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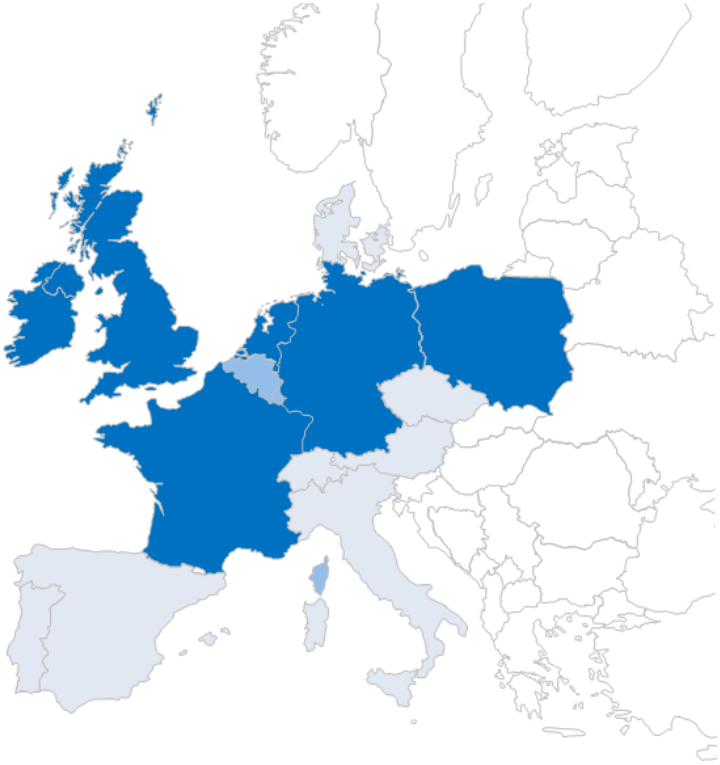
# The economics of co-location

Public Webex

# Aurora offers power market forecasts and market intelligence spanning Europe's key markets & Australia



## Comprehensive Power Market Services

- Power market forecast reports
- Forecast data in Excel
- Global energy market forecast reports
- Strategic insight reports
- Regular subscriber group meetings
- Bilateral workshops
- Analyst support

## Power Market Forecast Reports

- Power market forecast reports
- Forecast data in Excel
- Analyst support

## Bespoke forecasts

- Aurora can provide power market forecasts upon request

Source: Aurora Energy Research

# Co-ownership of RES and battery storage assets can protect assets from their specific risks

Key
- Negative Impact
- Positive Impact

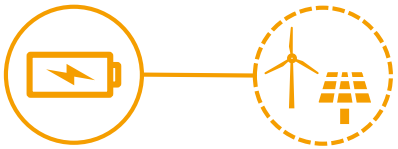
| Risks | Impact on standalone asset: Solar PV | Impact on standalone asset: Battery | Other hedging options available |
|---|---|---|---|
| **High RES** Higher RES capacity due to cost innovation or subsidies | Decreases revenue for solar asset due to greater price cannibalisation | High RES results in more volatile prices and higher spreads | ✓ Regional and technological diversification |
| **Low price volatility** Caused by high penetration of smart EVs and/or demand response | Low price volatility implies reduced cannibalisation for solar asset | Less price spread for battery assets reducing margins | ✓ Co-ownership of EV charging infrastructure as low price volatility will benefit EV owners |
| **Low commodity prices** Lower gas and carbon prices than expected in central case | Decreases wholesale prices and capture price for renewables | Decreases wholesale prices and spread available to batteries | ✓ Co-ownership with gas assets – gas prices can be hedged against up to 6 years in advance |

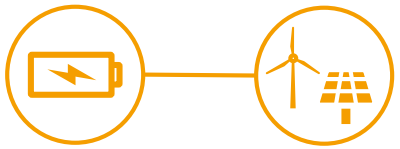
# Co-locating new RES assets with battery storage provides the greatest opportunity for optimised configuration

Key

- Full benefits
- Partial benefits
- No benefit
- Negative impact

Focus of today





| | Standalone | Retrofit | New build co-located |
|---|---|---|---|
| | Own and operate each asset separately and independently | Co-locating batteries with existing subsidy supported assets | Subsidy free assets co-located with new build batteries |
| **Portfolio benefits** | Full portfolio benefits | Full portfolio benefits | Full portfolio benefits |
| **Cost savings** | | Partial cost savings, extent limited by existing design | Cost savings can be fully realised |
| **Asset oversizing** | Partially possible though cannot capture spilt power | Some subsidised assets have oversized solar to grid | Solar can be oversized and battery captures spilt power |
| **Sub optimal dispatch** | No sub-optimal dispatch of storage assets | Storage output restricted by RES asset generation | Storage output restricted by RES asset generation |
| **Self balancing** | FPNs[1] can be settled at a portfolio level | Self balancing possible | Self balancing possible |

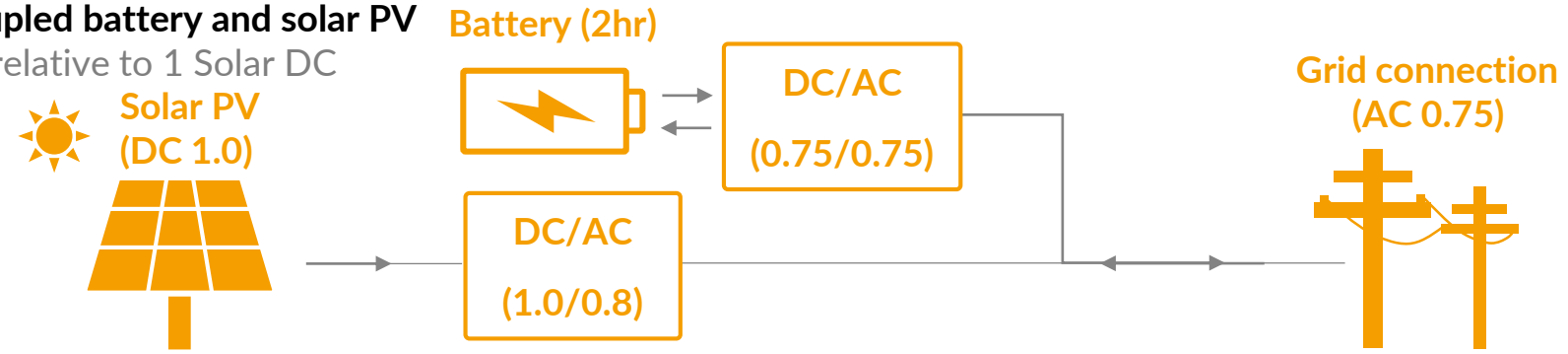
Notes: 1) Final Physical Notification

Sources: Aurora Energy Research

# The optimal configuration for co-located new build Solar PV has 0.75 kW of battery capacity and 0.75 kW of grid

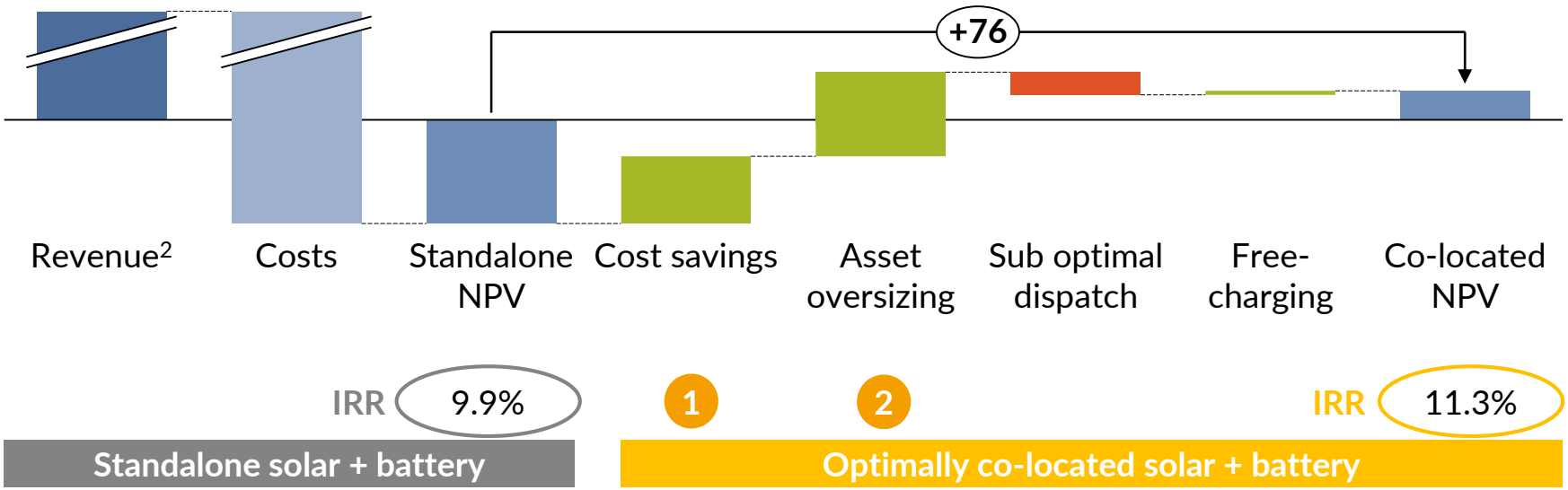
**AC-coupled battery and solar PV**

Ratios relative to 1 Solar DC




**Cost and revenues breakdown for optimal configuration in 2025,** X Deep dive

Present value with 11% discount rate, £/kWp[1], real 2018

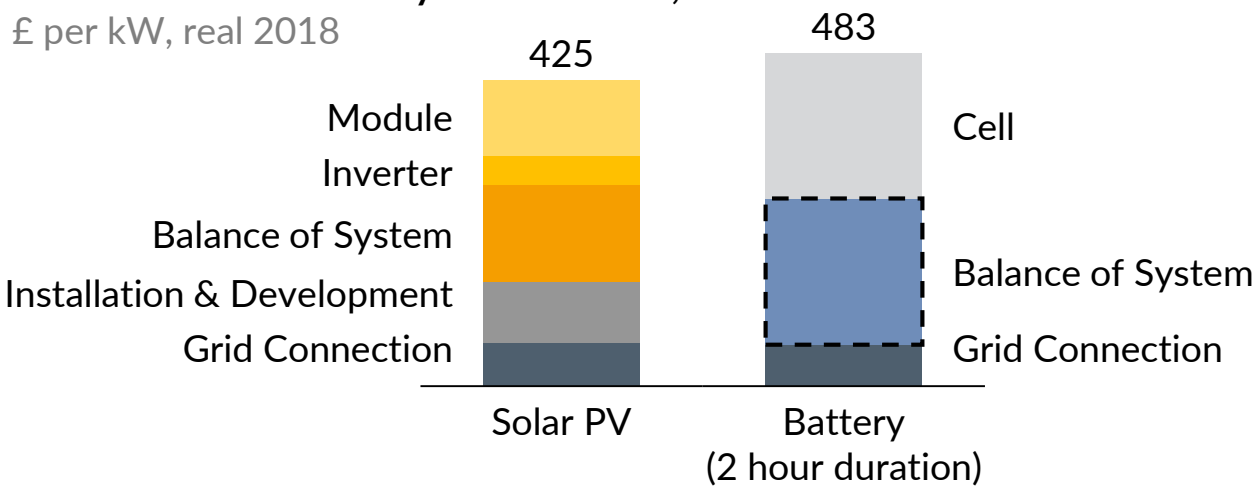



Notes: 1) Discounted at 11% pre-tax real, 30 year lifetime, with refurbishment of battery after 15 years. Present value per kilowatt of DC solar capacity, with 0.75 kW battery and 0.75 kW grid connection. 2) Includes wholesale, BM, CM and embedded benefits.

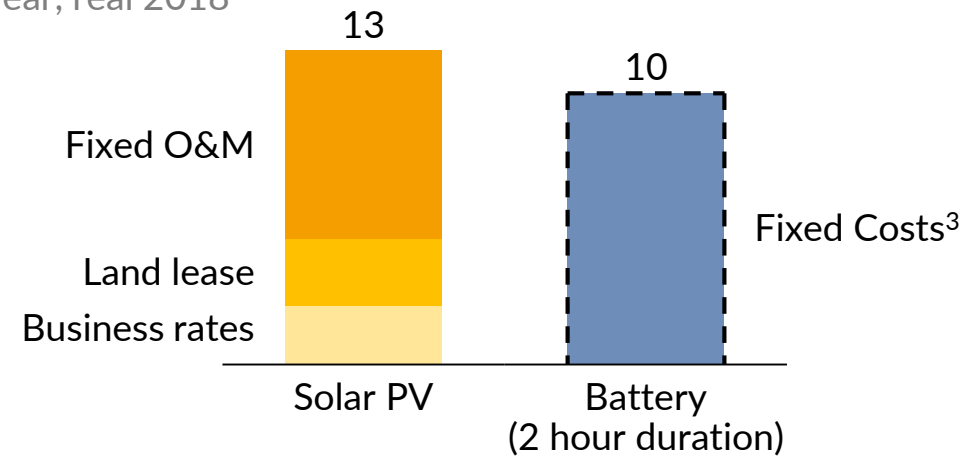
Source: Aurora Energy Research

# Sharing Balance of System results in a £21/kW reduction in battery CAPEX

**Standalone CAPEX utility scale[1] in 2025,**
£ per kW, real 2018




**Standalone OPEX[2] for new build asset in 2025,**
£ per kW/year, real 2018




**Co-location cost assumptions**

✓10% of the battery's **BoS** can be saved through shared foundations, access roads etc.

?Grid connection can be shared – this restricts the asset operation and is considered in Asset Oversizing

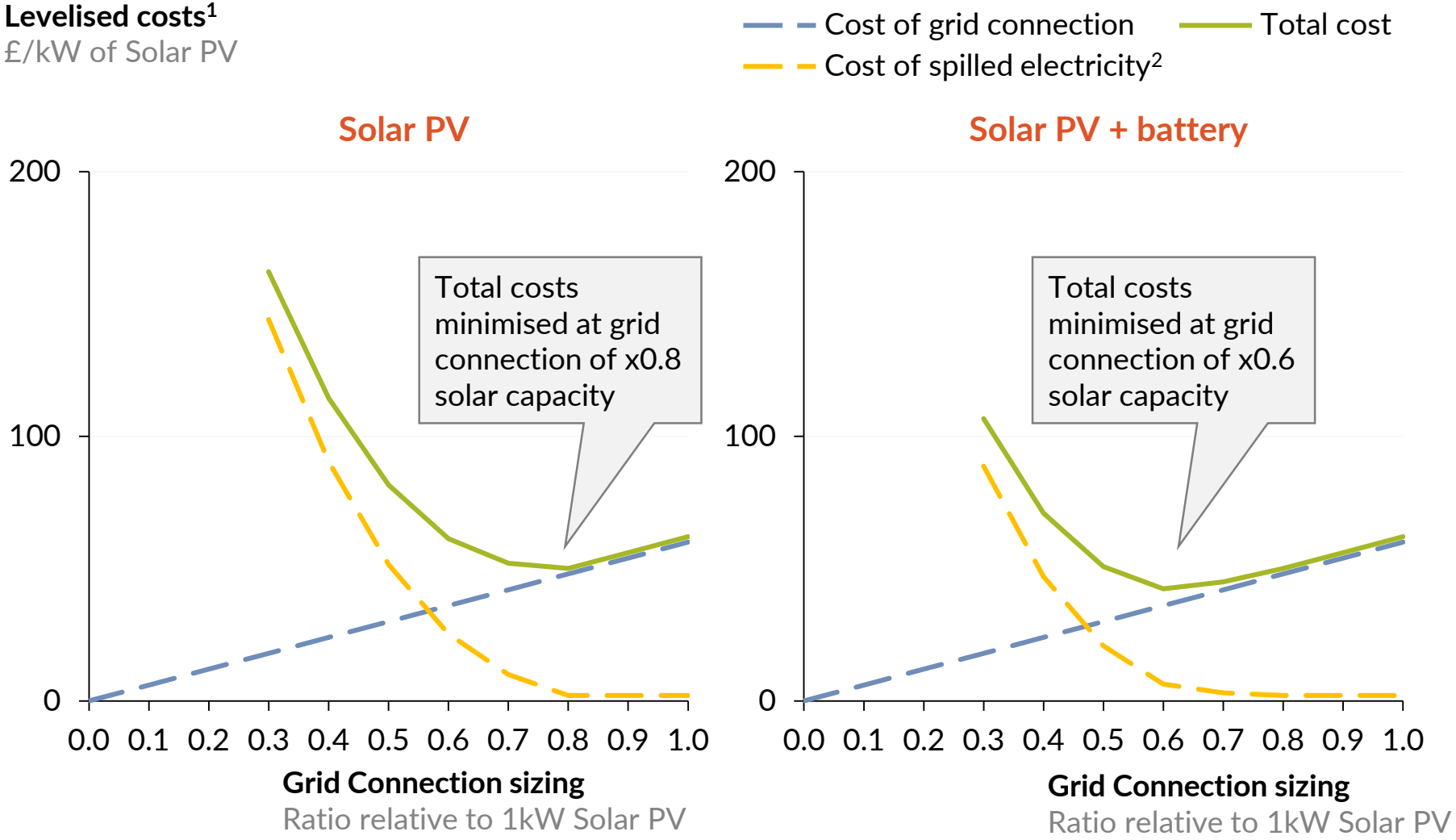
✓20% of the battery Fixed costs can be saved by utilising the same teams and optimising maintenance schedules

Notes: 1) Ground mounted utility scale farm over 10 MWp. Assumed project lifetime of 30 years. All components are in per kilowatt DC aside from grid connection in per kilowatt AC. 2) OPEX costs include fixed costs but exclude network charges and imbalance charges. 3) Includes business rates, land lease etc.

Sources: Aurora Energy Research, STA, Agora, industry interviews

# Optimal sizing of assets minimises the cost of the grid connection and the cost of spilled electricity

**Levelised costs**[1]
£/kW of Solar PV




Notes: 1) Future cash flows discounted at 11%. Assumes a project entering in 2025 with a lifetime of 30 years, 0.3 kW battery with 2hr duration and an inverter loading ratio of 1.25. 2) The value of spilled electricity is the generation of the solar asset that could not be exported because of the restricted grid connection multiplied by the half-hourly wholesale price. This is then summed to get the total value of spilled electricity in a year.

Sources: Aurora Energy Research

# The optimal configuration of asset sizes is revealed by the Net Present Value and Internal Rate of Return

**Revenue[1], £/kW/yr**

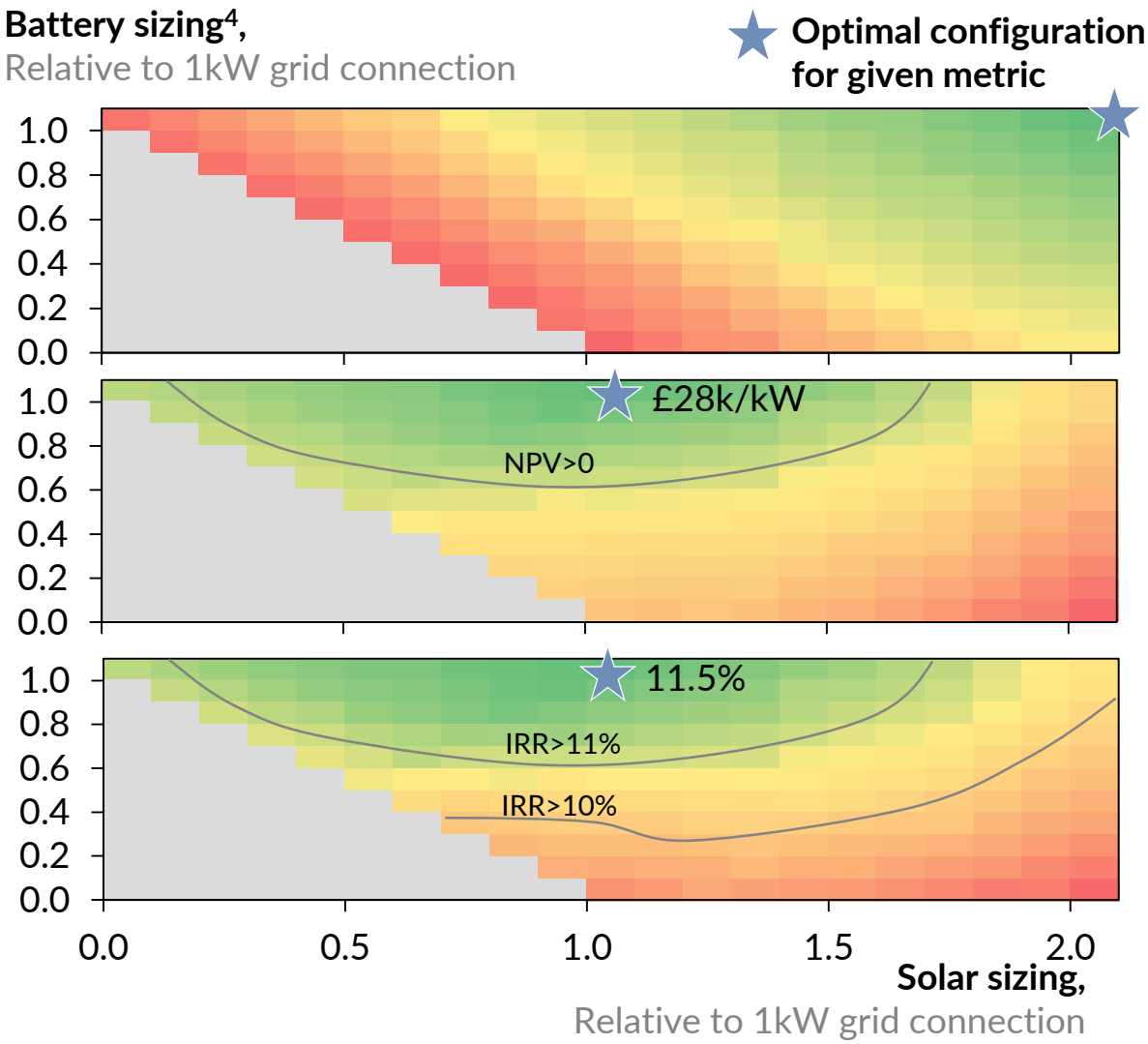
For a given grid connection, the objective may be to maximise revenue

**Net Present Value[2], £/kW grid[3]**

Maximising the NPV considers the additional capital cost requirements from oversizing assets relative to grid connection

**Internal Rate of Return, %**

Maximising the IRR highlights where the best returns can be achieved if upfront capital investment is finite




Notes: 1) Average annual revenue for 30 years. 2) Discount rate of 11%, pre-tax real. 30 year lifetime of system, includes battery repowering after 15 years. 3) NPV values are for 1kW grid connection. 4) 2 hour duration battery. 5) Includes inverter clipping ratio of 0.8.

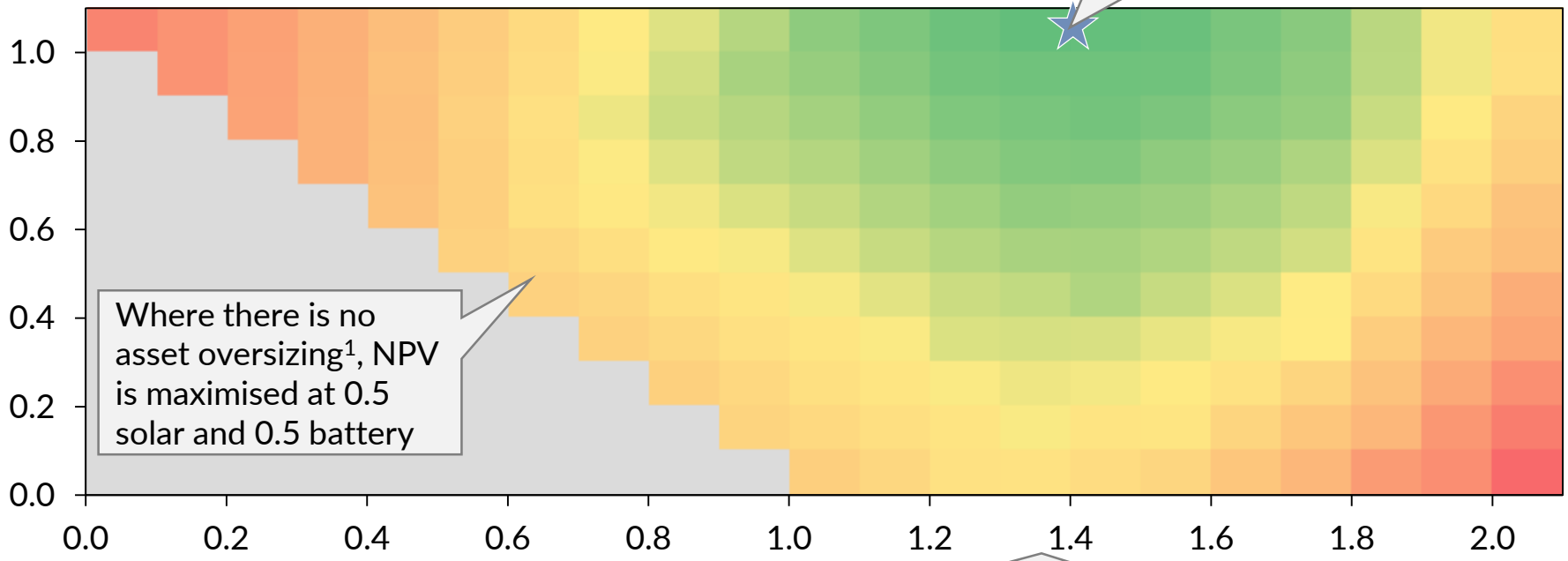
Sources: Aurora Energy Research

# Discounting the battery arbitrage business model at a higher rate results in solar PV oversizing relative to grid

**Net Present Value, £/kW**
Discount rate of 9% for Solar PV and 13% for battery

NPV maximised with a ratio of 1 battery and 1.3 solar PV to 1 grid connection

**Battery sizing[2],**
Relative to 1kW grid connection




Where there is no asset oversizing[1], NPV is maximised at 0.5 solar and 0.5 battery

With standalone solar (no battery) NPV is maximised when solar size 1.3 relative to grid connection

**Solar PV sizing[3],**
Relative to 1kW grid connection

Notes: 1) No asset oversizing where battery capacity + solar DC capacity = grid capacity. 2) 2 hour duration battery. 3) Includes inverter clipping ratio of 0.8.

Sources: Aurora Energy Research

# Current barriers limit the benefits from co-locating assets and restrict the battery energy arbitrage business model

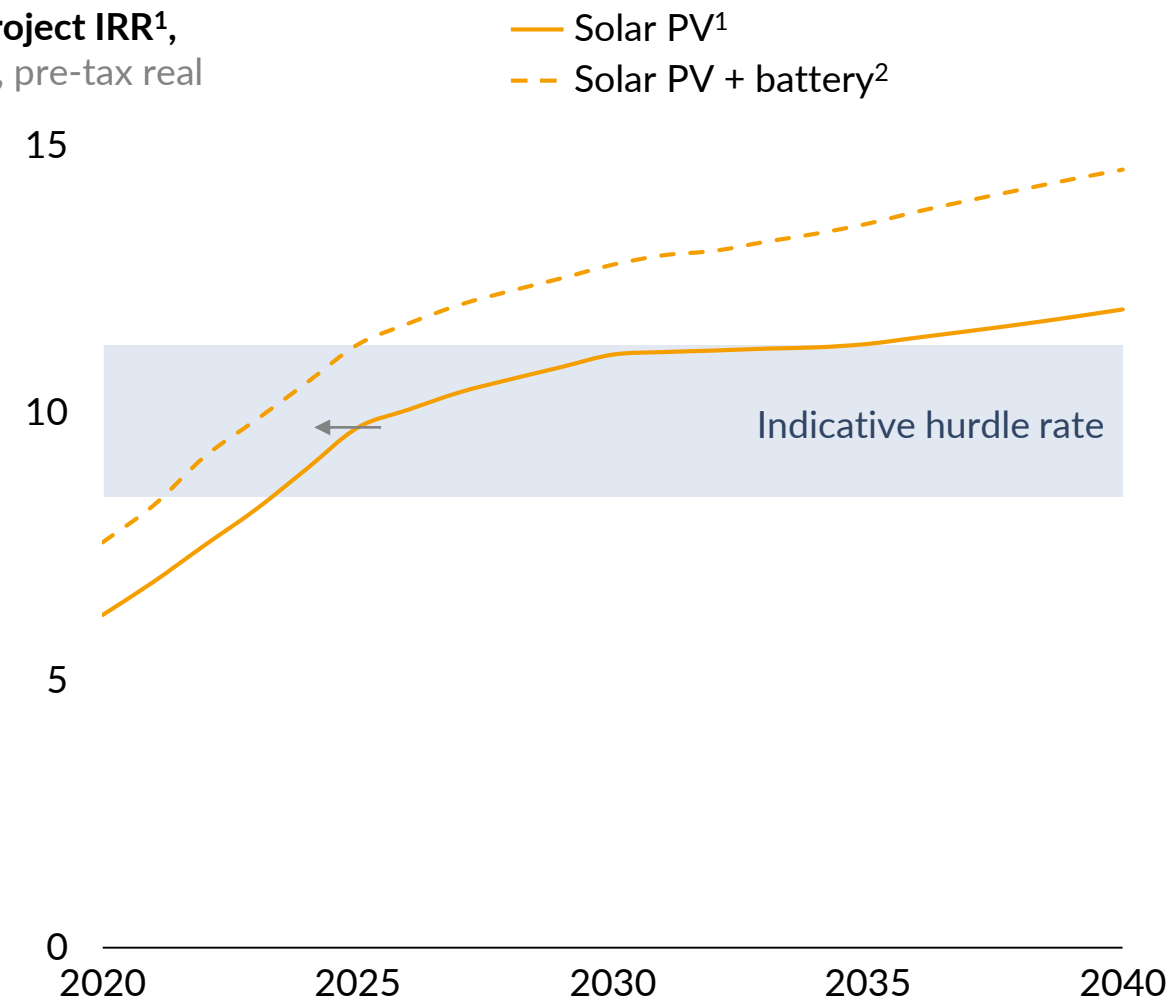
| Barrier | Impact/ Severity | Status |
|---|---|---|
| **Final consumption levies** charged when importing from Grid. Charges include FiT, CfD, RO and CM | Battery/ *High*<br>Prevents energy arbitrage business case from being economical | Introduction of modified generation licence (and therefore removal of FCL) for storage due 'shortly' - indicated by Ofgem in Dec 2018 |
| **Storage Import BSUoS Charge.** Volume imported and exported considered in allocation of BSUoS charges | Battery/ *Medium*<br>Impacts the cost incurred by battery | CMP281 will remove for transmission assets. Ofgem has stated that BSUoS should be removed for embedded |
| **Wider access to BM.** BM limited to BSP[1]s ≥50 MW in GB | Battery/ *Medium*<br>Restricts participation of small batteries in BM | Project TERRE and Wider Access to BM approved to resolve and allow European entry- go live in Q4 2019 |
| **Congested distribution networks** limit potential for new solar sites | Solar/ *Medium*<br>Connections are either too expensive or unavailable in some regions | Considered on a location and DNO basis. Network Access consultation considering time-profiled access and definitions of non-firm access and curtailment expectations |
| **Nationally Significant Infrastructure Projects (NSIP).** Currently, co-located projects with total capacity over 50MW must apply for BEIS approval | System/ *Resolved*<br>This would have delay planning process or restricted build out of projects to 20-30MW | BEIS is creating a new threshold for composite projects, which means State approval required only if an individual element is more than 50MW |
| **Capacity Market.**<br>Uncertainty over solar + storage participating in CM | Battery/ *Resolved*<br>Initial derating factors for solar suggest a de-rating factor of 1-2% for standalone solar PV | Ofgem confirmed assets can claim RO/FiT and CM contracts corresponding to solar and battery respectively if separately metered[2] |

Notes: 1) Guidance for generators, 7 Dec 2018, Ofgem. 2) Balancing Service Providers

Sources: Aurora Energy Research, Ofgem

# Co-locating storage with solar PV brings subsidy free entry ahead by 3 years

**Project IRR[1],**
%, pre-tax real




- Optimally configured co-located Solar PV and battery project increases IRR by 1.6% on average between 2020 and 2030
- This brings subsidy-free solar PV forward by 3 years compared to standalone Solar PV
- If the key barriers can be overcome then co-located assets represent huge potential for subsidy-free deployment

Notes: 1) For a Solar PV project located in the South of the UK with a load factor of 12%. Assumes solar PV with inverter loading ratio of 1.25. 2) Uses a ratio of solar to grid connection to battery of 1:0.75:0.75 and a 2-hour battery. Assumed battery is refurbished after 15 years.

Sources: Aurora Energy Research

# Key takeaways

- Ownership of both solar PV and battery storage assets can protect assets from specific downside risks
- Co-locating new solar PV with battery storage provides several additional benefits including asset oversizing and cost savings of £21/kW of battery CAPEX
- Current barriers limit the benefits from co-locating assets and restrict the battery energy arbitrage business model
- Once these barriers are removed, co-locating storage with solar PV brings subsidy free entry ahead by 3 years

Sources: Aurora Energy Research

# GB Renewables Service

## *Summary of service*

| | | |
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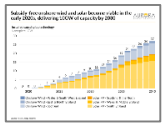
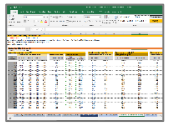
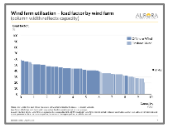
|  | **Biannual market outlook reports** | • Market outlook and capacity development to 2040<br>• Forecasts for wholesale, balancing, capacity and ancillary markets<br>• Regional comparison for load factors and capture prices<br>• Business-model-specific revenue stacking |
|  | **Forecast data** | • Full forecast dataset in .xls until 2040 for use in investment cases<br>• Wholesale prices, annual BM, ancillary services and CM forecast |
|  | **Monthly market summaries** | • Go-to source of up-to-date data on asset and market performance<br>• Includes monthly summaries of RES participation in wholesale and balancing markets with comparisons to previous months |
|  | **Historical market data** | • Live wholesale and balancing market and system data, with fully customisable charts and dashboards |
|  | **Strategic Insight reports** | • Regional deep-dive analysis on topical issues in the evolving renewables market and new business models (e.g. pricing structures in corporate PPAs, valuing merchant risks, co-location business models) |
|  | **Group Meetings** | • Presentation of forecast update and new research<br>• Networking opportunity with developers, investors and Government |
|  | **Workshops and analyst support** | • Bilateral workshops to discuss Aurora's analysis and specific implications<br>• Ongoing analysis support to answer questions about our research |
|  | **Summer Renewables Summit** | • The annual summit brings original analysis from the Aurora team together with provocative insight and discussion from leading industry figures in a focused, half day session in London |

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Source: Aurora Energy Research