ALCAP GROUP

ALCAP EDUCATIONAL RESEARCH DOCUMENT | SOLAR AND ENERGY STORAGE

Sizing Grid-Tied PV and Hybrid PV-BESS Systems

A commercial-site method for minimising weekend curtailment, increasing self-consumption and selecting battery power and energy

The correct PV size is not obtained by dividing annual consumption by annual solar yield. A commercial site must be modelled interval by interval because Saturday, Sunday, holiday and shutdown demand can be far below weekday demand while solar production remains high.

A battery can capture part of this otherwise curtailed energy, but its power rating (kW), energy rating (kWh), state-of-charge reserve, conversion path, degradation and end-of-life capacity must be sized as separate constraints. Economic energy shifting and outage resilience may produce very different battery sizes.

THE CENTRAL DESIGN PRINCIPLE

Size PV and BESS against time-aligned site demand, solar resource, export permissions, tariff intervals and operational constraints. Optimise the whole system and dispatch strategy; do not optimise annual PV yield, PV capacity or battery duration in isolation.

Prepared for South African commercial and industrial energy users

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01 | EXECUTIVE FINDINGS

Five decisions determine a robust design

The objective is to maximise useful energy and whole-life value while respecting export, network, equipment, safety and resilience constraints.

- Use at least 12 months of validated interval data, preferably 15-minute data or finer. Preserve day-of-week, holidays, seasonal shutdowns and coincident demand; synthetic load shapes are screening tools only.[2,3,4]
- For a zero-export site, low weekend demand often creates the practical PV ceiling. Annual energy balance can hide thousands of short intervals in which PV production exceeds load.
- Distinguish export-control curtailment from inverter clipping. Curtailment is created by site/export/dispatch constraints; clipping is created when available DC power exceeds the inverter or shared conversion-stage capability.[7,8]
- Battery kW and kWh solve different problems. kW captures the instantaneous surplus or supports the critical-load peak; kWh carries energy over time and must include efficiency, usable SOC, degradation and reserve.
- If backup is required, outage duration and critical-load power can dominate the economic energy-shifting battery. Keep backup reserve explicit and test the system with chronological outage simulations.

> **A USEFUL SCREENING QUESTION**
> At the lowest recurring weekend daylight load, how much PV can operate before the export limit is reached - and how often would a larger array produce energy valuable enough to justify curtailment, storage or flexible-load control?

Decision map

Objective	Dominant sizing inputs	Primary output
Minimise imports	Interval load, PV shape, import tariff	PV/BESS combination with lowest lifecycle cost
Minimise weekend curtailment	Weekend/holiday load, export limit, PV profile	PV ceiling or storage/flexible-load requirement
Reduce demand charges	Billing demand interval, coincident peak shape	PCS kW and dispatch window
Provide backup	Critical-load kW, duration, starting, reserve	Grid-forming PCS kW and firm kWh

02 | DATA FOUNDATION

Model the hours when the site behaves differently

A valid sizing study must preserve chronology. Aggregating weekdays and weekends into monthly totals destroys the exact relationship that causes curtailment.

NREL's REopt guidance recommends actual 15-minute, 30-minute or hourly data where available, and stresses preservation of day-of-week and annual chronology. Fifteen-minute data is especially valuable where tariffs use interval demand, loads ramp quickly or export control has a tight setpoint.[2,3]

- Electricity: import/export kW and kWh, kvar, power factor, maximum demand, tariff periods, voltage and outages.
- Operations: shift calendar, Saturdays, Sundays, public holidays, maintenance shutdowns, production changes and planned electrification.
- Solar: site-specific weather or bankable resource, shading, orientation, temperature, soiling, availability and degradation.
- Network: approved export limit, point of common coupling, transformer and feeder ratings, protection, fault level and SSEG conditions.
- Battery: charge/discharge efficiency, SOC window, PCS limits, auxiliary consumption, calendar/cycle degradation, throughput warranty and end-of-life criterion.

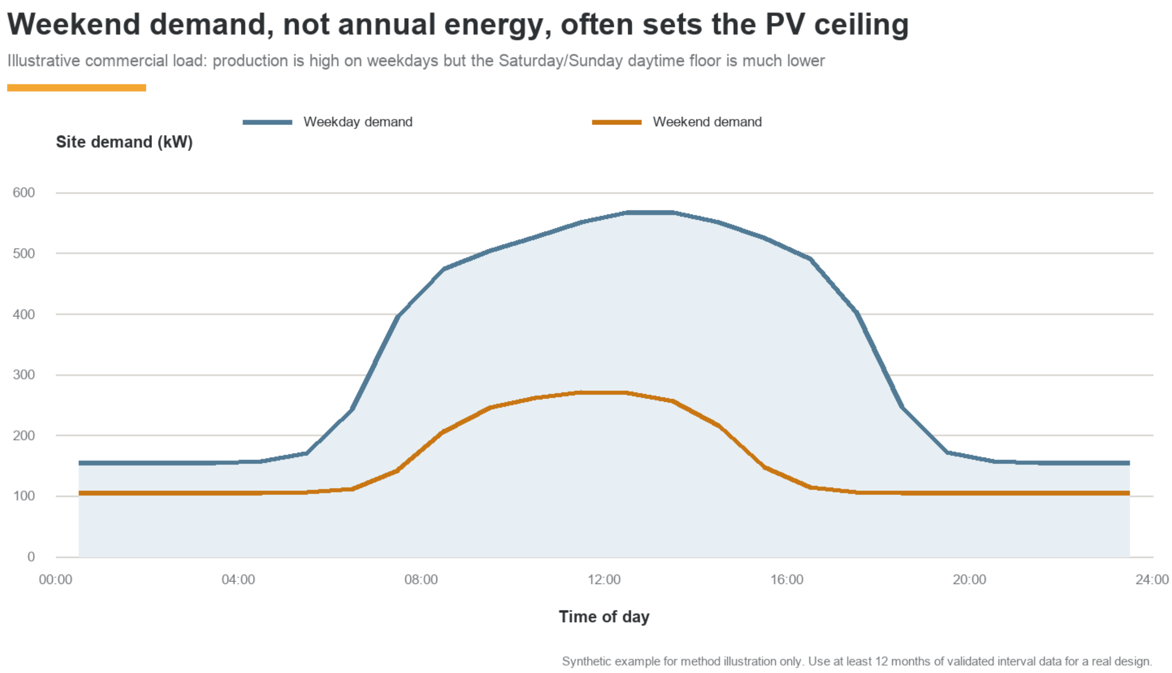

Figure 1: Synthetic commercial demand illustrates why annual or weekday-only sizing can materially oversize a zero-export PV system.

Data-quality checks should reconcile interval energy with invoices, identify meter gaps and daylight-saving/time-zone errors, confirm sign conventions, isolate non-recurring outages and document any substituted intervals. The final design should test low-, base- and high-load futures rather than treating last year's profile as permanent.

03 | GRID-TIED PV SIZING

Test candidate array sizes against every interval

For each candidate, calculate available PV, inverter output, direct use, permitted export, curtailment and grid import in chronological order.

1. Build the validated chronological load and operating calendar.
2. Generate a normalised PV production series for each proposed orientation and loss case.
3. Apply module, string, MPPT, inverter, transformer, feeder and point-of-connection limits.
4. Apply the approved export limit and model the response time and accuracy of the export controller.
5. Calculate direct self-consumption, export, inverter clipping and curtailment as separate energy paths.
6. Repeat for each candidate DC size, inverter AC size, DC/AC ratio and sensitivity case.
7. Value each path using the correct tariff period, export credit, demand charge and escalation assumptions.

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P_PV,screen(t) = [Load(t) + permitted export(t)] / normalised PV output(t)
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E_curtail = sum max[P_PV(t) - Load(t) - permitted export(t), 0] x interval duration
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The first equation is a screening calculation for daylight intervals where normalised output is meaningful. It is not a final array size: cloud transients, orientation, inverter limits, ramp control, minimum stable load and export-controller behaviour must still be simulated.

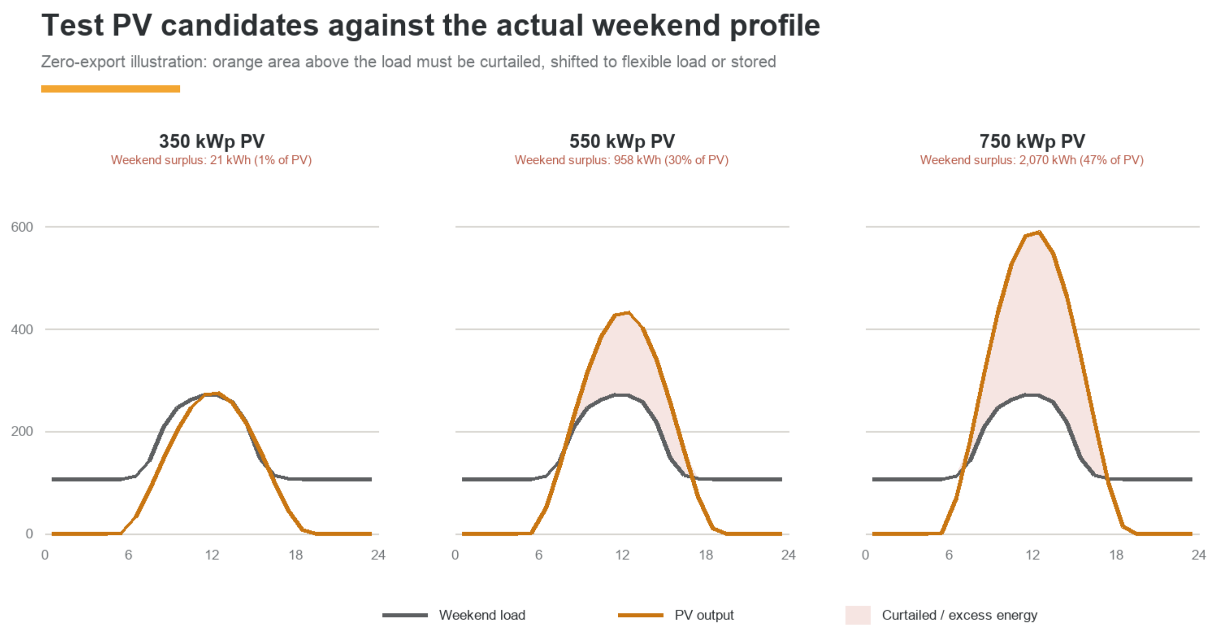

Figure 2: Three candidate PV sizes against the same representative weekend profile. The shaded area is energy that needs export permission, storage, flexible demand or curtailment.

04 | MARGINAL VALUE

Oversizing can be rational - if the extra energy remains valuable

A larger array produces more useful energy in mornings, afternoons and weak-sun periods, but creates progressively more surplus near midday and on low-load days.

The economically preferred size is therefore not necessarily the size with zero curtailment. A modest curtailment rate can be acceptable where extra PV is inexpensive and the marginal morning, winter or cloudy-day energy has high value. Conversely, oversizing can destroy value when export is prohibited, the battery is full, demand is inflexible and the marginal array requires expensive network work. REopt and similar chronological optimisation methods compare technology size and dispatch against lifecycle tariff value.[1,2,5]

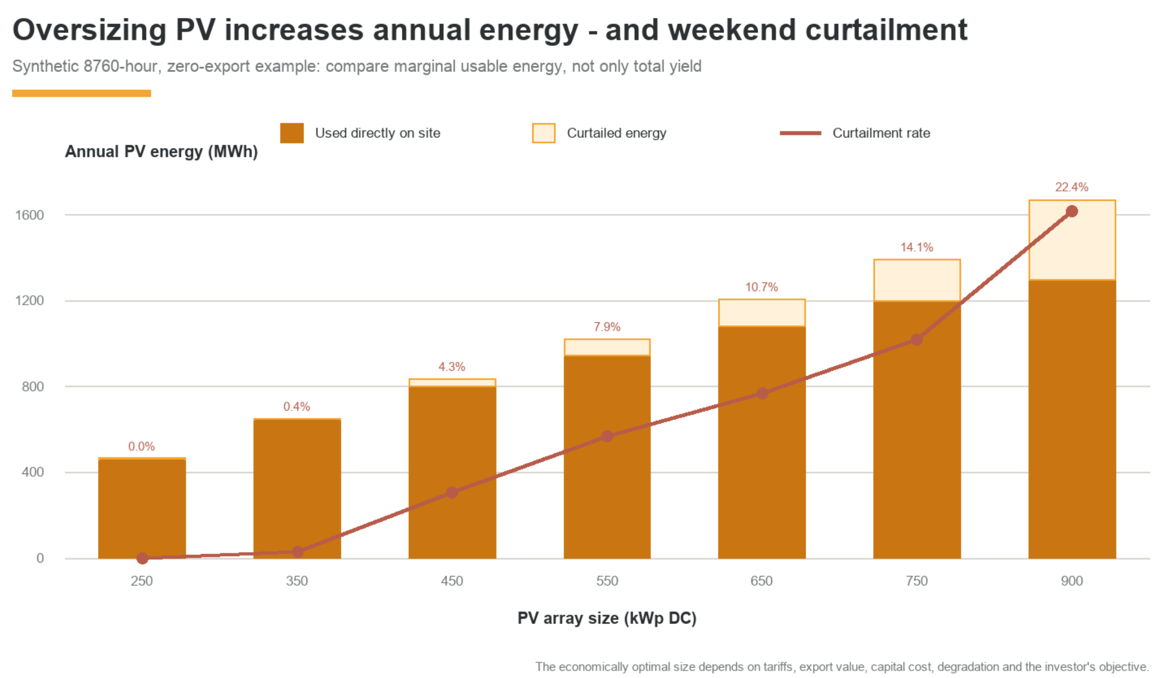

Figure 3: Synthetic 8,760-hour zero-export results. Curtailed MWh and curtailment percentage both rise as the PV array grows.

Marginal-energy test

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Marginal usable PV = [usable energy at size B - usable energy at size A] / [B - A]
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In the worked example, moving from 550 to 650 kWp adds about 186 MWh of gross annual PV but only about 137 MWh of additional directly usable energy without storage. The balance is additional curtailment. The investment decision must value that marginal 137 MWh - not the array's average yield.

SENSITIVITY REQUIREMENT

Test PV capex, import tariff, export value, load growth, degradation, downtime, soiling, curtailment, financing and replacement assumptions. A single payback period based on average annual kWh is not a sufficient investment case.

05 | WEEKEND COINCIDENCE CURVE

Use percentiles to screen - not to finish the design

A coincidence curve ranks the interval-by-interval PV capacity that would just match weekend load before export or curtailment.

For every weekend daylight interval, divide available load plus permitted export by the normalised PV output. Sorting those limits creates a fast screen. A P10 capacity means approximately 10% of the assessed weekend daylight intervals have a lower no-surplus capacity. It does not mean that 10% of energy is curtailed because intervals have different irradiance and duration.

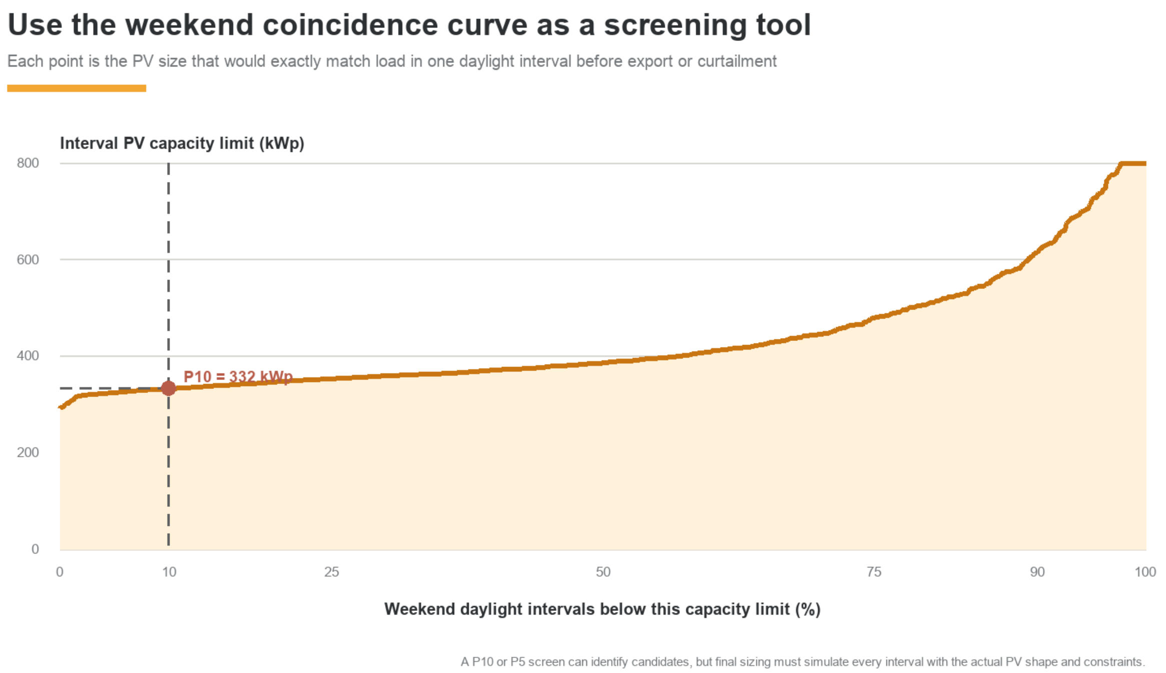

Figure 4: The synthetic site's P10 screening value is 332 kWp. Candidate selection still requires full chronological simulation.

Percentile	Capacity screen	Interpretation
P1	305 kWp	Very conservative; close to the recurring minimum
P5	324 kWp	Screens a low-curtailment candidate
P10	332 kWp	Useful starting point, not a design limit
P25	353 kWp	Accepts more frequent short surplus
P50	387 kWp	Half the daylight intervals have a lower limit
P75	479 kWp	Requires export, storage, flexibility or curtailment often
P90	614 kWp	Only the highest-load/high-yield intervals absorb this directly

Run the curve separately for ordinary weekends, public holidays, annual shutdowns and future operating scenarios. Long weekend shutdowns can govern a zero-export design even when normal Saturdays are busy.

06 | CLIPPING AND CURTAILMENT

Do not combine two different losses

DC/AC ratio, inverter saturation and export control are different design variables and should have different lines in the energy balance.

Loss path	Cause	Design response
Inverter clipping	Available PV DC exceeds the AC conversion limit or another inverter current/voltage limit	Optimise DC/AC ratio, orientation, inverter capacity and thermal design
Export curtailment	PV AC output would exceed the site load plus permitted export	Adjust PV size, add BESS/flexible load, obtain export permission or accept curtailment
Network curtailment	Distributor or plant controller reduces output for voltage, congestion or grid-code reasons	Model operating rules, network limits and compensation explicitly
Availability loss	PV or BESS is unavailable because of faults, maintenance or protection	Use realistic availability and O&M; assumptions

PVWatts and SAM define the DC/AC ratio as array nameplate DC rating divided by inverter AC rating. A high ratio can increase annual inverter utilisation while increasing clipping. Sandia's PV Performance Modeling Collaborative notes that clipping occurs when the array's available DC power exceeds the inverter's maximum conversion capability.[6,7,8]

Illustrative candidate comparison

PV DC size	Gross PV	Curtailed	Rate	Screening interpretation
250 kWp	464 MWh	0 MWh	0.0%	Low surplus; may leave roof/tariff value unused
350 kWp	649 MWh	3 MWh	0.4%	Near the low-curtailment screen
450 kWp	835 MWh	36 MWh	4.3%	Moderate oversizing; test marginal value
550 kWp	1,020 MWh	80 MWh	7.9%	Storage or flexible load becomes more valuable
650 kWp	1,206 MWh	129 MWh	10.7%	Selected hybrid example
750 kWp	1,391 MWh	196 MWh	14.1%	High weekend surplus
900 kWp	1,669 MWh	375 MWh	22.4%	Large marginal-value penalty without export/storage

These values use a synthetic Johannesburg-like hourly solar profile with an illustrative gross yield of approximately 1,855 kWh/kWp-year. They are method examples, not a forecast for any real site.

07 | HYBRID PV-BESS FUNDAMENTALS

Battery power and battery energy must be sized separately

A battery may have enough energy but insufficient PCS power, or enough power but insufficient duration. Both failures are common when a single 'hours of storage' ratio is used.

Battery / PCS power (kW)

- Maximum surplus capture rate after direct site consumption and permitted export.
- Target demand-charge reduction over the relevant billing interval.
- Critical-load steady-state power, motor starts, step loads and grid-forming requirements.
- Charge/discharge asymmetry, inverter overload capability, transformer and switchgear limits.

Battery nominal energy (kWh)

- Cumulative surplus that should be shifted to later loads, not only the peak surplus kW.
- Round-trip conversion losses and battery/PCS auxiliary consumption.
- Permitted SOC window, minimum backup reserve, end-of-life capacity and temperature derating.
- Outage duration, critical-load variability and whether PV/generator recharge is firm or conditional.

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E_nameplate >= E_service / [path efficiency x usable SOC fraction x end-of-life retention]
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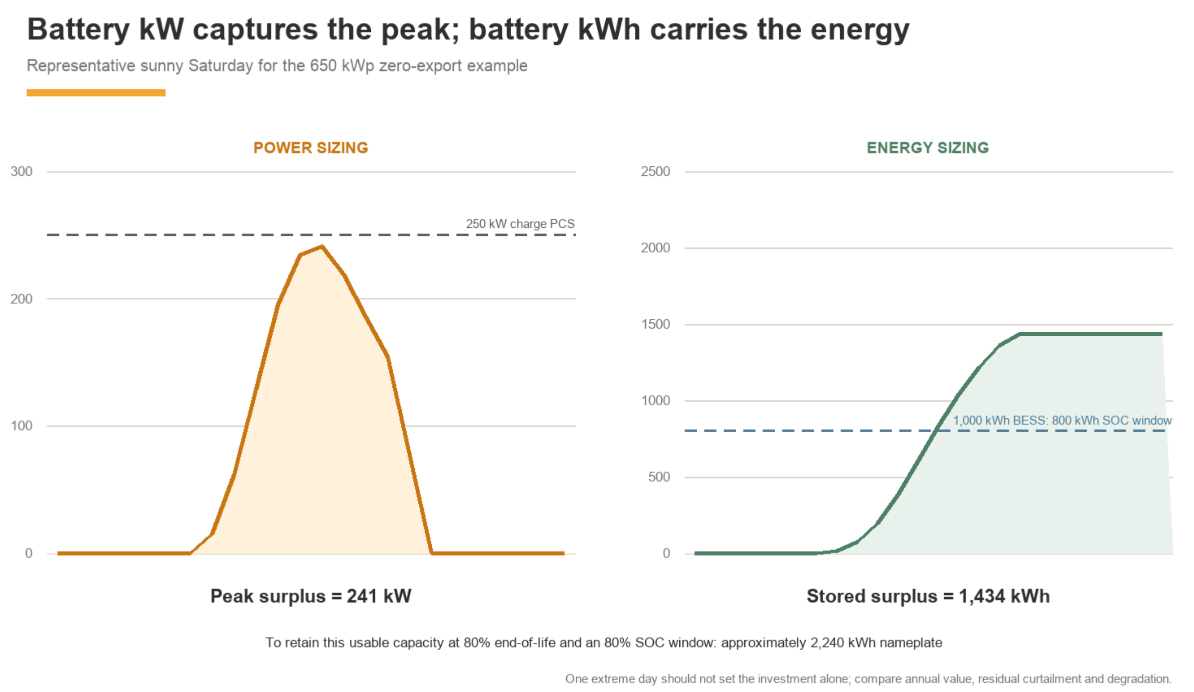

Figure 5: A representative day has a 241 kW surplus peak but approximately 1,509 kWh of surplus energy. A 250 kW PCS can capture the peak, while a 1,000 kWh battery cannot retain the full day's energy once SOC and end-of-life margins are applied.

08 | WORKED BATTERY CALCULATION

Convert service energy into a defensible nameplate size

The following calculation is deliberately conservative and shows how apparently small margins compound.

Input	Value	Interpretation
Representative PV surplus	1,509 kWh	Energy above coincident weekend load
Charge conversion efficiency	95%	Energy stored = 1,509 x 0.95 = 1,434 kWh
Usable SOC window	80%	For example, operating between 10% and 90% SOC
End-of-life retention	80%	Required service must still be available at the design EOL
Indicative nameplate	2,240 kWh	1,434 / (0.80 x 0.80), rounded

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1,509 x 0.95 / (0.80 x 0.80) = 2,240 kWh nominal
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This does not prove that 2,240 kWh is economic. It shows the nameplate required to retain the selected one-day service at the stated end-of-life criterion. A smaller battery may have better whole-life value if some curtailment is accepted; a larger one may be required if backup, demand reduction or future load growth is also valuable.

AVOID DOUBLE COUNTING

If the same kWh is expected to provide solar shifting, demand-charge reduction and outage reserve, the dispatch model must prove that these services coincide without violating SOC reserve. Adding the three energy requirements is often too conservative; assuming perfect overlap is often too optimistic.

Battery inputs that materially change the answer

- Charge and discharge power versus SOC and temperature, including overload duration.
- One-way efficiencies, rather than a single round-trip figure applied twice.
- Calendar ageing, cycle ageing, expected throughput, augmentation and replacement timing.
- Warranty restrictions on depth of discharge, average SOC, temperature, C-rate and annual throughput.
- Heating, ventilation, cooling, fire systems, controls and transformer auxiliary consumption.

09 | CHRONOLOGICAL DISPATCH

The controller needs headroom before the weekend

Battery capacity has no value for curtailment reduction if the battery arrives at midday already full, or if backup reserve prevents charging and discharging as assumed.

The synthetic example uses a 650 kWp PV array and a 300 kW / 1,000 kWh BESS with a 10%-90% SOC window, 95% charge efficiency, 95% discharge efficiency and zero export. The battery charges from surplus and discharges into later load. This simple self-consumption rule is illustrative; an economic controller may also consider tariff periods, demand limits, weather forecasts and reserve.

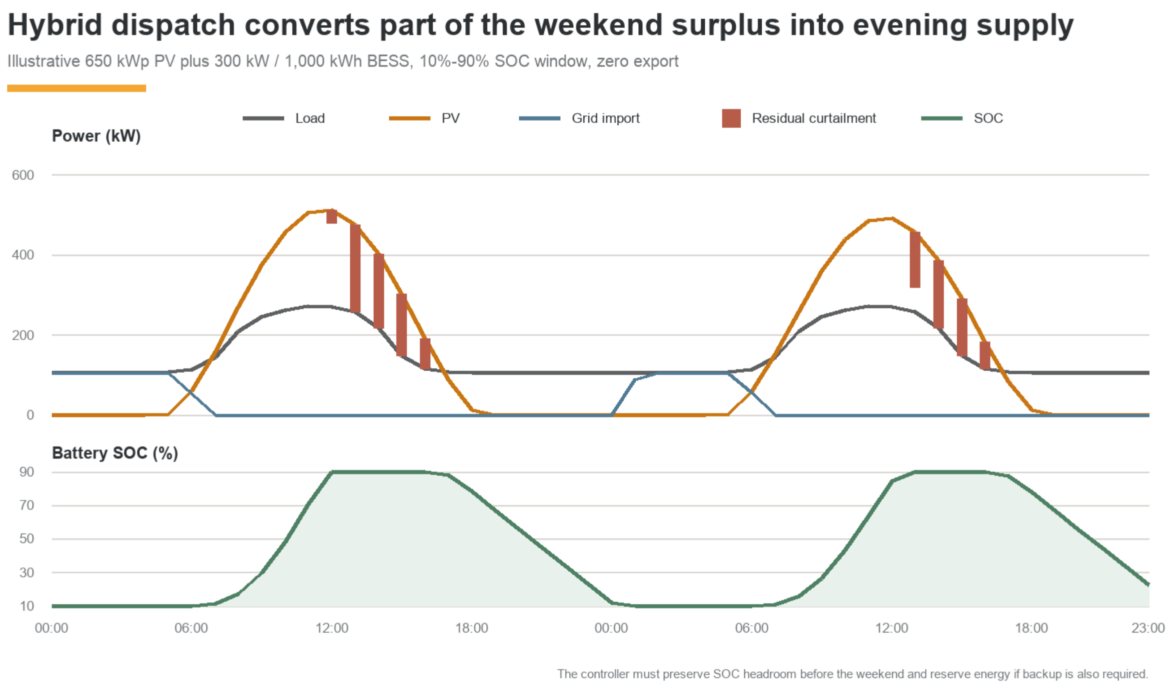

Figure 6: Two representative weekend days. SOC headroom before solar production is essential; once the battery reaches 90%, additional surplus is curtailed.

Control rules to document

Control element	Required definition
Charge priority	PV-only, grid-enabled or price-responsive; export limit override
Discharge priority	Self-consumption, peak shaving, tariff arbitrage or resilience
Reserve	Fixed minimum SOC or forecast/outage-dependent reserve
Demand control	Billing interval, measurement point, target and recovery rule
Failure mode	Safe action for meter, communications, PCS or export-controller failure

Hourly dispatch may understate short export or demand peaks. Match the model interval to metering, control response and contractual limits; validate the selected controller with higher-resolution data where necessary.

10 | JOINT PV-BESS OPTIMISATION

There is no single battery size for a PV array

Each PV/BESS pair produces a different combination of direct use, battery throughput, residual curtailment, imports, peak demand, degradation and resilience.

PV and BESS must be sized together

Annual curtailment rate (%) for the synthetic zero-export site; BESS power is fixed at 300 kW

		BESS nominal energy (kWh)					
		0	250	500	750	1,000	1,500
	450 kWp	4.3%	1.7%	0.3%	0.0%	0.0%	0.0%
	550 kWp	7.9%	5.7%	3.6%	1.7%	0.6%	0.0%
PV array size	650 kWp	10.7%	8.9%	7.0%	5.2%	3.4%	0.9%
	750 kWp	14.1%	11.3%	9.7%	8.1%	6.5%	3.4%
	850 kWp	19.6%	15.0%	12.0%	10.3%	9.0%	6.2%

Assumptions: hourly dispatch, 10%-90% SOC window, 95% charge and discharge efficiency, self-consumption priority.
This matrix is illustrative; use site interval data, actual PCS limits, warranty constraints and tariff rules.

Figure 7: Annual curtailment rate for combinations of PV size and BESS energy with BESS power fixed at 300 kW. Values use the synthetic hourly model.

At 650 kWp, increasing storage from 0 to 1,000 kWh reduces annual curtailment from 10.7% to 3.4%. Increasing to 1,500 kWh reduces it further to 0.9%, but the incremental reduction may not justify the additional capital and degradation. At 850 kWp, even 1,500 kWh leaves 6.2% curtailment because the array creates more and longer surplus events.

Selection criteria for the short list

- Net present value and lifecycle cost using interval tariff and export values.
- Residual curtailment and marginal useful energy per extra kWp or kWh.
- Battery cycles, throughput, average SOC, degradation and replacement/augmentation.
- Demand-charge performance under alternative production and weather years.
- Network, inverter, transformer, protection, fire and space constraints.
- Resilience service with explicit reserve and black-start/grid-forming capability.

PREFERRED OPTIMISATION APPROACH

Use a transparent chronological model to screen many combinations, then subject the short list to detailed electrical design, tariff verification, degradation analysis, outage modelling and commercial sensitivity. The mathematically lowest cost is not bankable if its controls, warranties or network approvals cannot be implemented.

11 | ANNUAL ENERGY BALANCE

Every generated kWh must have a destination

A credible report reconciles PV generation, battery charge/discharge losses, grid import, export, curtailment and site load within a stated numerical tolerance.

Follow every annual energy path

Illustrative 650 kWp PV plus 300 kW / 1,000 kWh BESS; annual values rounded to MWh

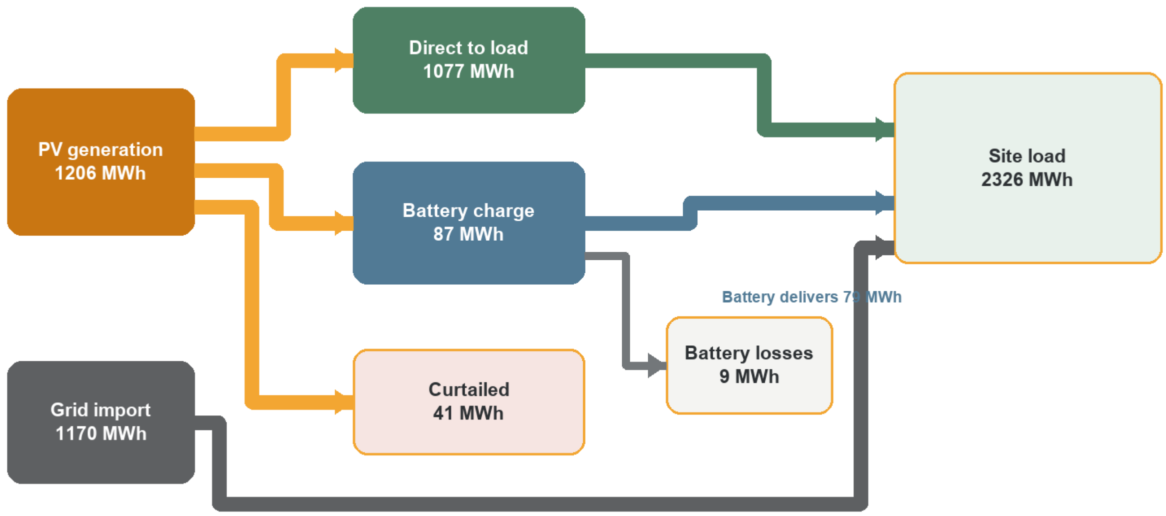

Figure 8: Annual energy paths for the 650 kWp plus 300 kW / 1,000 kWh example. Rounded labels can create a small apparent difference; the unrounded model is reconciled.

Energy path	Annual value	Meaning
Site load	2,325.6 MWh	Total metered demand served by PV, BESS and grid
PV generation	1,205.7 MWh	Synthetic available AC energy before export curtailment
Direct PV to load	1,077.0 MWh	PV consumed without passing through battery
Battery charge	87.2 MWh	PV accepted into the BESS conversion path
Battery discharge	78.7 MWh	BESS energy delivered to site load
Residual curtailment	41.5 MWh	3.4% of available PV
Grid import	1,169.9 MWh	Energy supplied by the utility

Self-consumption and self-sufficiency are different: self-consumption describes the share of PV retained on site, while self-sufficiency describes the share of load supplied by PV/BESS. State the numerator, denominator and treatment of battery losses whenever reporting either metric.

12 | AC OR DC COUPLING

Architecture changes conversion paths and bottlenecks

Choose the topology before final sizing because the same PV, PCS and battery nameplates can behave differently when conversion stages are shared.

AC-coupled and DC-coupled systems move energy differently

Select architecture before final PV, PCS and battery sizing because conversion paths and bottlenecks change

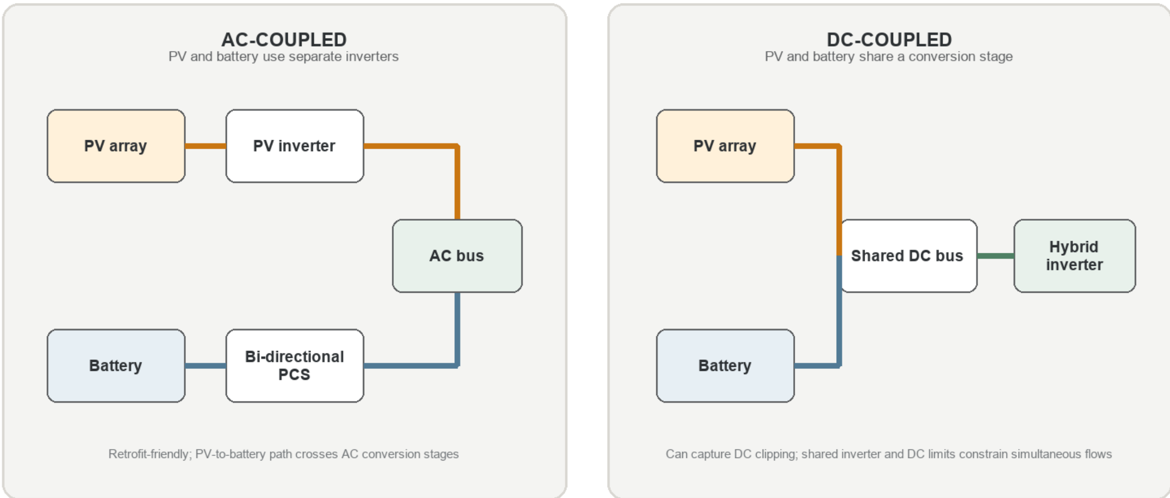

Figure 9: Simplified functional comparison. Real designs also include protection, isolation, metering, transformers, controls and auxiliary systems.

Consideration	AC-coupled	DC-coupled
Retrofit suitability	Usually strong; independent PV and BESS systems	Often best planned as an integrated new system
PV-to-battery path	Passes through AC conversion stages	Can remain on a shared DC path
Clipping capture	Limited by PV inverter output already delivered to AC bus	May capture energy above the shared inverter AC rating, subject to DC limits
Simultaneous flows	Separate inverter ratings can provide flexibility	Shared conversion stage may constrain combined PV/load/battery flow
Availability	A PV or BESS inverter fault may be more isolated	Shared equipment can create common-mode limitations
Controls/protection	Coordination across separate systems	Integrated DC protection, controls and OEM boundary

DOE/FEMP guidance describes both topologies and recommends sizing around the primary service objective, site load coincidence and operating constraints. Compare complete conversion efficiencies at the intended operating points rather than assuming one architecture is always superior.[1,9]

13 | RESILIENCE

Backup sizing can dominate the economic battery

A battery selected for weekend surplus may be too small to support a critical load through a long outage - and a resilience battery may spend much of the year reserved rather than cycling economically.

```
E_nameplate = Critical load x outage hours x auxiliary margin / [discharge efficiency
                        x usable SOC x EOL retention]
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Backup sizing can dominate the economic battery

Conservative nameplate energy (kWh): no PV or generator credit, 10% auxiliary margin, 95% discharge efficiency, 80% SOC window, 80% end-of-life capacity

	2 hours	4 hours	8 hours	12 hours
100 kW critical load	362	724	1,447	2,171
200 kW critical load	724	1,447	2,895	4,342
300 kW critical load	1,086	2,171	4,342	6,513
400 kW critical load	1,447	2,895	5,789	8,684

Battery PCS power must also support the critical-load peak, motor starting, step loads and grid-forming requirements.

Credit PV or a generator only through an outage simulation that includes weather, fuel, controls and minimum SOC reserve.

Figure 10: Conservative nameplate sizing without PV or generator credit. PCS power must separately support steady load, motor starting, step loads and grid-forming operation.

Example: 200 kW of critical load for eight hours requires approximately 2,895 kWh nameplate under the stated 10% auxiliary margin, 95% discharge efficiency, 80% SOC window and 80% end-of-life retention. This exceeds the 1,000 kWh economic-shifting battery in the worked example.

Credit PV or generation carefully

- Use chronological outage simulations across seasons, including poor-solar sequences and the time of outage onset.
- Confirm that the PCS is grid-forming and can black-start the intended bus; ordinary grid-following PV may not operate during an outage.
- Model generator minimum load, fuel availability, start reliability, synchronisation and charging capability.
- Reserve SOC before the outage and include post-outage recovery without creating a new demand peak.
- Segment truly critical loads and verify motor-starting, harmonics, protection selectivity and load-shedding sequence.

14 | COMMERCIAL AND TARIFF MODEL

Value energy in the interval where it occurs

The same annual kWh can have very different value depending on tariff period, maximum-demand timing, export compensation and operating constraints.

Value stream	Modelling requirement
Energy charge	PV direct use and BESS discharge avoid import at the interval tariff; include losses
Demand charge	Model the utility's exact measurement window, ratchet and billing rule
Export credit	Apply only where export is approved and under the correct tariff/agreement
Curtailment	Usually zero revenue, but may avoid network upgrades or contractual penalties
Battery degradation	Assign throughput/cycle and calendar cost to dispatch decisions
Availability	Include planned/unplanned downtime and maintenance windows
Tax/finance	Use project-specific capital structure, incentives, tax and residual value

Eskom distinguishes embedded-generation tariff treatment and requires the applicable application, registration and connection agreements. A no-export configuration is still a generator installation and does not remove the need to follow the relevant Eskom or municipal process.[10,11]

Minimum sensitivity set

Category	Cases to test
Load	-20%, base, +20%; weekend shift; shutdown weeks; future electrification
Solar	Alternative weather years; soiling; degradation; shading; availability
Tariff	Energy/demand escalation; TOU periods; export value; tariff migration
Technology	PV/BESS capex; efficiency; degradation; augmentation; replacement
Finance	Discount rate; debt; tax; project life; residual value
Constraints	Zero export; partial export; transformer limit; reserve SOC; outage target

INVESTMENT GATE

Select the design that remains acceptable under plausible downside cases, not simply the scenario with the highest base-case NPV. State which assumptions are contractual, measured, forecast or illustrative.

15 | SOUTH AFRICAN COMPLIANCE AND SAFETY

Technical optimisation does not replace approval and detailed design

The project must satisfy the relevant distributor process, wiring and interface standards, protection requirements and energy-storage safety obligations.

- Confirm whether Eskom or the local municipality is the distributor and obtain the current SSEG application, registration and connection requirements before procurement.[10,11]
- Apply the current edition of the relevant NRS 097 requirements and distributor rules for the utility interface, anti-islanding, protection, power quality and testing.[12]
- Assess voltage quality and harmonics against the applicable South African requirements, including the current NRS 048 framework where relevant.[13]
- For BESS projects, use current IEC 62933 safety requirements and IEC 62619 industrial lithium-cell/battery safety requirements as applicable, together with local fire, building and occupational-safety requirements.[14,15,16]
- Complete electrical studies for load flow, short circuit, protection coordination, arc flash, earthing, harmonics, transformer loading, cable ampacity and islanded operation as applicable.
- Obtain OEM confirmation for battery location, separation, ventilation, temperature, fire detection/suppression, emergency response, warranty and maintenance.

Commissioning evidence

System	Evidence to retain
PV	String tests, insulation, polarity, IV/operating checks, inverter settings, clipping/export tests
Export control	Meter direction, fail-safe response, communications loss, step/ramp tests, logging
BESS	Capacity/SOC calibration, charge/discharge kW, efficiency, thermal and auxiliary systems
Protection	Settings, secondary injection/functional tests, anti-islanding, intertrips, emergency stop
Resilience	Black start, transfer, load steps, motor starts, load shedding, generator coordination
Handover	As-builts, settings register, training, spares, emergency plan, warranty baselines

Grid and safety requirements evolve. Verify the latest effective standards, distributor forms and approval conditions at project start and again before commissioning.

16 | IMPLEMENTATION CHECKLIST

A practical sequence from meter data to operating plant

Use formal decision gates so that procurement does not outrun data validation, network approval or the safety case.

1. Define the business objective and rank self-consumption, demand reduction, export, resilience and carbon outcomes.
2. Collect and reconcile at least 12 months of interval load, billing, operational and outage data.
3. Confirm the point of connection, distributor, export permission, tariff, network capacity and application path.
4. Develop the site-specific PV resource, roof/land layout, shading, structural and electrical constraints.
5. Screen PV sizes using weekend/holiday coincidence and full-year chronological energy flow.
6. Screen BESS kW and kWh separately for surplus capture, tariff value, peak shaving and critical-load service.
7. Optimise PV, inverter, BESS, PCS and dispatch combinations with degradation and sensitivity cases.
8. Select AC- or DC-coupled architecture and define metering, controls, export fail-safe and operating reserve.
9. Complete detailed electrical, structural, civil, fire, protection and grid-compliance designs.
10. Obtain approvals, lock the functional specification and procure against measurable performance guarantees.
11. Commission every operating mode and compare measured performance with the model.
12. Monitor load, PV, SOC, export, demand, alarms, degradation and curtailment; re-optimise as tariffs and operations change.

REQUIRED DELIVERABLES FROM THE SIZING STUDY

Interval data audit; assumptions register; PV/BESS candidate matrix; annual energy balance; tariff and degradation model; electrical constraints; resilience analysis; sensitivity results; control philosophy; compliance plan; commissioning acceptance criteria; and a documented recommendation with alternatives.

Final design questions

- What happens on the lowest-load sunny public holiday?
- What happens when communications or the export meter fails?
- What SOC is available when an outage starts at the end of a high-tariff day?
- Which component limits simultaneous PV output, battery charging and site supply?
- Will the promised service remain available at end of life and at maximum site temperature?
- Can the measured commissioning data reproduce the modelled result?

17 | CONCLUSION

Optimise useful energy, not nameplate capacity

The best commercial PV-BESS design is the one whose energy paths, controls, network limits, safety case and financial value remain coherent in every important interval.

Weekend curtailment is a timing problem. It arises because solar production and site demand do not coincide under an export constraint. The solution may be a smaller PV array, permitted export, flexible loads, a BESS, different orientations, accepted curtailment or a combination. The preferred option depends on the marginal value of each additional kWp and kWh.

Hybrid sizing adds a second time-coupled decision. Battery kW determines how quickly energy can move; battery kWh determines how long it can move; SOC reserve determines how much is actually available; and degradation determines whether it remains available over the project life. Resilience must be designed as an explicit service, not assumed from the presence of a battery.

ALCAP DESIGN POSITION

Use measured interval data and a transparent chronological model to create a short list. Then verify the short list through detailed electrical studies, approved controls, current standards, supplier guarantees and commissioning tests. This is the route from an attractive spreadsheet result to a dependable operating asset.

Scope and limitation

This document is educational and uses a synthetic commercial load and solar series to explain the method. It is not a design, quotation, grid application, fire-engineering report or investment recommendation for a specific site. A site-specific project requires verified data, current tariffs and standards, qualified professional design, distributor approval, OEM input and formal safety review.

Synthetic example summary

Item	Illustrative result
Load	2,325.6 MWh/year; weekday peak about 569 kW; weekend daytime peak about 260 kW
PV-only case	650 kWp; 1,205.7 MWh gross; 10.7% curtailed under zero export
Hybrid case	650 kWp plus 300 kW / 1,000 kWh; curtailment reduced to 3.4%
Extreme sunny weekend	241 kW peak surplus; 1,509 kWh surplus energy; about 2,240 kWh nominal to retain full service at stated EOL margins
Resilience example	200 kW for 8 hours requires about 2,895 kWh nominal without PV/generator credit

18 | REFERENCES

Selected technical and regulatory sources

Accessed August 2026. Verify current editions, tariffs and distributor requirements for every project.

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18. National Renewable Energy Laboratory, Evaluating the Technical and Economic Performance of PV Plus Storage Power Plants. https://www.nrel.gov/docs/fy20osti/75270.pdf

Note: The NRS standard link above is a publicly accessible copy used for reader convenience; confirm the official current document and the distributor's adopted requirements before design or commissioning.