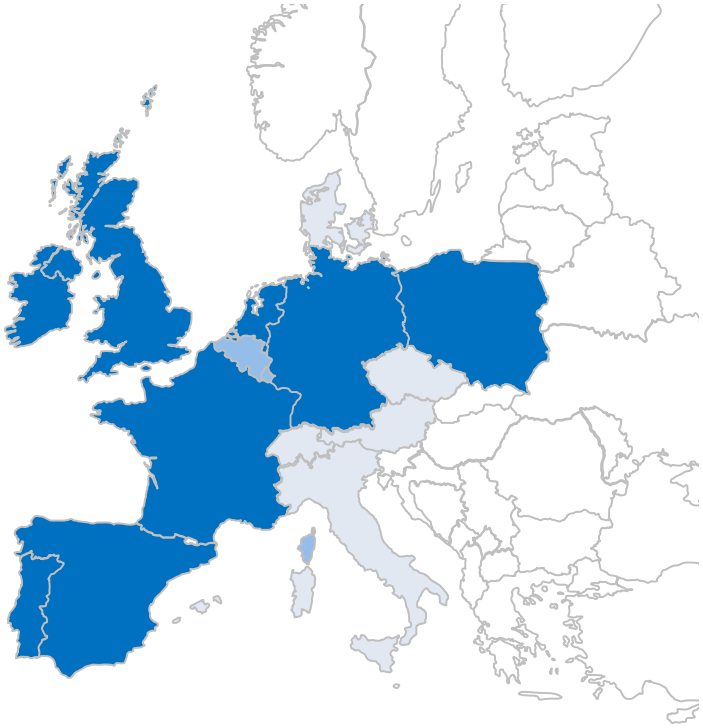
AURORA ENERGY RESEARCH

The economics of merchant solar co-located with battery storage systems

5th November 2019

CONFIDENTIAL: NOT FOR EXTERNAL DISTRIBUTION

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



Comprehensive Power Market Services	Power Market Forecast Reports	Bespoke forecasts
✓ Power market forecast reports	✓ Power market forecast reports	✓ Aurora can provide power market forecasts upon request
✓ Forecast data in Excel	✓ Forecast data in Excel	
✓ Global energy market forecast reports	✓ Analyst support	
✓ Strategic insight reports		
✓ Regular subscriber group meetings		
✓ Bilateral workshops		
✓ Analyst support		

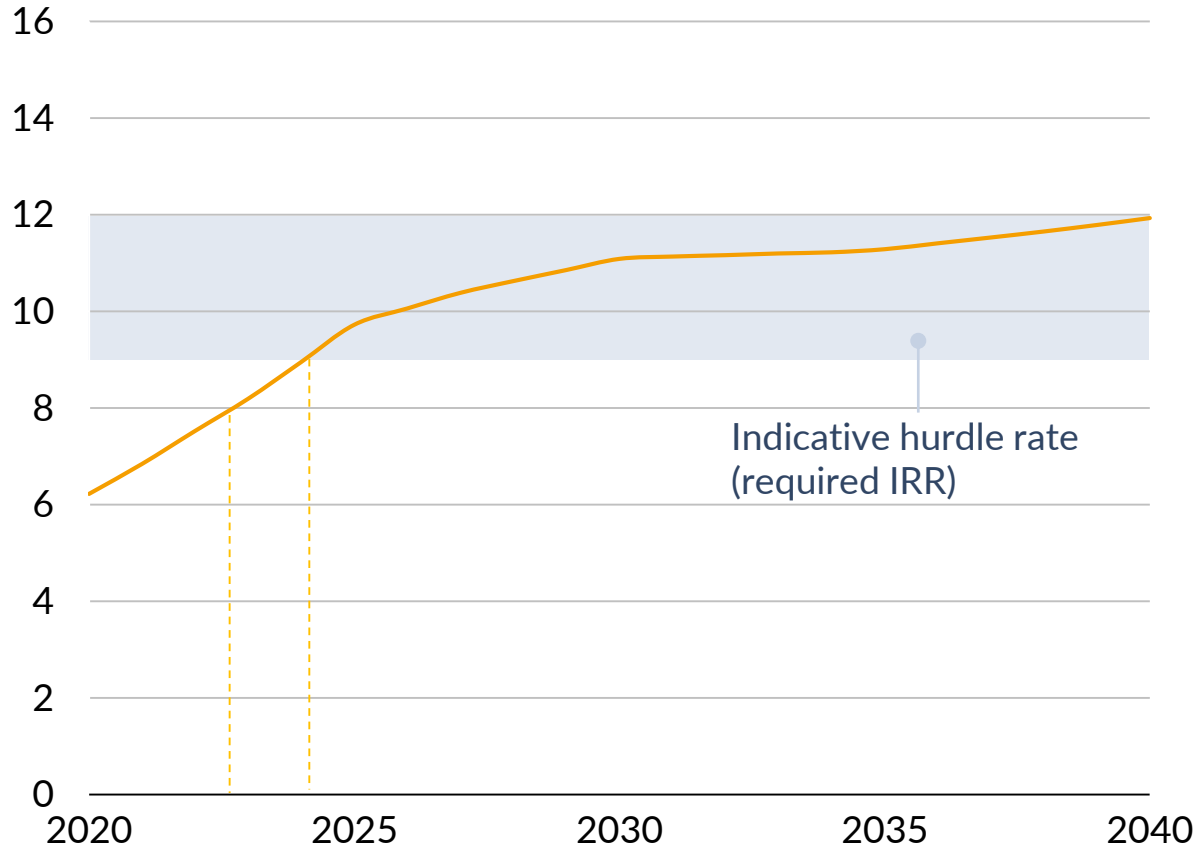
The content we'll discuss today is based on a recent Aurora report that was commissioned by **Wyelands Bank** and **Anesco**.

Source: Aurora Energy Research

1. Economics of merchant solar
2. Co-location of solar and batteries
3. Economics of co-location in different market scenarios
4. Conclusions

Better understanding of investment risk could drive earlier deployment of subsidy-free solar

Project internal rate of return (IRR)[1],
%, pre-tax, real and unlevered



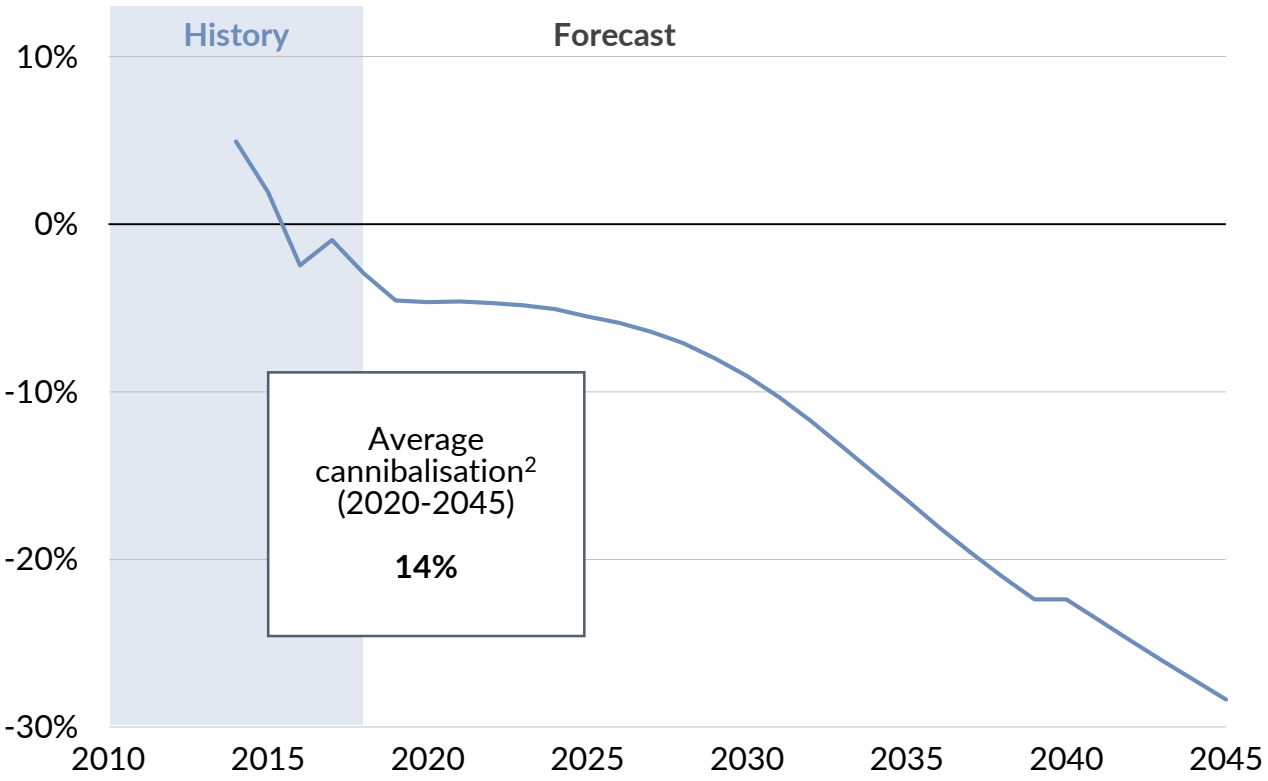
- We estimate the range of hurdle rates for merchant solar projects is between 9% and 12%
- IRR for average new project has been rising, mainly due to CAPEX reductions
- Higher investor confidence in revenues could reduce the hurdle rate needed
- All else equal, reduction of the hurdle rate by 1pp could make merchant solar economic by 2022

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

Source: Aurora Energy Research

Price cannibalisation increases the perceived level of risk in subsidy-free solar PV investment

Difference of solar PV capture price from baseload price[1],
%



- Solar faces a risk of cannibalisation, where high deployment reduces captured prices
- We expect solar capture prices 14% lower than average baseload prices for 2020-2045
- Co-location of merchant solar assets with batteries could help mitigate this risk

Subsidy-free installed solar capacity (GW)

0.2	1.9	6.0	11.7	19.0

1. Baseload is time weighted, capture prices are generation weighted average across all regions. 2. Discount to baseload price

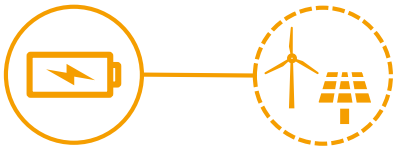
Source: Aurora Energy Research

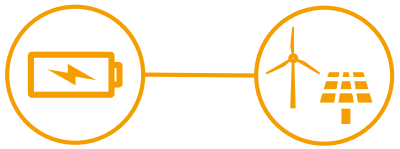
1. Economics of merchant solar
2. Co-location of solar and batteries
3. Economics of co-location in different market scenarios
4. Conclusions

Co-location of solar and battery systems can help hedge risks in standalone assets

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

Focus of today





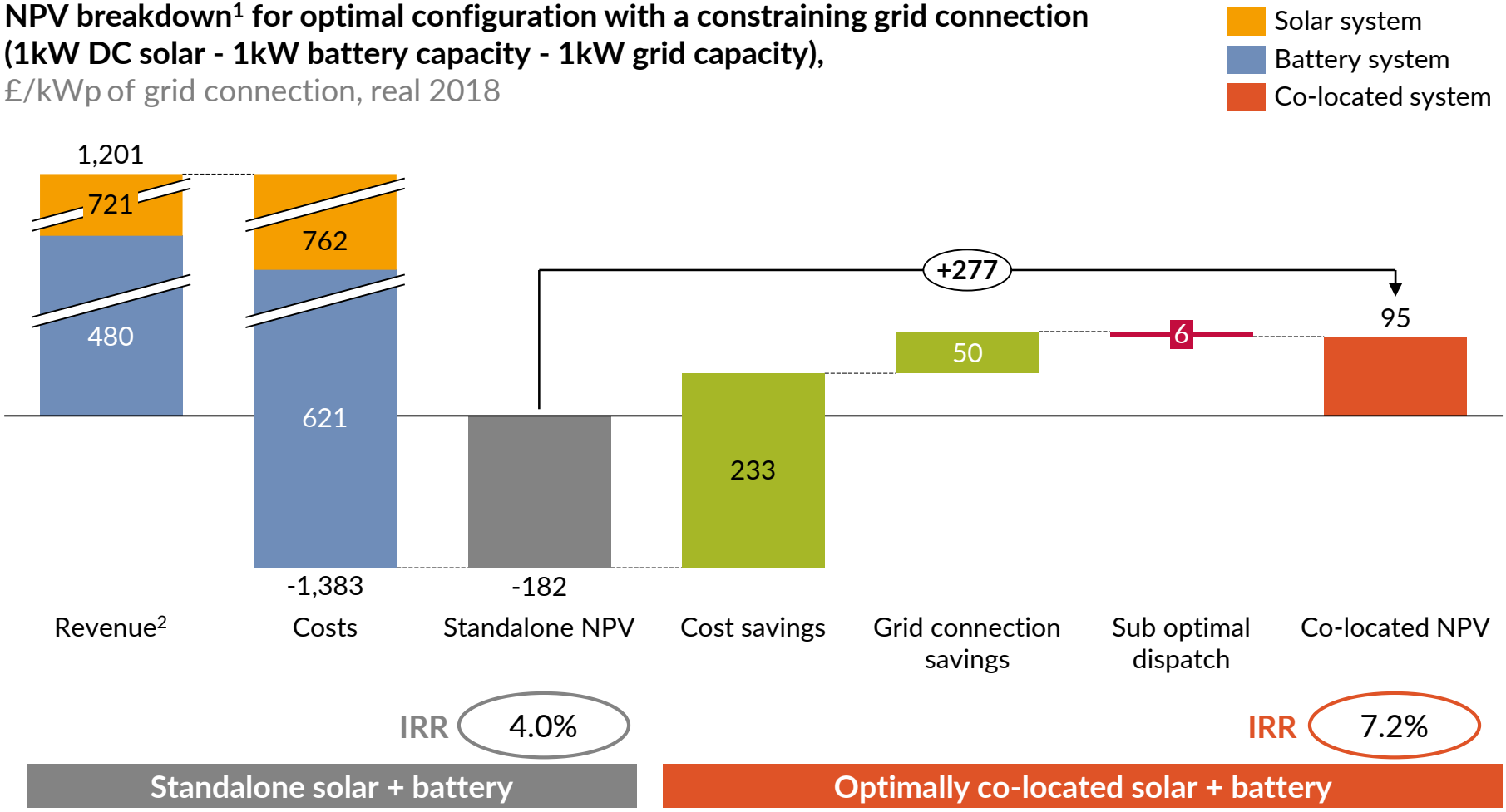
	Standalone	Retrofit	New build co-located
	Own and operate each asset separately and independently	Co-locating batteries with existing subsidy supported assets	Subsidy free assets co-located with new build batteries
Portfolio benefits	Full portfolio benefits	Full portfolio benefits	Full portfolio benefits
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

1. Final Physical Notification

Source: Aurora Energy Research

Co-location of solar and batteries may increase project IRR of standalone assets by c. 3.2pp

NPV breakdown[1] for optimal configuration with a constraining grid connection (1kW DC solar - 1kW battery capacity - 1kW grid capacity),
£/kWp of grid connection, real 2018

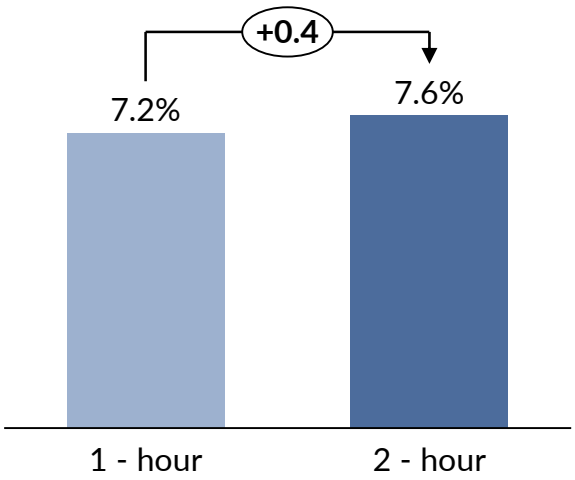


1. Discounted at 6% pre-tax real. Assuming 25 year lifetime, battery duration of 1-hour and refurbishment of battery cells after 8 and 16 years. 2. Includes wholesale, BM, CM and embedded benefits.

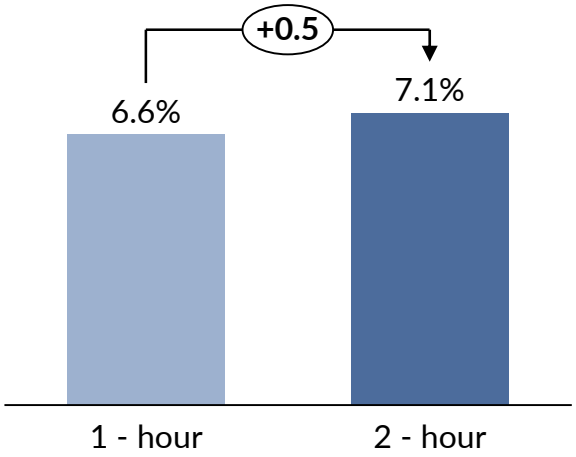
Source: Aurora Energy Research

Longer-duration batteries and higher participation in the BM could increase project IRR

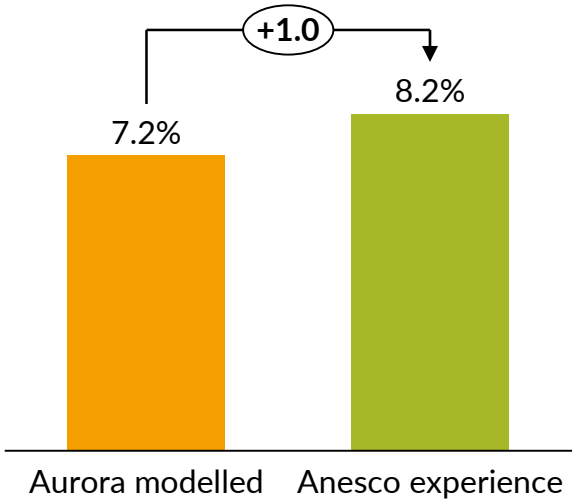
IRR for systems with a constraining grid connection[2]



IRR for systems with a non-constraining grid connection[1]



IRR for optimal modelled system and Anesco experience[3]



- Figures in this analysis reflect model outputs for an average hybrid asset
- Sites with higher solar resource, lower grid connection costs and more sophisticated trading strategies could be able to achieve even higher NPV and IRR outcomes
- Co-located assets with battery systems of longer storage durations achieve higher IRR in 2020 by up to 0.5pp
- In addition, increasing participation in the balancing market (BM), has led to higher gross margins for Anesco of up to 27% more than the modelled average
- Assuming these higher margins can be sustained over the asset lifetime, a project would achieve IRR of up to 1pp higher than in our model

1. Assumes a co-located system with 1kWp DC solar, 1kW of battery storage and a 1 kW grid connection. 2. Assumes a co-located system with 0.5kWp DC solar, 0.5kW of battery storage and a 1 kW grid connection. 3. Reflecting gross margins of the best Anesco asset, and maximum BM access of 16 hours per day.

Source: Aurora Energy Research

1. Economics of merchant solar
2. Co-location of solar and batteries
3. Economics of co-location in different market scenarios
4. Conclusions

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

AURORA ENERGY RESEARCH

Risks	Impact on standalone asset: Solar PV	Impact on standalone asset: Battery
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
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
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

- Understanding how assets might perform in different market conditions is key for investors
- Risks have different impacts on standalone and hybrid asset revenues
- Fuel and carbon prices have the largest impact on the value of solar and battery projects

Key

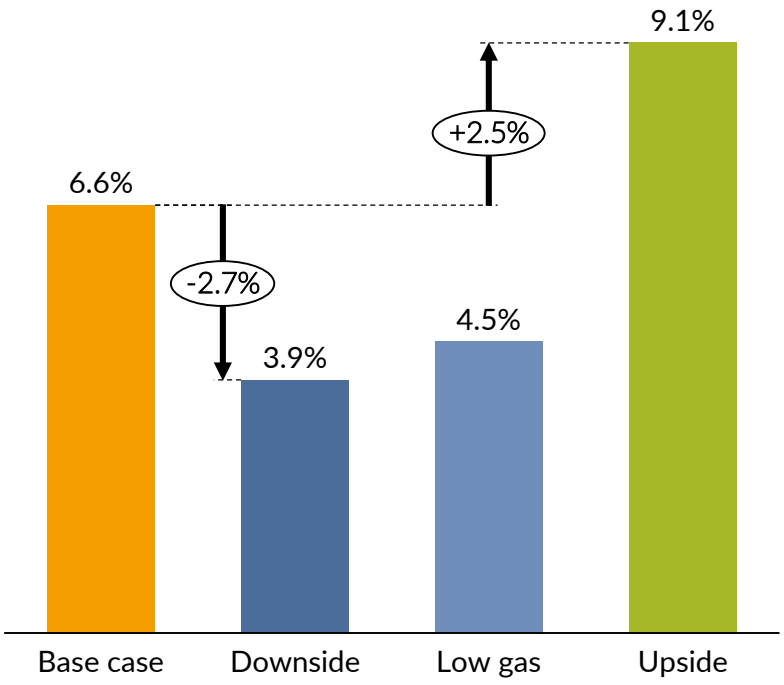
Negative Impact

Positive Impact

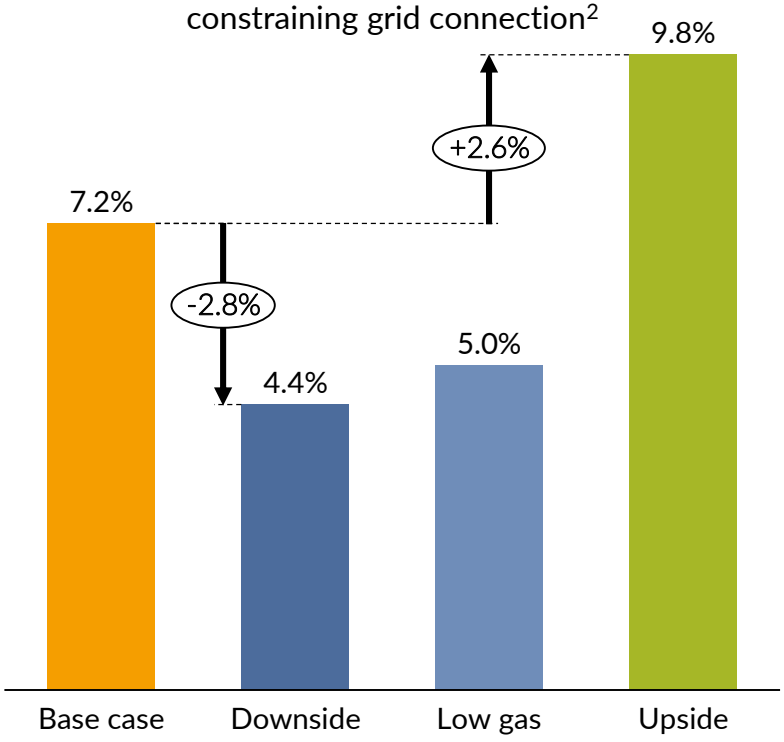
Source: Aurora Energy Research

Project IRR varies between market scenarios, with differences of up to 2.8% from our base case

IRR for systems with a non-constraining grid connection[1]



IRR for systems with a constraining grid connection[2]



	Units	Base Case	Downside	Low gas	Upside
NBP gas price	€/MWh	27.3	16.3	16.3	39.6
ARA coal price	€/tonne	60.7	46.6	60.7	74.6
EUA carbon price	€/tonne	34.4	19.8	34.4	50.0

1. Assumes a co-located system with 1kWp DC solar, 1kW of battery storage (1-hour) and a 1 kW grid connection. 2. Assuming a co-located system with 0.5kWp DC solar, 0.5kW of battery storage (1-hour) and a 1 kW grid connection

Source: Aurora Energy Research

1. Economics of merchant solar
2. Co-location of solar and batteries
3. Economics of co-location in different market scenarios
4. Conclusions

Key takeaways

- Rapid reductions in the costs of solar technology mean that subsidy-free projects, with exposure to power market prices, could soon be widely deployed
- Co-location of new solar assets with battery storage systems can unlock additional revenue streams and reduce the risks of merchant business models
- Hybrid assets deployed in 2020 can achieve IRRs of up to 7.6% in our base case market scenario, compared with 4.0% for standalone solar and battery assets
- System IRR may vary by ±2.8pp across a range of alternative market scenarios, while debt leverage can increase the returns for equity owners by 0.3pp
- Although regulatory and network barriers have limited deployment of co-located assets in the past, changes to regulation are resolving key issues

Source: Aurora Energy Research