Concept Level Techno Operational Assessment of a Grid Connected Rooftop PV BESS Inverter System for a 60 Office Building in South England

Dr Emad Al-Mahdawi
Department of Electrical and Mechanical Engineering
MidKent College
Chatham, United Kingdom
emad.almahdawi@midkent.ac.uk

Mr Christopher Harley
dept. Electrical & Mechanical Engineering
Royal School of Military Engineering
Kent, United Kingdom cwh1805@protonl.me

Abstract-*This paper evaluates a grid-connected rooftop photovoltaic (PV), battery energy storage system (BESS), and inverter concept for a three-floor commercial office building containing 60 offices in South England. The case system comprises 64 monocrystalline 550 W PV modules, a 120 kWh lithium iron phosphate BESS, two 15 kW three-phase PV string inverters, a 60 kW bidirectional battery power conversion system, and an hourly dispatch model. The research gap addressed is the limited availability of compact concept-stage frameworks that connect academic PV-BESS self-consumption literature with practical design checks, including load modelling, DC/AC ratio, string voltage, roof area, critical-load backup, export behaviour, monitoring, connection requirements, and battery safety. The annual building demand is 163,820 kWh and the annual PV generation is 35,200 kWh. The simulation gives a grid import after PV-BESS operation of 128,805.6 kWh, zero annual export, a gross solar fraction of 21.49%, and a net grid import reduction of 21.37%. The usable 108 kWh BESS supports approximately 5.4 h at 20 kW or 2.7 h at 40 kW of selected critical load. The results show that the proposal is technically plausible as a grid-connected demand-reduction and resilience measure, but not as full-building autonomy.*

Keywords- *battery energy storage, commercial buildings, DC/AC ratio, inverter sizing, photovoltaics, PV self-consumption, rooftop solar, South England.*

I. INTRODUCTION

Commercial buildings are an important part of the electricity decarbonisation challenge because they combine daytime occupancy, heating, ventilation and air-conditioning loads, lighting, information technology, security systems and an increasing dependence on digital services. Rooftop PV is attractive in this sector because its production is partly coincident with office use. Behind-the-meter BESS assets can also provide limited backup, reduce short duration peaks and allow future operation under time-varying tariffs or flexibility services.

The United Kingdom is pursuing rapid growth in low-carbon electricity infrastructure, including solar and battery capacity [1], [2]. However, the practical question for a building owner is not only whether PV and storage are desirable, but whether a particular proposal is of the correct order of magnitude for the building load, the roof area, the inverter rating and the critical-load expectation. Many concept reports overstate the benefits of batteries by treating annual generation, storage capacity and autonomy as if they were interchangeable.

This paper reframes a preliminary engineering design for a 60-office building in South England as a scientific case-study article. The proposed system comprises a 35.2 kWp rooftop PV array, 120 kWh nominal BESS, 30 kW of PV inverter capacity and a 60 kW battery power conversion system (PCS). The central research question is: how can an early-stage commercial PV-BESS design be evaluated transparently enough that stakeholders can understand roof-constrained PV capacity, storage sizing, inverter selection and dispatch assumptions before committing to detailed surveys and procurement?

The contribution is a reproducible concept-screening method that integrates annual energy balance, hourly PV-first BESS dispatch, string and inverter checks, critical-load backup duration and practical recommendations for measured load data, roof survey, grid connection, monitoring and fire-safe battery siting. The paper does not replace a construction design, a distribution network operator (DNO) application or a measured performance study. Instead, it provides an auditable bridge between early design evidence and detailed engineering.

II. LITERATURE REVIEW AND RESEARCH GAP

PV self-consumption in buildings has been widely reviewed, particularly for residential systems. Luthander et al. define self-consumption as the share of PV production consumed locally and report that batteries and demand-side management can increase local use of PV energy [15]. Commercial buildings differ from homes because their daytime loads are stronger, tariffs may include demand elements, and electrical-safety duties are more complex. Merei et al. show that commercial PV-battery performance depends strongly on load profile, tariff structure, battery price and PV size [16].

Recent reviews have expanded the field from simple self-consumption to PV-BESS integration, optimisation, control and energy sharing [17]. Office-building studies often use advanced scheduling methods. Li et al. use dynamic programming for grid-connected PV-battery systems in office buildings under time-of-use pricing [18], while Jin et al. present hierarchical microgrid energy management in an office environment [19]. These methods are valuable once reliable measured data are available, but they may be too data-intensive for the first feasibility decision.

Temporal resolution is also a modelling concern. Beck et al. show that the time resolution of load and PV profiles affects estimates of self-consumption and storage sizing [20]. Ayala-Gilardon et al. similarly demonstrate that self-consumption and self-sufficiency results vary with sampling interval [21]. The hourly model used in this paper is therefore appropriate for first-order energy screening, but it must not be used as a substitute for final inverter transient analysis, demand-charge modelling or protection studies.

Inverter sizing and DC/AC ratio form the practical link between PV capacity and electrical design. NREL distinguishes DC module capacity from AC inverter capacity through the inverter loading ratio [11]. Hazim et al. and Wang et al. show that optimum PV/inverter ratio depends on location, losses, inverter efficiency and economics [27], [28]. For BESS installation, the IET Code of Practice, ENA connection rules and lithium-ion hazard literature

demonstrate that storage is both an energy asset and a safety-critical electrical installation [7]-[9], [35].

The research gap is the absence of a compact concept-stage framework for medium office buildings that connects assumed load profiles, rooftop PV yield, PV-first battery dispatch, string voltage, DC/AC ratio, backup duration and UK practical constraints in one auditable sequence. The contribution is not a new optimisation algorithm; it is a disciplined screening method that prevents exaggerated autonomy claims and identifies the evidence required for detailed design.

TABLE I. Key Literature Themes and Relevance to the Case Study

Theme	Representative sources	Relevance
PV self-consumption	Luthander et al. [15]; Merei et al. [16]	Shows why local PV use depends on load coincidence, storage and tariff structure.
Office-building control	Li et al. [18]; Jin et al. [19]	Advanced optimisation is useful after measured data and tariffs are known.
Temporal resolution	Beck et al. [20]; Ayala-Gilardon et al. [21]	Hourly results are acceptable for screening but not for final detailed studies.
Inverter and BESS safety	NREL [11]; IET [7]; Conzen et al. [35]	Design must include inverter sizing, grid compliance, isolation and battery safety.

TABLE II. Compact Visual Summary of the Building Context and Rooftop PV Layout



Fig. 1. Conceptual rooftop PV and plant-room arrangement for the South England office-building case study.

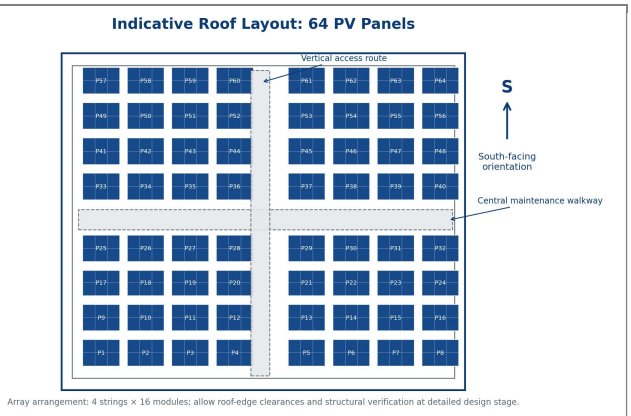

Fig. 3. Indicative roof layout for 64 PV panels, including orientation and maintenance access notes.

III. METHODOLOGY

The methodology follows a deterministic case-study simulation. It begins with a synthetic office load profile, sizes the PV array from the specified number and rating of modules, checks inverter and string quantities, defines usable BESS capacity and simulates one year with 8,760 hourly timesteps. PV generation is allocated to the building first. Surplus PV, if present, charges the battery subject to state-of-charge headroom, charge efficiency and PCS power limit. When load exceeds PV generation, the BESS discharges subject to available energy, discharge efficiency and PCS rating. The remaining deficit is imported from the grid and the remaining surplus is exported.

The method is intentionally transparent. A more advanced model could include measured irradiance, shading, module temperature, soiling, detailed inverter efficiency curves, battery degradation, stochastic occupancy and model predictive control. These elements are not ignored; they are deferred to detailed design. The value of the present method is that every input can be checked and replaced while preserving the core energy relationships needed for feasibility screening.

A. Building and Load Model

The building is assumed to contain 60 offices over three floors in South England. The diversified peak demand estimate is 82 kW and includes lighting, computers, printers, small power, HVAC, common services and IT/security loads. For annual simulation, weekday occupancy from 08:00 to 18:00 is assumed at 40 kW. Weekday shoulder periods from 06:00 to 08:00 and 18:00 to 20:00 are assumed at 15 kW. The out-of-hours base load is 8 kW. Weekend reduced activity from 09:00 to 16:00 is 12 kW and otherwise 8 kW. These assumptions produce 540 kWh per weekday, 220 kWh per weekend day and 163,820 kWh/year.

The load model is a screening profile and must be replaced with at least twelve months of measured half-hourly or hourly electricity data before procurement. CIBSE benchmarking practice demonstrates that non-domestic energy performance depends on building type, occupancy, weather and separable energy uses [4]. Therefore, the assumed profile is adequate for concept sizing, but not for financial approval or final control design.

B. PV Array, Inverter and String Checks

The PV array contains 64 modules rated at 550 W, giving 35.2 kWp DC. A normalised planning yield of 1,000 kWh/kWp/year gives 35,200 kWh/year. A detailed design should replace this assumption with PVGIS, PVWatts or a comparable bankable workflow including tilt, azimuth, horizon, shading, soiling, temperature, inverter efficiency, cable losses and degradation [3], [10].

The inverter arrangement comprises two 15 kW three-phase PV string inverters, giving 30 kW AC. The DC/AC ratio is therefore 35.2/30 = 1.17. This is a moderate ratio for a temperate UK rooftop and is unlikely to be the limiting factor. The preliminary string arrangement is four strings of 16 modules. With an assumed maximum-power voltage of 41.5 V per module, string operating voltage is 664 V. With an assumed open-circuit voltage of 49.5 V, string Voc is 792 V before cold-temperature correction. Final design must use

manufacturer datasheets, lowest expected cell temperature, MPPT windows, current limits, isolator ratings and cable/protection calculations [5].

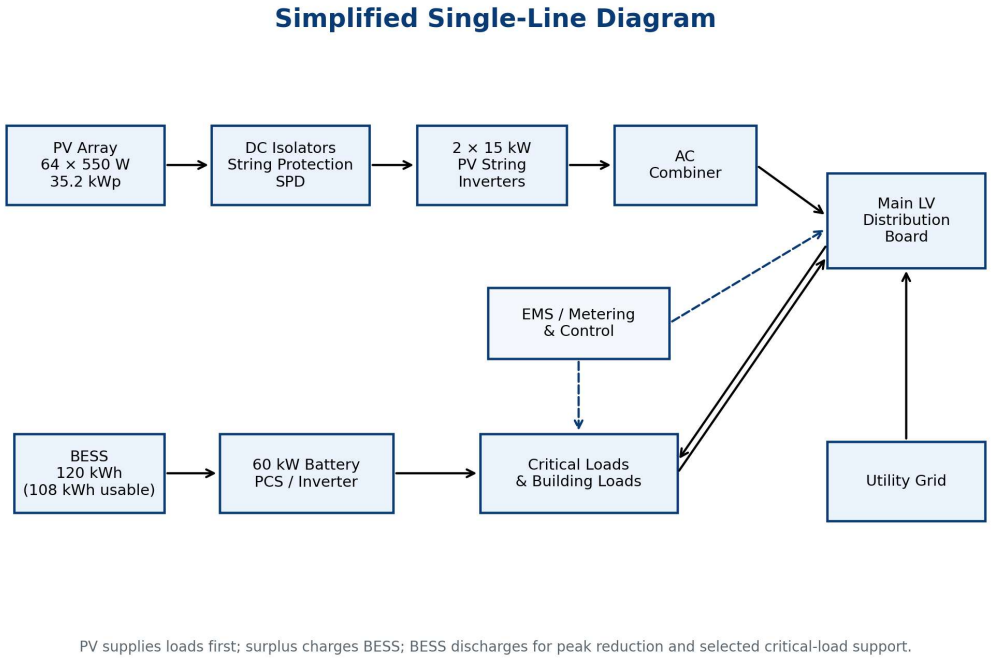

Fig. 2. Simplified single-line electrical architecture used in the concept design.

C. BESS Dispatch and Performance Indicators

The BESS is assumed to be lithium iron phosphate with 120 kWh nominal capacity and a 90% usable operating window, giving 108 kWh usable energy. The battery PCS is rated at 60 kW, equivalent to a power-to-energy ratio of 0.50 C. Backup duration is calculated separately from the energy simulation because resilience is not the same as self-consumption. The usable battery can support 20 kW of selected critical load for 5.4 h, or 40 kW for 2.7 h.

At each hour k, net PV is calculated as PV(k) minus load(k). If net PV is positive, the battery charges within the remaining state-of-charge headroom, conversion efficiency and PCS power limit. If net PV is negative, the battery discharges within available stored energy, discharge efficiency and PCS rating. The principal outputs are annual load, annual PV generation, grid import, export, PV self-consumption, gross solar fraction, net grid import reduction, battery losses and critical-load runtime.

Gross solar fraction is calculated as self-consumed PV divided by annual load. Net grid import reduction is annual load minus annual grid import divided by annual load. PV self-consumption ratio is self-consumed PV divided by annual PV generation. These indicators are deliberately separated from backup duration because a building can have high PV self-consumption while still remaining strongly dependent on the grid.

TABLE III. Principal Assumptions, Sizing Checks and Simulation Results

Metric	Formula or basis	Result
Annual building demand	(261 weekdays x 540) + (104 weekends x 220)	163,820 kWh/year
Installed PV capacity	64 modules x 550 W	35.2 kWp
Annual PV generation	35.2 kWp x 1,000 kWh/kWp/year	35,200 kWh/year
PV inverter capacity	2 x 15 kW three-phase inverters	30 kW AC
DC/AC ratio	35.2 kWp / 30 kW	1.17
Usable BESS energy	120 kWh x 90%	108 kWh
Battery PCS rating	Design selection	60 kW
Backup at 20 kW	108 kWh / 20 kW	5.4 h
Backup at 40 kW	108 kWh / 40 kW	2.7 h
Grid import after PV-BESS	Hourly simulation	128,805.6 kWh/year
Grid export	Hourly simulation	0.0 kWh/year
PV self-consumption ratio	Self-consumed PV / annual PV	100.00%
Net grid import reduction	(Load - import) / load x 100	21.37%

LISTING 1. Core Dispatch Algorithm Used for the Hourly PV-BESS Simulation

```
Inputs: load_kW, pv_kW, bess_kWh_usable, bess_kW, eta_ch, eta_dis, dt
soc(1) = 0.5 * bess_kWh_usable
for k = 1:8760
    netPV = pv_kW(k) - load_kW(k)
    if netPV >= 0
        maxChargeBySOC = (bess_kWh_usable - soc(k)) / (eta_ch * dt)
        charge_kW = min(netPV, bess_kW, maxChargeBySOC)
        soc(k+1) = soc(k) + charge_kW * eta_ch * dt
        gridExport_kW(k) = max(netPV - charge_kW, 0)
        gridImport_kW(k) = 0
    else
```

```
        required_kW = -netPV
        maxDischargeBySOC = soc(k) * eta_dis / dt
        discharge_kW = min(required_kW, bess_kW, maxDischargeBySOC)
        soc(k+1) = soc(k) - discharge_kW / eta_dis * dt
        gridImport_kW(k) = required_kW - discharge_kW
        gridExport_kW(k) = 0
    end
end
selfConsumed_kWh = annualPV_kWh - annualExport_kWh
grossSolarFraction = 100 * selfConsumed_kWh / annualLoad_kWh
netGridReduction = 100 * (annualLoad_kWh - annualImport_kWh) / annualLoad_kWh
```

IV. RESULTS

The simulation confirms that the PV array is useful but substantially smaller than the annual office load. Annual demand is 163,820 kWh/year, while annual PV generation is 35,200 kWh/year. Because the assumed office load is normally greater than PV output, all PV generation is consumed on site and the model produces zero annual export. After PV-BESS operation, annual grid import is 128,805.6 kWh/year. The gross solar fraction is 21.49%, while the net grid import reduction is 21.37%. The small difference is caused by battery conversion losses of approximately 185.6 kWh/year.

The first result is that the proposal should be described as a grid-connected demand-reduction and resilience measure, not as an autonomous or net-zero electricity system. The grid remains the dominant energy source because the roof-constrained PV array supplies only about one fifth of annual demand. The second result is that the BESS should not be justified mainly as a surplus-solar absorber under the assumed profile. Since annual export is zero, the building already absorbs the PV output. The BESS therefore requires a resilience, peak-management, tariff-response or operational-flexibility rationale.

The third result is that the PV inverter and string design are plausible at concept level. The DC/AC ratio of 1.17 is moderate, and the preliminary 16-module string voltage is compatible with a 1,000 V DC class design before final temperature correction. The direct module area is approximately 166.4 m2, with a practical roof requirement of about 220-250 m2 after maintenance access, spacing and safe routes are included. This makes roof survey, structural verification, cable routing and fire-service access decisive next steps.

The hourly result also explains why battery utilisation is constrained. During many occupied periods, building demand exceeds available PV generation, so there is little surplus to charge the BESS. A tariff-aware strategy could reserve battery capacity for evening shoulder periods or peak-price windows, but this requires tariff data and a control philosophy beyond the PV-first screening logic used here.

TABLE IV. Result Figures from the Hourly PV-BESS Concept Simulation

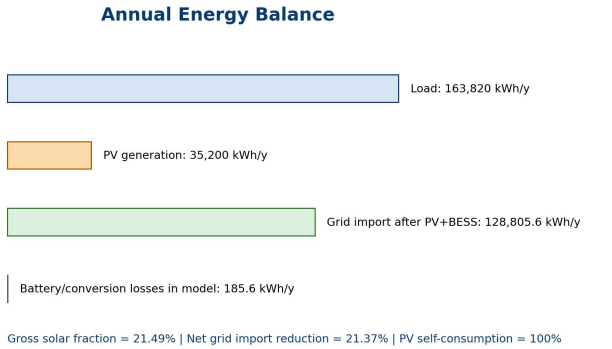

Fig. 4. Annual energy balance, including load, PV generation, grid import and conversion losses.

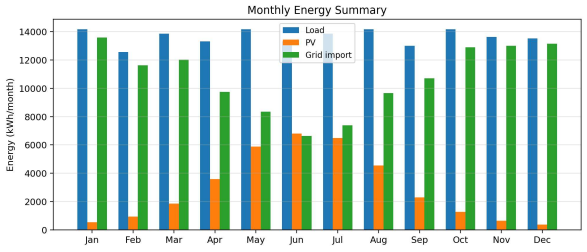

Fig. 7. Monthly load, PV generation and grid import summary.

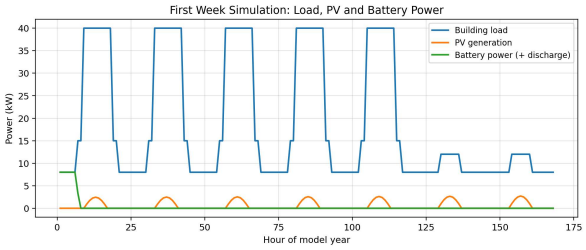

Fig. 5. First-week hourly load, PV generation and battery power.

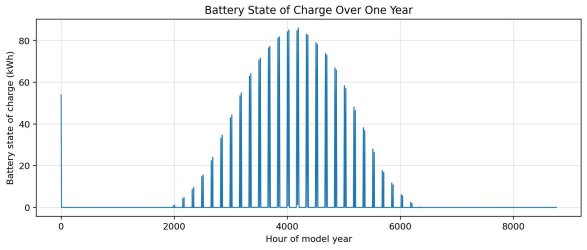

Fig. 6. Battery state of charge over the modelled year.

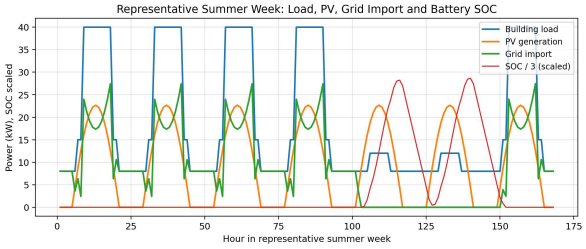

Fig. 8. Representative summer week showing PV contribution, grid import and battery state of charge.

Interpretation note: the result figures should be read together. Fig. 4 confirms the annual energy contribution; Fig. 7 shows the seasonal trend; Fig. 5 and Fig. 8 show the hourly mismatch between PV and load; and Fig. 6 shows that the BESS state of charge depends strongly on available surplus PV. The figures therefore support the conclusion that the battery has clearer value for resilience and flexibility than for additional solar absorption in this constrained rooftop case.

V. DISCUSSION

The results are best interpreted by separating energy, power and resilience. Annual energy analysis shows that the 35.2 kWp PV array offsets about one fifth of the building consumption. Power analysis shows that the 30 kW PV inverter capacity is below both the 82 kW diversified peak and the 40 kW weekday occupied load. Resilience analysis shows that the 108 kWh usable battery can support selected critical loads for a few hours, but not the whole building for a normal working day. These three conclusions answer different engineering questions and should not be collapsed into one headline percentage.

The zero-export result is particularly important. Many PV-battery studies focus on increasing self-consumption by storing surplus midday PV. In this case, the office load profile already absorbs the PV output. This does not make the BESS redundant, but it changes the value proposition. If the client expects the battery to increase PV self-consumption, the incremental benefit is limited. If the client values critical-load continuity, demand control, time-of-use arbitrage or operational flexibility, the battery may be justified for reasons beyond pure solar shifting.

A second interpretation concerns scale. The roof-constrained PV array is not large enough to approach energy independence. To materially increase the renewable fraction, the project would need more PV area, such as additional roof zones, car-park canopy PV, facade-integrated PV, nearby off-site procurement or power purchase arrangements. Alternatively, the building could reduce demand through lighting upgrades, HVAC optimisation, controls, fabric improvements, plug-load management and occupancy-responsive operation. The most robust decarbonisation strategy is therefore PV plus efficiency plus controls plus measured performance.

A third interpretation concerns BESS sizing. A 120 kWh battery paired with a 35.2 kWp PV array gives approximately 3.4 kWh/kWp, which is high if the only aim is PV self-consumption. Since the model produces no export, the battery may be oversized for surplus PV absorption but reasonable for critical-load support or peak management. Final sizing should therefore be driven by a priority-circuit schedule, measured peaks, outage tolerance, tariff analysis and battery degradation modelling rather than by PV capacity alone.

Safety and compliance shape the feasibility outcome as strongly as energy modelling. A BESS in or near an office building requires restricted access, ventilation, fire detection, emergency isolation, suitable enclosure, signage, maintenance procedures and integration with the fire strategy. Lithium-ion BESS studies identify thermal runaway, flammable gas and explosion hazards under fault conditions [35]. The preliminary design should therefore assume a dedicated service room or external plant-room arrangement, with separation from normal escape routes and site-specific liaison with competent fire and electrical specialists.

TABLE V. Research Gap, Case Evidence and Design Contribution

Research issue	Case evidence	Contribution
Early-stage data scarcity	Synthetic load profile and normalised PV yield.	Shows what can be concluded before measured data are available.
PV-BESS value ambiguity	PV self-consumption is 100%, but grid import remains high.	Reframes the BESS as resilience/flexibility, not only solar shifting.
Rooftop constraint	64 modules give 35.2 kWp and about 21.5% gross solar fraction.	Quantifies the difference between useful PV contribution and autonomy.
Electrical feasibility	DC/AC ratio is 1.17 and string Voc is 792 V before cold correction.	Links simulation to inverter and string sanity checks.
Practical compliance	BESS siting, DNO connection, fire strategy and monitoring remain open.	Bridges academic modelling and deliverable engineering tasks.

VI. SENSITIVITY AND IMPLEMENTATION CONSIDERATIONS

The screening result is sensitive to several practical variables that should be tested before procurement. The first variable is PV area. If the roof survey confirms additional usable zones or car-park canopy potential, the annual renewable fraction could increase more effectively through additional PV than through a larger battery. However, a larger PV array may create midday export, inverter clipping or export limitation issues, so the BESS value may change from resilience-led to a mixture of self-consumption, peak reduction and curtailment avoidance.

The second variable is demand reduction. The baseline annual load of 163,820 kWh can be reduced through LED lighting, occupancy control, HVAC scheduling, set-point optimisation, power-management policies and monitoring of standby loads. Demand reduction changes the denominator of the solar fraction and may allow the same 35.2 kWp PV array to provide a higher percentage contribution. It may also reduce peak demand and therefore influence the required PCS rating for critical-load support.

The third variable is the control objective. A PV-first algorithm is transparent, but it is not necessarily financially optimal. Under time-of-use tariffs or demand charges, it may be better to reserve battery capacity for peak-price periods or to discharge only above a demand threshold. Under resilience-led operation, a minimum state-of-charge reserve may be required, which reduces available energy for daily cycling. The energy management system should therefore allow selectable modes rather than a fixed control philosophy.

The fourth variable is critical-load definition. The same 108 kWh usable BESS can appear either generous or inadequate depending on whether it supports emergency lighting and communications only, or a larger package including server room, security, controls, selected sockets and HVAC auxiliaries. A priority-circuit schedule should therefore be agreed before final BESS procurement. This schedule should include acceptable interruption, restart sequence, manual override, maintenance bypass and responsibilities during an outage.

TABLE VI. Sensitivity Factors Affecting the Final PV-BESS Design

Sensitivity factor	Potential effect	Design response
Larger PV area	May increase renewable fraction and create surplus PV.	Rerun yield and export-limited dispatch simulations.
Lower building demand	Improves solar fraction and may reduce PCS needs.	Combine PV-BESS with efficiency and controls.
Time-of-use tariff	May shift battery value from solar absorption to price response.	Add tariff-optimised control cases.
Minimum SOC reserve	Improves resilience but reduces daily cycling energy.	Define operating modes for normal and resilience periods.
Critical-load scope	Strongly changes backup duration and PCS requirements.	Create a protected-load schedule and test islanding duties.
Export limitation	Can increase curtailment risk for larger PV arrays.	Coordinate early with the DNO and EMS provider.

VII. CONCLUSION AND RECOMMENDATIONS

This paper converted a preliminary PV, BESS and inverter design report into an IEEE-style research paper for a 60-office building in South England. The case demonstrates that a 64-module, 35.2 kWp rooftop PV system paired with a 120 kWh nominal BESS and a 30 kW PV inverter arrangement can reduce grid electricity use, but it cannot make the building independent from the grid. The simulation produced 35,200 kWh/year of PV generation against 163,820 kWh/year of building load, giving a gross solar fraction of 21.49% and a net grid import reduction of 21.37%. The BESS provides critical-load support of about 5.4 h at 20 kW or 2.7 h at 40 kW.

The main recommendation is to obtain at least twelve months of measured half-hourly or hourly electricity data and repeat the dispatch simulation. The second recommendation is to complete a roof and structural survey covering usable area, shading, wind loading, membrane condition, access routes and fire clearances. Third, DNO engagement should begin early to confirm connection requirements, export limits, metering, protection settings and commissioning tests. Fourth, the client must define the critical-load schedule before BESS sizing is finalised. Fifth, a BESS fire and ventilation strategy should be developed with competent specialists. Sixth, the site should install monitoring and an energy management system so that measured performance can be compared against the concept model.

Future work should replace the synthetic load with measured data disaggregated into HVAC, lighting, small power, server and common-service loads. PV yield should be recalculated using PVGIS, PVWatts or equivalent software with final roof geometry and shading. The BESS model should include tariffs, export value, degradation, replacement timing and revenue stacking. Finally, the same screening method should be tested on schools, warehouses, retail buildings and healthcare facilities to identify when batteries mainly increase self-consumption and when they mainly provide peak management or resilience.

TABLE VII. Recommended Actions for Progressing to Detailed Design

Action	Reason	Expected improvement
Measured load study	The present load profile is synthetic.	Improves demand, peak and BESS sizing estimates.
PV yield and shading model	Annual yield is normalised.	Provides monthly and hourly site-specific generation.
Roof and structural survey	Usable area is only estimated.	Confirms deliverable array layout, access and loading.
DNO engagement	PV and storage must meet connection rules.	Clarifies export limits, protection and commissioning duties.
Critical-load schedule	The BESS cannot support the whole building.	Aligns resilience claims with priority circuits and runtime.
BESS fire strategy	Lithium-ion systems create specific hazards.	Improves siting, detection, ventilation, isolation and procedures.
EMS and monitoring	Concept results need operational verification.	Enables reporting, fault detection and future tariff control.

VIII. LIMITATIONS AND FUTURE WORK

The first limitation is the synthetic load profile. The weekday and weekend assumptions are internally consistent and useful for first-order sizing, but they cannot represent real diversity in occupancy, seasonal HVAC operation, server-room demand, plug-load behaviour, cleaning periods, tenant variation or public-holiday schedules. Future work should replace the synthetic profile with measured half-hourly meter data, ideally disaggregated into HVAC, lighting, small power, server and common-service loads. This would allow the same method to be recalibrated without changing the research framework.

The second limitation is the simplified PV model. Annual production is normalised to 1,000 kWh/kWp/year and then interpreted through the concept simulation. This is suitable for explaining the energy balance, but it does not capture local shading, roof pitch, azimuth, module temperature, inverter efficiency, soiling, spectral effects, cable losses, mismatch, degradation or temporary curtailment. Future work should compare the screening result with PVGIS, PVWatts or another bankable yield model using the final roof layout. That comparison would show whether the preliminary 35,200 kWh/year estimate is conservative, optimistic or close to the site-specific expectation.

The third limitation is the absence of tariff and degradation modelling. The dispatch algorithm maximises local PV use and does not optimise against import tariffs, export prices, demand charges, capacity charges or flexibility-service revenue. It also treats the BESS as a usable energy block with fixed charge and discharge efficiencies. A detailed techno-economic study should include battery ageing, replacement timing, variation in round-trip efficiency, state-of-charge limits, temperature, cycle counting, PCS standby losses and revenue stacking. This would move the work from feasibility screening towards lifecycle optimisation.

The fourth limitation is the simplified treatment of backup. Dividing usable BESS capacity by selected critical load gives a helpful runtime estimate, but true resilience design needs a protected-load schedule, islanding philosophy, transfer arrangement, protection coordination, neutral and earthing strategy, black-start assumptions, life-safety interfaces, maintenance bypass, commissioning tests and operator procedures. Future work should develop a resilience matrix that maps each critical circuit to required runtime, permissible interruption, restart sequence and responsible owner. The same screening method should also be

tested on schools, warehouses, retail buildings and healthcare facilities to distinguish projects where batteries increase self-consumption from those where batteries mainly provide peak management or resilience.

ACKNOWLEDGMENT

The case-study data, system assumptions, diagrams and dispatch logic were derived from the preliminary PV, BESS and inverter design report for a three-floor, 60-office building in South England. The present paper reorganises that engineering material into conference-paper form and emphasises the methodology, results, limitations and practical design implications.

REFERENCES

[1] Department for Energy Security and Net Zero, "Clean Power 2030 Action Plan: A new era of clean electricity," GOV.UK, 2025.

[2] Department for Energy Security and Net Zero, "Solar photovoltaics deployment," GOV.UK, 2026.

[3] European Commission Joint Research Centre, "PVGIS user manual," PVGIS 5.3.

[4] CIBSE, TM46: Energy Benchmarks. London, U.K.: Chartered Institution of Building Services Engineers, 2008.

[5] International Electrotechnical Commission, IEC 62548-1:2023, Photovoltaic arrays - Part 1: Design requirements. Geneva, Switzerland: IEC, 2023.

[6] International Electrotechnical Commission, IEC 61724-1:2021, Photovoltaic system performance - Part 1: Monitoring. Geneva, Switzerland: IEC, 2021.

[7] Institution of Engineering and Technology, Code of Practice for Electrical Energy Storage Systems, 3rd ed. London, U.K.: IET, 2024.

[8] Energy Networks Association, Engineering Recommendation G99: Requirements for the connection of generation equipment in parallel with public distribution networks. London, U.K.: ENA, 2025.

[9] SP Energy Networks, "G99 Generator Connections."

[10] National Renewable Energy Laboratory, "PVWatts Calculator."

[11] National Renewable Energy Laboratory, "Solar PV AC-DC Translation," Annual Technology Baseline Archive, 2018.

[12] UL Solutions, "UL 9540A Test Method for Battery Energy Storage Systems."

[13] National Fire Protection Association, NFPA 855: Standard for the Installation of Stationary Energy Storage Systems, 2023 ed. Quincy, MA, USA: NFPA, 2023.

[14] British Standards Institution, PAS 63100:2024, Electrical installations - Protection against fire of battery energy storage systems for use in dwellings - Specification. London, U.K.: BSI, 2024.

[15] R. Luthander, J. Widen, D. Nilsson, and J. Palm, "Photovoltaic self-consumption in buildings: A review," Applied Energy, vol. 142, pp. 80-94, 2015, doi: 10.1016/j.apenergy.2014.12.028.

[16] G. Merei, J. Moshovel, D. Magnor, and D. U. Sauer, "Optimization of self-consumption and techno-economic analysis of PV-battery systems in commercial applications," Applied Energy, vol. 168, pp. 171-178, 2016, doi: 10.1016/j.apenergy.2016.01.083.

[17] B. Li, Z. Liu, Y. Wu, P. Wang, R. Liu, and L. Zhang, "Review on photovoltaic with battery energy storage system for power supply to buildings," Journal of Energy Storage, vol. 61, Art. no. 106763, 2023, doi: 10.1016/j.est.2023.106763.

[18] Y. Li, J. Peng, H. Jia, B. Zou, Y. Lyu, and W. Liu, "Optimal battery schedule for grid-connected photovoltaic-battery systems of office buildings," Journal of Energy Storage, vol. 50, Art. no. 104557, 2022, doi: 10.1016/j.est.2022.104557.

[19] X. Jin, J. Wu, Y. Mu, M. Wang, X. Xu, and H. Jia, "Hierarchical microgrid energy management in an office building," Applied Energy, vol. 208, pp. 480-494, 2017, doi: 10.1016/j.apenergy.2017.10.002.

[20] T. Beck, H. Kondziella, G. Huard, and T. Bruckner, "Assessing the influence of the temporal resolution of electrical load and PV generation profiles," Applied Energy, vol. 173, pp. 331-342, 2016, doi: 10.1016/j.apenergy.2016.04.050.

[21] A. Ayala-Gilardon, M. Sidrach-de-Cardona, and L. Mora-Lopez, "Influence of time resolution in the estimation of self-consumption and self-sufficiency," Applied Energy, vol. 229, pp. 990-997, 2018, doi: 10.1016/j.apenergy.2018.08.072.

[22] W. L. Schram, I. Lampropoulos, and W. G. J. H. M. van Sark, "Photovoltaic systems coupled with batteries for household self-consumption," Applied Energy, vol. 223, pp. 69-81, 2018, doi: 10.1016/j.apenergy.2018.04.023.

[23] P. Gagnon, G. Barbose, N. Darghouth, A. Mills, A. Govindarajan, and L. Bird, Solar + Storage Synergies for Managing Commercial-Customer Demand Charges, NREL/TP-6A20-70360, 2017, doi: 10.2172/1405905.

[24] J. McLaren, K. Anderson, N. Laws, P. Gagnon, X. Li, and N. DiOrio, Identifying Critical Factors in the Cost-Effectiveness of Solar and Battery Storage in Commercial Buildings. Golden, CO, USA: NREL, 2018.

[25] J. Neubauer, Optimal Sizing of Energy Storage and Photovoltaic Power Systems for Demand Charge Mitigation. Golden, CO, USA: NREL, 2017.

[26] A. Baniasadi, D. Habibi, W. Al-Saedi, M. A. S. Masoum, C. K. Das, and N. Mousavi, "Optimal sizing design and operation of electrical and thermal energy storage systems in smart buildings," Journal of Energy Storage, vol. 28, Art. no. 101186, 2020, doi: 10.1016/j.est.2019.101186.

[27] H. I. Hazim, K. A. Baharin, C. K. Gan, A. H. Sabry, and A. J. Humaidi, "Review on optimization techniques of PV/inverter ratio for grid-tie PV systems," Applied Sciences, vol. 13, no. 5, Art. no. 3155, 2023, doi: 10.3390/app13053155.

[28] H. X. Wang, M. A. Munoz-Garcia, G. P. Moreda, and M. C. Alonso-Garcia, "Optimum inverter sizing of grid-connected photovoltaic systems," Renewable Energy, vol. 118, pp. 709-717, 2018, doi: 10.1016/j.renene.2017.11.063.

[29] L. Micheli, M. Muller, M. Theristis, G. P. Smestad, F. Almonacid, and E. F. Fernandez, "Quantifying the impact of inverter clipping on photovoltaic performance and soiling losses," Renewable Energy, vol. 225, Art. no. 120317, 2024, doi: 10.1016/j.renene.2024.120317.

[30] J. Hernandez, F. Sanchez-Sutil, and F. J. Munoz-Rodriguez, "Design criteria for the optimal sizing of a hybrid energy storage system," Energy, vol. 186, Art. no. 115827, 2019, doi: 10.1016/j.energy.2019.07.157.

[31] I. Javeed, R. Khezri, A. Mahmoudi, A. Yazdani, and G. M. Shafiullah, "Optimal sizing of rooftop PV and battery storage for grid-connected houses," Energies, vol. 14, no. 12, Art. no. 3520, 2021, doi: 10.3390/en14123520.

[32] S. Li, T. Zhang, X. Liu, and X. Liu, "A battery capacity configuration method of a photovoltaic and battery system," Energies, vol. 16, no. 5, Art. no. 2190, 2023, doi: 10.3390/en16052190.

[33] N. Collath, B. Tepe, S. Englberger, A. Jossen, and H. Hesse, "Aging aware operation of lithium-ion battery energy storage systems: A review," Journal of Energy Storage, vol. 55, Art. no. 105634, 2022, doi: 10.1016/j.est.2022.105634.

[34] M. A. Ali, C. M. Da Silva, and C. H. Amon, "Multiscale modelling methodologies of lithium-ion battery aging: A review," Batteries, vol. 9, no. 9, Art. no. 434, 2023, doi: 10.3390/batteries9090434.

[35] J. Conzen, S. Lakshmipathy, A. Kapahi, S. Kraft, and J. DiNenno, "Lithium ion battery energy storage systems hazards," Journal of Loss Prevention in the Process Industries, vol. 81, Art. no. 104932, 2023, doi: 10.1016/j.jlp.2022.104932.