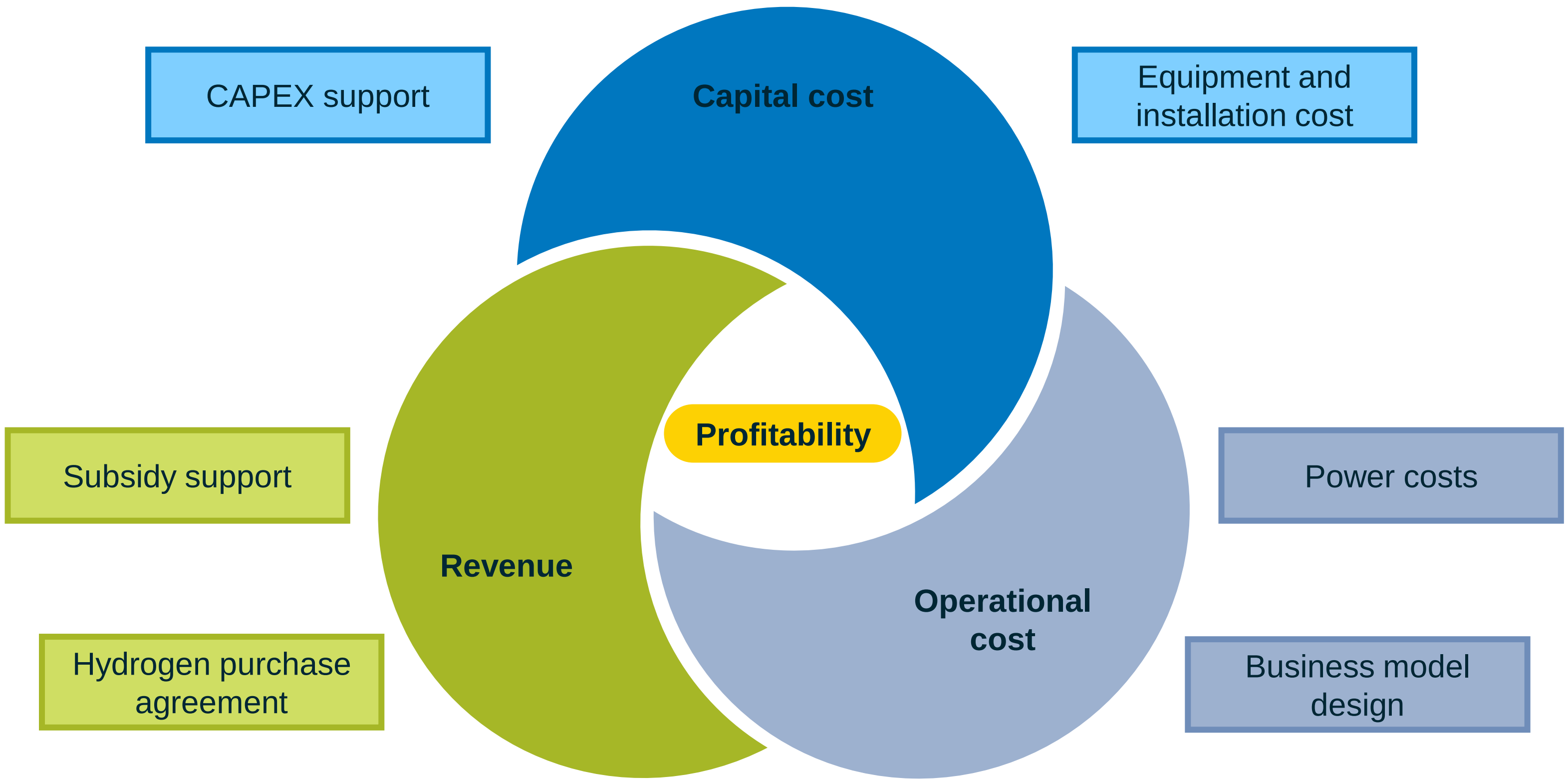
12 Offices
Oxford | Berlin | Madrid | Athens
Paris | Sydney | Austin | Oakland
Rome | Stockholm | Tokyo
São Paulo

600+
market experts

750+
subscribing companies

150+
transactions supported in 2022

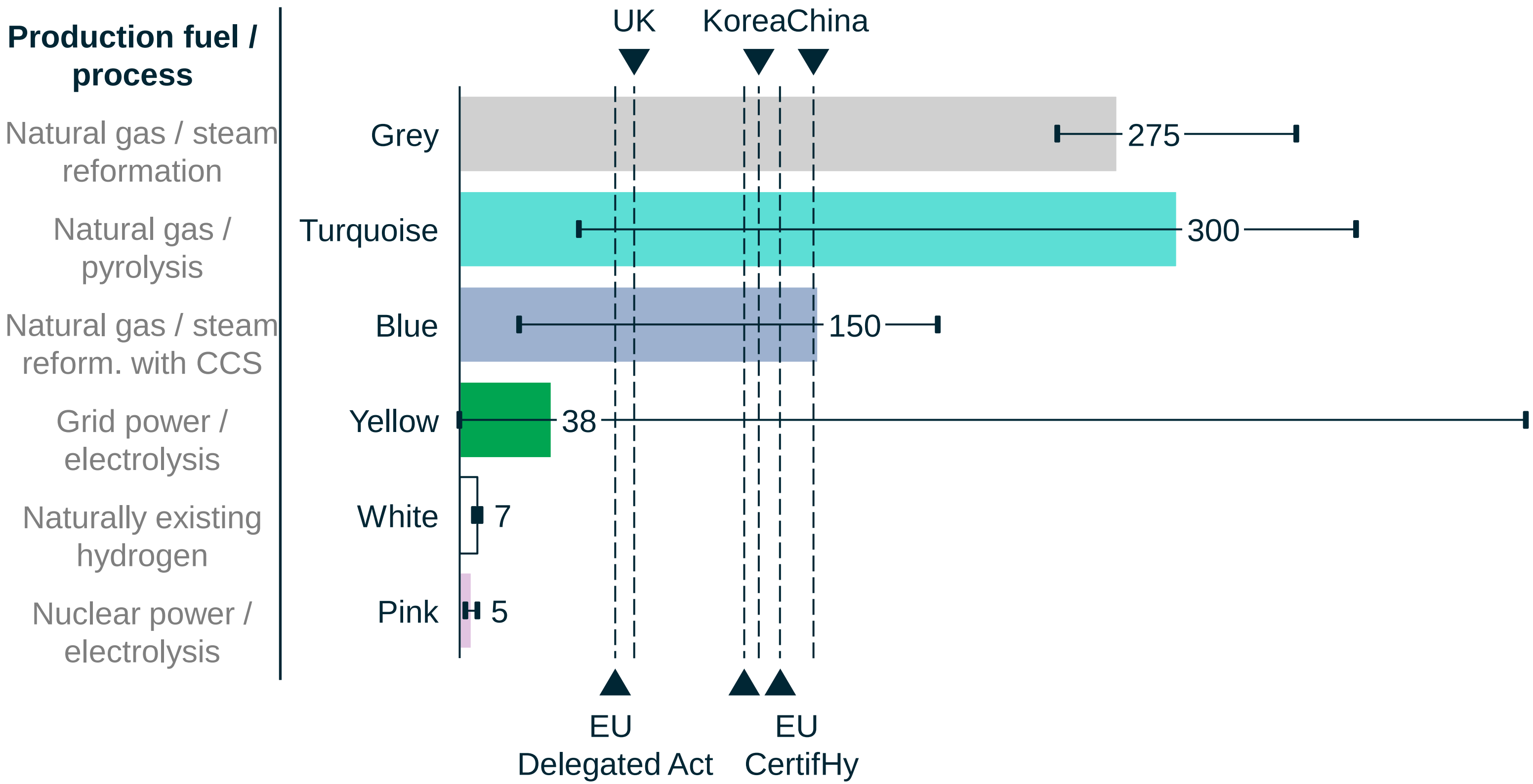
The profitability of a hydrogen production project depends on three key components: capital cost, operational cost and revenue



Hydrogen producers must navigate a variety of standards to attract subsidy support and ensure project viability

Carbon intensity per hydrogen colour in 2023

gCO$_2$/kWh



2023 PORTUGAL RENEWABLE ENERGY SUMMIT

The EU's definition for green (renewable) hydrogen is the most complex; the criteria and exemptions make a number of business models possible

Additionality | **Temporal correlation[1]** | **Geographic correlation**

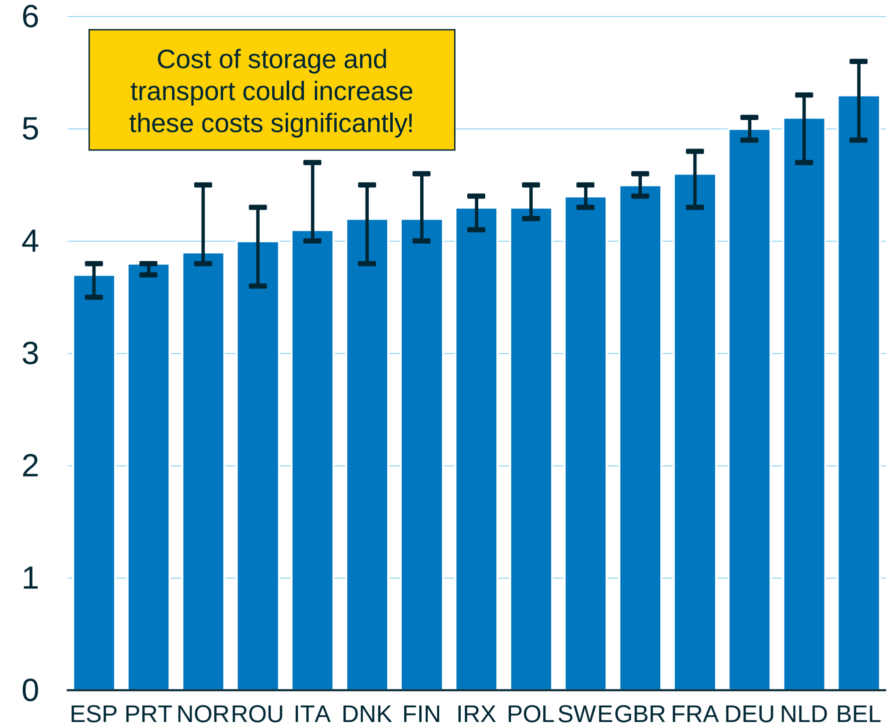
Business models that are exempt from one or more criteria	Avoided Criteria
Co-location (islanded)	
>90% RES in power grid[2]	
Curtailed and/or <20 €/MWh power	
Grid carbon intensity <64.8 gCO_2/kWh	

1) Temporal correlation is complied in an hourly period when the clearing price is <20 €/MWh or 0.36 times the price allowance to emit one tonne of CO_2 equivalent at the time of hydrogen production. 2) Defined by gross RES consumption divided by total demand.

The cost of islanded production varies greatly across Europe due to renewable potential of each country

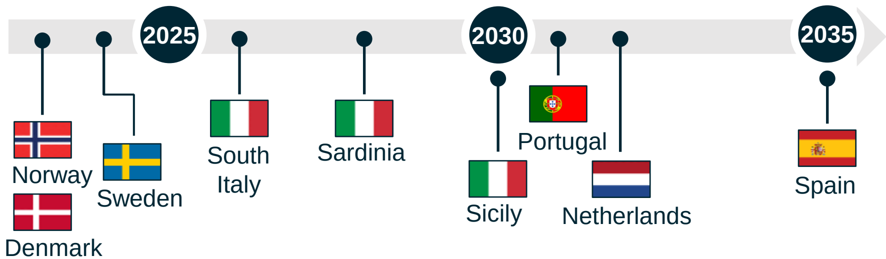
Levelised cost of hydrogen production for COD 2030, PEM electrolyser[1]

€/kg H_2 (real 2022)

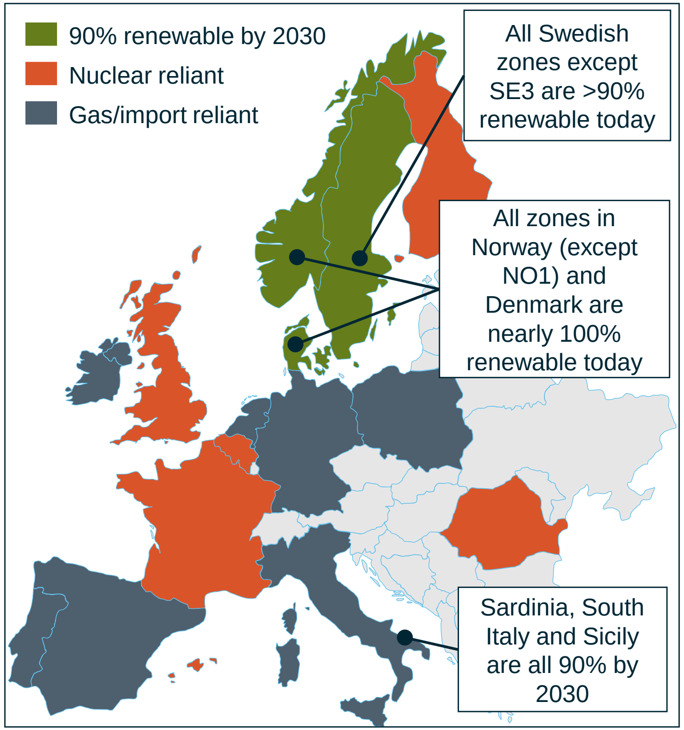


1) Lower and upper LCOHs are calculated for an average fleet performance of today and future, respectively.

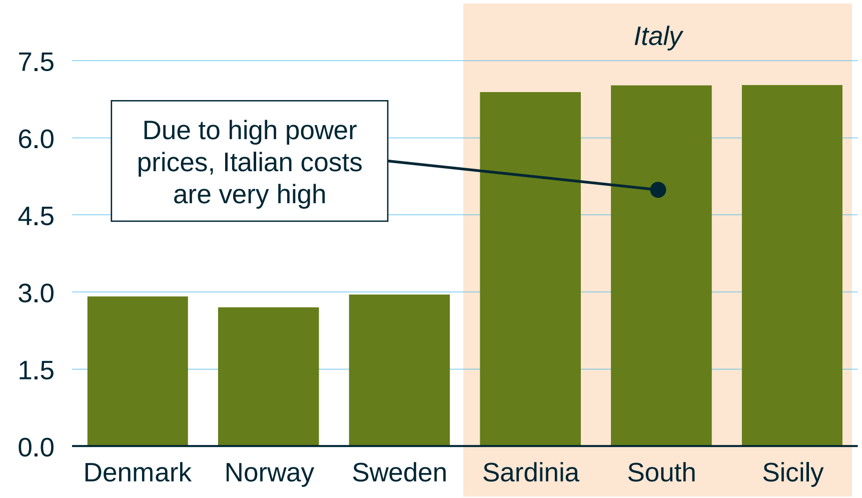
Electrolysers can produce REDII compliant hydrogen via highly renewable grids in Scandinavia and Italy by 2030



2030 snapshot of RES mix

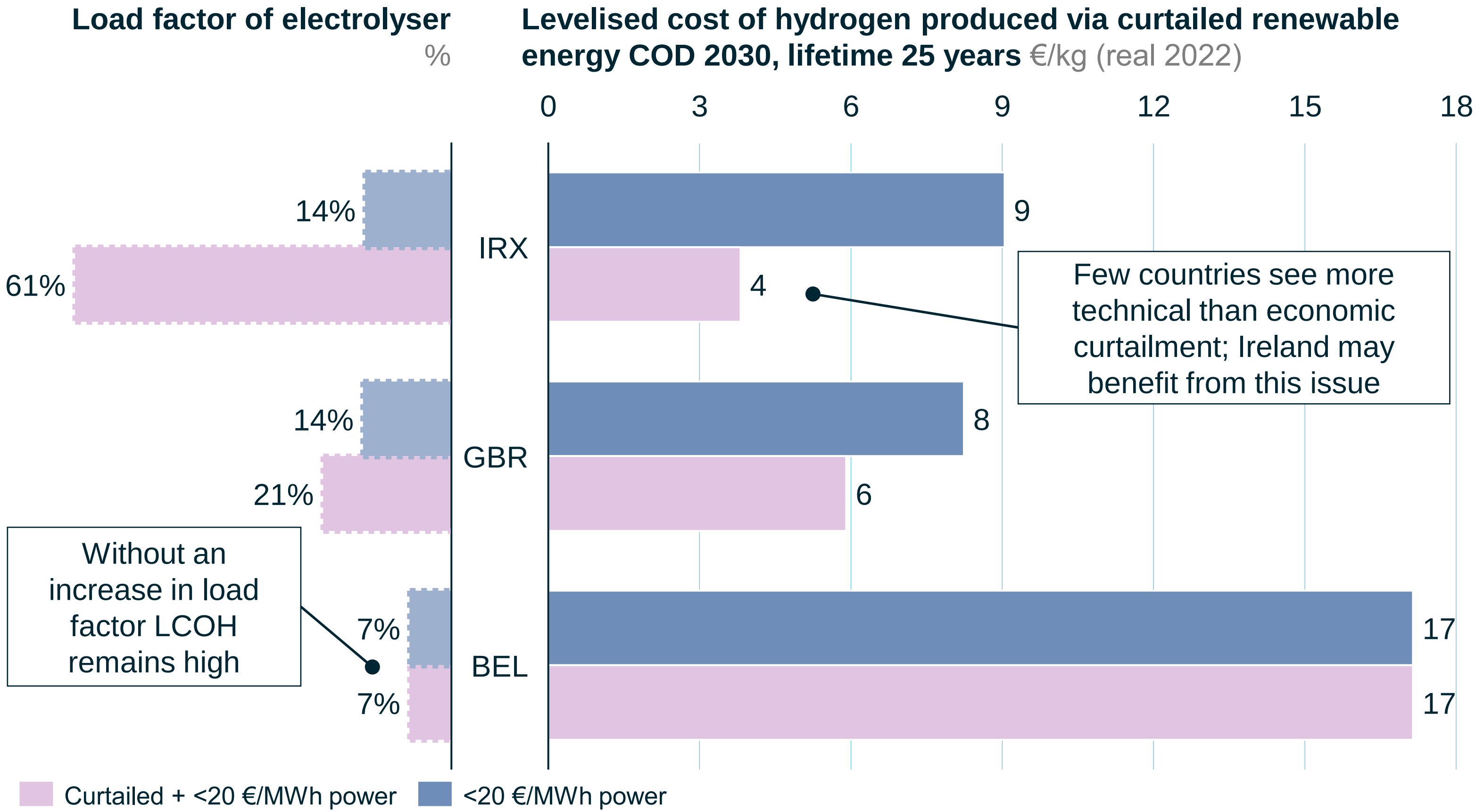


Levelised cost of hydrogen production for COD 2030, PEM electrolyser (Flexible >90% RES)1 €/kg H_2 (real 2022)



1) LCOHs in Denmark, Norway, and Sweden are reported for the bidding zone each country has the lowest cost. These zones are DK2 in Denmark, NO2 for Norway, and SE2 for Sweden.

Use of curtailed power is not viable in any country other than Ireland where increased load factor significantly reduces LCOH

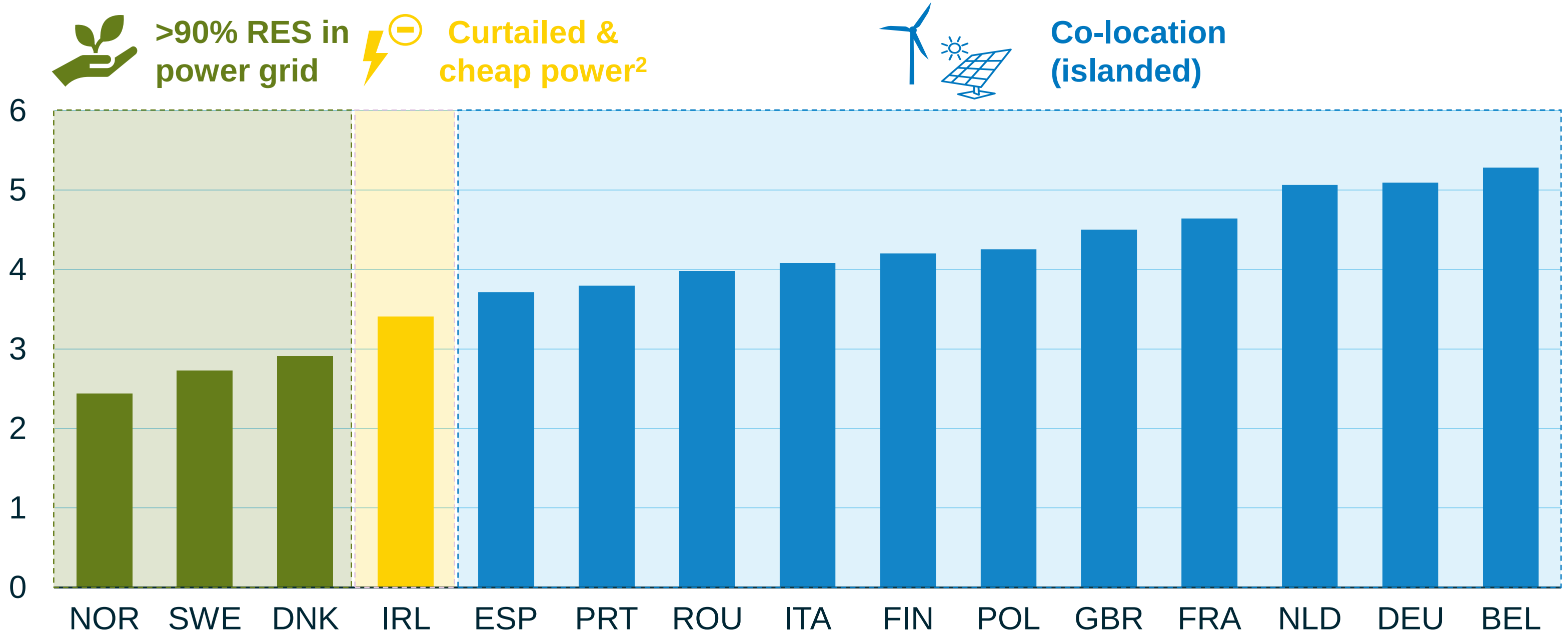


2023 PORTUGAL RENEWABLE ENERGY SUMMIT

The lowest cost business model varies by country; although off-grid co-location is the most popular one across many countries

Levelised cost of hydrogen production for COD 2030, PEM electrolyser (cheapest business model)[1]

€/kg H2 (real 2022)

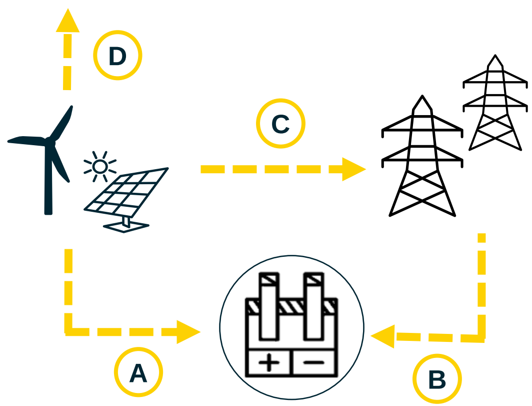


Production costs only! The cost of delivering the hydrogen to the offtaker would also need to consider storage and transport costs. Guaranteeing baseload hydrogen production, with the help of tank gas storages, could double cost estimates.

1) LCOHs are calculated with 8% WACC. 2) Grid connected electrolyser that is powered with curtailed energy or when power prices <20 €/MWh.

Aurora covers four electrolyser business models and their compliance with low-carbon/renewable hydrogen standards

Overview of connections we considered in our business models

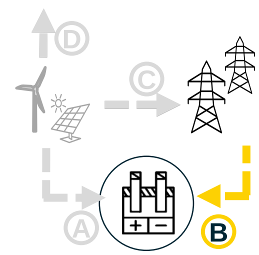


- **A** Electrolyser imports power from RES[1]
- **B** Electrolyser imports power from grid
- **C** RES exports power to grid
- **D** RES spills power

Stand-alone grid connected electrolysers

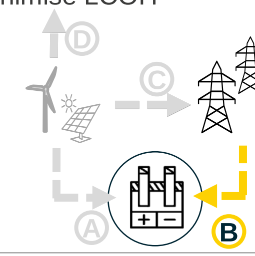
1 Inflexible

- Grid electricity **only** and runs at **95%** load factor



2 Flexible

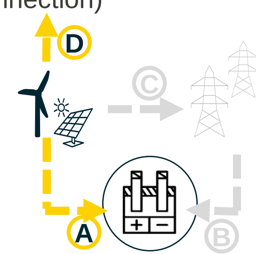
- Grid electricity **only** and ability to choose operating hours to minimise LCOH[2]



Co-located electrolysers

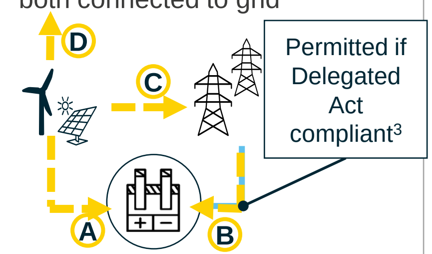
3 Co-located (island)[4]

- Electrolyser connected to renewable asset only (no grid connection)



4 Co-located (grid)[4]

- Direct connection between electrolyser and RES asset, and both connected to grid



1) RES: Renewable energy asset 2) LCOH: Levelised cost of hydrogen 3) Grid top up to electrolyser permitted only if the grid has >90% renewable penetration. 4) Note that our analysis does not differentiate between the risk profile of co-located (island) vs. grid-connected business models. Empirical evidence suggest that co-located (island) business models have a much higher risk, requiring higher discount rates.

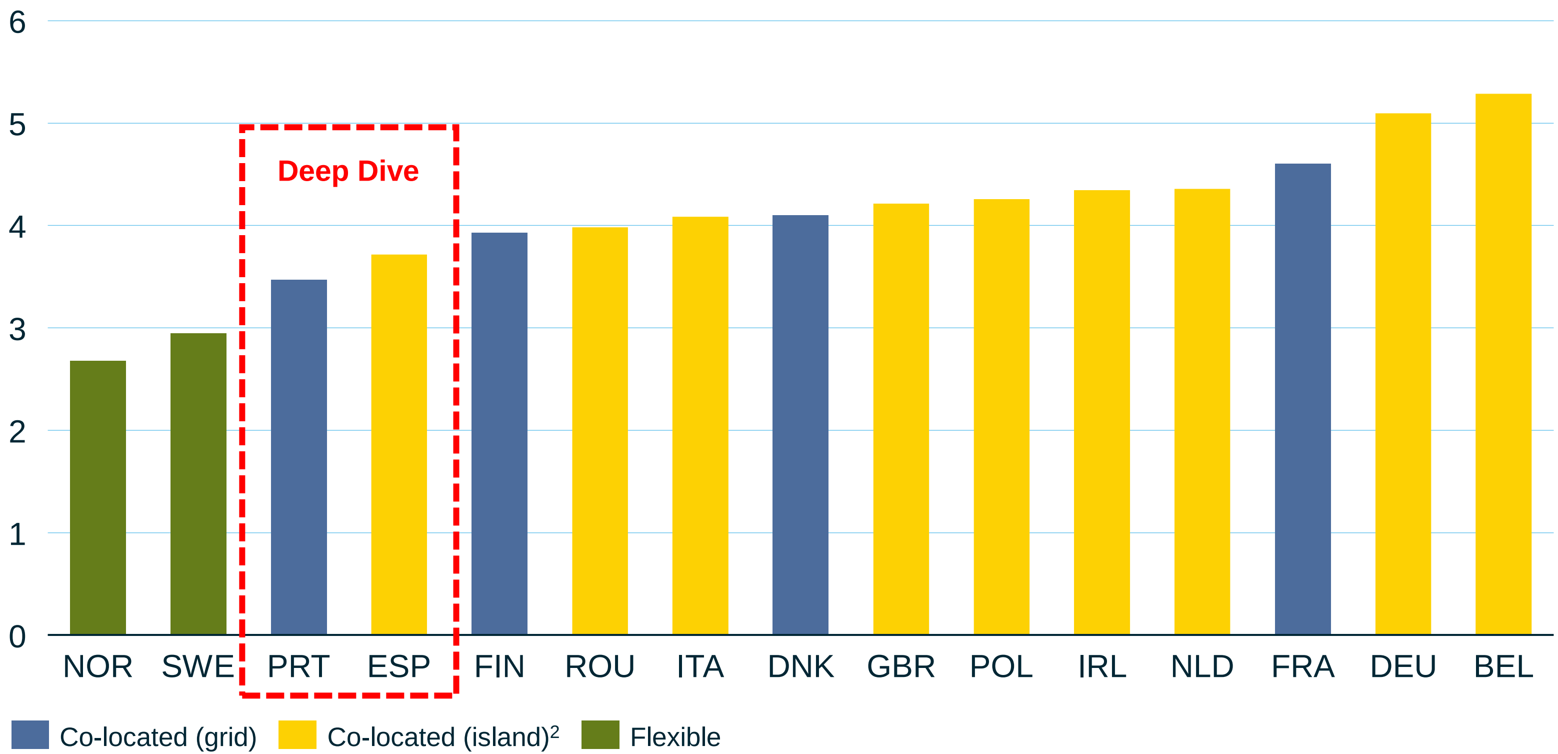
2023 PORTUGAL RENEWABLE ENERGY SUMMIT

AURORA

The lowest cost business model varies by country; although off-grid co-location is the most applicable across many countries

Levelised cost of hydrogen production for COD 2030, PEM electrolyser (cheapest business model)[1]

€/kg H_2

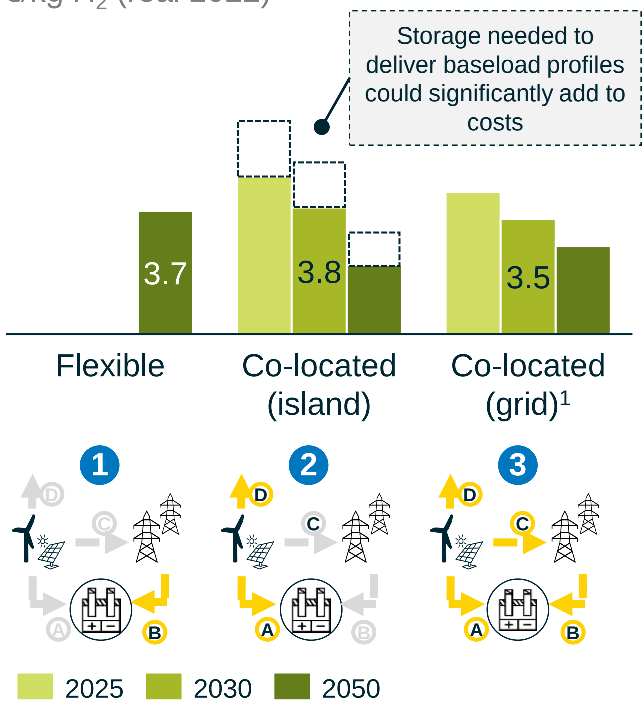


1) LCOHs are calculated with 8% WACC. 2) Excluding storage and transportation costs.

High wind and solar load factors in Portugal leads to the lowest co-located LCOH in Europe

Country deep-dive: Portugal

Levelised cost of hydrogen production
€/kg H_2 (real 2022)

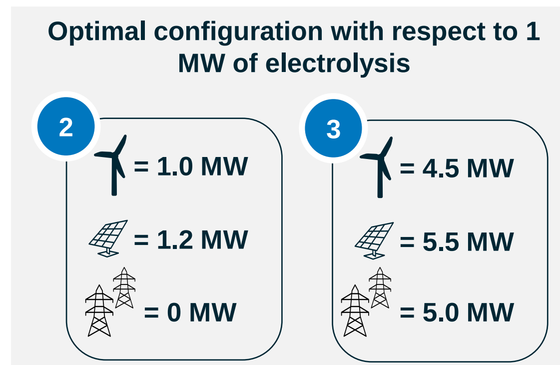


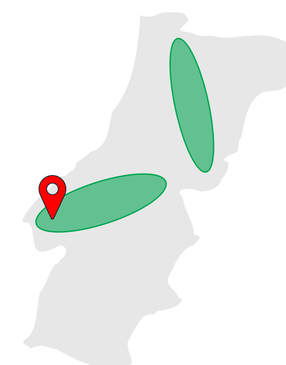
1 Grid connected business model (Flexible)

By 2031, Portugal meets the highly renewable power grid criterion of the REDII Delegated Act[2], which requires more than 90% renewables. The share of renewables in Portugal increases in early 2030s and reaches close to 100% by 2050.

2 3 Co-located business models

Portugal sees complementary wind and solar load factors allowing for high electrolyser load factors. Co-located cost of H_2 production is lowest in Portugal when grid-connected as renewable LCOE[3] can be fully utilised by exporting any otherwise curtailed power.





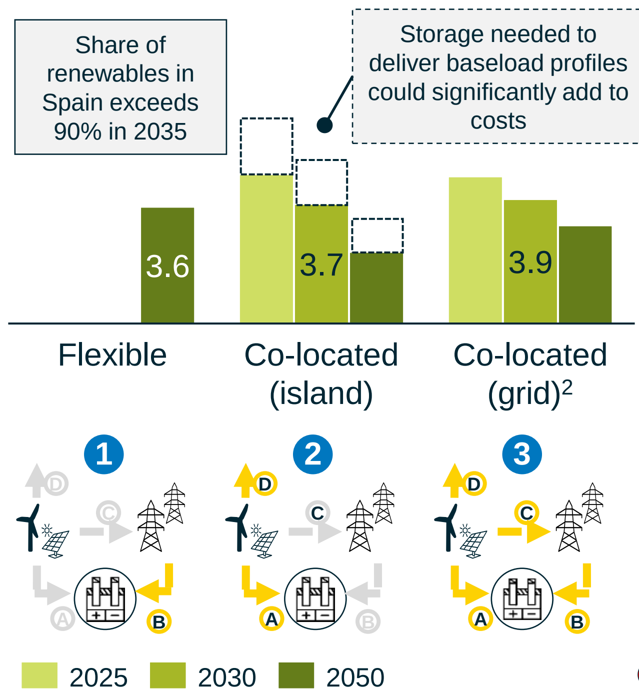
1) Grid connection for export only to ensure "renewable nature of hydrogen" as per RED II Delegated Act. 2) Article states that if a bidding zone sees a ratio of consumption from renewable sources to total production (minus exports plus imports) exceeding 90%, an electrolyser can produce renewable hydrogen from grid imports. 3) l

The cheapest renewable H2 via off-grid electrolysers is produced in Spain; but not as cheap as grid-connected electrolysers in Nordics

Country deep-dive: Spain

Levelised cost of hydrogen production

€/kg H_2 (real 2022)

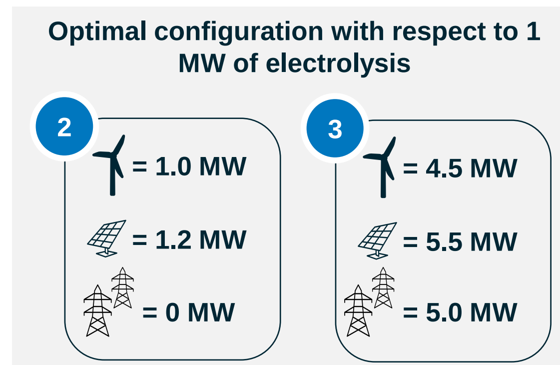


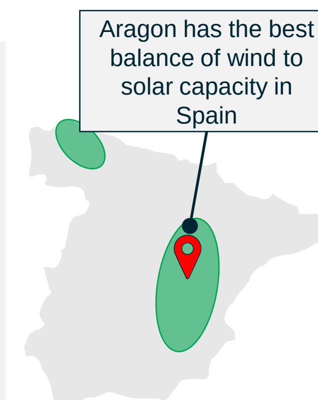
1 Grid connected business model (Flexible)

Spain remains below the 90% renewable share defined in the Delegated Act3 of REDII until 2030. The share of renewables increases from 85% to 90% between 2030 and 2035, thereafter it remains above the threshold through 2050.

2 3 Co-located business models

Like Portugal, Spain sees complementary wind and solar load factors allowing for high electrolyser load factors. Low LCOE can also be utilised to give the lowest islanded cost of production (excluding cost of storage.





1) Internal rate of return. 2) Grid connection for export only to ensure "renewable nature of hydrogen" as per RED II Delegated Act. 3) Article states that if a bidding zone sees a ratio of consumption from renewable sources to total production (minus exports plus imports) exceeding 90%, an electrolyser can produce renewable hydrogen from grid imports. 4) Onshore wind and solar. 5) Renewable energy systems. 6) Levelised cost of electricity.

Key takeaways

REDII compliance is required for EU Hydrogen Bank subsidies as well as many national or import support schemes for renewable hydrogen.

The cheapest REDII compliant electrolyser business model differs in each country. Fully grid connected electrolysers in Scandinavia produces renewable hydrogen less than 3 €/kg in 2030, but storage and transport costs can increase the cost of hydrogen delivered to offtakers significantly.

Spain and Portugal have the renewable resources to be some of the lowest cost producers of hydrogen in Europe, but subsidy support is still required to enable the early deployment of projects.

Disclaimer and Copyright

General Disclaimer

This document is provided "as is" for your information only and no representation or warranty, express or implied, is given by Aurora Energy Research Limited and its subsidiaries Aurora Energy Research GmbH and Aurora Energy Research Pty Ltd (together, "**Aurora**"), their directors, employees agents or affiliates (together, Aurora's "**Associates**") as to its accuracy, reliability or completeness. Aurora and its Associates assume no responsibility, and accept no liability for, any loss arising out of your use of this document. This document is not to be relied upon for any purpose or used in substitution for your own independent investigations and sound judgment. The information contained in this document reflects our beliefs, assumptions, intentions and expectations as of the date of this document and is subject to change. Aurora assumes no obligation, and does not intend, to update this information.

Forward-looking statements

This document contains forward-looking statements and information, which reflect Aurora's current view with respect to future events and financial performance. When used in this document, the words "believes", "expects", "plans", "may", "will", "would", "could", "should", "anticipates", "estimates", "project", "intend" or "outlook" or other variations of these words or other similar expressions are intended to identify forward-looking statements and information. Actual results may differ materially from the expectations expressed or implied in the forward-looking statements as a result of known and unknown risks and uncertainties. Known risks and uncertainties include but are not limited to: risks associated with political events in Europe and elsewhere, contractual risks, creditworthiness of customers, performance of suppliers and management of plant and personnel; risk associated with financial factors such as volatility in exchange rates, increases in interest rates, restrictions on access to capital, and swings in global financial markets; risks associated with domestic and foreign government regulation, including export controls and economic sanctions; and other risks, including litigation. The foregoing list of important factors is not exhaustive.

2023 PORTUGAL RENEWABLE ENERGY SUMMIT

APREN Associação de Energias Renováveis