Grid limitation and why co-location is the answer



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The increasing electrification of industrial and commercial operations, coupled with heightened volatility in wholesale electricity markets, has intensified interest in behind-the-meter renewable energy solutions.

Organisations with significant electrical demand are increasingly seeking methods to reduce operating costs, improve energy resilience, support corporate net-zero objectives, and mitigate exposure to future fluctuations in grid-supplied electricity prices.

At the same time, growing demand from energy-intensive sectors, particularly data centres, advanced manufacturing facilities and large commercial campuses, is placing increasing focus on secure, predictable and sustainable electricity supply.

On-site solar photovoltaic (PV) generation and battery energy storage systems (BESS) have become an increasingly attractive component of modern microgrid and distributed energy strategies. Continued reductions in the capital cost of both solar PV and battery technologies, alongside improvements in system performance and operational flexibility, have strengthened the economic case for behind-the-meter deployment. When implemented in combination, solar PV and BESS can enable a greater proportion of site demand to be met from locally generated renewable energy while reducing reliance on imported electricity.

However, determining the optimal balance between generation capacity, storage capacity, operational performance and facilitating on-site consumption remains a challenge. The value delivered by a solar PV and BESS system is highly dependent on the interaction between site-specific demand characteristics, renewable generation profiles and storage dispatch strategies. Conventional sizing approaches based on annual energy balances or simplified assumptions can overlook the temporal dynamics that ultimately drive project performance. Time-series analysis provides a more robust framework, enabling the assessment of energy flows on a timestep basis.

Drawing upon Natural Power's extensive experience in renewable energy generation, energy yield assessment and energy storage projects, this study demonstrates how detailed time-series modelling can be used to optimise integrated solar PV and BESS systems for commercial and industrial energy users.



This case study presents a high-level optimisation of solar PV generation and battery energy storage capacity for a commercial energy user. The objective of the assessment was to evaluate how co-located renewable generation and energy storage could reduce grid electricity imports while maximising the utilisation of locally generated solar PV energy.

The analysis combines four key inputs:

- Historical electricity consumption data from the client facility.
- Finance-grade solar PV generation profiles derived from an energy yield assessment carried out by Natural Power.
- A bespoke Natural Power timeseries energy model, simulating interactions between site demand, solar PV generation, BESS charge/ discharge and residual grid imports.

CAPEX and OPEX assumptions informed by Natural Power's experience across utility-scale solar PV and energy storage developments.

The modelling framework quantifies how solar PV generation is consumed directly by the facility, identifies periods of surplus generation available for BESS charging and simulates the discharge of the BESS during periods with residual grid imported electricity.

To identify an optimal BESS solution, multiple battery sizing scenarios were evaluated. Each scenario was assessed against estimated capital expenditure (CAPEX) and operational expenditure (OPEX) estimates, with resulting energy and economic performance metrics used to calculate a Levelised Cost Of Energy (LCOE) for each configuration. The lowest LCOE scenario was considered the optimum balance between system performance and project cost, providing a consistent basis for comparing alternative storage capacities.

As part of an initial development and design optimisation exercise, Natural Power identified a 10 MWDC / 8 MWAC solar PV facility as the preferred configuration to facilitate the on-site electricity consumption, considering available land areas, permitting limitations and available CAPEX for the solar PV array. Following definition of the solar PV layout, a site constraints assessment was undertaken to identify potential developable areas for a co-located battery energy storage system and establish the maximum feasible BESS capacity that could be accommodated within the available land area.

The primary objective of the project was to minimise imported electricity consumption and maximise the utilisation of energy generated by the solar PV facility. To achieve this, the battery energy storage system was modelled exclusively as a solar-coupled asset, charging only from surplus solar generation. The BESS therefore performs two key functions:

- Capturing excess solar PV generation that would otherwise be curtailed.
- Time-shifting solar PV generation to periods when solar production is insufficient to meet site demand.

A common challenge offtakers face when developing behind the meter solar PV and BESS is local grid constraints, whereby there is limited or no available export capacity, which is the case for this project. Therefore, the project was not permitted to export produced energy to the grid. The analysis therefore focuses solely on the value derived from increasing solar self-consumption and reducing reliance on imported grid electricity.

The following plot shows the on-site consumption and solar PV plant production over the course of a day and year.

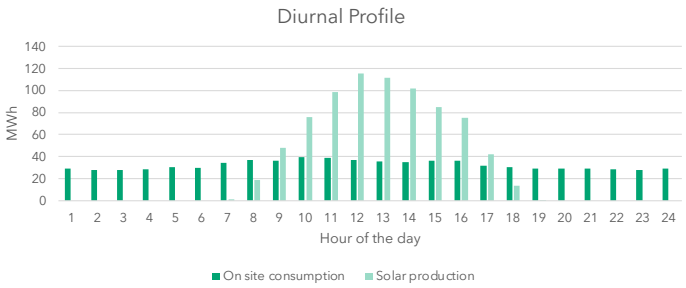


Figure 1: Daily solar production and on-site consumption profile

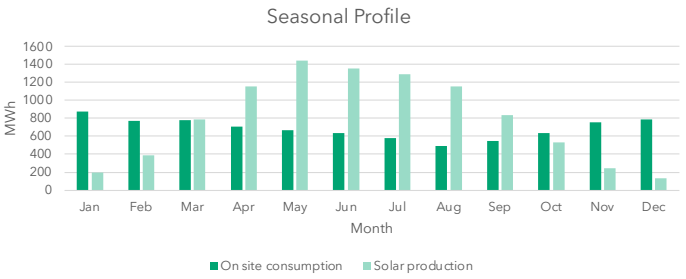


Figure 2: Monthly solar production and on-site consumption profile

The BESS capacity scenarios assessed ranged from 4 MW to 8 MW with a 1-hour duration. These BESS scenarios were determined following a review of the project's on-site demand and solar PV production. The BESS was modelled for a typical year of on-site consumption with the solar farm production and the annual results presented in the table below. The seasonal mismatch between on-site demand and solar PV production profiles results in imported electricity during the winter months, whereas during the summer months imported electricity is materially reduced.

Table 1: Analysis results for varying BESS capacities

Parameter	4 MW	5 MW	6 MW	7 MW	8 MW
On-site consumption provided by the solar farm directly	41%				
On-site consumption provided by BESS	11%	13%	15%	17%	19%
On-site consumption imported from the grid	48%	46%	44%	42%	40%

To benchmark each scenario assessed against one another and identify an optimal BESS scenario, the CAPEX and OPEX estimates were derived based on Natural Power's experience working on solar and BESS projects throughout the UK and Europe. The volume of electricity that was provided annually by the solar farm and BESS was used in conjunction with the respective CAPEX/ OPEX estimates to derive a cost of electricity produced by the solar and BESS plant (£/ MWh). Following which, the volume of electricity imported from the grid and the respective import tariff was then added to calculate a cost of electricity for each scenario assessed, which is presented in the graph and table below.

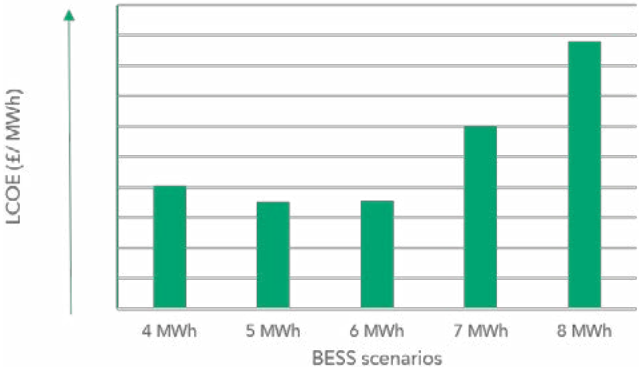


Figure 3: LCOE analysis results for each scenario

Table 2: Reduction in electricity tariff for each scenario

BESS scenario	4 MW	5 MW	6 MW	7 MW	8 MW
Reduction in electricity tariff	19%	20%	20%	18%	15%

Natural Power's modelling identified the 5 MWh BESS as the lowest-LCOE option, delivering a modelled 20% reduction in the client's electricity tariff. The 6 MWh option produced a closely comparable LCOE, giving the client a clear basis for weighing marginal performance gains against additional capital cost. Beyond 6 MWh, LCOE increased rapidly because the extra stored solar energy did not justify the higher installation cost.

For this client, a flat electricity tariff and solar-only charging limited the BESS to one charge/discharge cycle per day. The study nevertheless showed how the selected system could lower annual electricity costs, increase solar self-consumption and reduce reliance on imported power. It also gave the client a transparent investment case based on site-specific demand, generation and cost assumptions rather than simplified annual averages.

The assessment also established a route to additional value if the client's commercial or grid arrangements change. Variable tariffs could enable lower-cost overnight charging and additional daily cycling, while future export permission could create revenue through time-shifted exports or participation in grid services such as the Balancing Mechanism and Capacity Market.

Natural Power's Advisory and Analytics specialists support offtakers and developers with solar, wind and BESS feasibility, optimisation, modelling and operational performance analysis. By combining finance-grade renewable energy assessment with site-specific time-series modelling, we help clients select investable configurations and identify opportunities to reduce cost, manage risk and maximise asset value throughout the project lifecycle.

Client benefits:

- **Lower electricity costs:** the preferred 5 MWh BESS scenario was modelled to reduce the client's electricity tariff by 20%.
- **Reduced grid dependence:** the assessed configurations increased the share of demand met by stored solar energy from 11% to as much as 19%, reducing grid imports to between 49% and 40%.
- **Better-informed investment:** consistent LCOE comparison identified the point at which additional storage capacity no longer justified the extra capital cost.
- **Greater use of on-site renewable energy:** surplus solar generation could be captured rather than curtailed and shifted to periods of higher on-site demand.
- **A clear route for future value:** the analysis highlighted further savings and potential revenues where variable tariffs, grid charging or export become available.

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