Designing for Value: Innovative Power Procurement Strategies for Electrolyser Business Models

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Introducing Aurora's Hydrogen team

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Source: Aurora Energy Research

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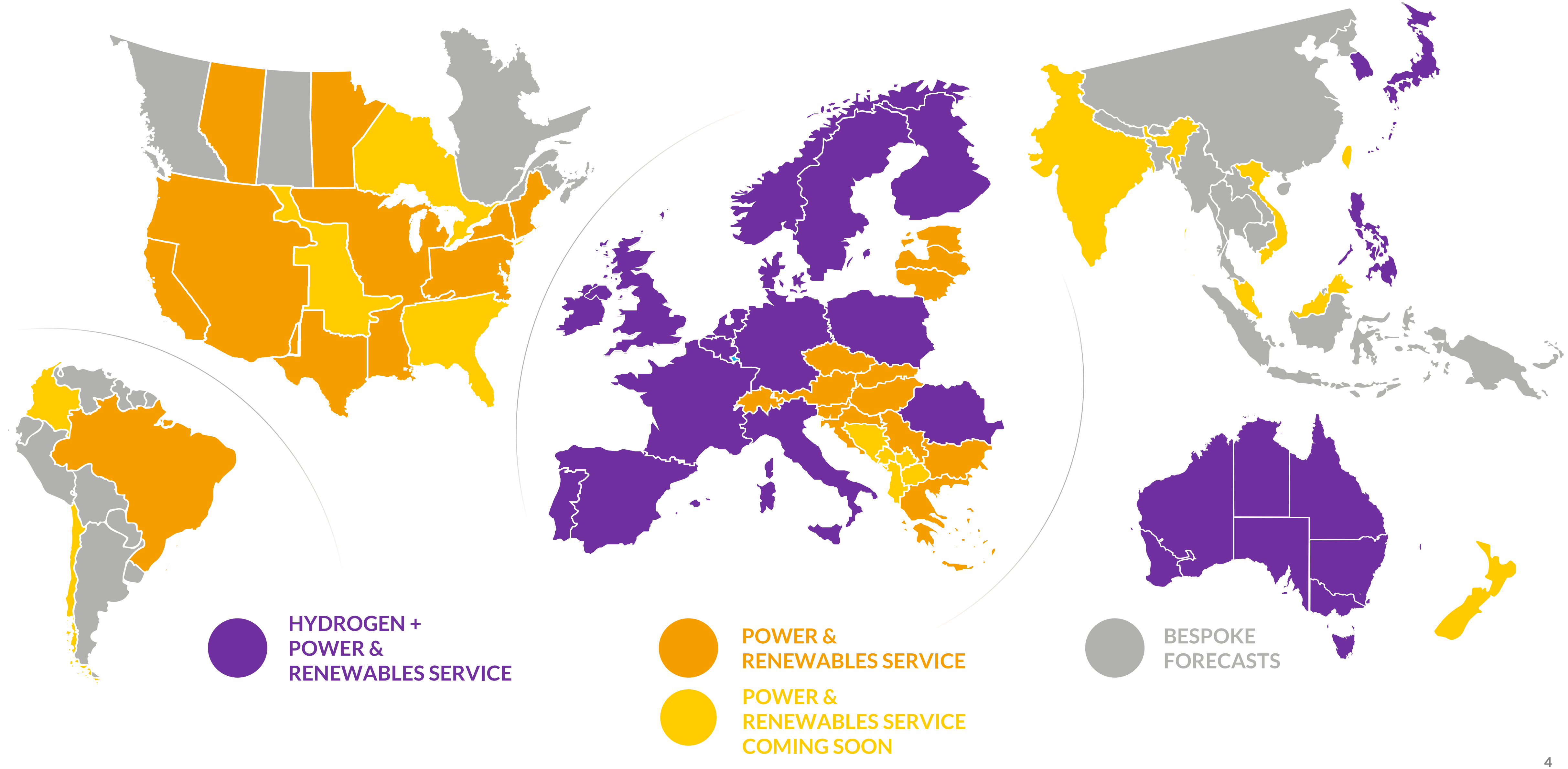

Discover the major players across the value chain utilising Aurora's hydrogen market analytics

Utilities & Renewables

- EDF Energy
- RWE
- e.on
- uniper
- CEZ GROUP
- sse
- eew Energy from Waste
- steag
- Wärme Hamburg
- Trianel
- TRITON POWER
- ONYX POWER
- VIRIDI
- NICE SOLAR ENERGY
- eregio
- Ørsted
- BSR Energy
- axpo
- edp
- fortum
- amp
- ScottishPower
- centrica
- octopus energy

Supply Chain

- BASF We create chemistry
- urenco The Energy to Succeed
- ITM POWER Energy Storage | Clean Fuel
- SIEMENS
- SALZGITTER AG Stahl und Technologie
- MITSUBISHI POWER
- Port of Rotterdam

Financiers

- THE CROWN ESTATE
- SEB
- PJT Partners
- 丸紅株式会社 Marubeni
- BlackRock
- BARCLAYS
- meridiam INVESTING FOR THE COMMUNITY
- low carbon powering tomorrow

Government & regulation

- Schweizerische Eidgenossenschaft / Confédération suisse / Confederazione Svizzera / Confederaziun svizra
- Ministerie van Economische Zaken en Klimaat
- JETRO JAPAN EXTERNAL TRADE ORGANIZATION
- Department for Business, Energy & Industrial Strategy
- Bundesnetzagentur
- CREG
- Committee on Climate Change
- Department for Transport
- National Infrastructure Commission

Upstream gas & networks

- REPSOL
- Shell
- equinor
- Naturgy
- OGE
- nationalgrid
- Thyssengas
- Vitol
- fluxys

Source: Aurora Energy Research

Our European Hydrogen Market Service keeps you up-to-date with regular insights, policy & market updates, and roundtable discussions

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Full European Hydrogen Market Subscription Analytics Service

Forecast Reports & Data

Hydrogen Market Report (HyMaR) & Investment Case Analysis

- Summary of policy & regulatory developments and incentives across Europe
- Hydrogen market sizing: demand scenarios by country and sector
- Analysis of demand and supply drivers
- Hydrogen production economics based on our in-house power, gas & carbon prices
- Pricing approach and fundamentals-based benchmarking for bilateral hydrogen purchase agreements and for offtaker willingness to pay
- Market evolution and long-term forecasted Hydrogen market prices out to 2060
- Global electrolyser project database

Interactive Online Database and Scenario Explorer

Explore scenarios through EOS, our dynamic online platform featuring a full library of reports and datasets.

Strategic Insights

Strategic Insight Reports

Regular insight reports on topical issues in the evolving European hydrogen market covering country, policy, and technology deep dives

Policy Updates

- Regular updates on European Hydrogen policy developments and incentive schemes
- Thought leadership on required policies and incentives to grow the hydrogen sector

Group Meetings

- Presentation of Market Reports and Strategic Insight reports
- Networking opportunity with developers, investors, and Governments—the 'go-to' roundtable to discuss hydrogen developments in Europe

Analyst Support

Bi-annual workshops and support from our bank of analysts, including native speakers and on-the-ground experts

A typical year in the European Hydrogen Market Service

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Selected existing reports[1]

Strategic Insights	Country deep-dives
▪ Seas of opportunity: economics of hydrogen from offshore co-location	▪ Hydrogen in the NLD: From natural gas to green hydrogen hub
▪ A traded hydrogen market in Europe: what will prices and market structures look like?	▪ The role of green hydrogen in the I-SEM
▪ The economics of hydrogen imports: Better to stay local?	▪ Policies, regulation, and economics of green hydrogen in France
▪ Financing electrolysers: Overview of market trends in Europe	▪ Green hydrogen in Germany- Could colocation become a new business model for renewables?
▪ Hydrogen in transport: understanding the economics and incentives	▪ The role of green hydrogen in Iberia
▪ Shades of green (hydrogen) – optimising electrolyser business models	▪ Hydrogen for a Net Zero Great Britain
▪ "THG Quoten" and electrolyser profitability in Germany – more than hot air?	▪ Low carbon hydrogen in the Nordics
	▪ Net Zero and the role of hydrogen for the Italian power system

Major deliverables of European Hydrogen Service in 2024

- **Feb 2024** – Hydrogen purchase agreements
- **April 2024** – Hydrogen Market Report (HyMaR)
- **June 2024** – Hydrogen offtakers' willingness-to-pay
- **Oct 2024** – Hydrogen Market Report (HyMaR)
- **Dec 2024** – Power purchasing strategies
- **Feb 2025** – Short-term hydrogen demand sizing

1) Existing reports are available in our EOS platform under the European Hydrogen Product

Source: Aurora Energy Research

Agenda

I. **Setting the scene**

II. Exploring innovative power procurement strategies

III. Bridging the gap to offtakers' willingness to pay

IV. Key takeaways

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The EU's definition of RFNBO hydrogen has three rules, which can be expanded into several electrolyser business models

The European Commission published two delegated acts in June 2023, setting out detailed rules on the EU criteria for renewable hydrogen, providing regulatory certainty to investors.

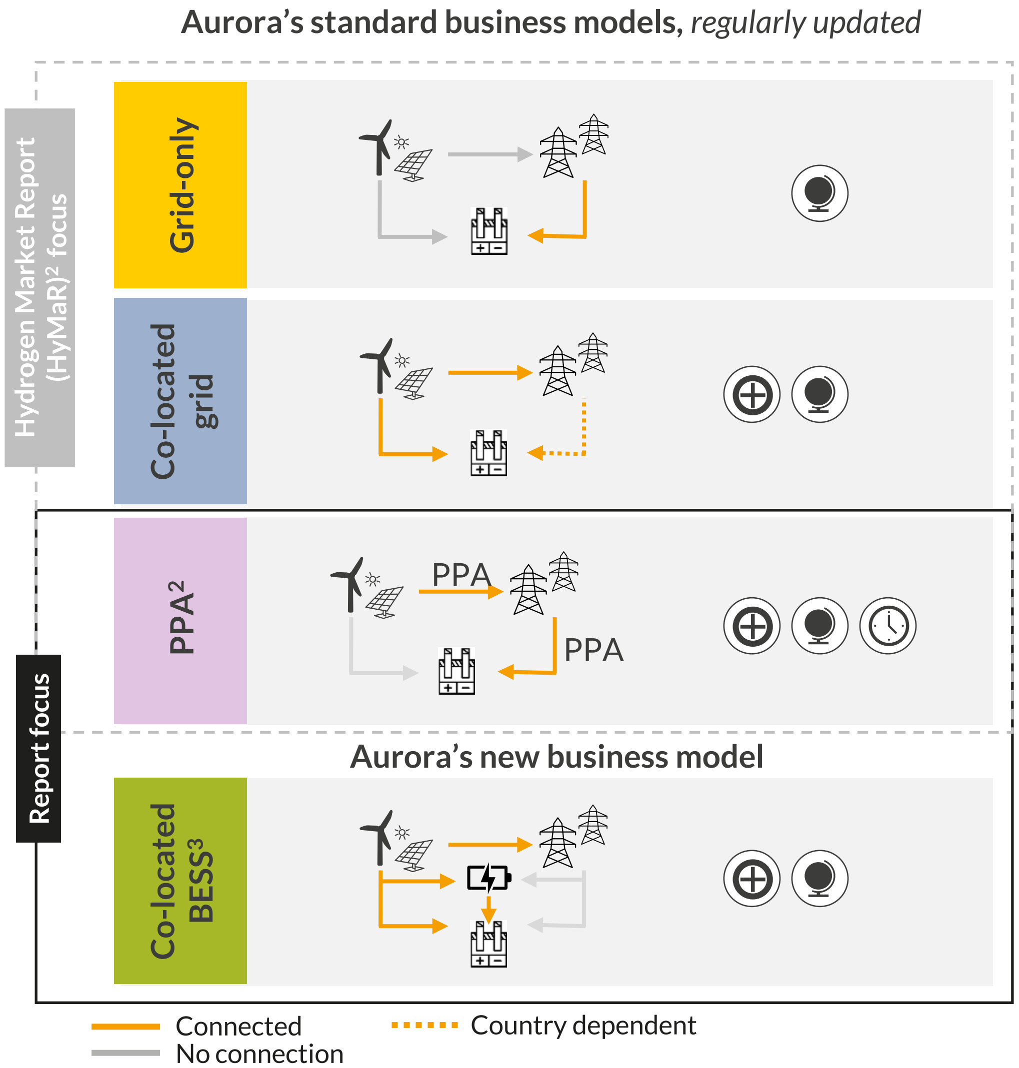
To qualify as producing renewable H_2[1], the electrolyser must meet all three criteria:

Additionality: There must be a newly-built renewable assets that comes into operation at maximum 36 months before the electrolyser. The renewable assets must not have received subsidies. Subsequent PPAs are allowed.

Geographical correlation: The renewable assets and the electrolyser should be geographically correlated. The renewable assets and electrolyser should be within the same bidding zone or neighbouring ones.

Temporal correlation: The power generation and hydrogen production must match in a certain timeframe. This is monthly until 1 January 2030, and hourly afterwards (can be shifted with a new storage asset).

- Temporal correlation is compiled within 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.



1) Renewable hydrogen also referred to as RFNBO (Renewable fuel of non-biological origin) hydrogen; 2) PPA: Power purchase agreement; 3) BESS: Battery energy storage system; 2) Hydrogen Market Report (HyMaR) is our bi-annual report, find the latest HyMaR report on EOS.

Sources: Aurora Energy Research, European Commission

This report explores available options to narrow the current cost gap to willingness-to-pay by lowering production costs

In this report, we take the existing levelised cost of hydrogen (LCOH) business models from our Oct-24 Hydrogen Market Report (HyMaR) and look at ways to reduce the 'cost gap' in the waterfall chart via various power procurement and electrolyser sourcing options.

Illustrative cost gap between LCOH and floor willingness to pay (WtP)

Electrolyser	Power procurement	Storage	Other	LCOH	Cost gap	Floor WtP[3]
Electrolyser CAPEX	RES asset's CAPEX and OPEX or cost of PPA[1] and grid charges	Used to address the mismatch between production and offtake profiles	Grid connection costs and FOM[2] for the electrolyser	The combined cost of H_2 production	Difference between LCOH and the price consumer are willing to pay	The minimum price consumers are willing to pay for H_2

1) PPA: Power purchase agreement; 2) FOM: Fixed operating and maintenance costs; 3) WtP is the minimum price at which H_2 equals the cost of a reference competing technology, making it economically competitive. WtP can also be increased by external factors, including green premium, subsidies, and avoided penalties;

Source: Aurora Energy Research

Modifying various LCOH parameters can increase or decrease the final costs of producing hydrogen

Adjusting the LCOH parameters listed below can significantly affect the final cost, either increasing or reducing it. In this report, we analyse how these adjustments impact the overall cost by modifying selected parameters.

LCOH parameters	Impact
Cost of power	Lower electricity costs directly reduce the LCOH, as power is the largest operational expense in renewable hydrogen production.
Electrolyser CAPEX	Lower capital costs for the electrolyser reduce upfront investment requirements, decreasing the LCOH.
Electrolyser efficiency	Higher efficiency means less electricity is needed per kilogram of hydrogen produced, reducing operational costs and the LCOH.
Green premium	A higher green premium (willingness to pay for renewable/low carbon hydrogen) doesn’t lower the LCOH but increases profitability, potentially justifying higher production costs.
Load factor	A higher load factor increases the utilisation of the electrolyser, spreading fixed costs over more hydrogen production and reducing the LCOH.
Offtaker profile	The LCOH will be influenced by whether the offtaker requires a consistent, baseload supply of hydrogen or can accommodate intermittent usage as well as what type of pricing structure the offtaker has agreed to.
Subsidies	Subsidies can offset capital or operational expenses, directly lowering the LCOH by reducing the total cost borne by the producer.
WACC[1]	A lower weighted average cost of capital decreases the financing cost of investments, which reduces the LCOH.

1) WACC: Weighted average cost of capital;

Source: Aurora Energy Research

In this our extended report we look into different ways to lower LCOHs, including power procurement strategies

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Exploring innovative power procurement strategies

Section II.a — PPA (power purchase agreement) stacking/ oversizing

Section II.b — Co-located BESS

Section II.c — Germany's 13k

Additional opportunities to lower LCOH

Section III — Low-cost, Chinese manufacturers; WACC[1]

Bridging the gap to offtakers' WtP[2]

Section IV — WtP[2]

Discussed in this presentation[3]

1) WACC: Weighted average cost of capital; 2) WtP: Willingness to pay; 3) The other topics are discussed in the full report, available to hydrogen subscribers;

Source: Aurora Energy Research

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1. **PPA stacking/oversizing**
2. Co-located BESS

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A diversified PPA portfolio allows for high load factors and the lowest hydrogen cost

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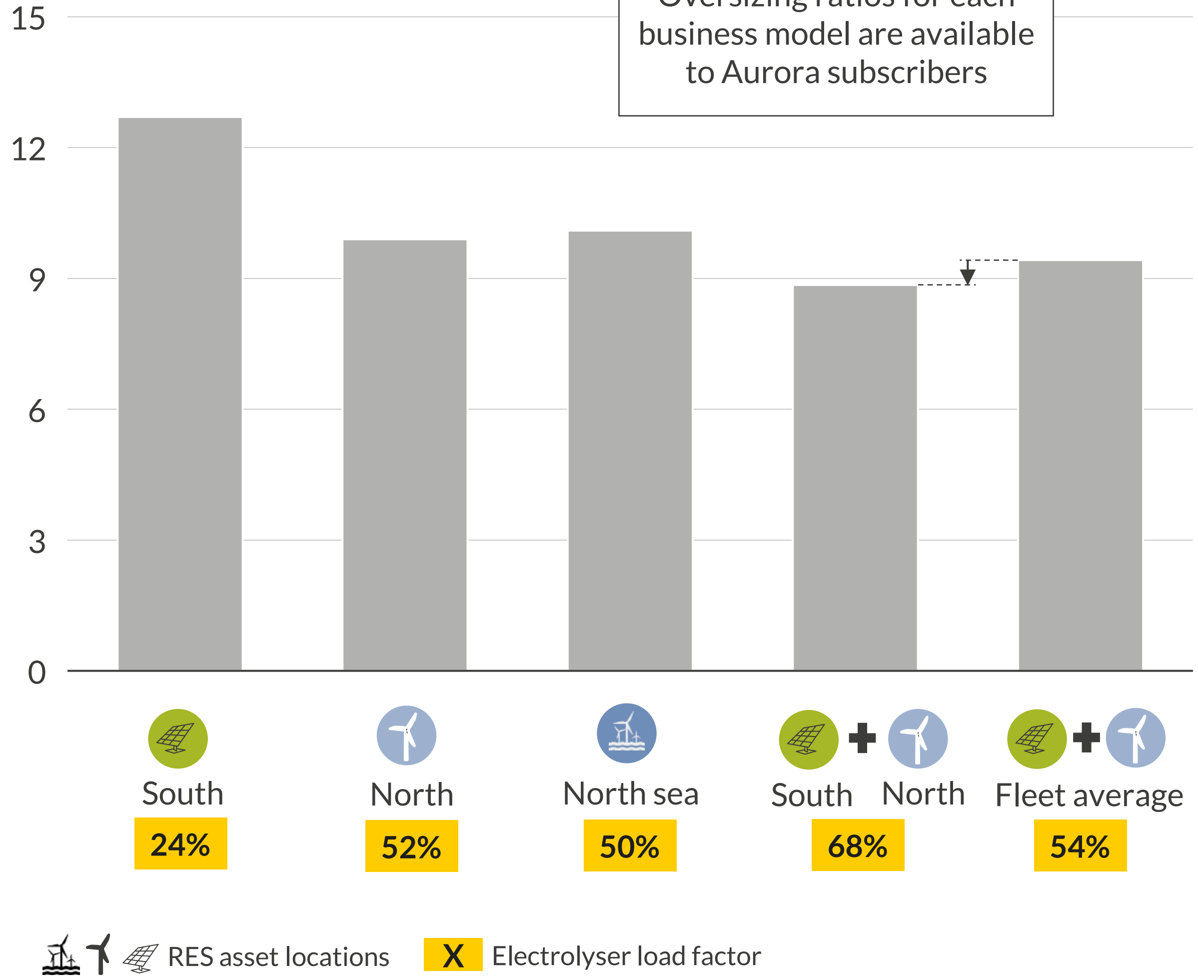
Germany's regional areas

Levelised cost of H_2 via PPA business model COD 2030 (PEM electrolyser)

€/kgH_2 (real 2023)

Oversizing ratios for each business model are available to Aurora subscribers



Oversizing the PPA portfolio beyond 5x in Germany brings baseload LCOHs to sub-10 €/kgH_2 levels

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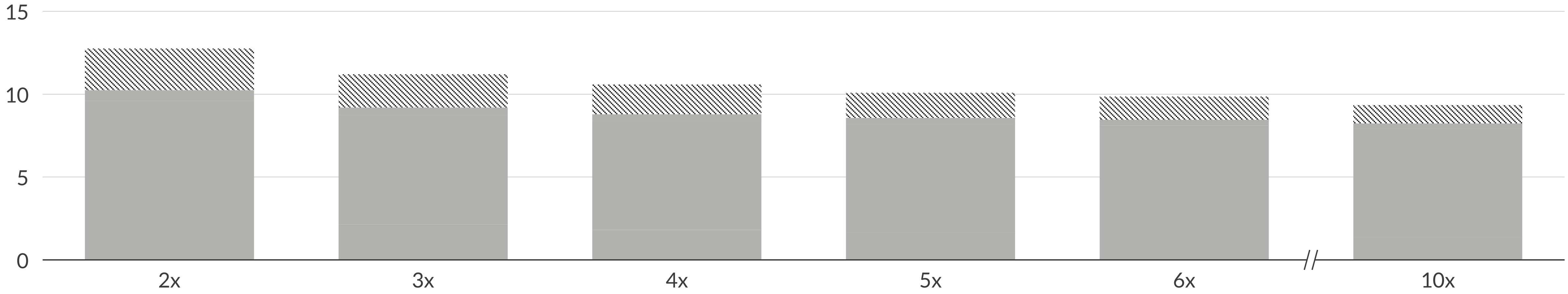
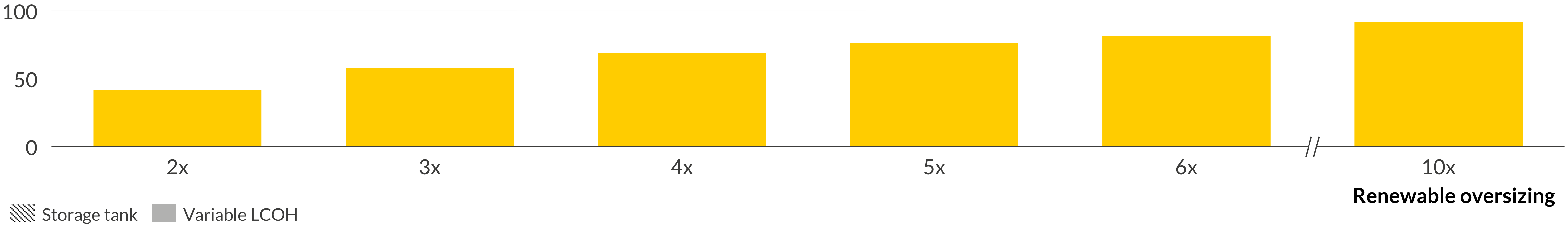
LCOH in Germany via a hybrid PPA business model (COD 2030, PEM electrolyser)
€/kgH_2 (real 2023)



Yearly average electrolyser load factor
%



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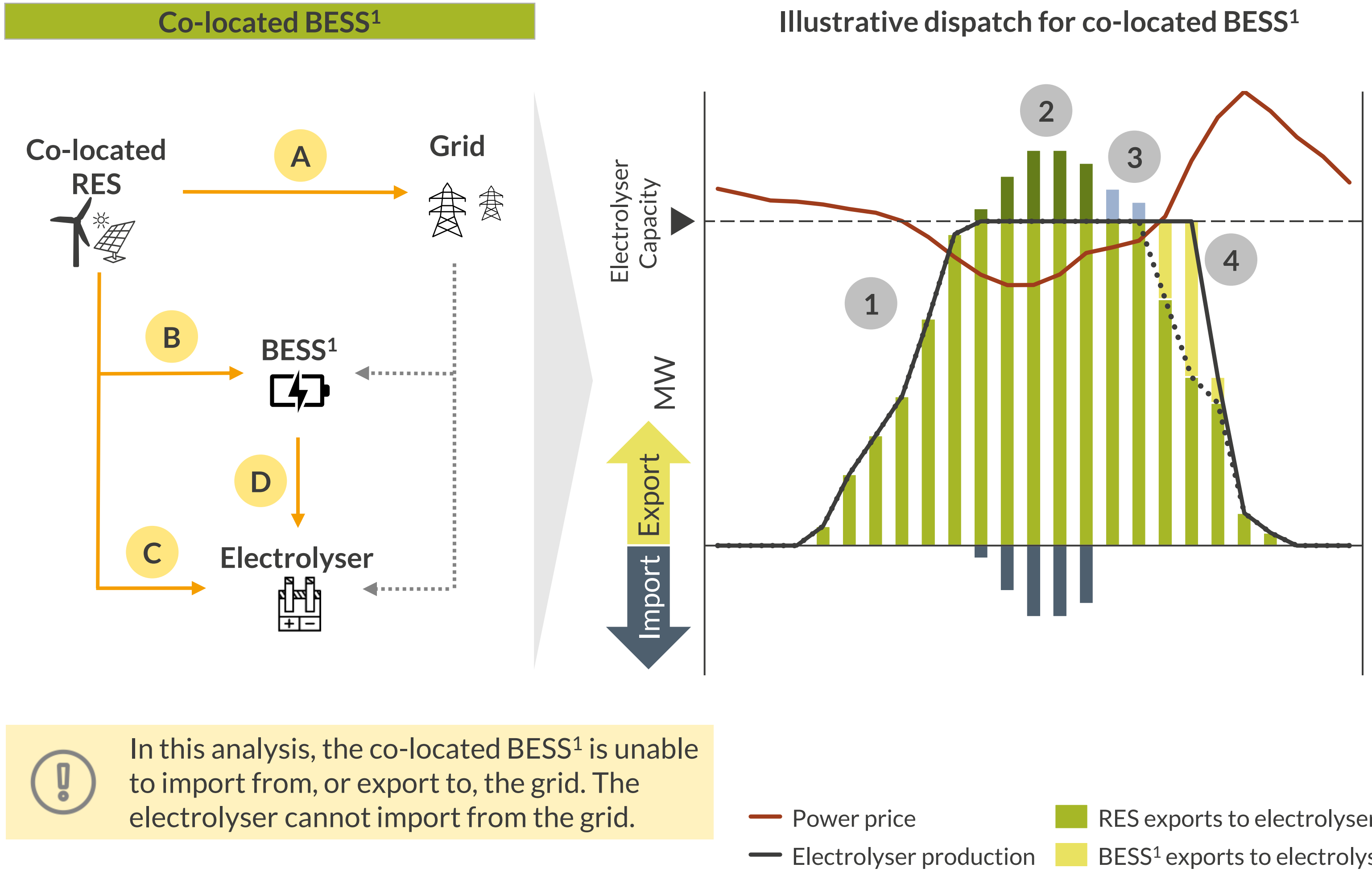
By shifting surplus RES generation onto the electrolyser, BESS[1] co-location can provide an alternate route to raising electrolyser load factors

The co-located BESS[1] electrolyser business model prioritises sending renewable energy generation to the electrolyser for hydrogen production. Excess RES generation above the electrolyser nameplate capacity is diverted to the BESS[1] during low power price periods to then be later redistributed to the electrolyser.



Dispatch decisions		Power flows
1	Electrolyser production is prioritised, so the electrolyser receives all available RES power	C
2	The electrolyser has reached maximum import capacity, so excess RES generation is stored in the BESS[1]	B + C
3	The BESS[1] is fully charged, allowing excess RES generation to be diverted to the grid during higher price periods	A + C
4	RES generation has fallen below the electrolyser capacity causing the BESS[1] to discharge to the electrolyser	C + D

In this analysis, the co-located BESS[1] is unable to import from, or export to, the grid. The electrolyser cannot import from the grid.

1) BESS: Battery energy storage system;

Source: Aurora Energy Research

Co-location with BESS[1] improves load factors but raises LCOH for hybrid and solar co-located systems in Germany and Portugal

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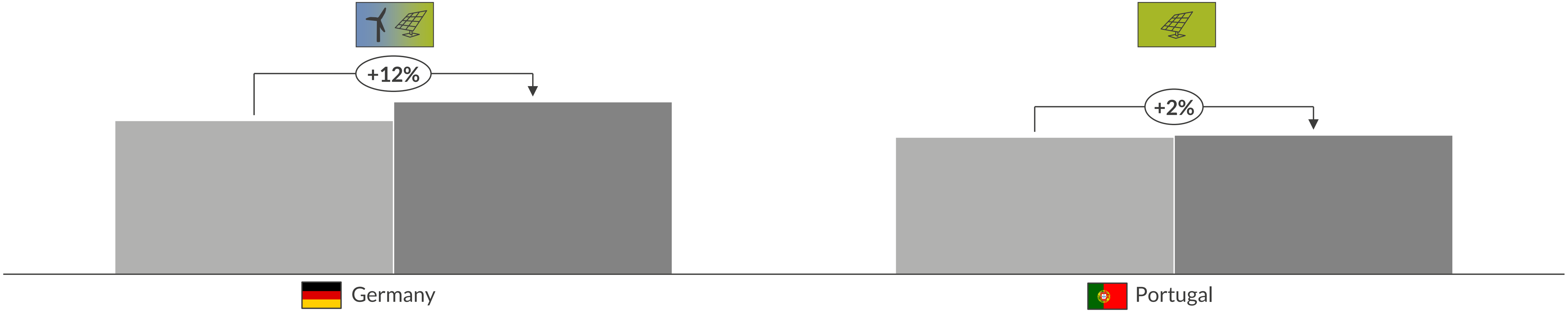
LCOH and load factors for each business model are available to Aurora's subscribers

Variable LCOH for PPA-powered business model with and without battery co-location (COD 2030, PEM electrolyser)
€/kgH_2 (real 2023)



Electrolyser load factor for PPA-powered business model with and without battery co-location (COD 2030, PEM electrolyser)
%

1) BESS: Battery energy storage system;

Source: Aurora Energy Research

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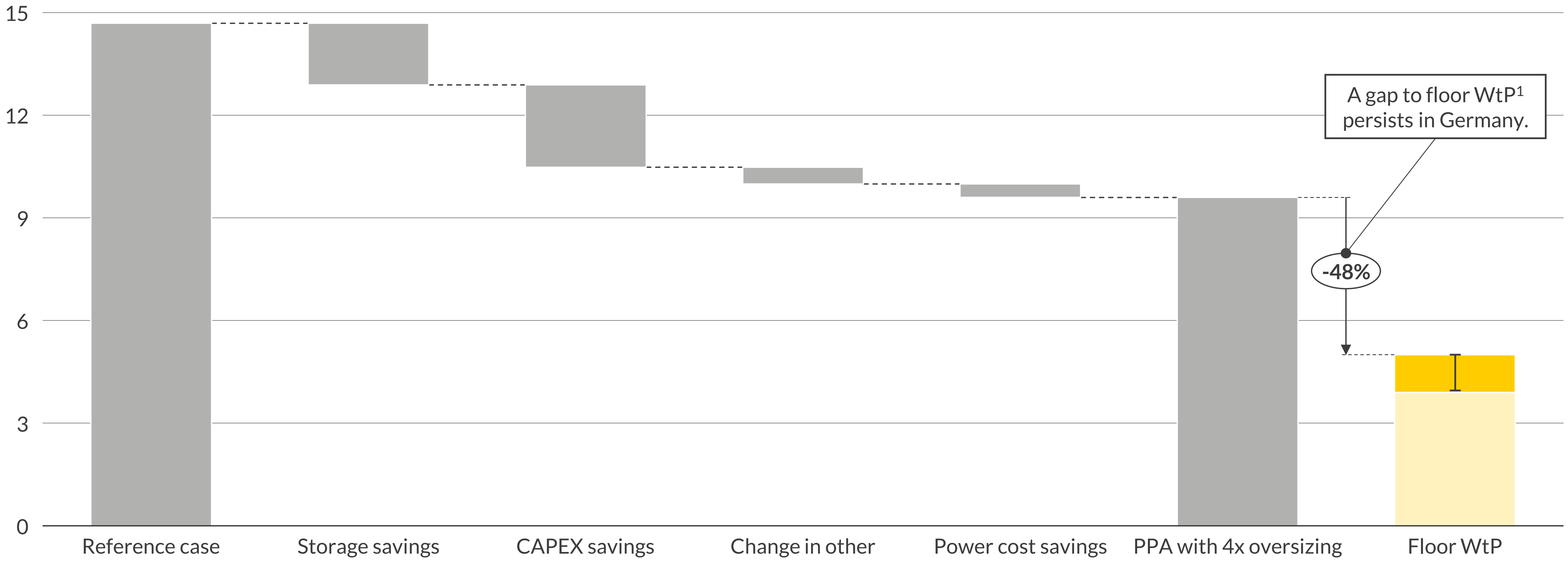
Despite achieving a significant reduction in baseload LCOH by leveraging various improvements, a notable gap remains to reach the minimum WtP[1]

Baseload LCOH in Germany – smart project design vs floor willingness to pay range (COD 2030, PEM electrolyser)

€/kgH_2 (real 2023)



1) WtP: Willingness to pay

Source: Aurora Energy Research

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Key takeaways

Exploring alternative power procurement methods can help reduce the 'cost gap' by optimizing power sourcing and electrolyser strategies. This includes increasing load factors, oversizing PPAs, integrating BESS[1], and optimizing power sourcing through PPAs.

Combining onshore wind and solar PV achieves the lowest LCOH through complementary production patterns. Additionally, oversizing PPAs beyond 4x can also significantly reduce LCOHs.

Adding a battery to co-located grid business models increases the LCOH for hybrid and solar co-located systems in Germany and Portugal. However, co-locating with solar and a BESS in Portugal can improve electrolyser load factors while maintaining comparable LCOHs.

Leveraging various improvements can achieve a significant reduction in baseload LCOH for Germany, however, a notable gap remains in order to reach the willingness to pay.

1) BESS: Battery energy storage system;

Source: Aurora Energy Research

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