

To Store or to Sell? Optimal Capacity Investment in Solar-Hydrogen Systems

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Hydrogen can win every extra megawatt-hour and still not be worth building.

At the German 2025 benchmark, converting solar electricity to hydrogen is the most valuable marginal use, yet optimal electrolyzer capacity is zero: the hydrogen price is just €1.6/MWh below the electrolyzer-entry threshold.

1 Why it matters

Firms electrifying industrial sites must decide not just how to use solar power, but whether to build the equipment that turns it into hydrogen. These are different decisions, and they can point in opposite directions.

Hydrogen matters here not because it is an efficient way to store electricity: round-trip conversion losses about 60% of the energy. Its distinctive advantage is that, unlike a battery, hydrogen can also be sold as a commodity.

THE QUESTION

Given electricity and hydrogen prices, which use of solar-generated hydrogen is most valuable, and how much solar and electrolyzer capacity should be built?

2 The Model

An operator chooses solar and electrolyzer capacity before solar output is realized. Then solar serves electricity demand directly, produces hydrogen for storage or sale, and the grid supplies any remaining demand.

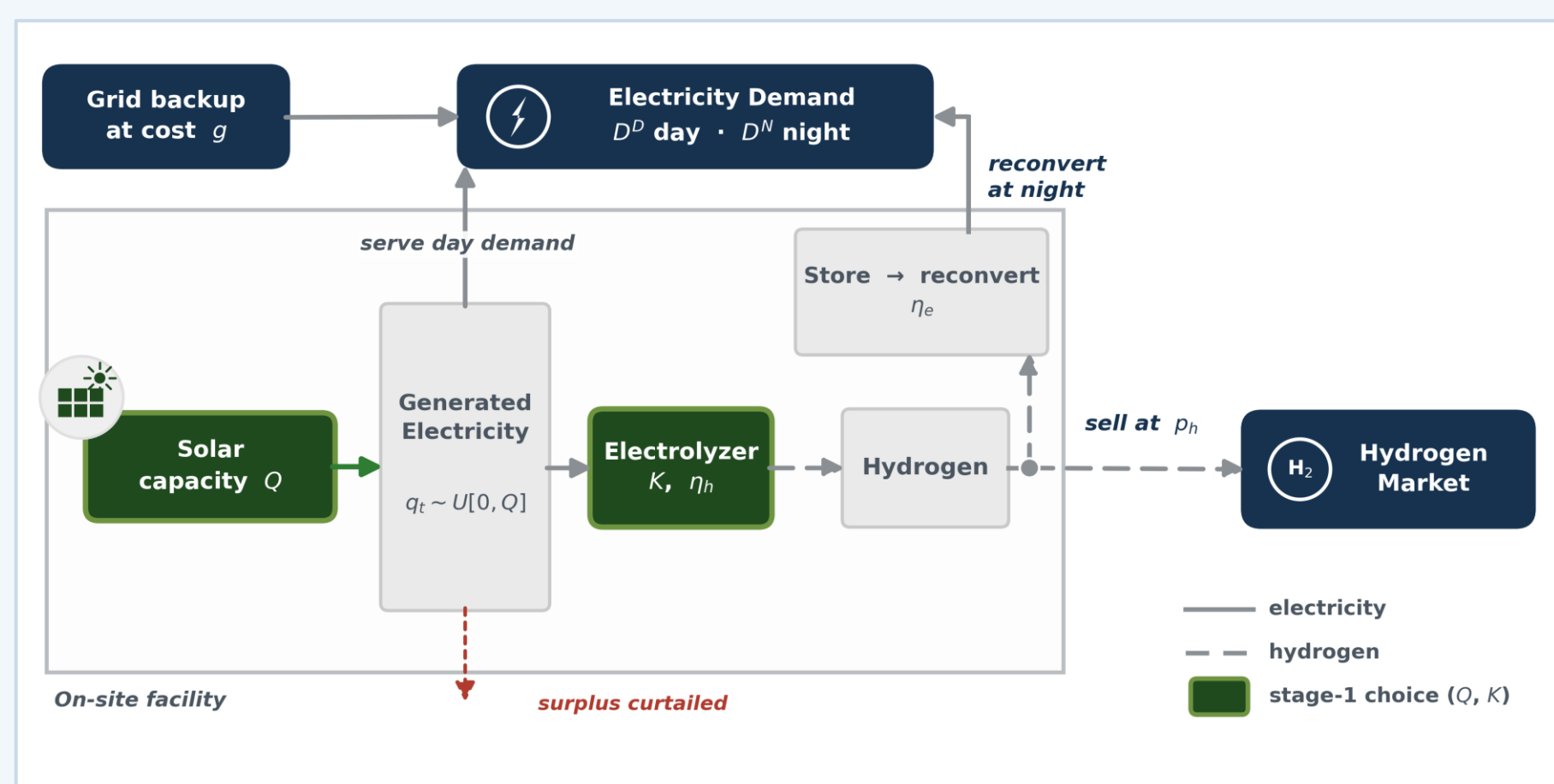


Figure 1. Energy flows. Grid electricity serves demand only; hydrogen is produced exclusively from solar power.

German benchmark calibration

Parameter	Value	Meaning
g	90 €/MWh	grid electricity price
p_h	130 €/MWh	hydrogen sale price
c_Q	40 €/MWh-day	solar capacity cost
c_K / η_h	125 €/MW-day	electrolyzer cost
η_h, η_e	0.70, 0.55	electrolysis / reversion
D^D, D^N	120, 100 MWh	day / night demand

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3 Different Ways to Use Hydrogen

Prices and conversion efficiencies determine the priority among direct electricity use, hydrogen storage, and hydrogen sales.

The operating regime is therefore not assumed; it emerges endogenously from market conditions.

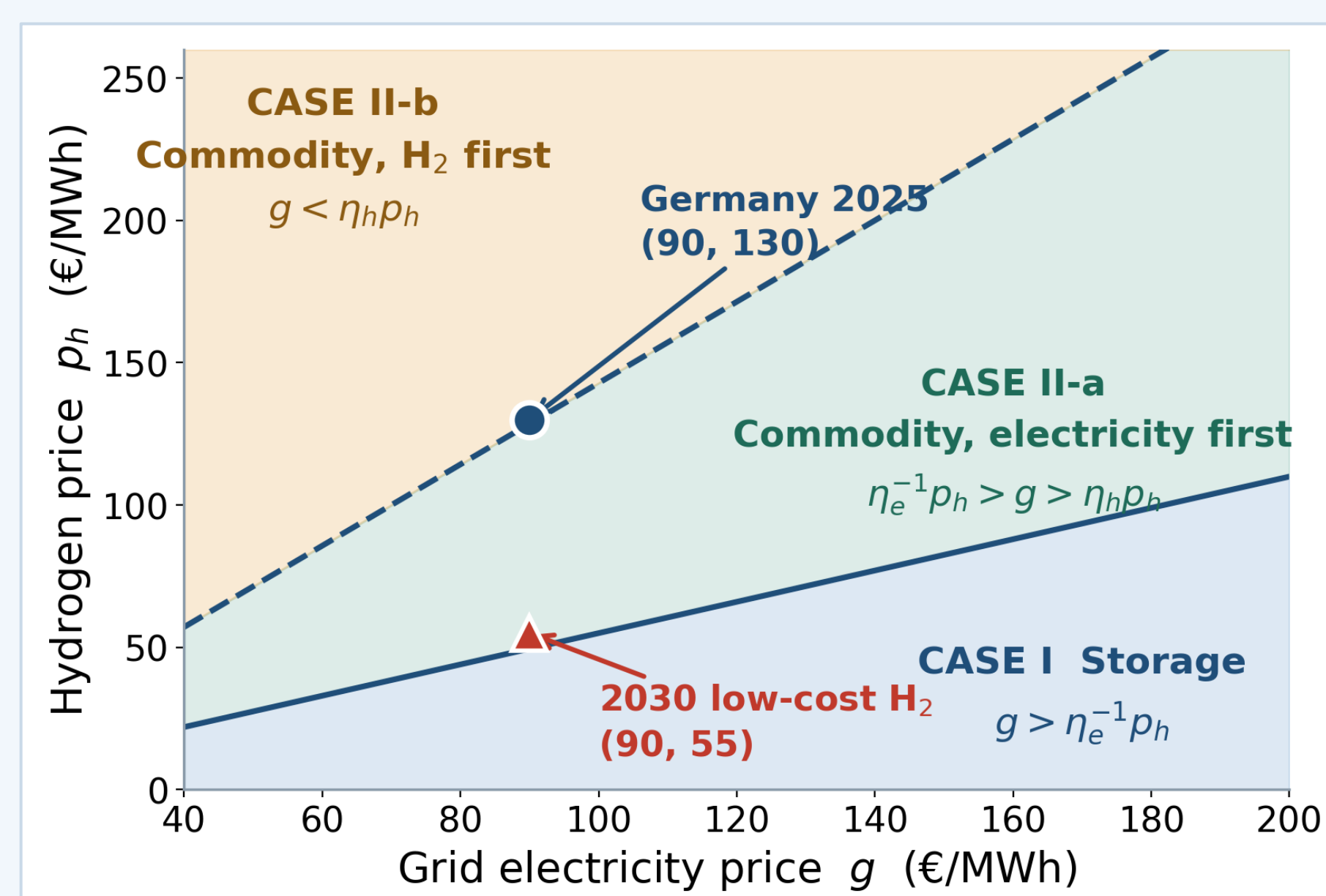


Figure 2. Prices and efficiencies decide which of the three regimes applies.

Case	Regime	What happens
I	Storage	Hydrogen is stored and reconverted at night
II-a	Sell, power first	Demand is met first; surplus becomes hydrogen
II-b	Sell, hydrogen first	Hydrogen is made first; demand takes the rest

NEVER BOTH AT ONCE

Except at the regime boundaries, hydrogen storage and sale simultaneously is never optimal.

4 What to Build

The storage and power-first regimes each give a closed-form optimum for both capacities at once, a newsvendor rule in which capacity scales with site demand and with the square root of a price-to-cost ratio.

The hydrogen-first regime is different, investment changes sharply as the hydrogen price rises:

Hydrogen price	Optimal electrolyzer
below the threshold	Not worth building: solar only
just above it	Finite positive solar and electrolyzer capacity
higher still	No finite unconstrained optimum, profit keeps growing

At high hydrogen prices, scale must be limited by factors outside the model, such as land, grid access, or market size.

SOLAR AND ELECTROLYSIS ARE COMPLEMENTS

Cheaper electrolyzers raise optimal solar capacity too, but only once building one is worthwhile at all. At the zero corner, electrolyser subsidies change nothing.

5 The Investment Paradox

Dispatch and investment switch at different thresholds. Between them lies a mismatch wedge: hydrogen has dispatch priority, yet no electrolyzer should be installed.

$$\mathcal{W}(g) = \left\{ p_h : \frac{g}{\eta_h} < p_h < p_h^+ \right\}$$

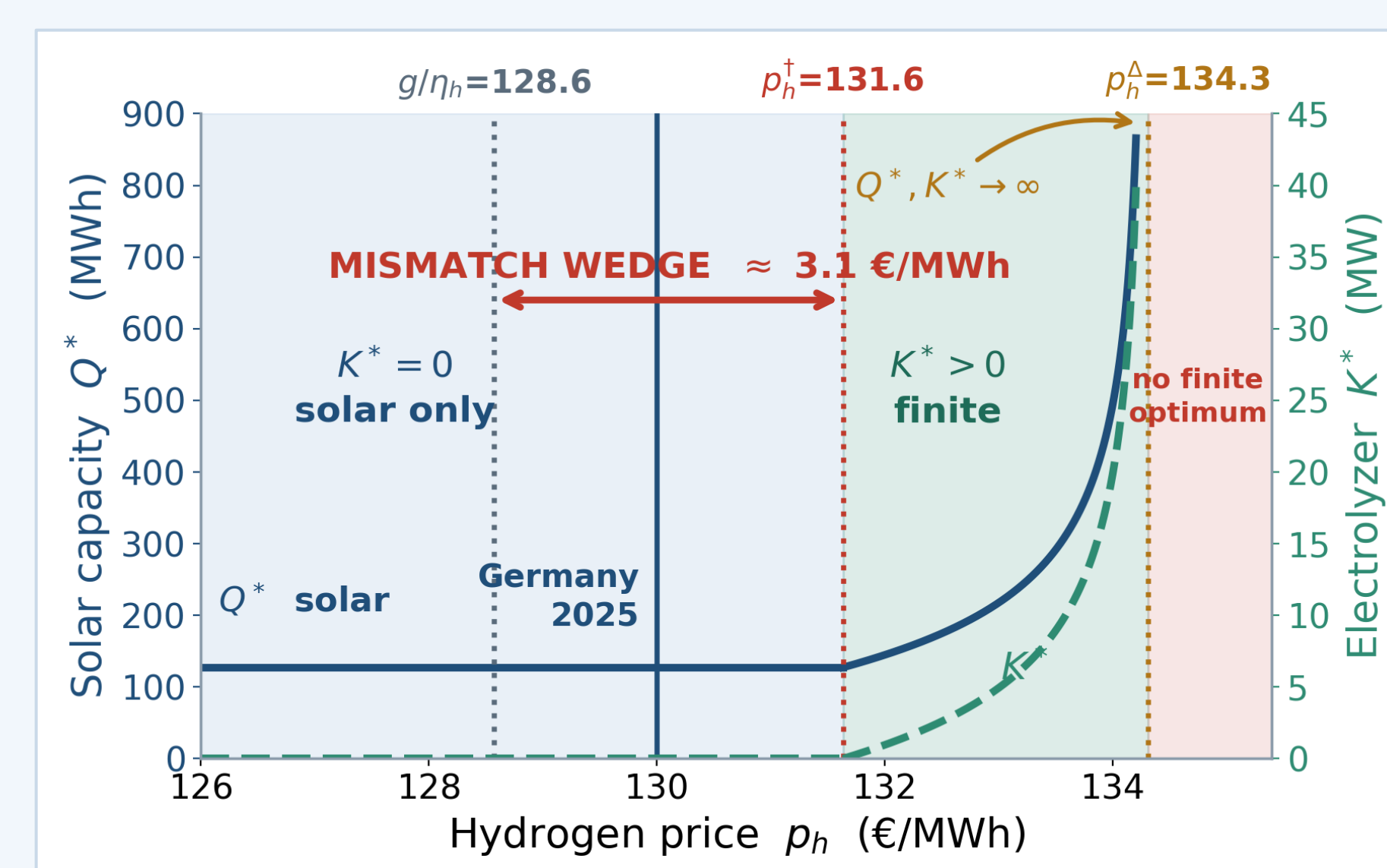


Figure 3. Germany 2025 sits 1.6 €/MWh below the price at which an electrolyzer becomes worth building.

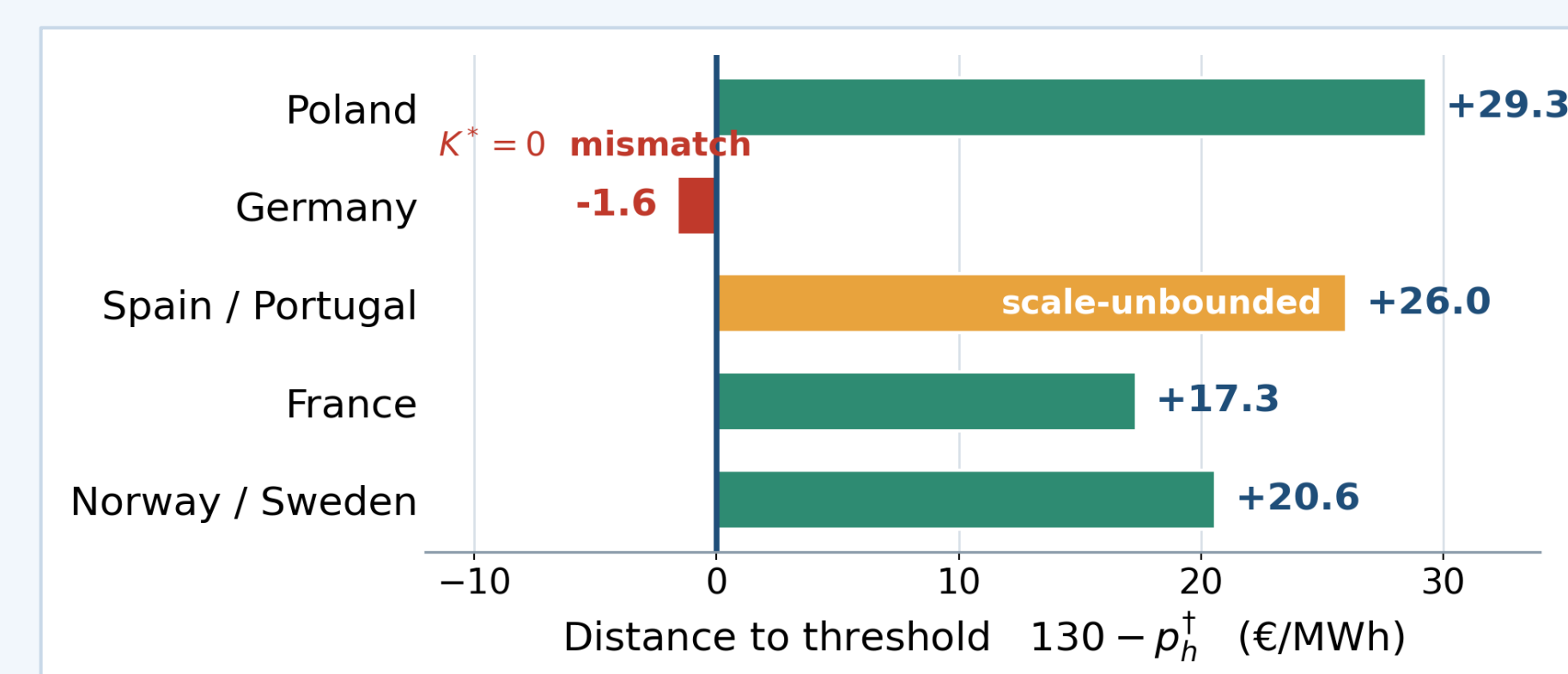
GERMANY 2025

Dispatch says hydrogen first. Investment says build no electrolyzer.

A roughly 16% reduction in electrolyzer cost would make investment break even.

6 Across Europe

Holding the hydrogen price fixed and varying electricity price and solar cost, five European market archetypes fall into different investment outcomes. Germany is the only one inside the mismatch wedge.



7 Conclusion

- Being in the right regime is not a business case. Hydrogen winning on dispatch does not mean an electrolyzer is worth building.
- Dispatch and investment have different thresholds. The mismatch between them can help explain why attractive hydrogen opportunities do not immediately translate into investment.
- Policy support must cross the investment threshold to trigger electrolyzer entry. Below it, the optimum remains at ($K^* = 0$).



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