Battery Energy Storage Systems

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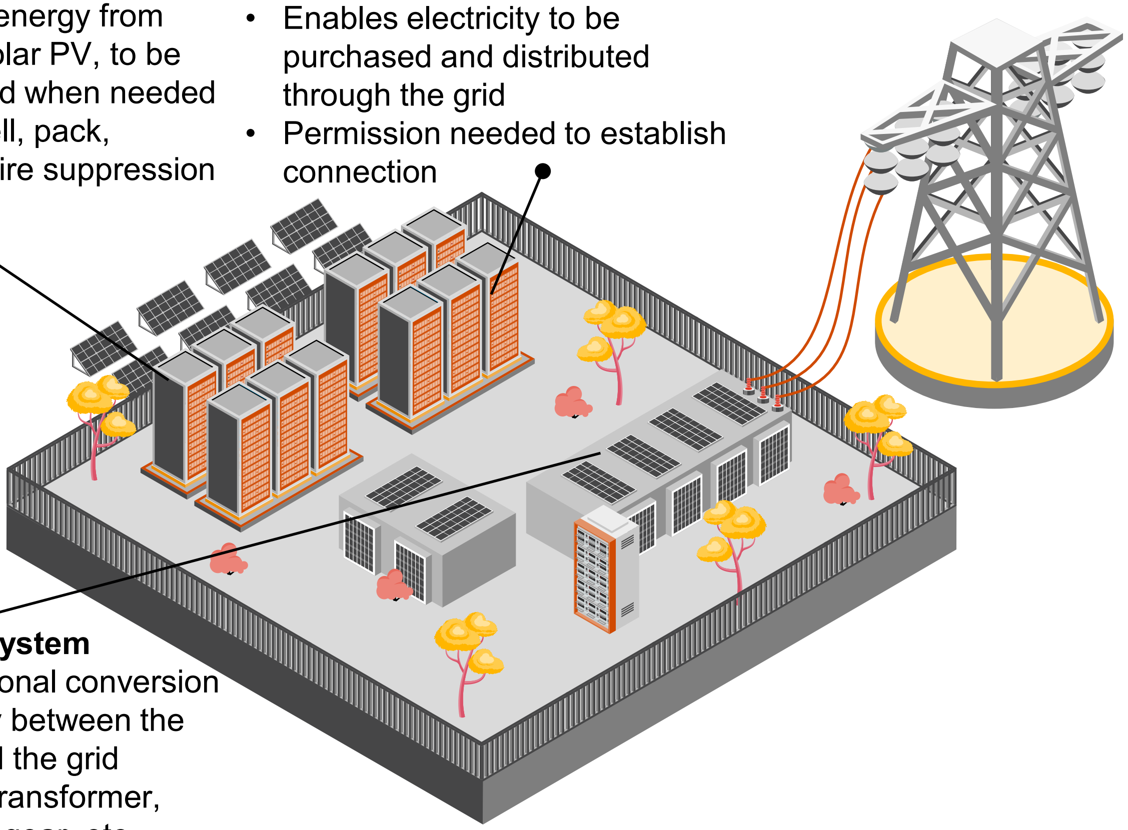
Battery energy storage systems provide multiple benefits incl. revenue potential, cost reductions, resiliency and sustainability

Battery energy storage systems (BESS) overview

Energy storage system
- Enable storage of energy from renewables, like solar PV, to be stored and released when needed
- Includes battery cell, pack, container, HVAC, fire suppression system, etc.

Grid connection
- Enables electricity to be purchased and distributed through the grid
- Permission needed to establish connection



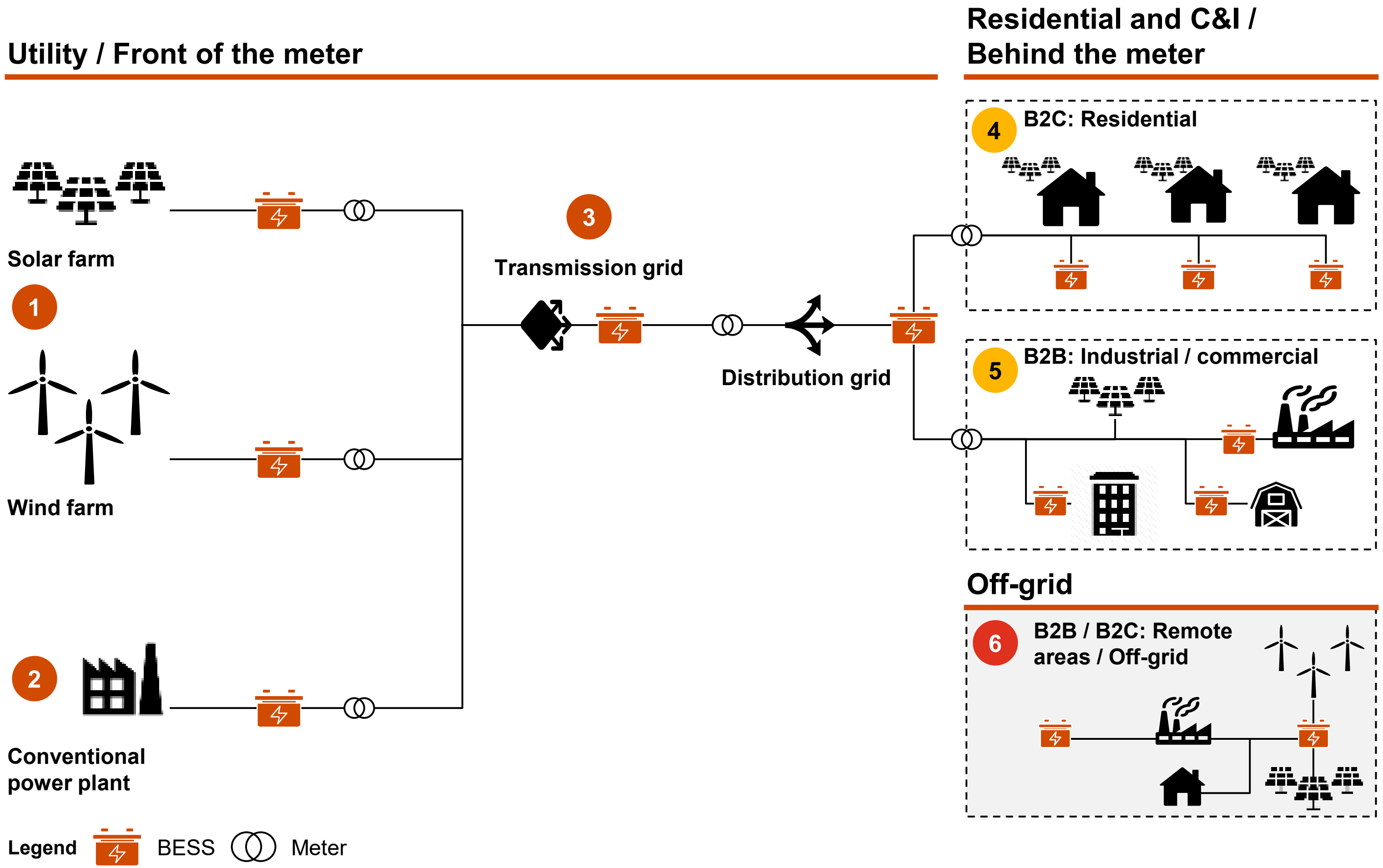
Power conversion system
- Device for bidirectional conversion of electrical energy between the battery system and the grid
- Includes Inverter, transformer, high voltage switchgear, etc.

Key benefits

Revenue	• Access to ancillary services (e.g. FCR) • Minimize curtailment, generate new revenue streams • Sell energy surplus on energy market
Savings	• Shift consumption to lower-cost hours • Optimize physical setup (e.g. oversizing) and self-consumption if co-located with on-site generation • Reduce reliance on the grid
Resiliency	• Provide backup power and black start capability • Leverage stored solar energy • Ensure power supply during outages
Sustainability	• Increases peak load for PV generation • Improves self-consumption of generation • Grows share of renewables to the grid

BESS have 'front of the meter', 'behind the meter' and 'off grid' applications

BESS applications



Location	Application	Main use cases
Front of the meter / Utility-Scale	1 Renewable power plants	✓ Arbitrage ✓ Reserves
	2 Conventional power plants	✓ Arbitrage ✓ Reserves ✓ Congestion relief
	3 Transmission / Distribution grids (stand-alone)	✓ Frequency regulation ✓ Congestion relief ✓ Peak shaving
Behind the meter	4 Residential	✓ Frequency regulation ✓ Arbitrage ✓ Peak shaving ✓ Reserves
	5 Commercial & Industrial (C&I)	
Off the grid	6 Off-grid	✓ Reserves

The BESS market is split into four customer segments – residential, small-scale C&I, large-scale C&I and front-of-the-meter Utility

BESS customer segments Typical battery size

Residential

5-15 kW

- Detached houses
- Row houses

- Lowest battery capacity
- Typically purchased in conjunction with Solar PV installation

Small-scale C&I

0.1 – 1 MW

- Farming
- Multi-unit dwelling
- Office buildings

- Low battery capacity as peak load is lower than other segments

Large-scale C&I

1 – 5 MW

- Industrial facilities
- Larger public buildings
- Standalone

- Battery size typically around 10-50% of peak load
- Used for reserve power in addition to revenue streams

Utility (Front of the meter)

5 – 300 MW

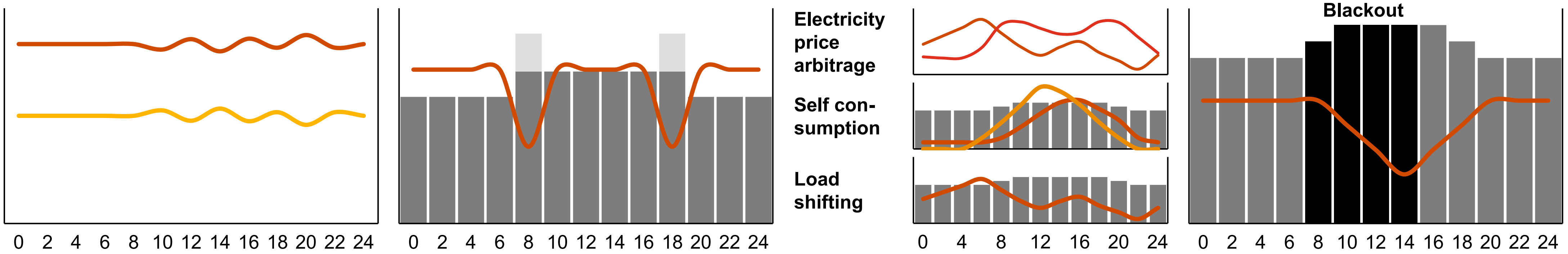
- Not connected to buildings

- Front of the meter with direct connection to the grid
- Can be built in combination with generation

BESS is utilized in different ways, with ancillary services representing the major application use case today

Current primary use cases for BESS

	Ancillary services	Peak shaving	Energy optimization	Backup power
Description	Balancing the grid to maintain ~50 Hz frequency, primarily FCR and aFRR services provided to TSOs	Reduces effect tariffs and grid connection costs by discharging BESS at peak consumption	Storing excess energy during off-peak hours to sell back to grid or use during peak demand	Replaces higher CO_2 substitute to provide back-up power and minimize operations downtime



Example customers

- Discrete manufacturing
- Power generation and transmission/distribution
- Hospitals
- Industrial real estate
- Public DC charging station
- Telecom

BESS charge · Grid frequency · Electricity price · Generation · Consumption

Sources: Desktop research, Strategy& analysis

A successful business case involves the optimal marketing of the BESS asset stacking different revenue sources from different markets

Utility use case stacking

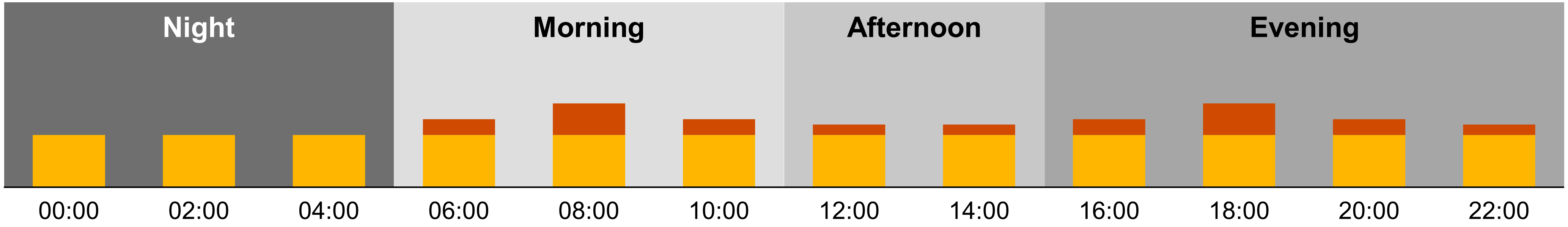
Long Term Hedging	Reserve markets[1]	Day-Ahead Market	Intraday Auctions / Continuous Market	Imbalance Management[2]
OTC	**ENTSO-E/TSOs**	**EPEX/NORDPOOL**	**EPEX/NORDPOOL**	**DELIVERY**
• Earnings from proxy and revenue hedging (Floors, Tolling) • Capacity markets • Financial asset backed trading	• Earnings from capacity prices for FCR (managed by ENTSO-E) • Earnings from frequency response capacity and actual power delivery prices (managed by local TSO)	• Earnings from day-ahead auction time spreads • Under constrained of reserve market position	• Earning from intraday auction spreads and from price volatility on continuous intraday market • Under restriction and optimization of position after day-ahead auction and respective intraday auctions	• Earnings from real time grid status • Local flexibility management

1) *In Great Britain Dynamic Response Services (DC/DM/DR) are contracted after day-ahead auctions*
2) *Only in jurisdictions wherever allowed or a Local Flexibility Market is established and/or Passive Balancing is allowed*

Deteriorating ancillary services remuneration requires ad-hoc use case stacking to unlock full BESS potential

Public EV DC charging station use case stacking

Electricity consumption



Charging station demand

Utilized use cases	**Ancillary services**	Ancillary services	**Ancillary services**	Ancillary services
	Energy optimization	Energy optimization	**Energy opt.**	Energy optimization
	Peak shaving	**Peak shaving**	Peak shaving	**Peak shaving**

: Low
: Medium
: High

Sources: Desktop research, Strategy& analysis

Accurate CapEx and OpEx estimates with proper financing are essential for changing regulatory and market conditions

Cost estimation in a BESS Project

Composition of CAPEX

CAPEX category	Description
System	• Battery cabinets • Management systems • Balance-of-system components
Grid connection	• Connection fee • Connection equipment • Energy-management system
Construction	• Engineering, procurement and construction • Labour and equipment costs
Land	• Costs associated with acquisition/leasing of land
Other[1]	• Permits, regulatory, tax

Components of OPEX

	OPEX category	Description
Variable costs	**Operations and maintenance (O&M)**	• Includes general, scheduled and unscheduled maintenance
Variable costs	**Replacement of parts**	• Replacement of consumable parts
Variable costs	**Grid fees**[2]	• Fees paid to transmission and distribution system operators
Variable costs	**Electricity costs**	• Cost of electricity used for charging and operating
Variable costs	**Optimiser costs**	• Costs incurred by optimiser
Fixed costs	**Operating labour**	• Labour for day-to-day operation
Fixed costs	**Property payments**	• Property taxes
Fixed costs	**Insurance**	• Insurance for BESS
Fixed costs	**Administrative**	• Administrative fees and labour

1) *Overall business case should appropriately consider degradation and efficiency effects*
2) *Different conditions and structures in different regions*

Within a general valuation framework regional differences should be properly considered

Overview of key European markets

	Revenue Streams								
	Long Term	Short Term	Wholesale						
Item (EU focus)	Capacity Market	Key Ancillary Services	Day Ahead	Intraday Auctions	Intraday Continuous	Real Time Grid Balancing	Local Flexibility Markets	Financing/EX	Policy Hurdles
	✗ In debate	FCR, aFRR, mFRR	✓	✓	✓	✗	~	Extension of grid fee exemption to 2029	➡
	✓	Frequency Response (DC/DM/DR), Reserve Services (STOR[4])	✓	✓	✓	✓ [2]	✓ Piclo Flex	Constructive policy framework, deep lending pools	⬇
	✓	FCR, aFRR, mFRR, and Replacement Reserves (RR)	✓	✓ [3]	✓	✓ [2]	~	Limited offtake and lending activity	➡
	✓	Primary Reserve (FCR), Secondary Reserve (aFRR), Tertiary Reserve (mFRR)	✓	✓	✓ [3]	1	~	Headwind from Terna 12-14 year inflation linked contracts backing high LTV, zonal and nodal value uplift	➡
	✓ In legislative process	FCR, aFRR, mFRR,	✓	✓	✓ [3]	1	~	Potential headwinds from capacity market introduction	⬆
	✗	FCR, aFRR, mFRR	✓	✓ [3]	✓	✓ [2]	✓ GOPACS	Grid Fees reform under discussion	➡

1) Either discouraged, restricted or no statement from responsible TSOs; 2) Generally allowed within a passive balancing grid management approach;
3) Limited liquidity depending on market conditions; 4) Expected partial or complete decommissioning
Source: Timera Energy, PwC Analysis

✓ : Yes
~ : Emerging
✗ : Restricted/No

⬇: Low
➡: Medium
⬆: High

Co-Location offers potential advantages in the joint management of a BESS and a RES-park

BESS exploits technical restrictions and grid congestion to generate additional sources of revenues

DC-Coupling

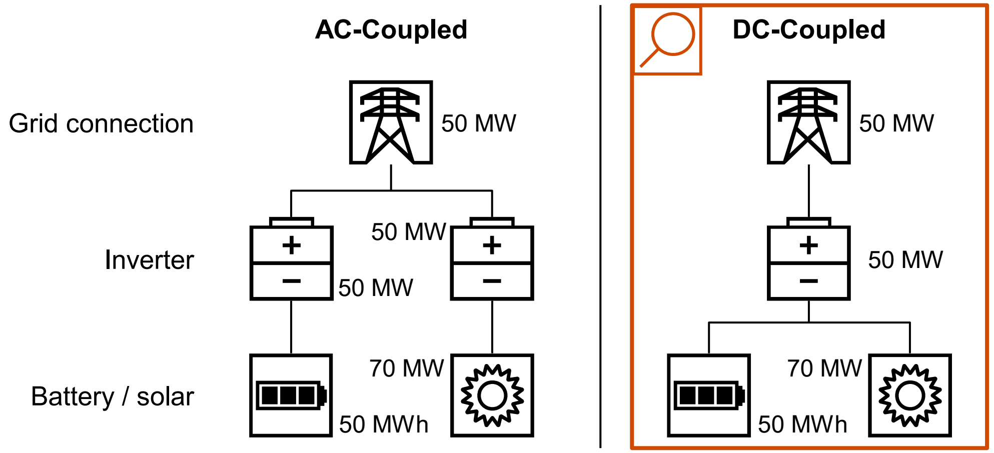
Co-location refers to a battery energy storage system physically located on the same site as generation, demand, or both, and shares a grid connection.

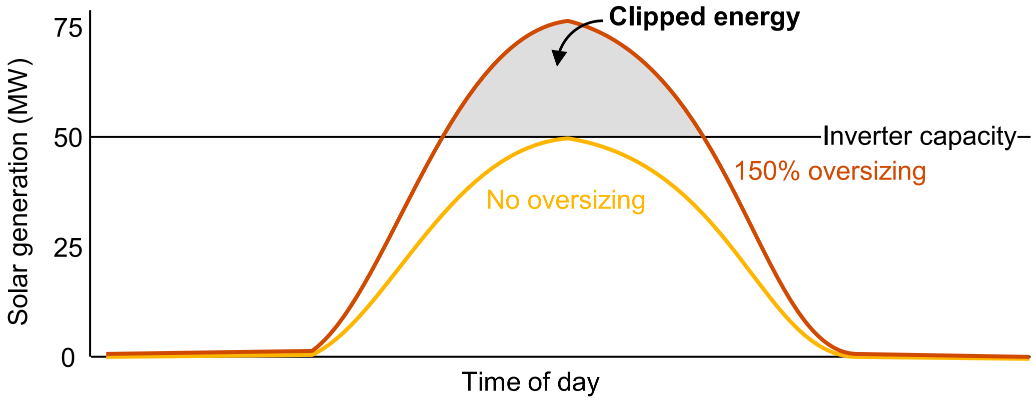
DC-coupling refers to a co-located battery and solar farm being connected **behind a shared inverter** where power is in direct current (DC). Both assets operate in DC - and require an inverter *to convert electricity to/from the alternating current (AC) in which the electricity grid operates*.

Pro: Reduced equipment duplication, lowering capital costs. DC-coupling a battery and solar farm eliminates the necessity for multiple inverters.

Con: Technical complexity. DC-coupling necessitates additional equipment, such as a DC-DC converter, to ensure that the battery and solar system operate at compatible voltage levels. This added complexity, along with reduced cost efficiencies in other areas, can diminish the overall cost benefits of DC-coupling.

The choice between AC-coupling and DC-coupling may ultimately depend on the operational advantages each offers. For DC-coupling, the primary benefit lies in oversizing the solar farm, which allows for capturing the value of the otherwise "clipped" energy.





Source: Modo Energy, PwC Analysis

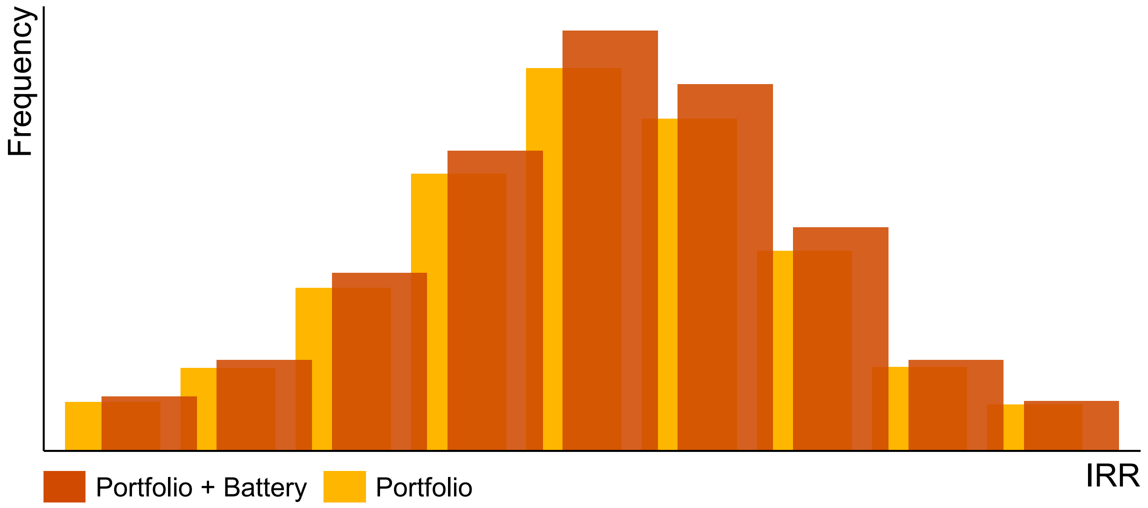
Combining renewables and batteries in one portfolio can create significant positive effects

Exemplary renewables and BESS portfolio

Illustrative Revenue Correlation of Selected Renewables & Batteries

Solar	1	0,58	0,97	-0,12
Wind	0,58	1	0,67	0,25
Solar	0,97	0,67	1	-0,02
Battery	-0,12	0,25	-0,02	1

Illustrative IRR portfolio comparison



Key Remarks

- **Ideal complementing potential to a renewable asset portfolio** given different solar assets display a strong correlation in revenues, batteries have weak to no correlation to renewable assets[1]
- **Improvement of capture rates** of renewable portfolio
- **Mitigating technical curtailments by grid operators** as co-location with solar PV parks would allow the battery storage systems to charge any technically curtailed energy during the day and discharge it at night without curtailment

1) Depending on location
Source: Aquila Capital, PwC Analysis

Curious to know more?

Find out more in our Whitepaper:

Empowering Europe's Energy Future: Navigating the Lifecycle of Battery Energy Storage System Deals

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