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Renewables Summit

LONDON 2024

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AURORA KEYNOTE

CO-LOCATION: THE SOLUTION WE'VE BEEN LOOKING FOR?

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Why co-location?

- What are the benefits of co-location?
- What configurations of co-location exist?

Economics of Co-location

- For a GB example, how much does co-location boost a standalone solar IRR?
- What is the optimal sizing to maximise returns?

Opportunities in Europe

- What are the push and pull factors towards co-location?
- How do these factors vary across Europe?

Source: Aurora Energy Research

Renewable generators must combat the impacts of economic curtailment, network constraints, and expensive grid connections

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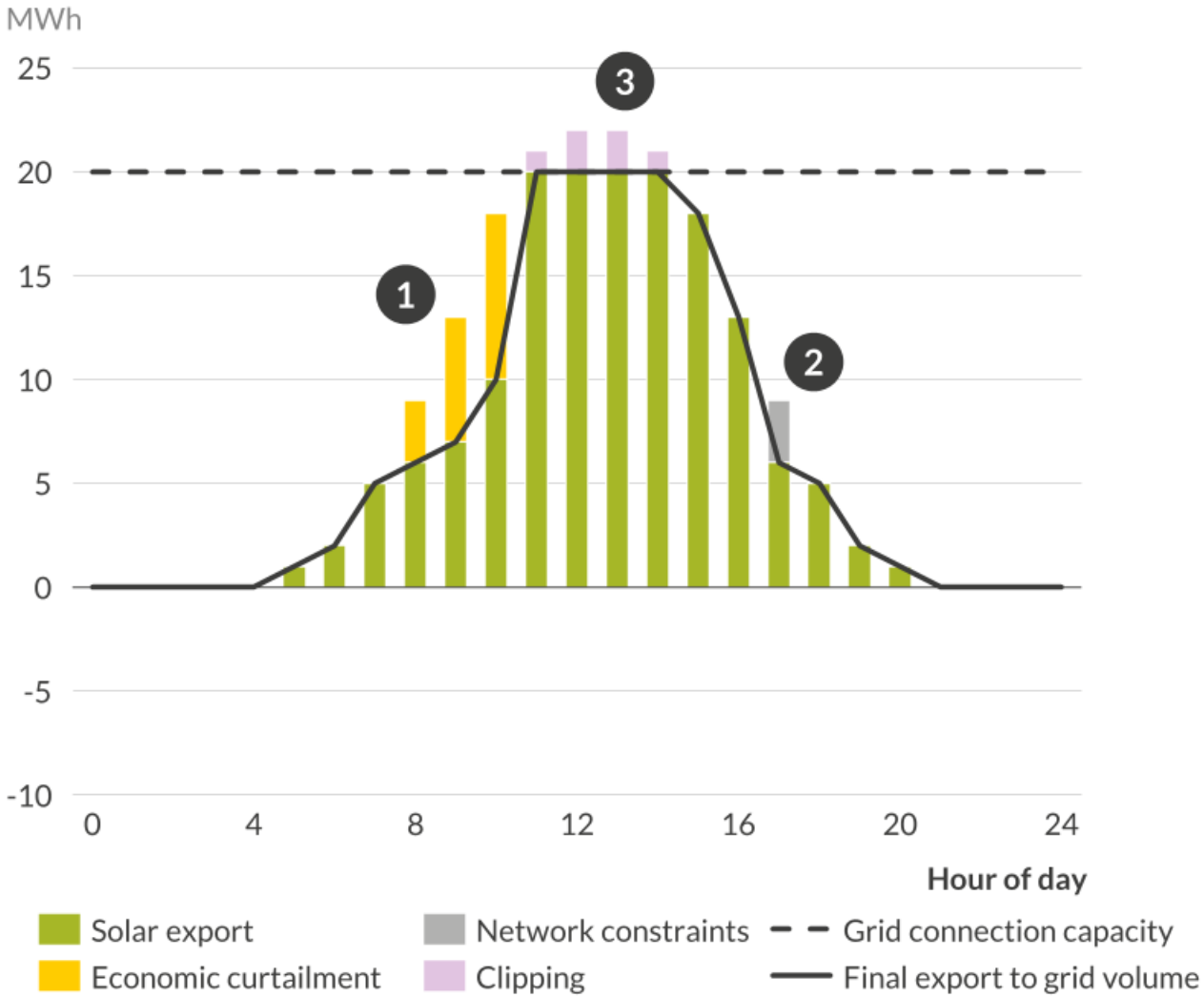
Typical daily generation profile of a standalone solar asset



1 Price Cannibalisation and Economic Curtailment

Increased renewable penetration leads to price cannibalisation, with oversupply resulting in negative wholesale prices. Assets will curtail as they cannot make back their operation costs.

2 Network Constraints

Limitations of grid infrastructure leads to localised constraints where generators may be forced to curtail, even when prices remain positive, and may not be remunerated.

3 Asset Oversizing and Clipping

To save costs on grid connections, renewable assets tend to be oversized relative to their grid connection, resulting in some generation being curtailed at full load.

Sources: Aurora Energy Research

Co-location with battery storage can help the project avoid this curtailment and add additional revenue

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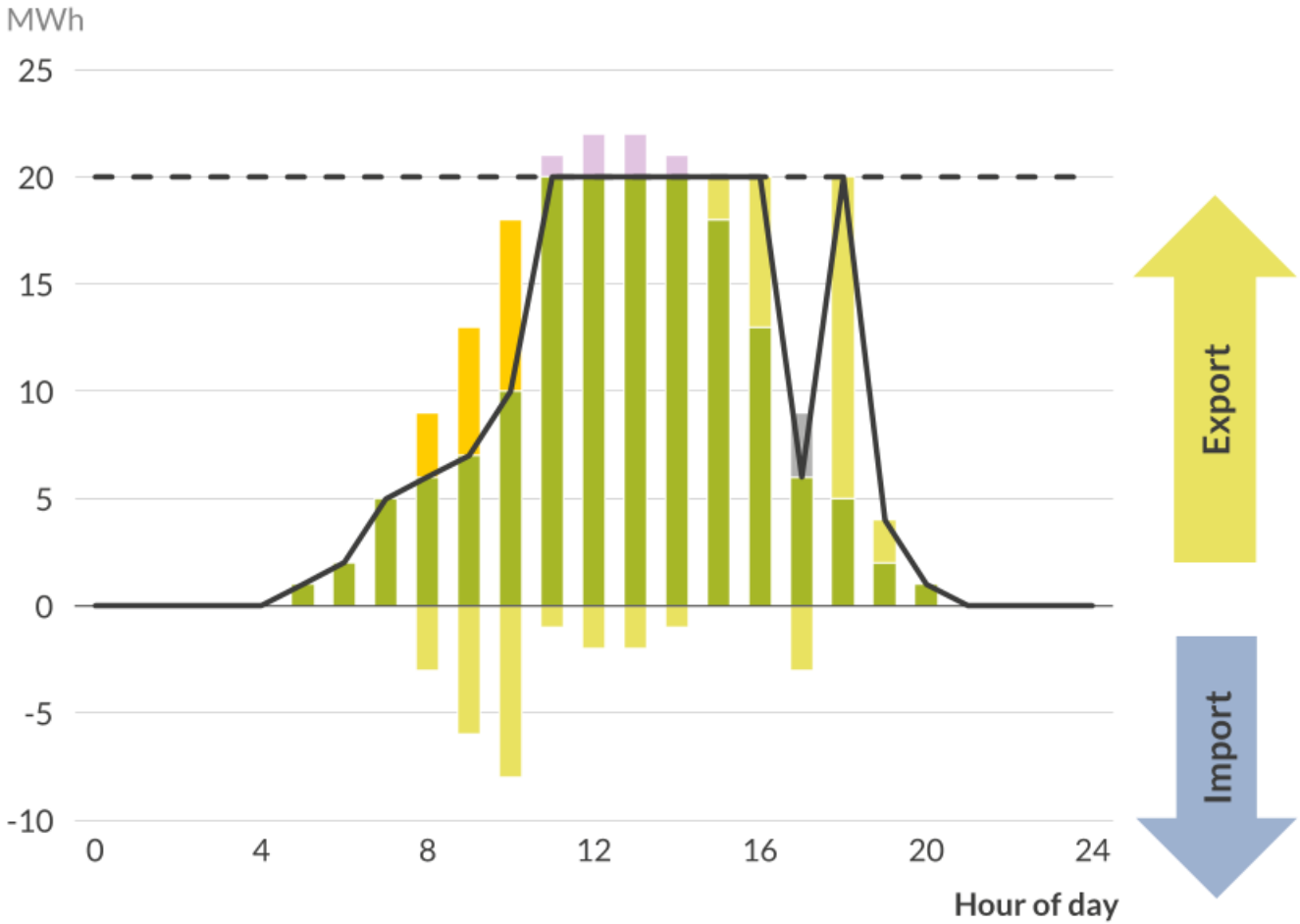
Typical daily generation profile of a standalone solar asset



Charge

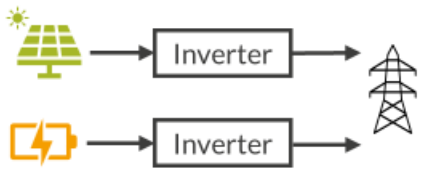
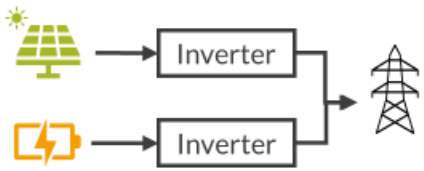
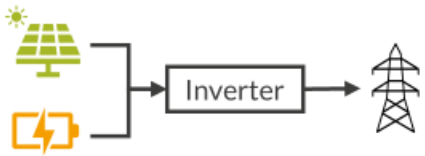
- Battery storage can charge from the otherwise curtailed solar generation, avoiding curtailment and network charges
- Most charging appears in the middle of the day when the price is low and excess solar generation is high

Discharge

- Battery storage tends to export during periods of peak demand and high prices
- Moving the absorbed solar generation from low price, low demand periods to high price, high demand periods is called load shifting and brings both economic benefits to the asset and balancing benefits to the system

Sources: Aurora Energy Research

Renewables and batteries can be co-located in multiple technical configurations, with AC co-location being the most prominent

	Assets not coupled	Solar PV AC-coupled	Solar PV DC-coupled
	Assets are on the same site, but are metered and managed individually	Solar and battery require separate inverters to connect to the grid	Solar and battery share a single inverter connected to the grid
			
Costs *CAPEX & OPEX*	No impact	Cost savings on development, balance of system, and OPEX	Further savings due to shared inverter
Portfolio diversification *Diversification of risk and revenue*	Some portfolio benefits	Full portfolio benefits due to protection from technology related downsides	
Asset oversizing *Potential to capture clipped power if RES asset is larger than grid connection*	Spilled power cannot be captured	Charging from spilled power depends on inverter sizing	Battery is able to capture spilled power without losses
Battery dispatch *Charging/discharging profile of the battery asset*	No impact	Asset output is constrained by inverter and grid connection	Asset output is constrained by the shared inverter and grid connection
Other aspects	-	Established set-up; easy-to-retrofit battery to an existing asset	Can complicate the metering of renewables generation for PPAs

Business case impact relative to standalone asset

Full benefit | Partial benefit | Neutral impact | Some negative impact | Negative impact

Sources: Aurora Energy Research

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Economics of co-location

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Opportunities in Europe

- What are the push and pull factors towards co-location?
- How do these factors vary across Europe?

Source: Aurora Energy Research

Developers must consider a potential site's yield, including curtailment and the type of connection available to determine profitability

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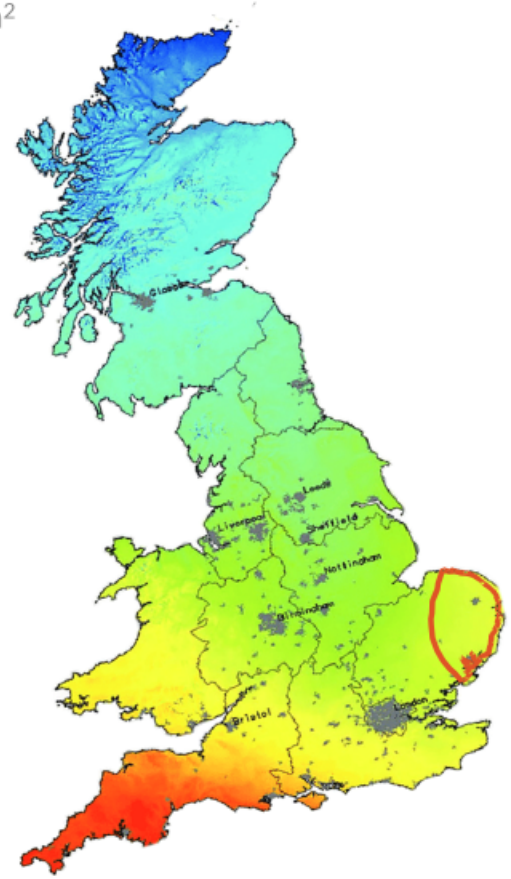
South England has the highest load factors, leading to higher revenues

Yearly total of global irradiation
kWh/m^2

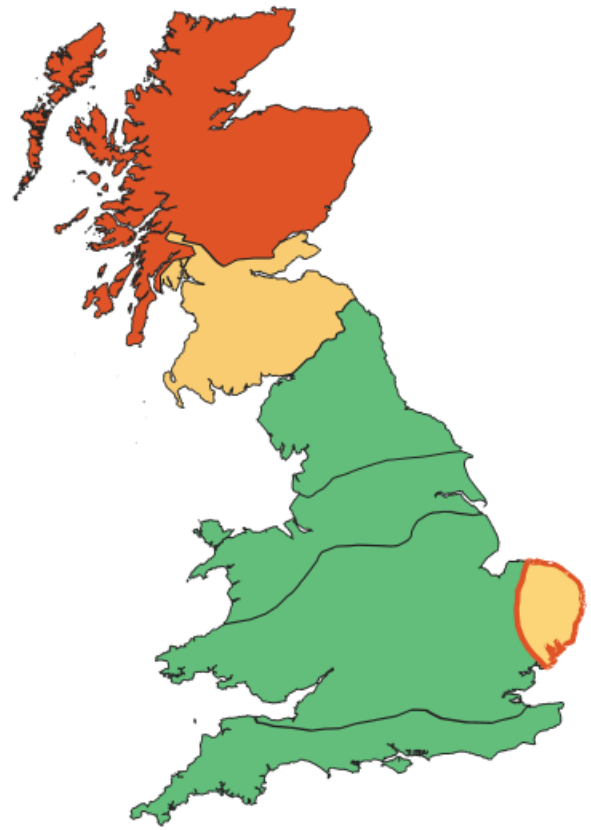


Area of interest

750 — 1100

However, East Anglia is constrained down, which will worsen over time

Expected grid constraints in 2030
% renewable generation



0% — 50%

And the majority of new build assets on the distribution network will be non-firm

Export-limited connections

- Limited by an agreed export level, above which it is curtailed

Time-limited connections

- Limited grid access during pre-agreed peak generation periods can be specified on a daily, weekly, or seasonal basis

Active Network Management

- Involves active network monitoring to identify real-time constraints
- Constraints are resolved by curtailing assets based on pre-defined principles:
  - Last in First Out (LIFO) regime
  - Pro-rata regime
  - Curtailment index regime

Sources: Aurora Energy Research, PVGIS, European Commission

Co-location boosts IRRs through cost savings, avoidance of curtailment, and additional revenues from the battery asset

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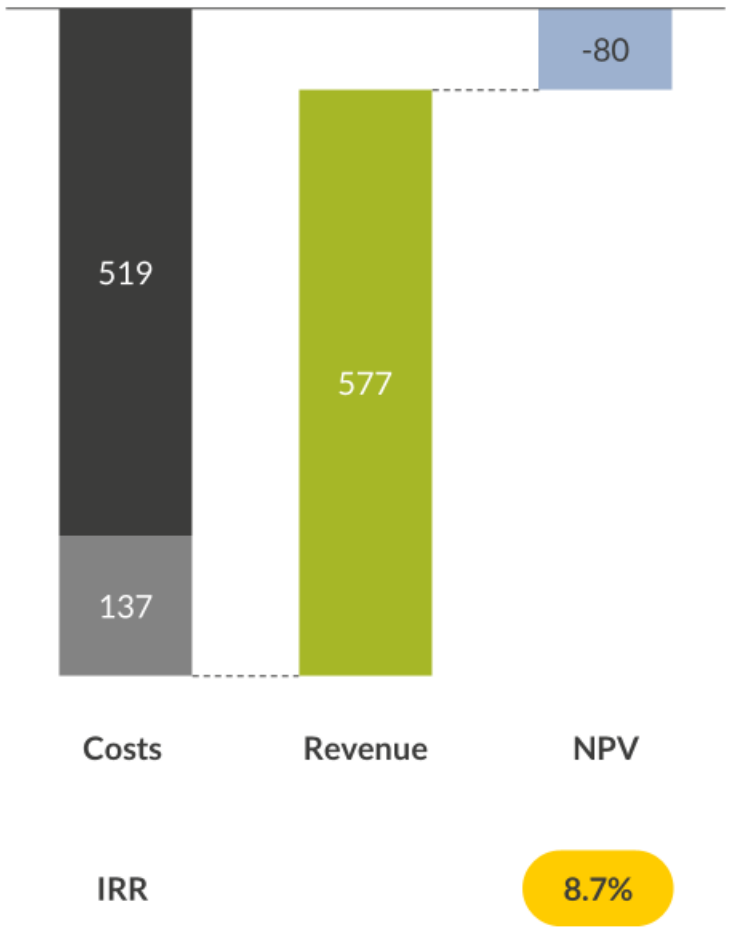
Standalone solar with firm connection NPV[1], 2025 entry
£/kW$_{grid}$



Firm connection 1.0 1.0

1) Discount rate of 11%

Sources: Aurora Energy Research

Co-location boosts IRRs through cost savings, avoidance of curtailment, and additional revenues from the battery asset

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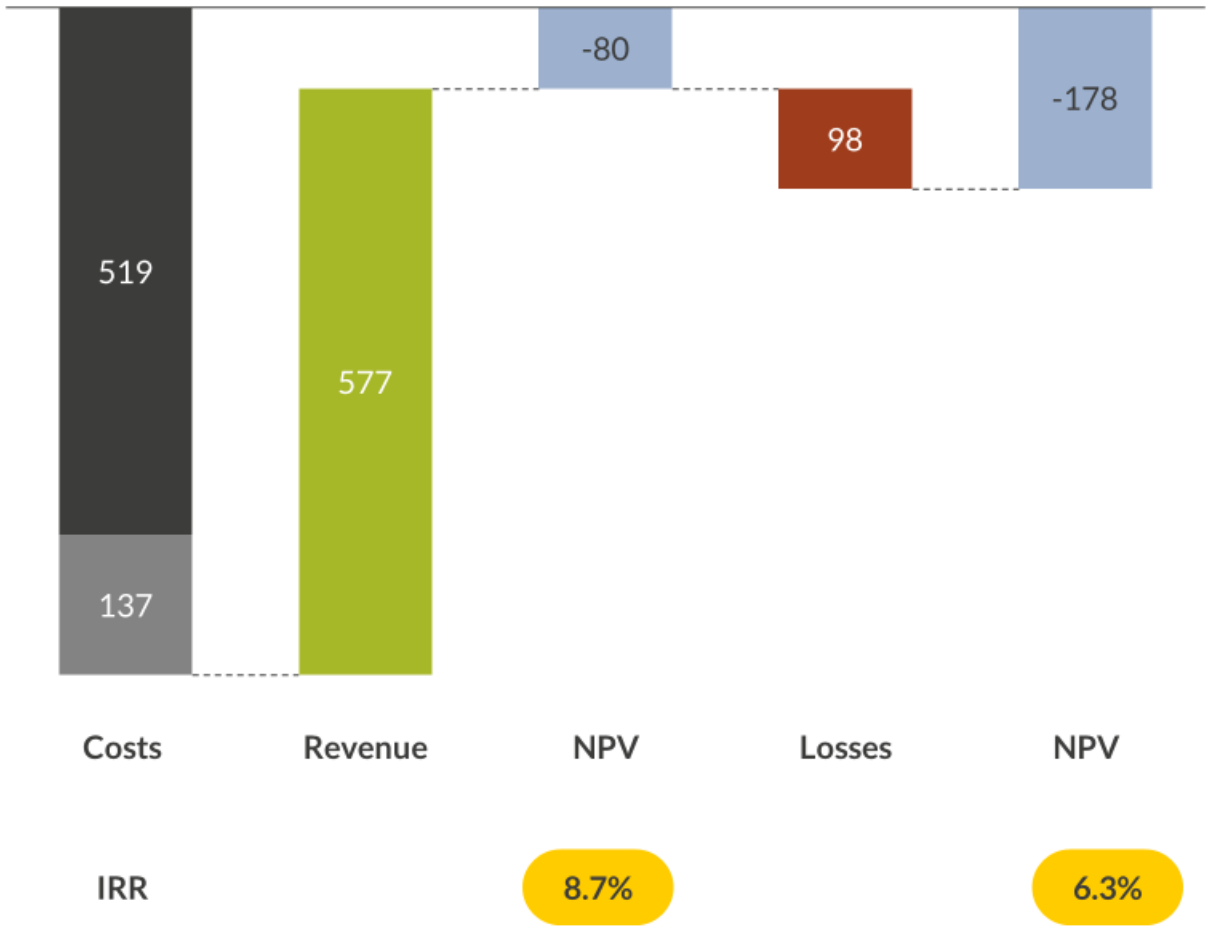
Standalone solar with non-firm connection NPV[1], 2025 entry

£/kW$_{grid}$

Non-firm connection	1.0	1.0



1) Discount rate of 11%

Sources: Aurora Energy Research

Co-location boosts IRRs through cost savings, avoidance of curtailment, and additional revenues from the battery asset

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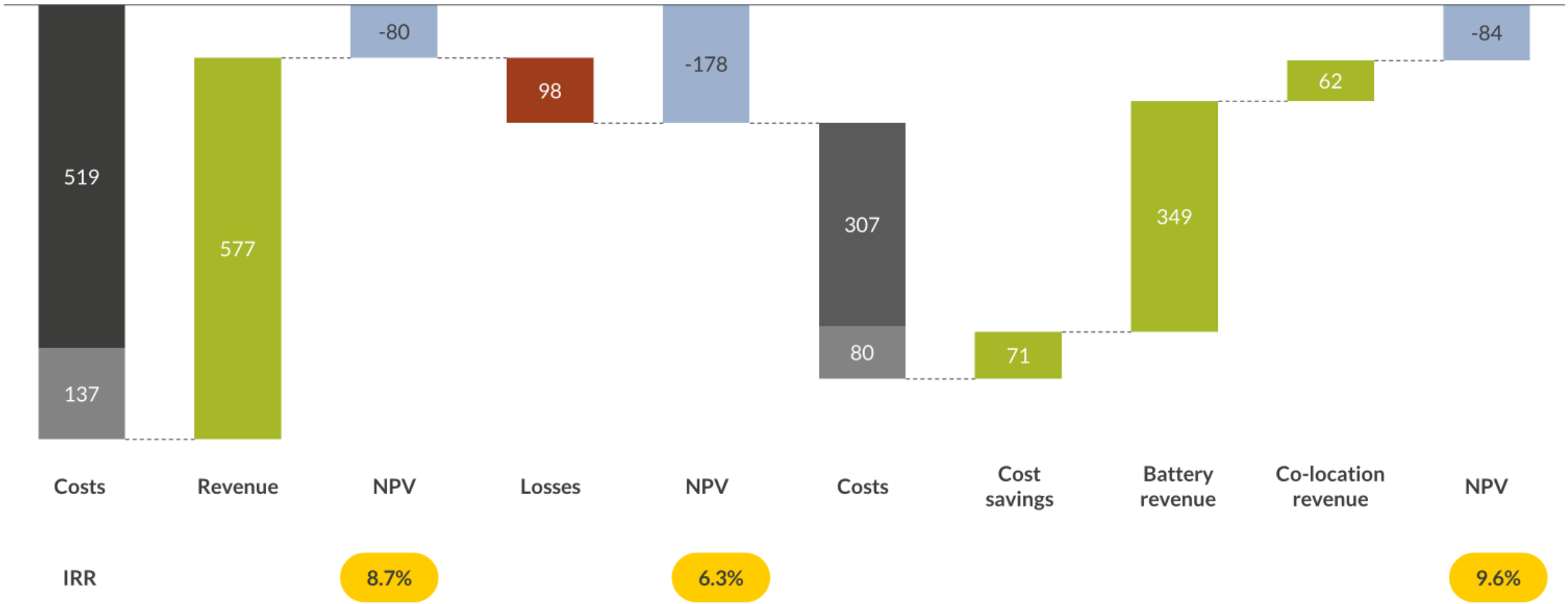
AC-co-located solar with non-firm connection NPV[1], 2025 entry
£/kW$_{grid}$

Co-located project 1.0 1.0 0.4



1) Discount rate of 11%

Sources: Aurora Energy Research

When co-located, a battery could import an average of 38% of its volumes from the renewable asset, further enhancing returns

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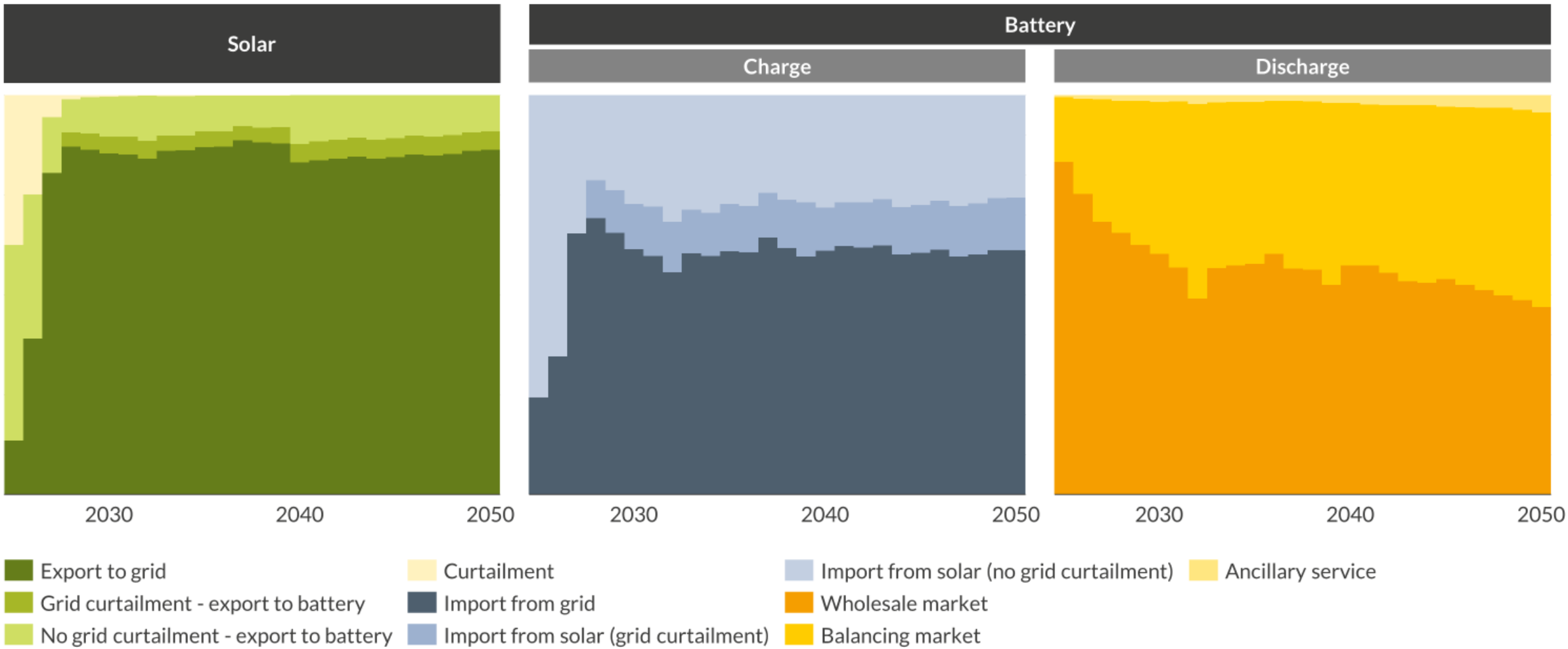
Asset Utilisation Hours Distribution
Distribution percentage



Source(s): Aurora Energy Research

Returns can vary by the sizing of the co-located elements through cost savings and the ability to transfer energy from the renewable to the battery

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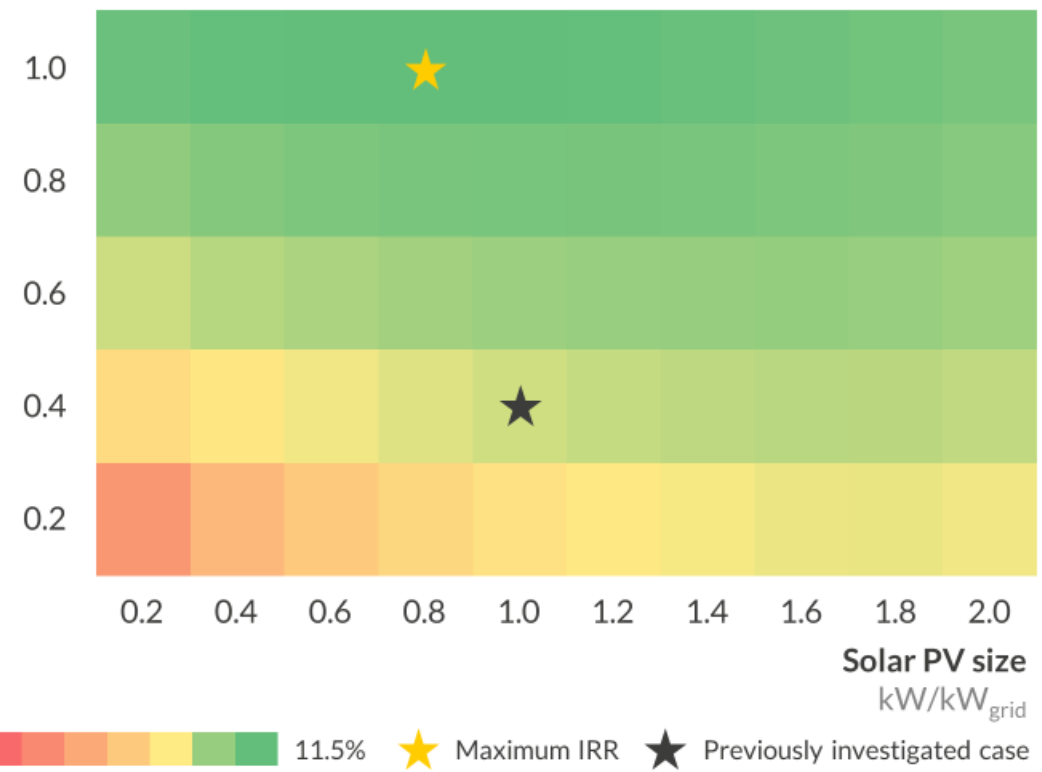
The optimal sizing ratio, to maximise IRR, favours a large battery and an undersizing of the solar asset

IRR comparison for variable co-location sizing
%, pre-tax (real 2023)



However, risk appetite will determine whether investors opt for a primarily battery storage driven business model

- High revenues can be gained by arbitraging with the day ahead, intraday, and balancing markets
- Additional revenue can be obtained by participating in ancillary services
- Battery storage merchant revenues are more uncertain given the risks of energy arbitrage
- The business model is more complex, requiring constant energy trading optimisation
- Battery storage dispatch is more optimal as solar generation does not utilise full grid connection capacity

Benefit of optimal sizing ratio | Drawback of optimal sizing ratio

1) 2025 entry solar asset assumed to have a 12.5% annual load factor co-located with a 2h 1.5 cycle battery

Sources: Aurora Energy Research

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Source: Aurora Energy Research

Examples from Europe show that co-location can be driven by market-push factors and/or policy-pull factors

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Market-driven deployment

- Capture price cannibalisation
- Unremunerated curtailment
- High imbalance costs
- Cost savings
- Revenue stacking

Example: Spain

Policy-driven deployment

- Support schemes
- Co-location a part of the national strategy
- Renewables and battery storage capacity targets
- Market access

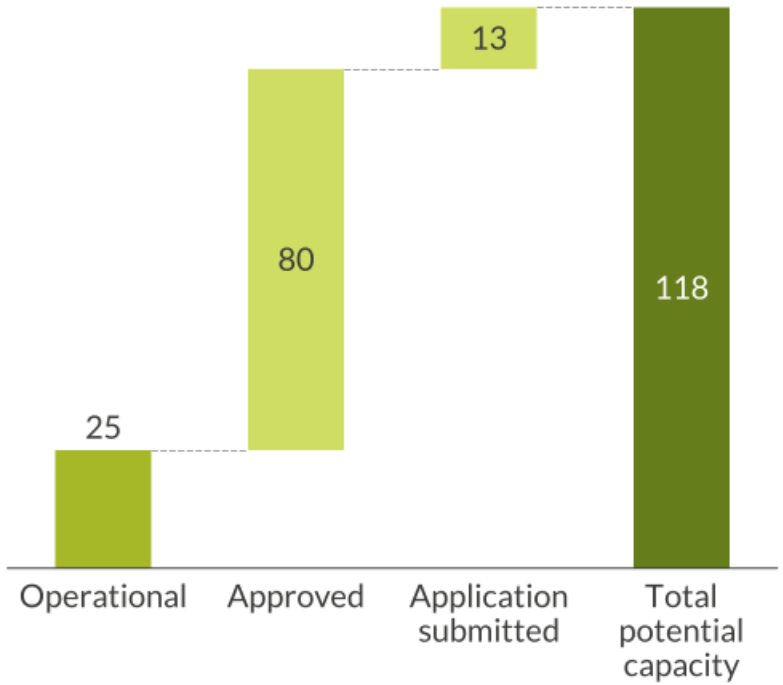
Example: Germany

Poor standalone solar economics in Spain results in co-location being the only profitable route to market, even without policy support

Spain has high load factors of 22–24%, which, combined with high penetration and increasing levels of unremunerated grid curtailment, leads to poor economics for merchant standalone solar

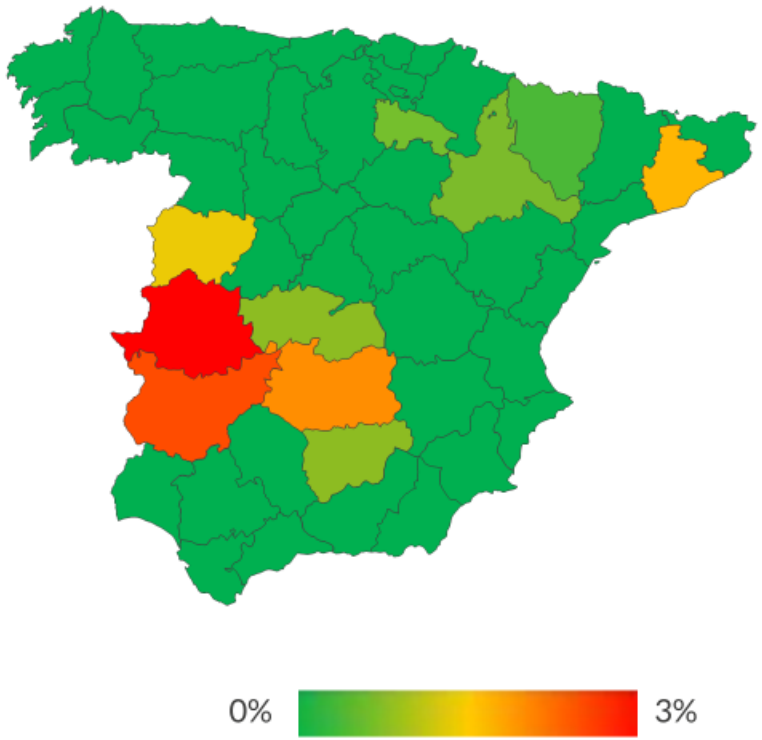
1 High load factors and strong deployment leads to cannibalisation and low power prices

Solar project pipeline
GW



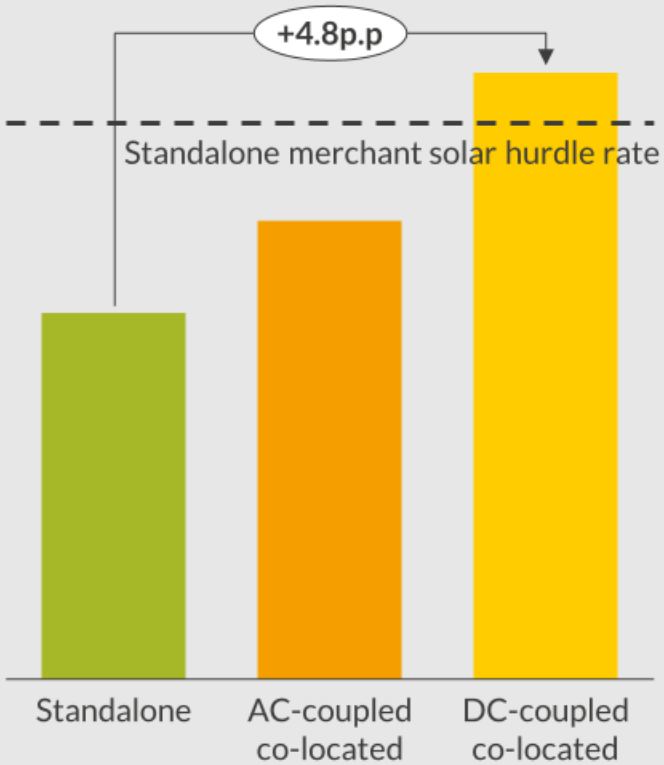
2 High levels of unremunerated grid curtailment further worsen solar economics

Solar curtailment in 2023[1]
%



Co-locating with battery storage rises the project IRR to above the hurdle rate

Merchant project IRR, 2027 entry year
%, pre-tax real



1) Curtailment from Day ahead Technical restrictions market phase 1

Sources: Aurora Energy Research, REE, ESIOS

The German innovation tenders offer a floating market premium with up to 91.2 €/MWh price floor, but grid charging is forbidden

The innovation tenders offer support to a variety of co-located projects

Technical requirements

- Storage capacity at least 25% of total capacity
- Minimum duration of 2h[1]
- Maximum solar capacity of 20 MW

However, given restrictions regarding capacity, grid charging, and market access, the support scheme does not prove the most profitable route to market in Germany

- Projects gain a floating market premium with a guaranteed price floor
- Battery storage can only access intraday and aFRR markets, prohibited from entering the Balancing Mechanism or other ancillary services
- Battery storage is prohibited from charging from the grid, limiting cycling opportunities
- All power exported from the project is fully green
- Asset sizing optimisation is limited due to capacity requirements

Benefit of scheme | Drawback of scheme

1) Must be fulfilled in every year to be eligible for subsidies. Therefore, due to degradation, either an initially longer storage duration or restacking of the battery must be considered.

Sources: Aurora Energy Research, Bundesnetzagentur

Key takeaways

1. Co-locating renewables with battery storage can help mitigate the effects of curtailment, both price- and grid-driven, and save costs by sharing a grid connection

2. Within GB, co-locating with battery storage improves the IRR of a non-firm solar asset by 330 bps, exceeding the profitability of a firm standalone asset

3. Co-location deployment can be driven by poor standalone renewable economics, such as in Spain, or through policy intervention, such as in Germany, but its vital support measures are well designed to avoid unwanted side effects

Generate bespoke co-location investment cases using our leading battery analytics software, Chronos

CHRONOS

Now available in

Great Britain

Iberia

Australia NEM

Italy

Compare market attractiveness across 12 European markets for co-location with our new report

European Renewable Co-Location Report

June 2024

Sources: Aurora Energy Research

Details and disclaimer

Publication
Co-location: the solution we've been looking for?

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