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ENERGY RESEARCH

Co-locating Batteries with Solar PV in France

October 19, 2023

Public Report

Agenda

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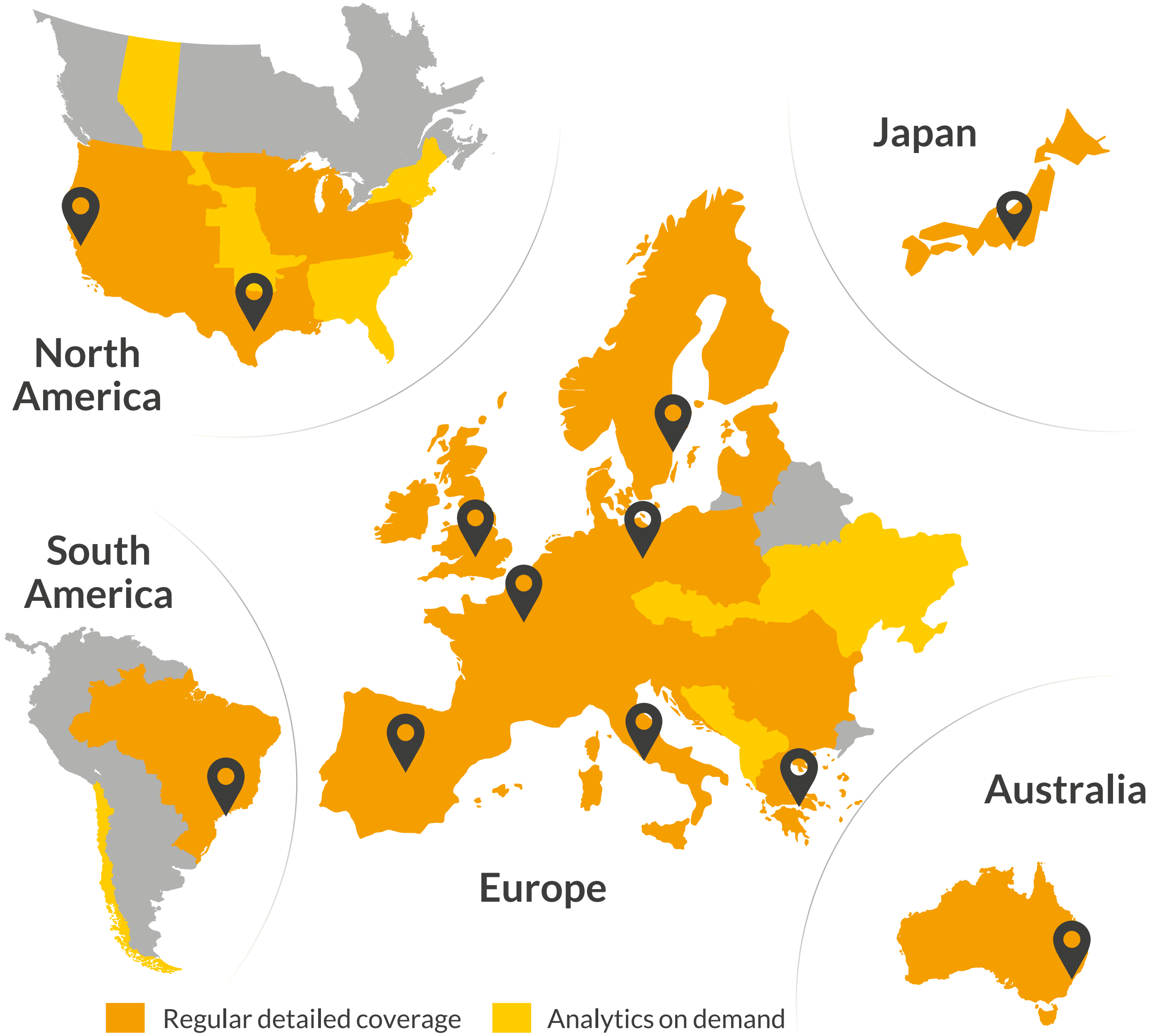

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Source: Aurora Energy Research

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Reach out to **Maricruz Alvarez, Senior Commercial Associate** to find out more.

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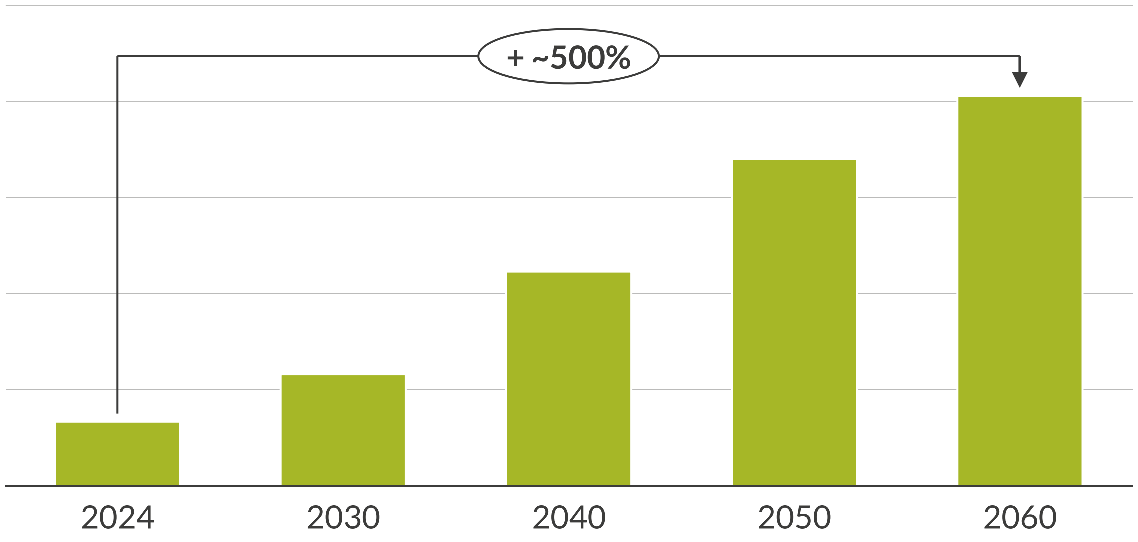
Source: Aurora Energy Research

Capture prices are expected to fall from their current levels due to higher solar PV capacity and corresponding cannibalisation

1 Installed solar PV capacity is expected to increase drastically in the coming decades…

Evolution of solar capacity[1]
GW

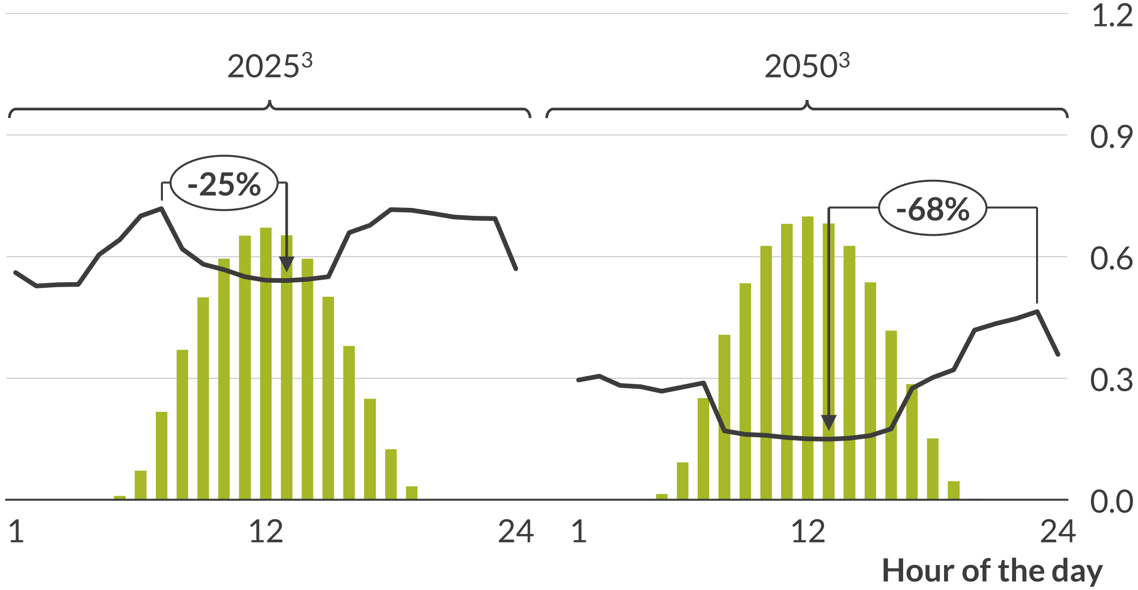


- In 2022, France saw significant RES volumes coming online, with 2.6 GW from solar PV alone. However further acceleration is crucial to meet public targets

2 … which leads to a significant drop in prices during peak solar production hours around noon

Baseload price
€/MWh (real 2022)

Solar production
FLH[2]



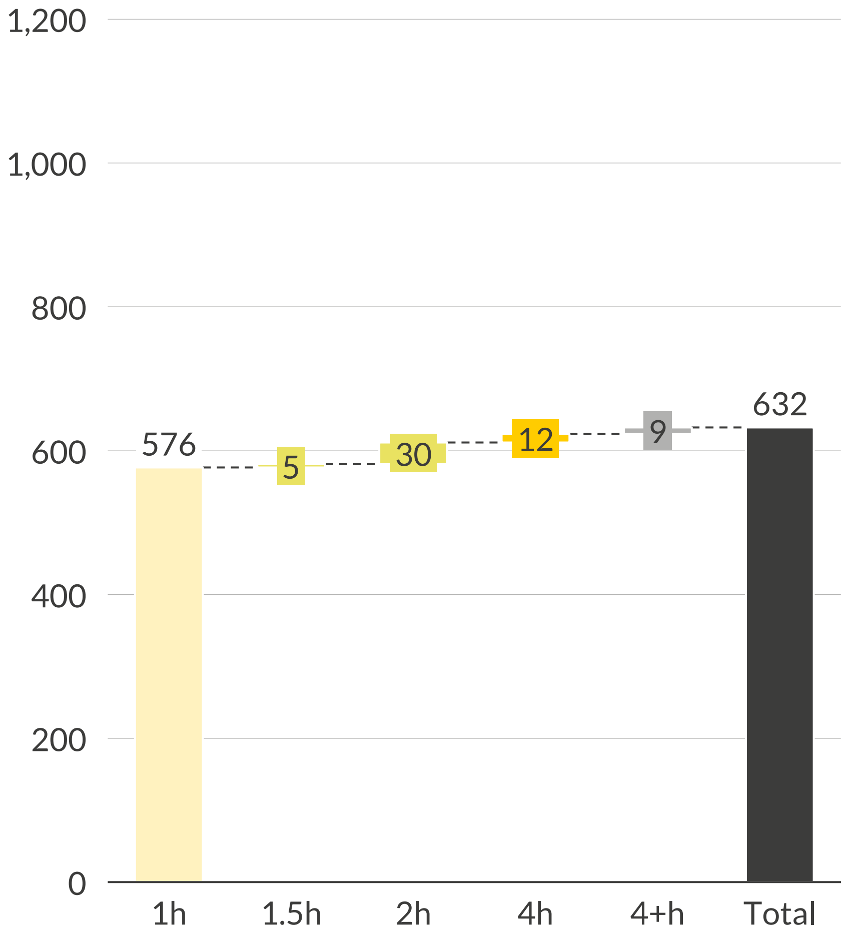
- Price gaps between day and night hours are wide. If electricity is stored during days and sold at nights, it could boost income from solar assets and batteries considerably

1) Based on Aurora French Central forecast from October 2023; 2) Full Load Hours; 3) The selected day is the 1st of July for each year.

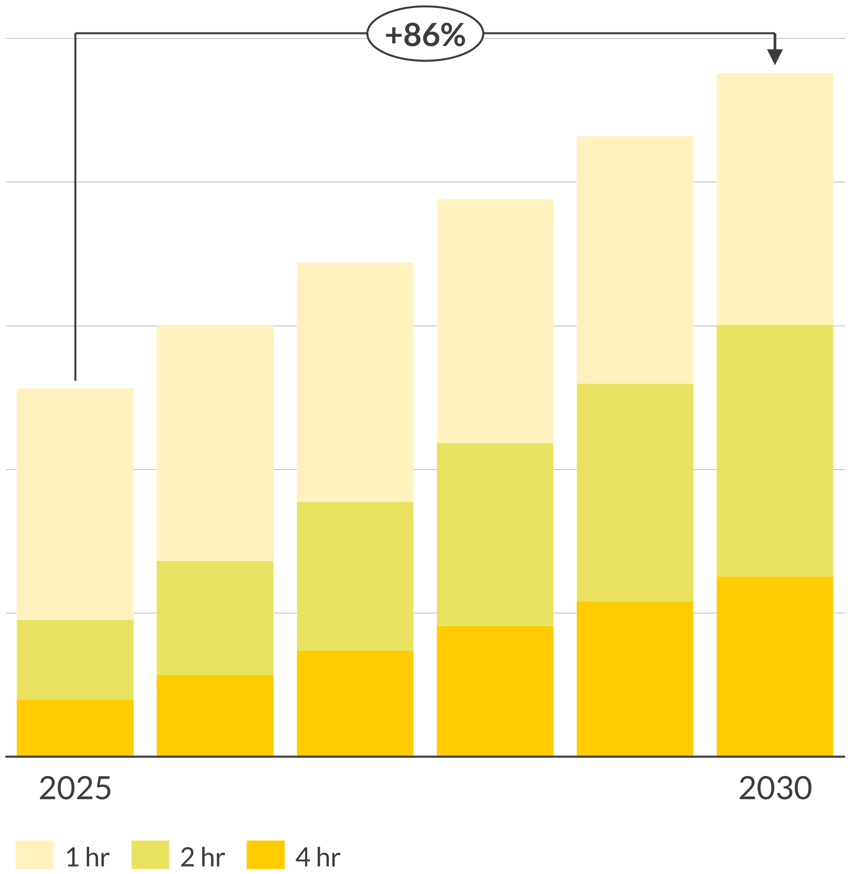
Source: Aurora Energy Research

Batteries can play a role in smoothing RES output and dampening cannibalisation, with 0.6GW already deployed in the French market

Operational grid-scale battery capacity in France[1]
MW-nameplate



France standalone battery capacity pipeline[2]
MW



Additional context

- In 2020, France began its grid-scale battery development resulting in the deployment of 632MW in July 2023 (dominated by 1hr-batteries)
- Currently, France is closely following Germany in terms of installed capacity (0.7GW) while being far behind Great Britain (2.6GW)
- ZE Energy is currently pioneering co-location battery projects in France with two projects:
  - 18MW solar asset with 8MW battery (Loir-et-Cher, Oct. 2022)
  - 18.6MW solar asset with 7.5MW battery (Centre-Val-de-Loire, May 2023)

1) Data published on the Open Data Réseaux Energies “Registre national des installations de production et de stockage d'électricité (au 31/07/2023)“; 2) Based on Aurora’s 2023 October Central scenario for France.

Source: Aurora Energy Research

Diverse revenues streams will be available for batteries, with ancillary services, wholesale and capacity markets as main sources

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Response time → **Delivery**

Years | Hours | Minutes | Seconds

Capacity Market

- Ensures national security of supply by procuring a sufficient level of firm capacity to meet peak electricity demand
- Payments are made on a capacity basis in €/kW/year and are de-rated based on contribution to security of supply

1-yr CM market

- Aims to incentivise lower demand in peak periods and capacity investments

7-yr CM market

- Built-up against the 1y CM market to provide greater revenue certainty

Wholesale Market

- The day-ahead market provides a platform to buy and sell power to meet demand every hour
- The intraday market procures continuous trading during the day
- Batteries can take advantage of arbitrage opportunities on both the day-ahead and the intraday markets

Ancillary services[1]

Frequency Containment Reserve (“Réserve Primaire”)

- Maintains operational grid requirements and provides primary balancing through sub-second to minutes-long response
- Contracted at the European level the day before the service can be procured

automatic Frequency Restoration Reserve (“Réserve Secondaire”)

- Ensures balance is maintained in the power system in each half-hour trading period
- Participation is not yet allowed for batteries[2]

Balancing markets (“mécanisme d’ajustement”, mFRR and RR)

- The battery business cases for this application are very narrow: capacity revenues (RR-RC tender) for batteries are limited and energy activation rates are low

Available to batteries | Not yet available for batteries | Not available anymore | Revenue potential for batteries

1) Tertiary Reserves (mFRR and RR) are not relevant for batteries due to the required duration of these products: 120 minutes for the manual Frequency Restoration Reserve (mFRR) and 90 minutes for the Replacement Reserve (RR); 2) aFRR is not procured through a market yet in France and will be from July 2024.

Sources: Aurora Energy Research

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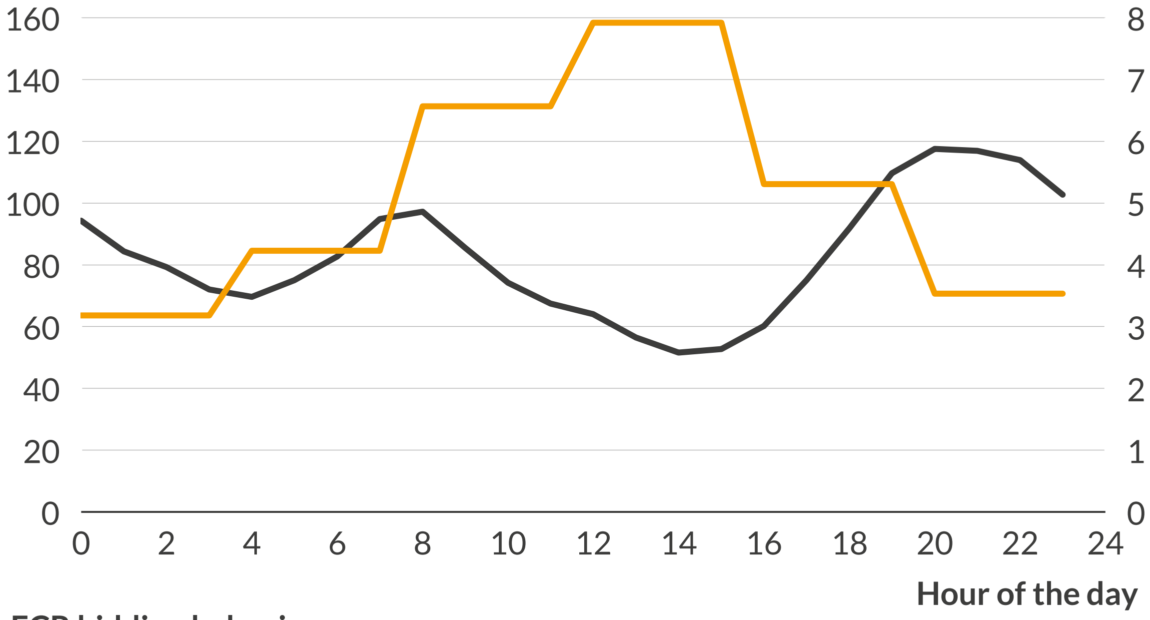
Agenda

Whether co-located or standalone, batteries have the potential to reduce risk for a PV only portfolio due to complementary revenue streams

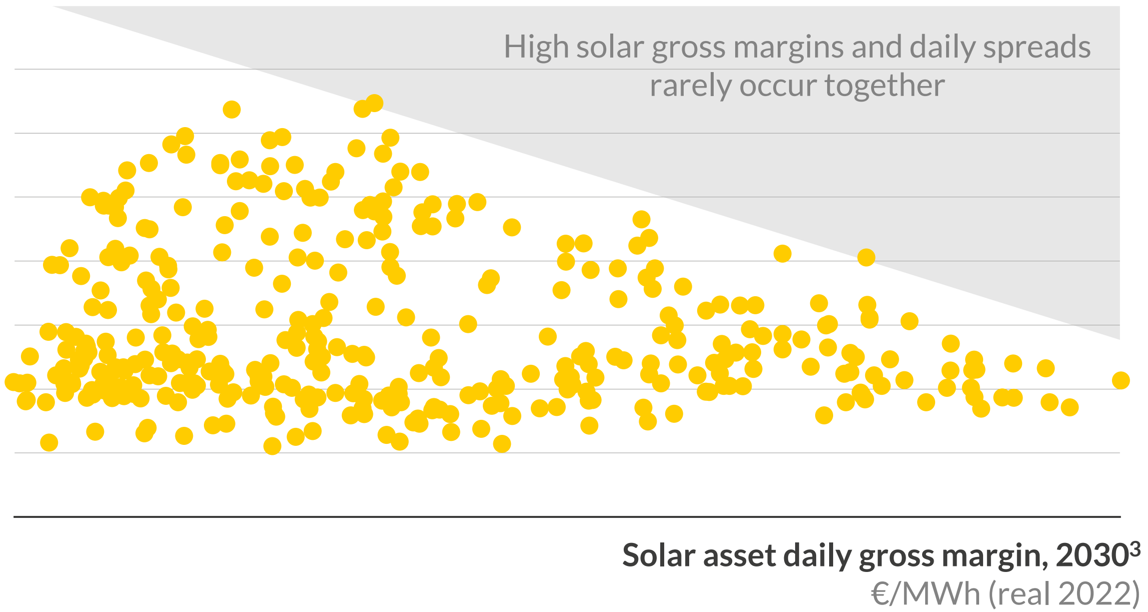
Hourly mean wholesale prices summer 2023[1] **Hourly mean FCR summer 2023[1]**
€/MWh (real 2022) €/MW/h (real 2022)



FCR bidding behavior:

1. *If WMP < SRMC of thermal assets:* FCR will be negatively correlated to wholesale market prices as thermal assets need to be higher to stay in the market or FCR merit order will allocate higher marginal assets
2. *If WMP > SRMC of thermal assets*: FCR prices follow wholesale market prices as assets will bid their opportunity cost with a premium in the FCR market

Wholesale daily spread, 2030[2]
€/MWh (real 2022)



- In hours with high solar gross margins, prices reduce less during daytime, correspondingly reducing the daily spread observed
- In terms of energy arbitrage revenues, the daily spread on the Day Ahead market is one of the key variables to look at for batteries
- If you would like to know more about how co-located or standalone batteries can add complexity but reduce risk get in touch with Maricruz Alvarez, Senior Commercial Associate: **maricruz.alvarez@auroraer.com**

1) Covering June, July and August of 2023; 2) Year 2030, based on Aurora's 2023 October Central forecast for France; 3) Assuming an asset in the French South.

Sources: Aurora Energy Research and ENTSO-E

In this session, we will look into the upsides of co-locating solar PV assets and batteries over standalone assets, in both an AC and a DC setup

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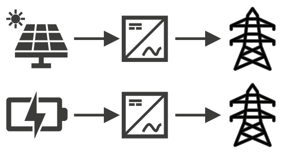

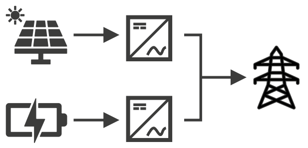

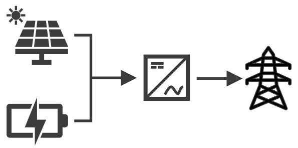

	I Standalone	II AC co-location	III DC co-location
	Assets are two different sites, therefore are metered and managed individually	*Solar and battery require separate inverters to connect to the grid*	*Solar and battery share a single inverter connected to the grid*
a **Costs** *CAPEX & OPEX*	Minimal cost savings	Cost savings on development, balance of system, and OPEX	Further savings due to shared inverter
b **Asset oversizing** *Oversize renewables asset relative to grid connection*	Spilled power cannot be captured	Free charging from spilled power minimal and depends on inverter sizing[1]	Solar can be oversized and battery is able to capture spilled power
Battery dispatch *Charging/discharging profile of the battery asset*	No impact	If grid connection is undersized, the storage output might be constraint by RES generation	
c **Inverter losses** *Avoiding losses from AC/DC conversion*	No impact	No impact	Losses are reduced when charging from the RES asset due to shared inverter
d **Exemption from grid tariffs** *No TURPE charges when charging*	No impact	No TURPE charges when the battery charges from the solar PV asset	

Full benefit | Partial benefit | Potential downside | X Deep-dive in the following section | X Additional business cases available to subscribers

1) Additional reduction in energy which can be captured due to inverter losses.

Source: Aurora Energy Research

Co-location allows for CAPEX and OPEX cost savings compared to equivalent standalone project

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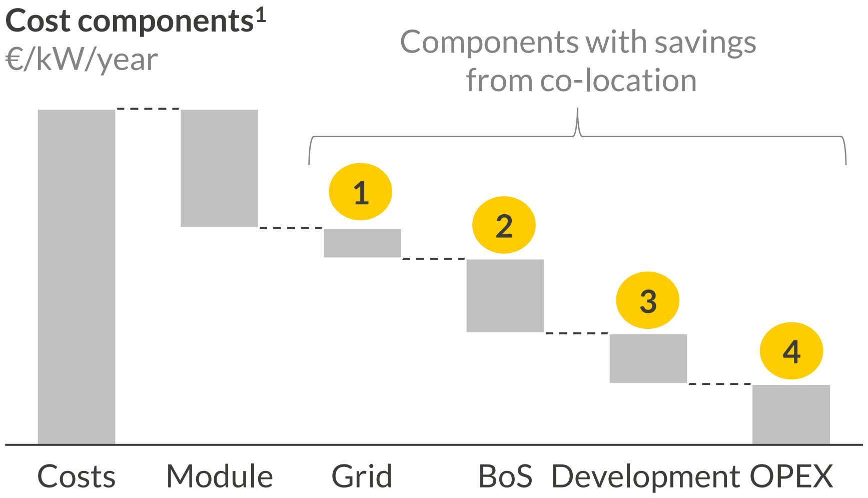
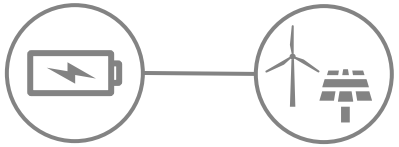
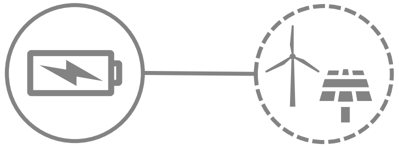


1 **Grid connection savings –** Using the same grid connection for both assets can lead to cost savings if there is oversizing of the renewable asset plus battery compared to grid capacity

2 **Balance of System savings –** Savings achievable from protection equipment, cabling, the inverter[2] and other installation accessories. We consider a **10%**[4] of savings in this costs

3 **Development savings –** Other CAPEX savings include cost of land, building and installation. We assume a **10%**[3] cost saving from the equivalent standalone project

4 **OPEX savings –** Additional savings stem from optimisation of operation and maintenance costs. We assume that the OPEX of the co-located project can be reduced by **10%**[3]

Types of co-located projects		Methodology
	**New build co-located –** co-locating new build batteries with new renewable assets	Total cost savings from co-location are split proportionally between renewable asset and battery considering the total kW of project's installed capacity. We assume that the grid costs are assigned to the renewable project
	**Retrofit –** co-locating new build batteries with existing assets	Total cost savings from co-location only correspond to battery cost savings considering the total kW of project's installed capacity. We assume that the grid costs are assigned to the renewable project

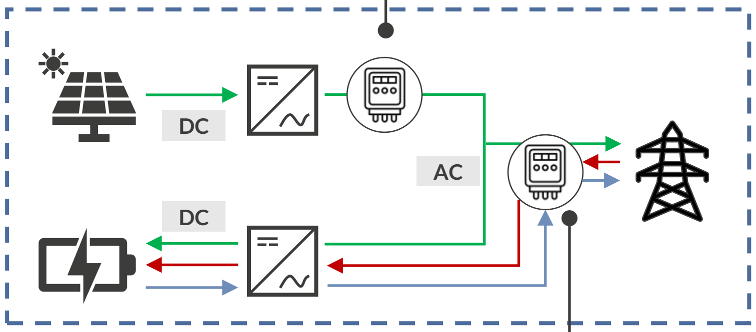
1) Illustrative example representative of the cost components share of a solar asset with an entry year of 2023 and a 30-year lifetime; 2) DC co-location only; 3) A 10% cost saving on the co-located project compared to standalone is achievable when the battery is smaller than the renewable asset.

Source: Aurora Energy Research

When it comes to co-location setups, the exact placements of technical elements is key for efficiency and accurate metering

II AC co-location

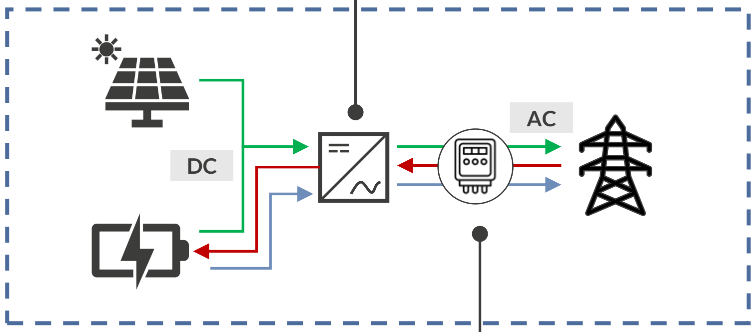
CRE meter: used to determine the output of the RES asset (i.e. for remuneration in the CfD scheme)



Grid meter: measures the entire flow to / from the grid of the entire co-located system

III DC co-location

Inverter losses in a DC-setup only occur when dispatching to the grid from either asset, not when the battery charges from the RES asset



Grid meter: measures the entire flow to / from the grid of the entire co-located system; generation from the RES asset cannot be determined individually

Solar PV asset · Battery · Inverter · Meter · Grid · Electricity from the grid · Electricity from the battery · Electricity from RES

- Standalone assets produce DC power, which needs conversion into AC to be injected to the grid[1]
- Inverters are required for the DC/AC conversion, with any losses being linked to the efficiency of the inverter itself[2]
- Within AC co-location setups, solar generation (DC) is initially converted to AC via its respective inverter before being reconverted to DC through the battery inverter for storage
- In contrast, DC co-location setups avoid this dual conversion by directly charging the battery with solar power (DC), reducing losses

1) AC is the standard used by most appliances and the electrical grid in France; 2) We currently assume a 97% efficiency for AC/DC converters.

Source: Aurora Energy Research

Battery developers will be significantly impacted by some components of the TURPE, which is a key revenue stream of French grid operator

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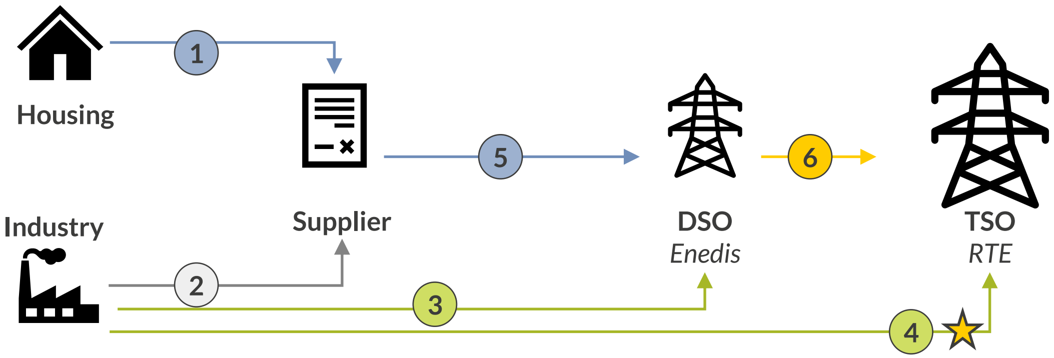
TURPE is a charge on operators in the electricity system to recover the costs of operating and maintaining the grid

- The TURPE comprises two tariffs: (i) sites connected to distribution networks pay TURPE HTA-BT[1], (ii) sites connected to the transmission network (including distribution network operators) pay TURPE HTB[2]



1. Clients pay a single bill incl. the transmission tariff (TURPE) and the energy price to the supplier
2. Industries pay the energy price to the supplier
3. Industries pay the TURPE (HTA[1]) to the DSO directly if under the Distribution Network Access Contract (CARD)
4. Industries pay the TURPE (HTB[2]) to the TSO directly if under the Transmission Network Access Contract (CART)
5. Suppliers pay the energy price/tariff to the DSO (from client's contracts)
6. The DSO pays the TURPE (HTB[2]) to the TSO

The general rules for applying the tariff, its structure and its level are set by CRE for a 4-year period

- Levels can be adjusted each year on the 1st of August. Within a tariff period, this annual adjustment may result in limited changes, upwards or downwards, to the tariff coefficients
- The TURPE is invoiced through several components, mainly management, metering and withdrawal:

F Management

- Charges are invoiced in the form of a fixed fee to all parties, depending on the voltage range the parties are connected to

F Metering

- Costs of metering, control, reading, transmission of billing data, related to the flow reconstitution process as well as, where applicable, costs of rental and maintenance of metering devices

V Withdrawal[4]

- The withdrawal component mainly covers operating and capital costs related to network infrastructures as well as the cost of purchasing losses
- It depends on the connection voltage range: the higher the voltage range, the lower the average quantity of network structures used, therefore the lower the withdrawal rate

Additional components specific to DSOs ★ Our case (CART, HTB tariff) F V Fixed/Variable Cost Components

1)"Haute tension"(HTA) and "Basse tension" (BT); 2) "Très haute tension" (HTB) ; 3) TURPE 6 has been introduced in 2021; 4) We will refer to this as the variable component of TURPE in the deck going forward.

Sources: Aurora Energy Research, RTE

Agenda

To arrive at an optimal co-location business case, main elements to consider are the technical setup, the asset sizing and the entry year

In this section, we will go through a series of co-location business cases in which we will cover varying aspects to consider when estimating the ideal configuration.

	Business case description	Key question to answer
a	**AC co-location with Day Ahead market only** *Both assets are only allowed to trade electricity on the Day Ahead market.*	Is the financial upside from generation shifting enough to cover the additional upfront investment required?
b	**AC co-location with full market access** *The battery can also access the Day Ahead, FCR and aFRR markets.*	What does the general business case of co-location in France look like if we assume a general 0.3:1 ratio between the battery and the solar PV asset?
c	**AC co-location asset sizing** *Based on b, we will look into various sizing ratios of the battery and RES asset.*	Assuming a constant grid connection size, what is the ideal sizing ratio of the battery vs. the solar PV asset under a solar merchant scheme and AC setup?
d	**DC co-location asset sizing** *We will look into various sizing ratios again but assuming a DC co-location setup.*	Assuming a constant grid connection size, what is the ideal sizing ratio of the battery vs. the solar PV asset under a solar merchant scheme and DC setup?
e	**AC co-location with battery repowering** *Accounting for the results of c, we allow the battery to repower once.*	Is the additional revenue captured by a non-degraded battery enough to justify the extra investment costs required for repowering?
f	**AC co-location with a CfD-backed solar PV asset** *The solar PV asset is assumed to be backed by a 20-year French CfD contract.*	How do the additional revenues from the Day Ahead market when the RES asset dispatches to the grid impact the co-location business case?
g	**Ideal entry year to retrofit an existing solar PV asset with a battery** *We will vary the entry year of the battery between 2025 – 2029.*	If we assume for the solar PV asset to come online in 2025, what is the best year to add a battery before 2030 in terms of system IRR?

X Deep-dive on following slides   X Additional business cases available to subscribers to Aurora's Flexible Energy Markets Service

Source: Aurora Energy Research

A battery in a co-located setup only used to shift generation and to trade on the Day Ahead achieves limited returns

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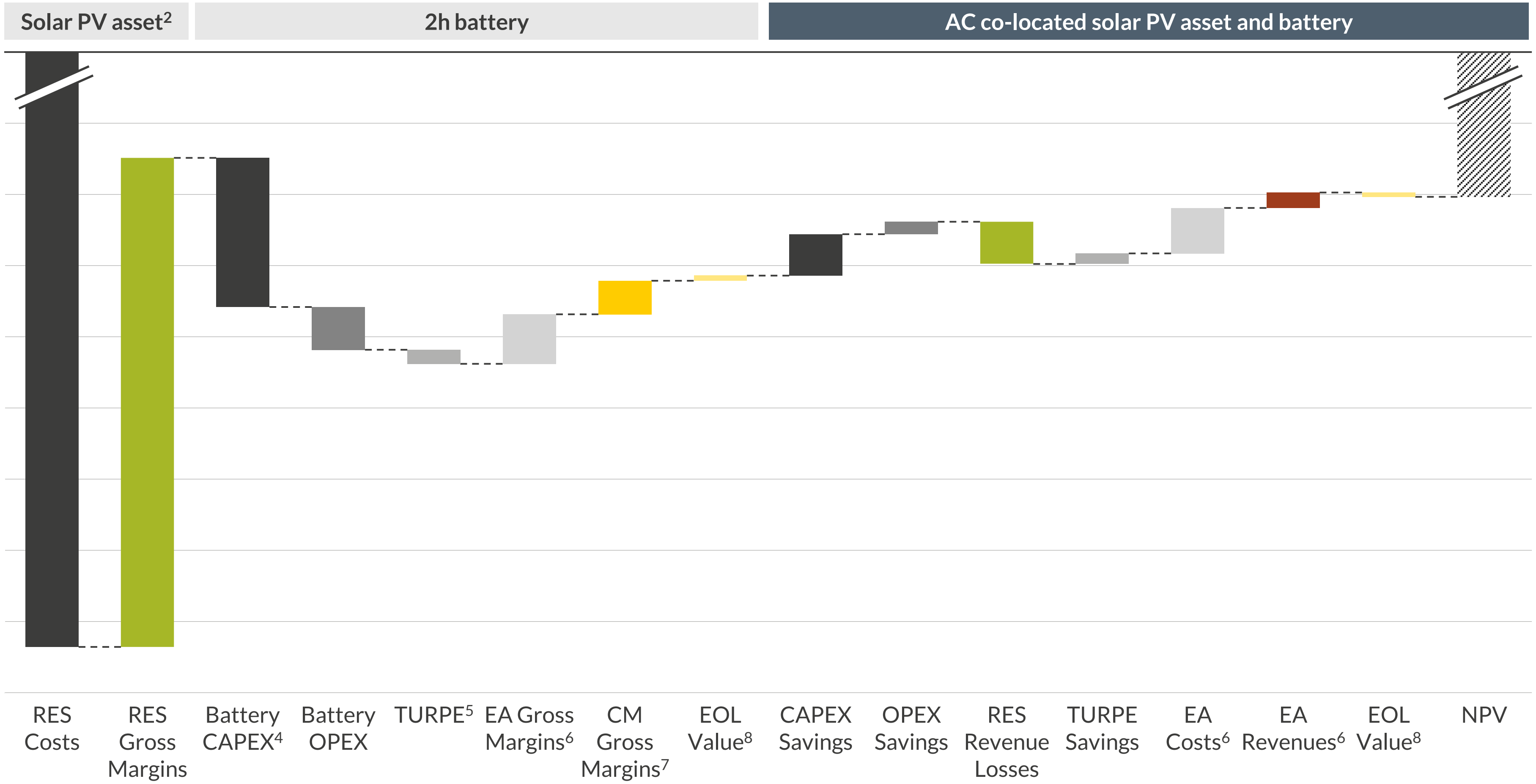
Merchant | II AC co-location

0.3 | 1.0 | 1.0

NPV calculations of a new-build co-location project with COD 2025[1]

€/kW of grid capacity (real 2022)



1) Discount rate of 10%; 2) Located in the South of France; 3) Assuming standalone assets; 4) Please note these assume an 0.3:1 ratio of the battery capacity compared to the grid connection size; 5) The withdrawal charge of TURPE; 6) EA = Energy Arbitrage; 7) CM = Capacity Market; 8) EOL = End-Of-Life.

Source: Aurora Energy Research

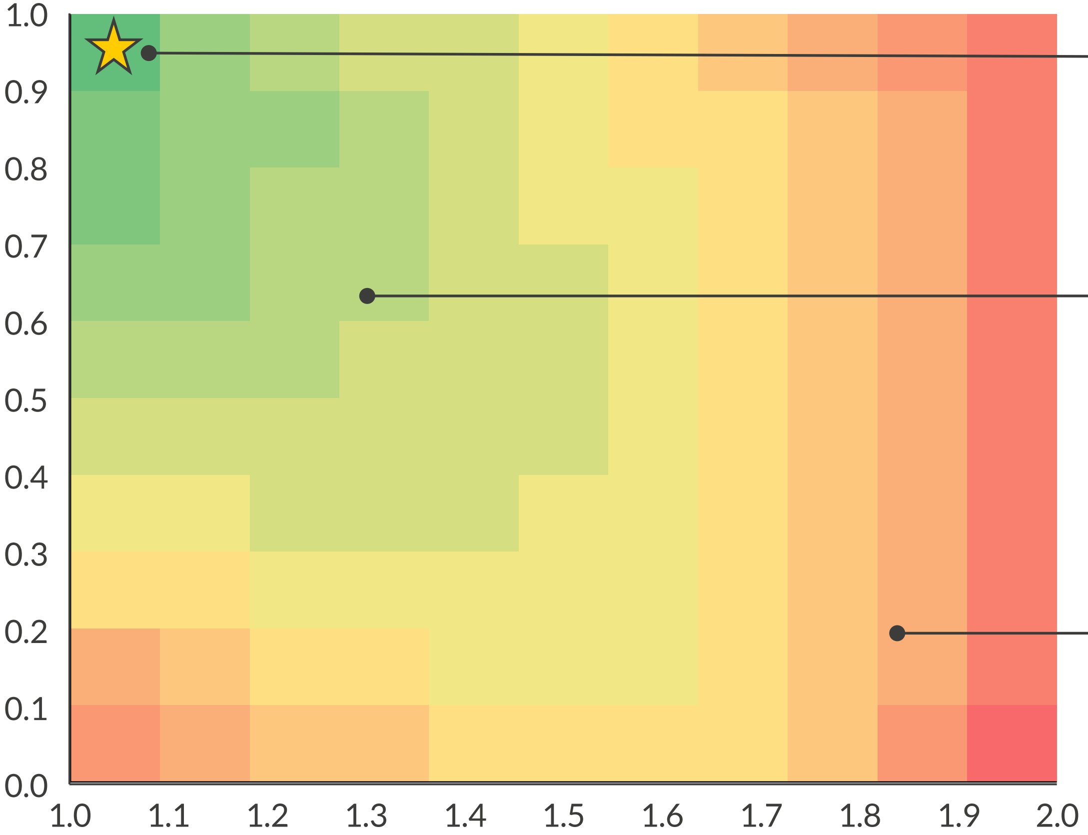
Business case context

- We assume for the battery to only trade on the Day Ahead
- The battery is allowed to charge from both the RES asset and the grid; the RES asset decides automatically if it's more profitable to dispatch its generated electricity to the grid (at the wholesale market price) or to the battery to be sold at a later point in time
- When looking at the system IRR of a co-located setup, we see significant upsides from CAPEX savings along (i.e. shared grid connection costs) and higher gross margins on the Day Ahead market
- However, the upsides are not enough to recover the extra upfront costs required to install the battery

Assuming a 2025 entry year, a battery with equal capacity as the RES asset is favorable due to high short-term balancing market prices

Merchant | II AC co-location

Battery sizing
kW, relative to 1kW grid connection



Solar PV sizing
kW, relative to 1kW grid connection

The highest system IRRs are currently achieved in a context with a larger battery and a smaller solar PV asset, due to high forecasted prices on the balancing markets until 2030, which lead to an environment very favorable for batteries

When your solar asset is oversized compared to the grid, adding a smaller to medium-size battery yields higher IRRs

When oversizing the solar PV asset compared to the battery, which would lead to reduced IRRs, we do not see the additional revenues gained make up for the required upfront investment costs for the battery

System IRR[1], %

Key:

Highest system IRR[1] with solar >= 1 kW

1) Assuming a discount rate of 10%.

Source: Aurora Energy Research

Business case context

- We assume for both assets to come online in 2025 and to be connected to the French transmission grid (tariff HTB)
- In a setup with a large battery compared to the solar asset, the system will mainly operate to optimize optimal battery dispatch, with significant shares of the solar asset's electricity generation being used to charge the battery
- This picture changes if we were to assume a CfD-backed solar PV asset, due to the increased prices at which electricity from the solar asset is sold, making energy arbitrage trades less attractive for the battery

Our detailed and precise storage asset data was obtained using Aurora’s cutting-edge proprietary battery dispatch engine: Chronos

CHRONOS

Chronos allows you to evaluate any storage asset or project using Aurora‘s cutting-edge proprietary battery dispatch engine

- Accounts for all site-specific value drivers
- Backed by Aurora‘s trusted forecasts and team of experts
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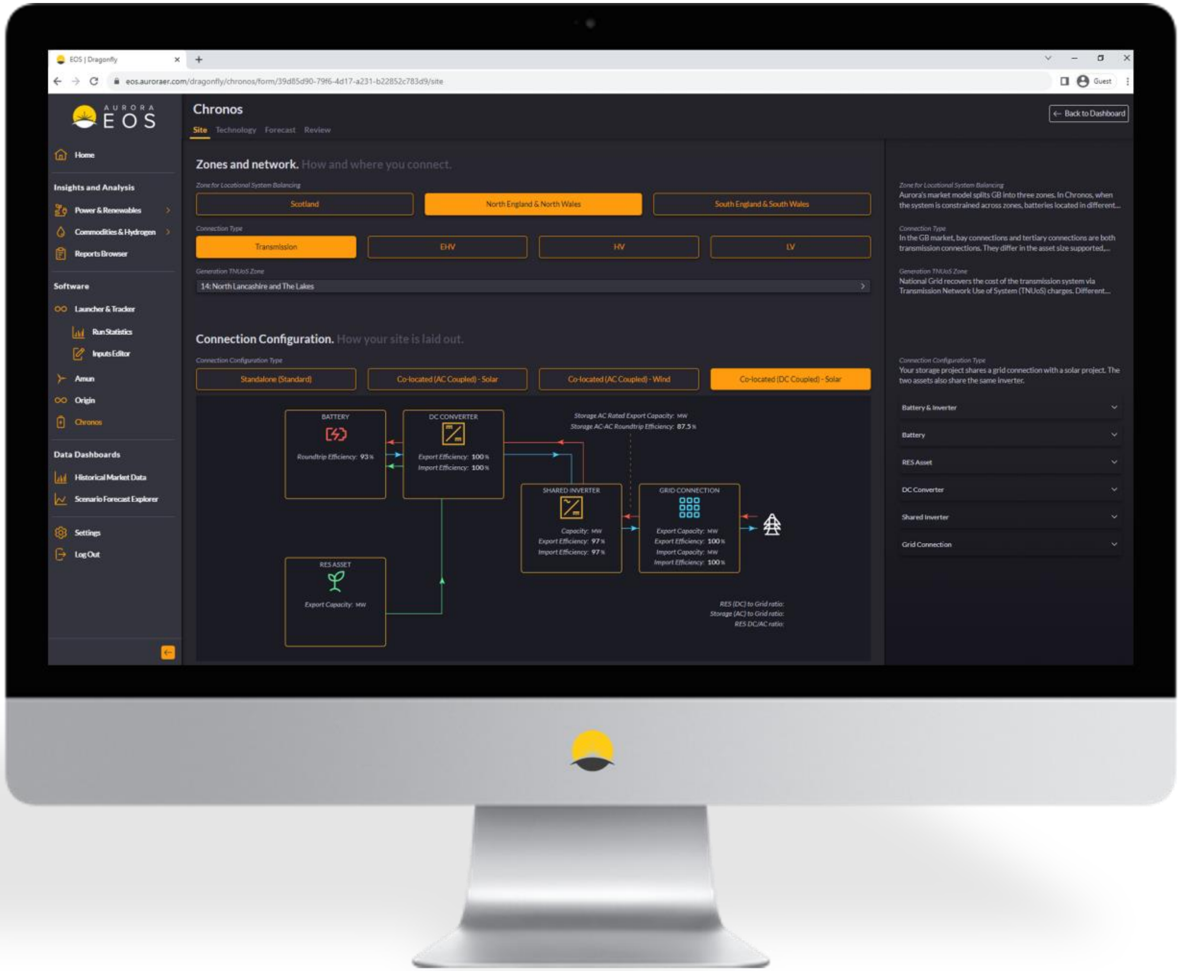


Transactions

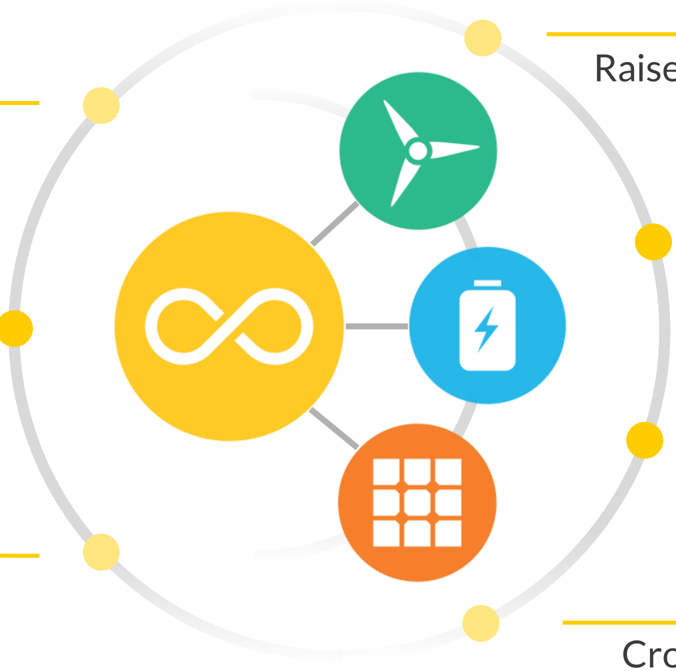
Project Design Optimisation

Portfolio Valuation

Optimisation Benchmarking

The leading battery analytics software

Power your key decisions with our integrated software suite



M&A transactions

Create asset-specific investment cases and analyse key sensitivities

PPAs

Power your contract negotiation with detailed price analysis

Project development

Choose the right tech and sites to maximise profits

Capital raising

Raise more capital by identifying unique value

Project finance

Borrow more by identifying asset-specific bankable value

Strategy

Inform and stress-test your investment strategies

Benchmarking

Cross-check and validate your in-house tools and analyses

Agenda

I. Introduction

II. The promise of combining batteries with solar

III. Business cases for co-located solar PV assets

IV. Key take aways

Key takeaways

1. Co-locating solar PV assets with batteries offers a series of financial upsides, most importantly the ability to access additional revenue streams in hours when selling electricity on the Day Ahead market is less attractive for solar plants and the potential to access these revenue streams at reduced costs due to savings in upfront and operational costs.

2. From a battery-perspective, the main upsides lie in the ability to charge cheaply from the RES asset, both by not facing wholesale market prices but mainly by reducing the TURPE costs when drawing electricity from the grid, which significantly impacts the business case of standalone battery assets.

3. In the short term, setups with equal capacities of the battery and the solar PV asset are the most attractive, due to high expected capacity prices on the aFRR and the FCR markets. With these markets seeing lower prices by 2030, the picture changes towards a more balanced setup being preferable.

Discuss how our Flexible Energy Market Service can help your business with **Maricruz Alvarez, Senior Commercial Associate**

maricruz.alvarez@auroraer.com

Source: Aurora Energy Research

Access detailed power market analysis and investment case data for batteries with our French Flexible Energy Add-On

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Flexible Energy Add-On

Forecast Reports & Data

Technology and Market Development Reports

- Overview of regulatory framework for batteries
- Revenue stacking models for batteries
- Projections for battery CAPEX and OPEX by delivery year
- Reports and datasets follow the same format with content tailored to specific markets

Forecast Data

- Central case forecast prices until 2050:
  - Hourly wholesale power prices
  - Yearly capacity market prices
  - 4-hourly FCR market prices
  - Hourly aFRR (energy and capacity, upward, and downward) prices

Investment Cases

Standalone battery

- Multiple investment cases per country or zone including:
  - Arbitrage of wholesale market, FCR, and aFRR market
- Annual project margins to 2050; IRR and NPV for two entry years

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