

# AURORA Renewables Summit

LONDON 2024



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**AURORA KEYNOTE**

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

## Why co-location?

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

## Economics of Co-location

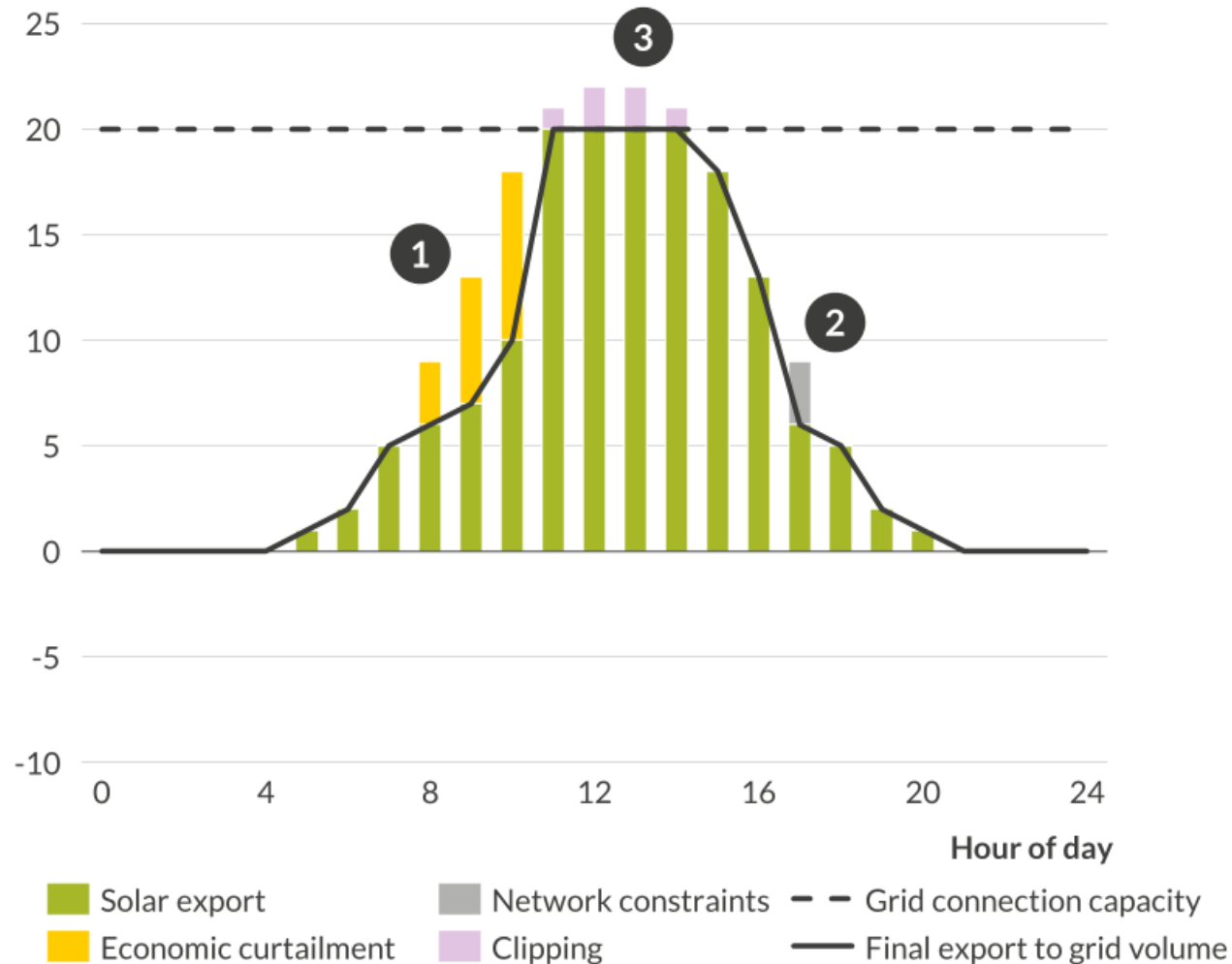
- For a GB example, how much does co-location boost a standalone solar IRR?
- What is the optimal sizing to maximise returns?

## Opportunities in Europe

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

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

Typical daily generation profile of a standalone solar asset  
MWh



## 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

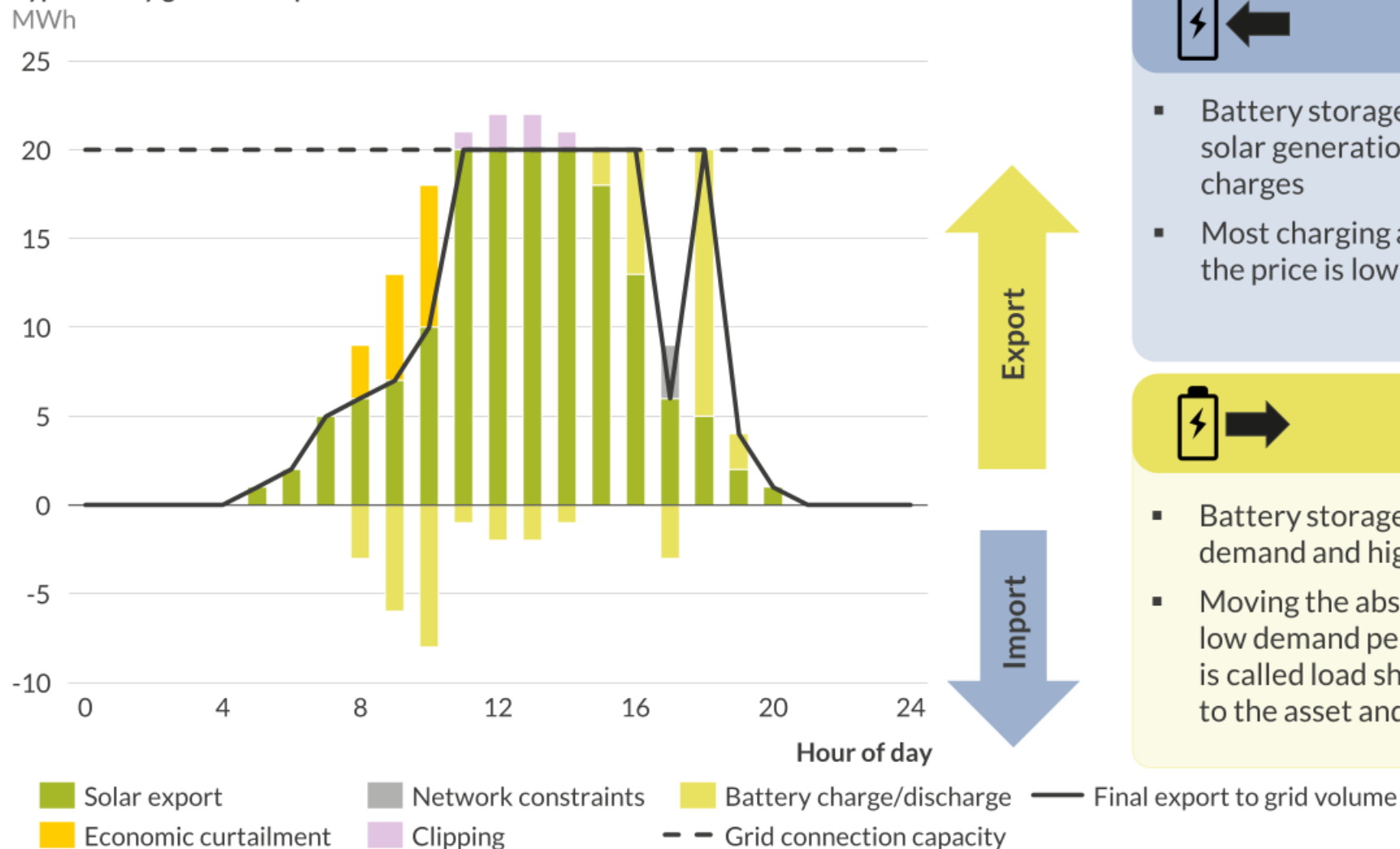
Limitations of grid infrastructure leads to localised constraints where generators may be forced to curtail, even when prices remain positive, and may not be remunerated.

## 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.

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

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

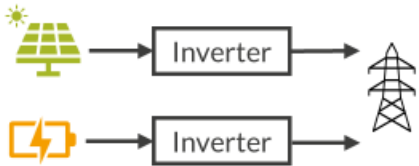
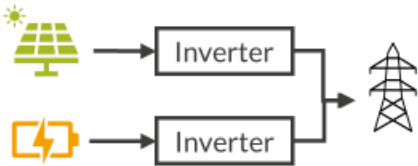
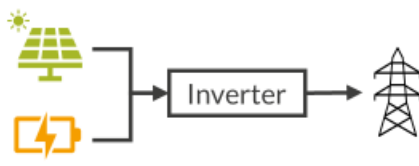


## Discharge

- 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



# 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
			
<b>Costs</b> CAPEX & OPEX	No impact	Cost savings on development, balance of system, and OPEX	Further savings due to shared inverter
<b>Portfolio diversification</b> <i>Diversification of risk and revenue</i>	Some portfolio benefits	Full portfolio benefits due to protection from technology related downsides	
<b>Asset oversizing</b> <i>Potential to capture clipped power if RES asset is larger than grid connection</i>	Spilled power cannot be captured	Charging from spilled power depends on inverter sizing	Battery is able to capture spilled power without losses
<b>Battery dispatch</b> <i>Charging/discharging profile of the battery asset</i>	No impact	Asset output is constrained by inverter and grid connection	Asset output is constrained by the shared inverter and grid connection
<b>Other aspects</b>	-	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
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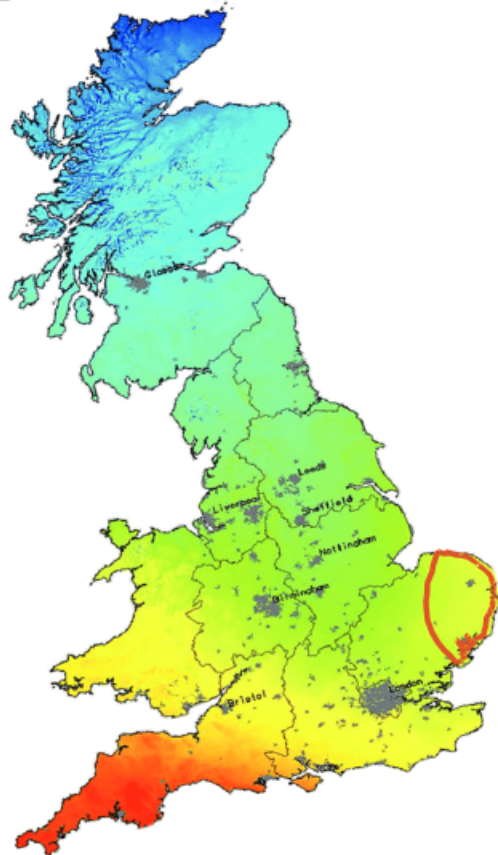
- What are the push and pull factors towards co-location?
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# Developers must consider a potential site's yield, including curtailment and the type of connection available to determine profitability



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

Yearly total of global irradiation  
kWh/m<sup>2</sup>

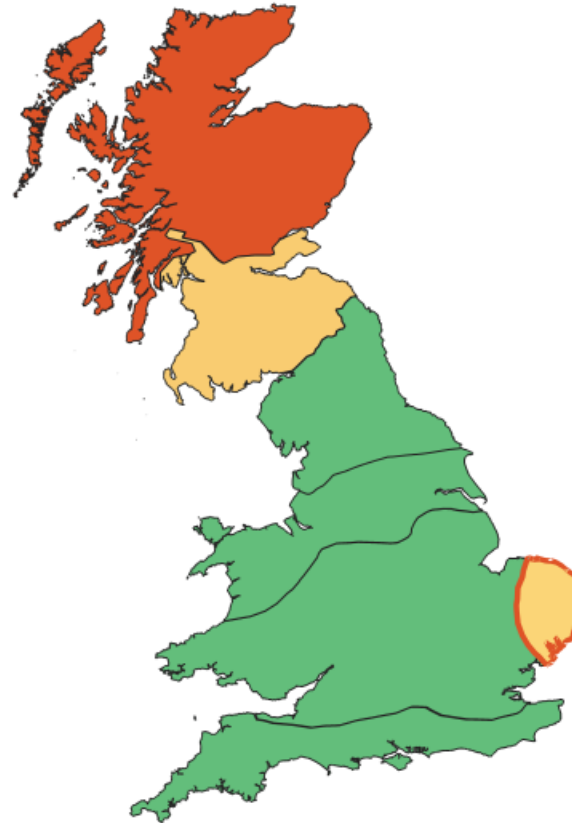


 Area of interest      750  1100



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:

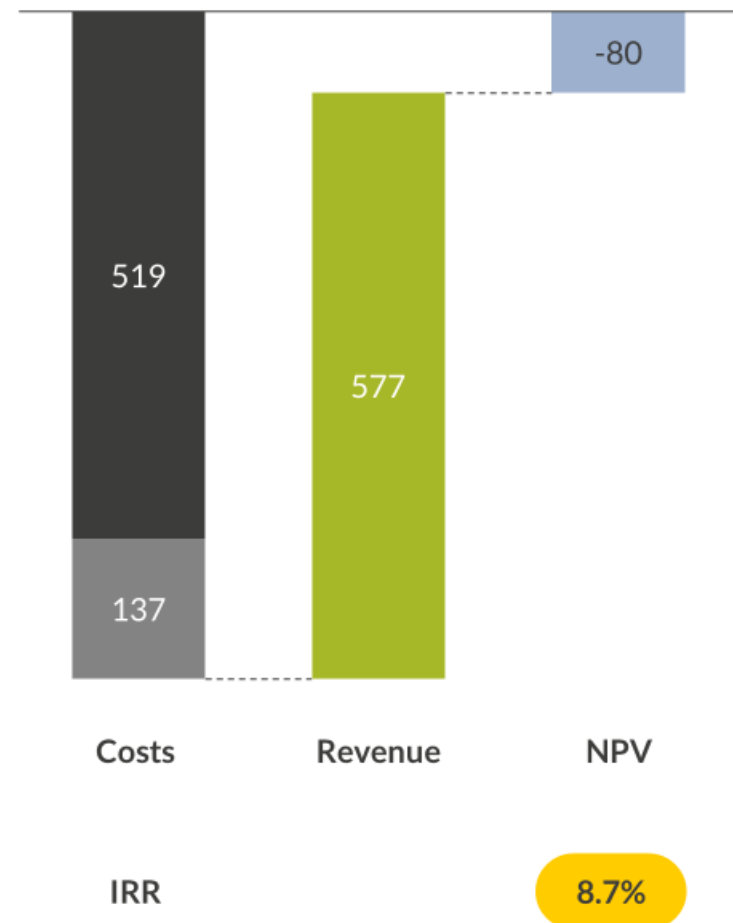
**Last in First Out (LIFO) regime**

**Pro-rata regime**

**Curtailment index regime**

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

Standalone solar with firm connection NPV<sup>1</sup>, 2025 entry  
£/kW<sub>grid</sub>



Firm connection



1.0



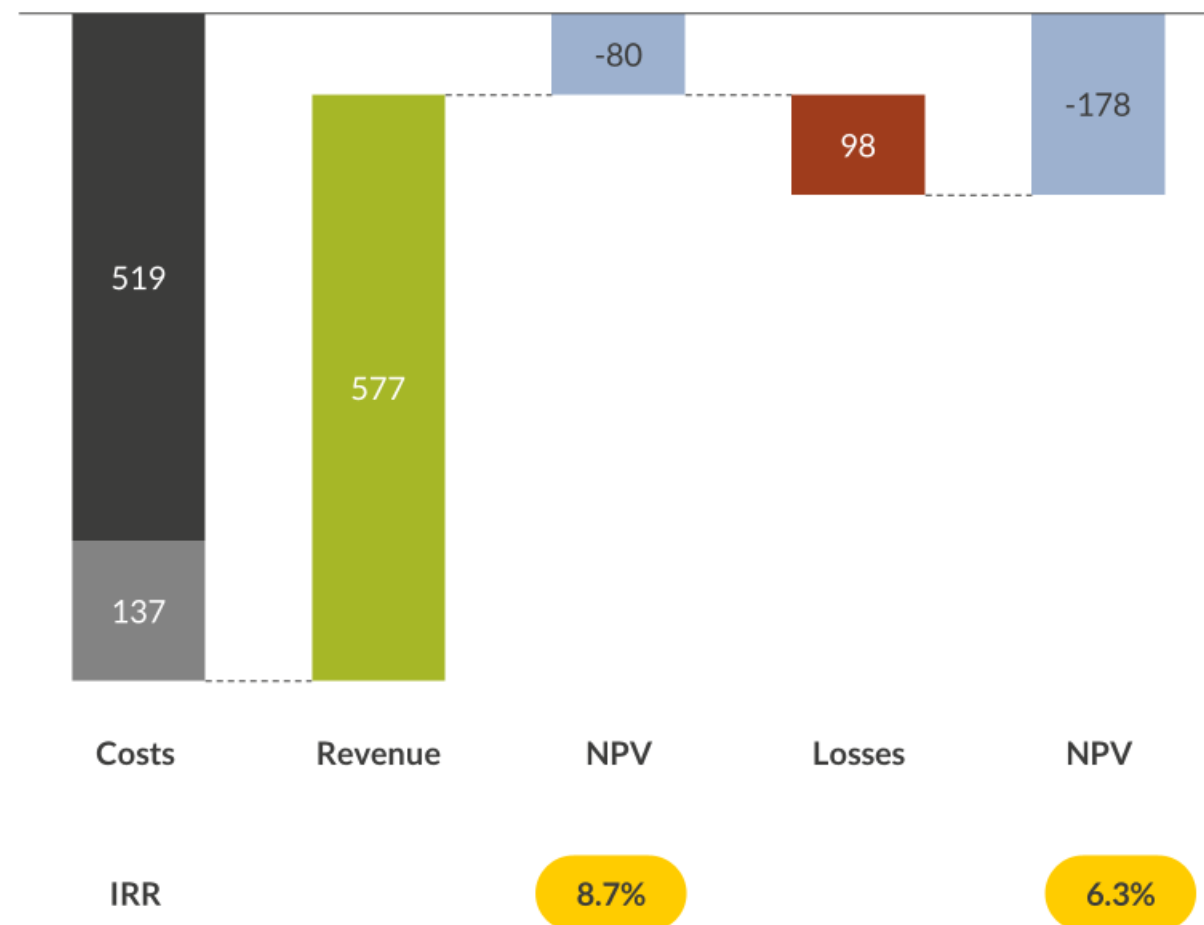
1.0

1) Discount rate of 11%



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

Standalone solar with non-firm connection NPV<sup>1</sup>, 2025 entry  
£/kW<sub>grid</sub>



Non-firm  
connection



1.0



1.0

1) Discount rate of 11%

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

AC-co-located solar with non-firm connection NPV<sup>1</sup>, 2025 entry  
£/kW<sub>grid</sub>

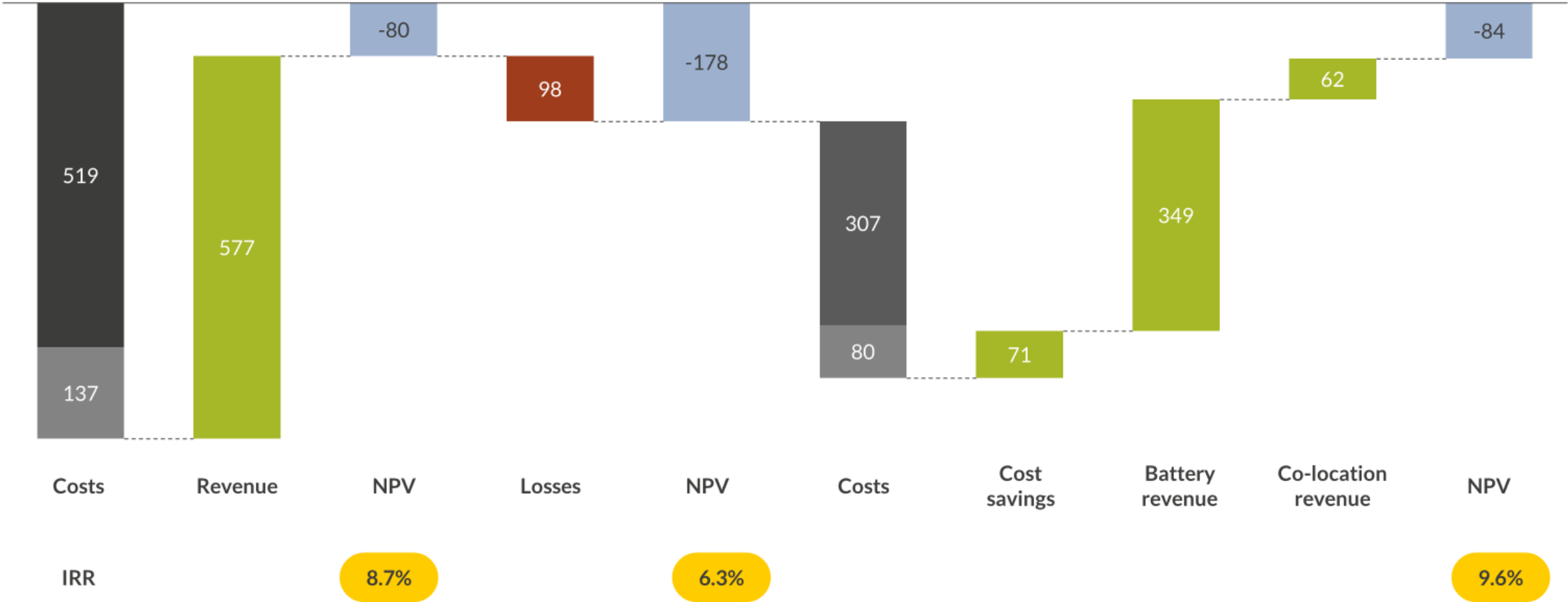


Co-located project

 1.0

 1.0

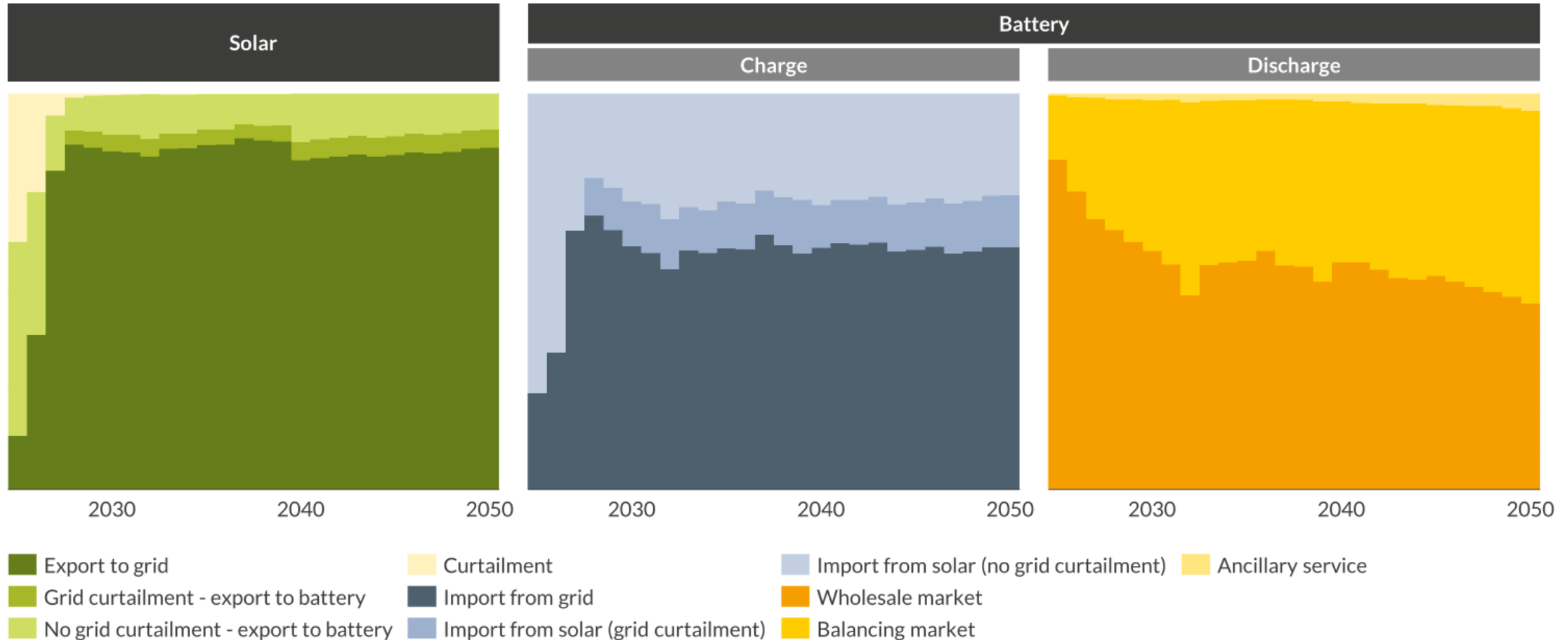
 0.4



1) Discount rate of 11%

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

Asset Utilisation Hours Distribution  
Distribution percentage



# 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

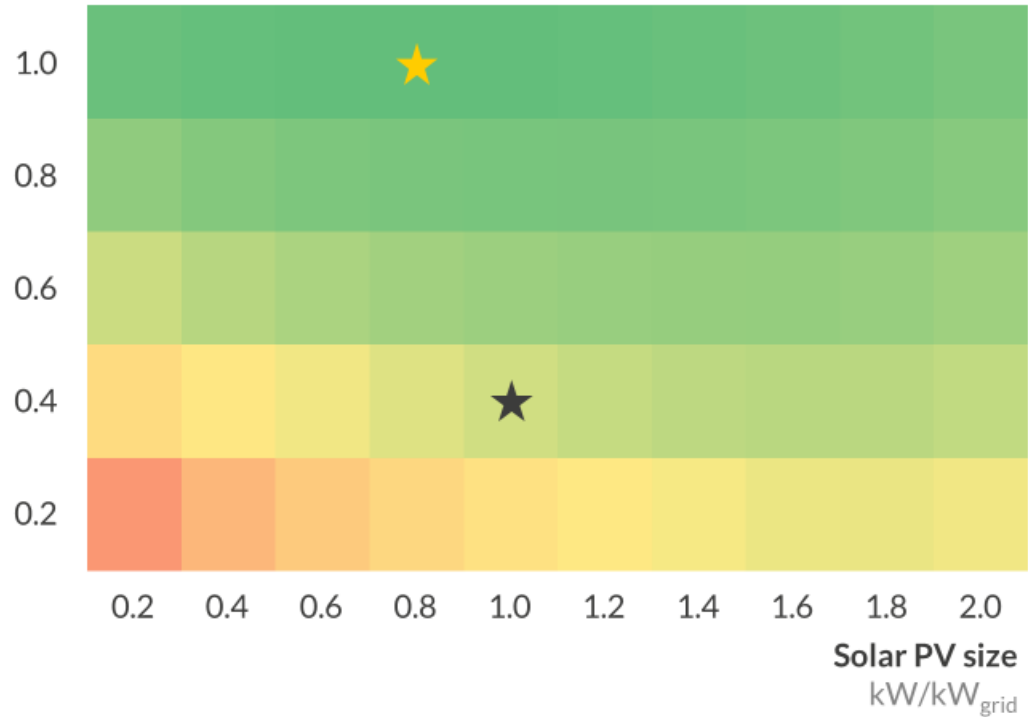


The optimal sizing ratio, to maximise IRR, favours a large battery and an undersizing of the solar asset

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

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

Battery size  
kW/kW<sub>grid</sub>



0%  11.5%  Maximum IRR  Previously investigated case



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



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



## 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

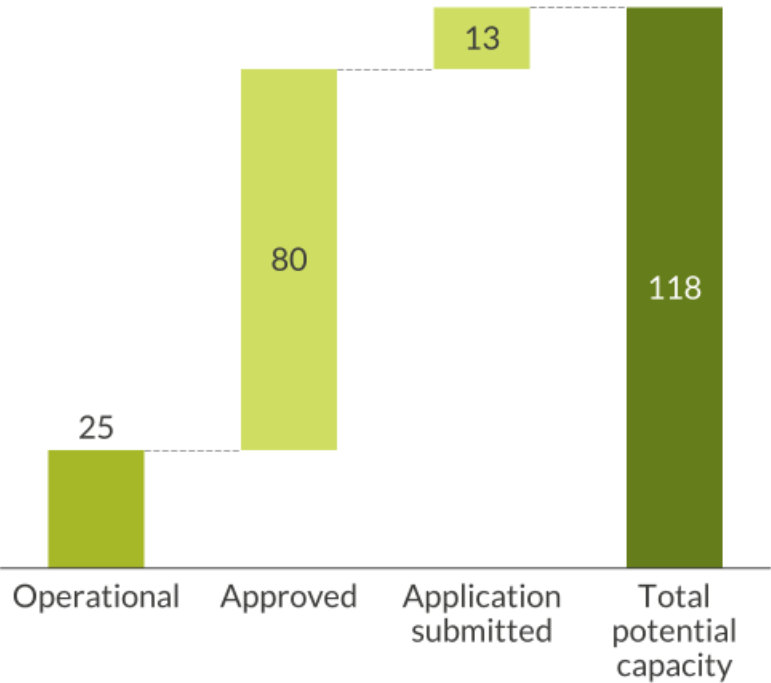
# Poor standalone solar economics in Spain results in co-location being the only profitable route to market, even without policy support



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

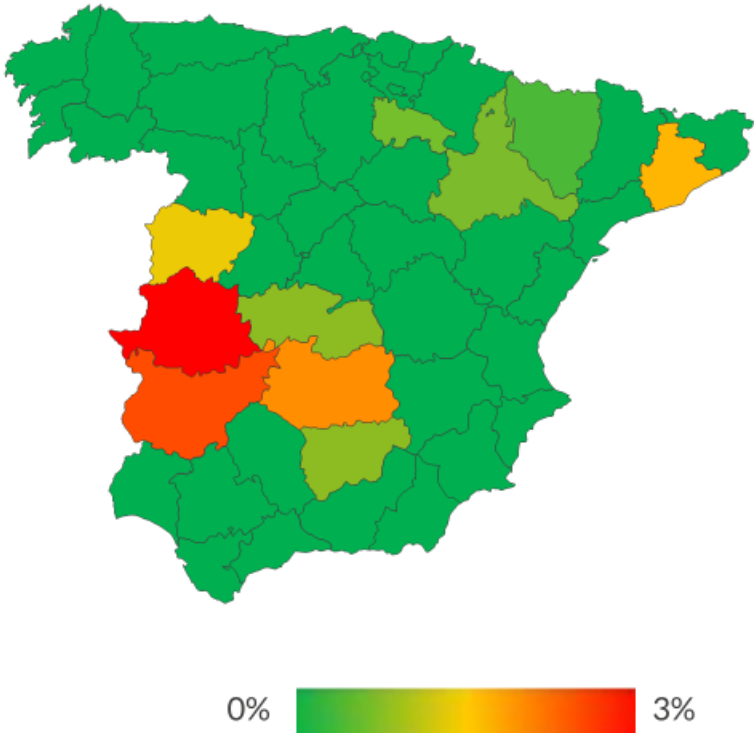
1 High load factors and strong deployment leads to cannibalisation and low power prices

Solar project pipeline  
GW



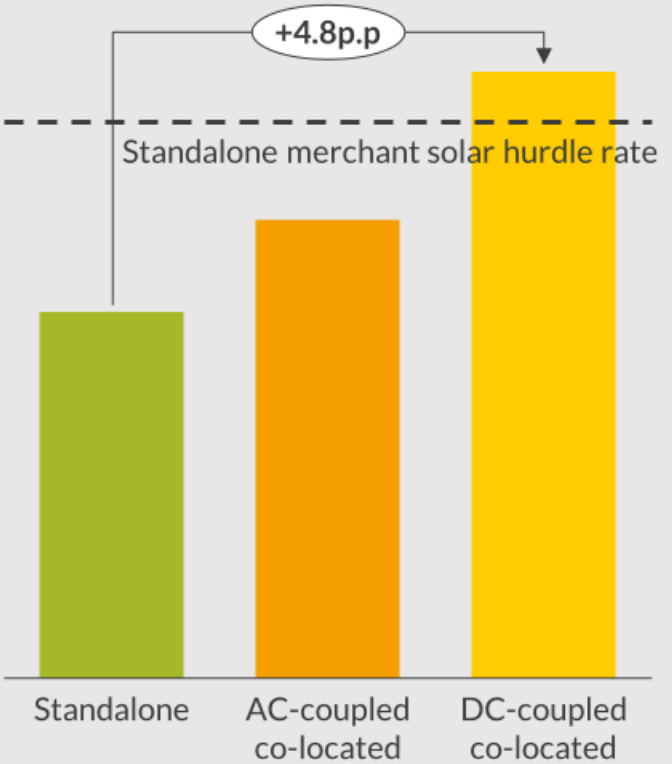
2 High levels of unremunerated grid curtailment further worsen solar economics

Solar curtailment in 2023<sup>1</sup>  
%



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

# 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


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




## Technical requirements



 Storage capacity at least 25% of total capacity

 Minimum duration of 2h<sup>1</sup>

 Maximum solar capacity of 20 MW



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.

- 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

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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



## Details and disclaimer

### Publication

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