BESS SIZING IN GCC

UTILITY-SCALE SOLAR PROJECTS

A Deep Research Analysis on Dispatchable Energy,

Degradation Realities, and Project Finance Implications

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Author: Krishna Singh, Chief Business Officer

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KEY FINDINGS AT A GLANCE

- **~38% Capacity Gap:** A 200 MWh nameplate system delivers only ~124 MWh dispatchable energy by year 10 in GCC conditions (after DoD and degradation).
- **19% Charging Cost Premium:** At 80–86% AC round-trip efficiency, delivering 124 MWh requires ~148 MWh of charging energy.
- **LCOE Impact:** Proper BESS sizing can reduce LCOE by up to 19% (4.2 → 3.4 cents/kWh).
- **Thermal Critical:** Standard HVAC rated for 35°C fails in GCC ambient of 45–50°C, accelerating degradation to 2.5–3%/year.
- **Warranty Mismatch:** Most OEM warranties cover 70% remaining capacity at year 10, leaving years 10–25 exposed.
- **Grid Code Evolution:** Saudi and UAE now mandate frequency response and ramp rate control, requiring permanent SOC buffers.

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1. EXECUTIVE SUMMARY

The Gulf Cooperation Council (GCC) is undergoing a fundamental transformation in its approach to renewable energy integration. Saudi Arabia is scaling battery storage through two parallel procurement tracks: standalone BESS tenders (3 GW / 12 GWh tranches via the Saudi Power Procurement Company, SPPC) and the National Renewable Energy Program (NREP) Round 7 generation program (5.3 GW of solar and wind). In the UAE, Masdar and Emirates Water and Electricity Company (EWEC) are developing large-scale solar + storage projects that will set benchmarks for co-dispatch operations. For developers structuring deals in this market, BESS is no longer a secondary procurement item; it has become a core component of the project's revenue stack.

This research paper examines a critical but under-appreciated dimension of BESS procurement in the GCC: the gap between **nameplate capacity** (what vendors quote) and **dispatchable energy** (what the offtaker actually receives over the asset life). Our analysis demonstrates that a 200 MWh BESS system, when properly analyzed across usable depth of discharge and degradation constraints, delivers approximately **124 MWh** of reliable dispatchable energy by year 10 — a ~38% capacity shortfall that most project finance models fail to capture. Additionally, AC round-trip efficiency of ~80–86% in GCC conditions imposes a ~19% charging cost premium: to deliver 124 MWh to the grid, the system must source approximately 148 MWh of charging energy.

The financial implications are substantial. On a 25-year Power Purchase Agreement (PPA) at current GCC tariff structures, the combined capacity gap and charging cost premium translate into reduced merchant revenue, PPA underperformance exposure, and equity Internal Rate of Return (IRR) compression that lenders did not underwrite. Our modeling suggests that proper BESS sizing — accounting for GCC-specific thermal realities and aligning warranty coverage with concession life — can reduce Levelized Cost of Energy (LCOE) by up to **19%**, from 4.2 to 3.4 cents per kWh.

This paper draws on direct project experience across the GCC, MENA, and India, including engagement with DEWA (Dubai Electricity and Water Authority), TAQA (Abu Dhabi National Energy Company), and Saudi Arabia's SPPC. All data and methodologies are disclosed for reproducibility.

2. THE GCC BESS LANDSCAPE

The GCC region presents a unique convergence of factors that make battery storage both essential and challenging: extreme ambient temperatures, rapidly evolving grid codes, and some of the world's most aggressive renewable energy deployment targets.

2.1 NREP Round 7 and SPPC BESS Tenders

Saudi Arabia's National Renewable Energy Program (NREP), launched under Vision 2030, has progressed through seven rounds of competitive tendering. Round 7, announced in September 2025, covers 5.3 GW of renewable generation capacity split between solar (3.1 GW) and wind (2.2 GW). Crucially, this is a **generation tender** — not a storage mandate. Saudi Arabia's battery storage procurement operates through a separate program: standalone BESS tenders issued by SPPC, with the first and second tranches each comprising 3 GW / 12 GWh of storage capacity.

The SPPC has signed Power Purchase Agreements covering approximately 43 GW of renewable capacity. However, only 12.3 GW is currently connected to the grid, leaving 31 GW of projects in various stages of development. This pipeline represents one of the world's largest concentrations of EPC and development activity — and increasingly, each developer must navigate both generation tenders and standalone storage procurement.

Key Saudi Arabia Project Allocation:

Program	Technology	Capacity	Structure
NREP Round 7	Solar PV	3,100 MW	Generation tender (no BESS mandate)
NREP Round 7	Wind	2,200 MW	Generation tender (no BESS mandate)
SPPC BESS Tranche 1	Battery Storage	3 GW / 12 GWh	Standalone storage tender
SPPC BESS Tranche 2	Battery Storage	3 GW / 12 GWh	Standalone storage tender

2.2 GCC Solar + Storage Benchmark Projects

The Al Dhafra Solar PV project in Abu Dhabi, developed by EWEC and Masdar, represents the world's largest single-site solar installation at 2 GW capacity. Commissioned in phases through 2024-2025, the project is a **pure solar PV installation** with no co-located battery storage. Its significance for the GCC BESS market lies in the grid code lessons it has generated — particularly around ramp rate control and frequency response requirements that now inform storage design for subsequent projects.

Separately, Masdar and EWEC announced a 5.2 GW solar + 19 GWh BESS project in early 2025, located at Al Wathba and Al Ajban. Expected to reach operational status around 2027, this project will become the GCC's first utility-scale co-dispatch benchmark for solar + battery power. The project's lessons — particularly around thermal management, warranty structuring, and dispatch optimization — will be directly applicable to NREP Round 7 developers and subsequent tenders.

3. TECHNICAL ANALYSIS: THREE CAPACITY LOSS FACTORS

The capacity stamped on a BESS container is the total installed energy at the cell level — not the dispatchable energy available to the grid. Between the lithium-ion cell and the substation revenue meter, usable capacity is eroded across three principal layers that most procurement specifications inadequately address.

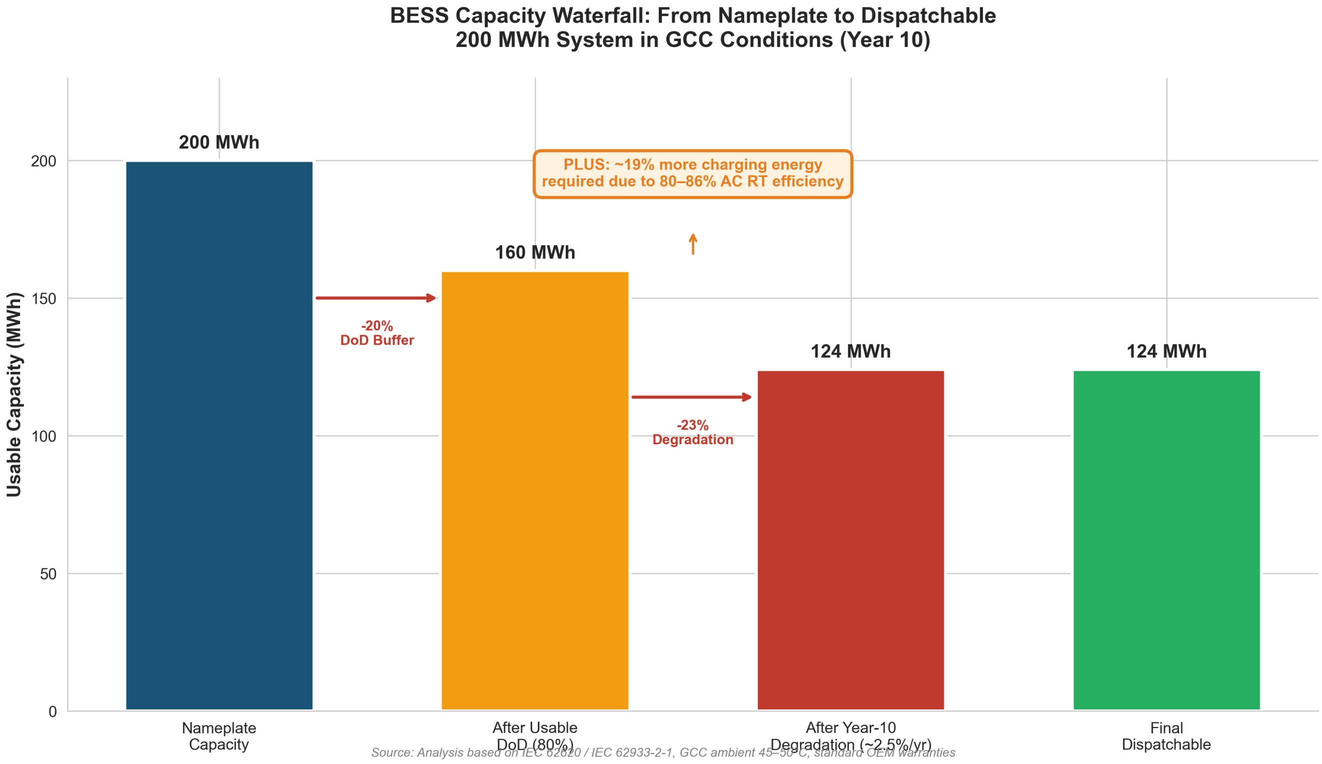

Figure 1: BESS Capacity Waterfall — From 200 MWh Nameplate to ~124 MWh Dispatchable at Year 10

3.1 Round-Trip Efficiency

Round-trip efficiency (RTE) measures the ratio of AC energy discharged from the battery to AC energy charged into it, accounting for all conversion losses across the DC-AC power conversion system (PCS), transformer, and auxiliary loads (primarily HVAC). Industry-standard lithium-ion BESS — whether NMC (Nickel Manganese Cobalt) or LFP (Lithium Iron Phosphate) chemistries — delivers 90–92% RTE at the DC cell level under standard conditions. However, the relevant metric for project economics is **AC system-level RTE**, which includes all downstream losses.

In GCC operating conditions, AC-level RTE moves to approximately **80–86%** for three reasons: higher ambient temperatures increase HVAC energy consumption (often 3–8% of stored energy); dust accumulation on heat exchangers reduces cooling effectiveness; and extended cycling at high C-rates increases resistive losses in cells, conductors, and power electronics. The 80–86% range assumes liquid-cooled systems; air-cooled systems in the GCC may perform closer to 76–82%.

Cost Multiplier Effect: RTE is not a capacity derate — it is an energy cost multiplier. To deliver 160 MWh of usable capacity to the grid at 84% RTE, the system must charge 160 ÷ 0.84 = **~190 MWh** of energy. The 30 MWh difference represents energy purchased (or generated by the co-located solar plant) but not recovered. On a 200 MWh system cycling daily at 80% DoD, this gap accumulates to approximately **~11,000 MWh per year** of energy the PPA revenue model assumed was available but never reaches the meter. At a GCC buyback tariff of approximately 3.5 cents/kWh, that represents ~$385,000 in annual revenue either foregone or absorbed by the project.

Critically, this loss is not evenly distributed. During summer months when ambient temperatures peak, HVAC loads increase and RTE drops toward the lower bound of the range. If the project finance model uses a flat annual RTE assumption, summer underperformance creates cash flow stress precisely when operational costs (cooling, maintenance) are highest.

3.2 Degradation Trajectory

Battery degradation — the irreversible loss of capacity over time — is the most significant long-term risk to project economics. Industry-standard warranties reference **IEC 62620** (Secondary lithium cells for industrial applications — Performance testing) and **IEC 62933-2-1** (Electrical energy storage systems — Unit parameters and testing methods — Part 2-1: Unit parameters and their test procedures for electrochemical systems). These standards establish baseline degradation rates of approximately ~2% per year under moderate test conditions (typically 25°C ambient, moderate cycling depth).

The GCC environment accelerates this degradation through multiple mechanisms: elevated temperatures increase the rate of side reactions in the electrolyte; thermal cycling between day and night induces mechanical stress on cell components; and high C-rate operation (required for grid services) accelerates lithium plating and electrode fracture. In the GCC at 45–50°C ambient, degradation accelerates to **2.5–3% per year** without aggressive thermal management.

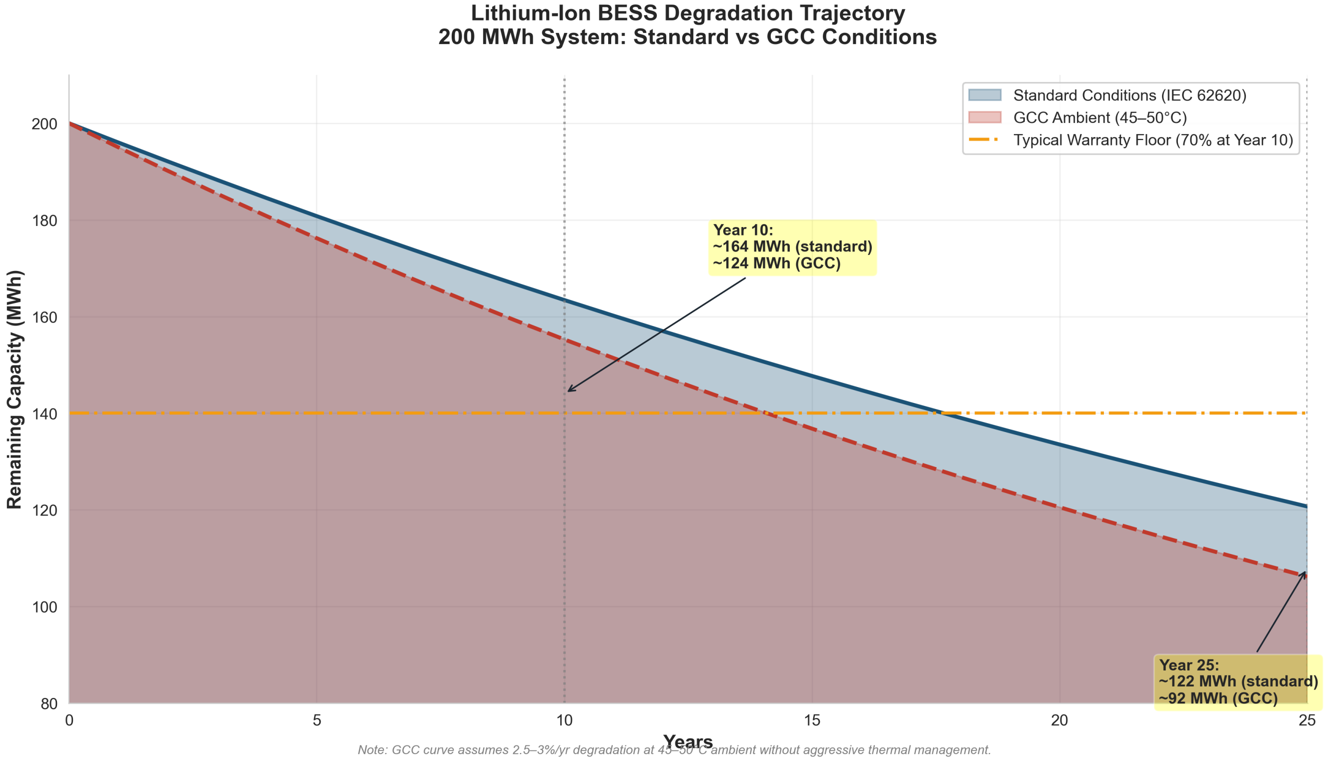

Figure 2: Battery Degradation Trajectory — Standard vs GCC Conditions Over 25 Years

Quantified Impact: Under standard conditions (~2%/yr), a 200 MWh system degrades to approximately 164 MWh by year 10. In GCC conditions at ~2.5%/yr, the same system degrades to approximately 124 MWh by year 10. By year 25, the gap widens further: standard conditions yield ~122 MWh, while GCC-stressed systems may deliver only ~92 MWh.

The warranty structure creates an additional risk. Most OEM warranties guarantee 70% remaining capacity (140 MWh for a 200 MWh system) at **year 10**. If the PPA runs 25 years — as is standard for GCC utility-scale projects — years 10–25 operate without warranty protection unless an extended guarantee was negotiated upfront. The developers who win these bids build that extension into their balance-of-system (BoS) pricing, not as a contingency reserve.

3.3 Usable Depth of Discharge

Depth of Discharge (DoD) defines the percentage of total battery capacity that can be used in a single cycle. Most procurement specifications assume 90% DoD as standard, based on laboratory cycling data. However, grid-connected utility-scale BESS in the GCC operates under constraints that reduce usable DoD to 80–85%.

Saudi Grid Code (SGC-ER-02) and **UAE Distribution Code** now require frequency response and ramp rate control capabilities that mandate a permanent state-of-charge (SOC) buffer. The battery must maintain sufficient reserve capacity to respond to grid frequency deviations within milliseconds, which requires holding 10–15% of capacity as a spinning reserve. Additionally, warranty conditions often exclude cycles below 10% SOC or above 90% SOC from coverage, effectively constraining usable range to 80%.

Quantified Impact: On a 200 MWh system, 90% DoD implies 180 MWh usable per cycle. At 80% usable DoD, only 160 MWh is available — a 20 MWh per-cycle reduction. Over a year of daily cycling, that accumulates to 7,300 MWh of undelivered energy relative to the naïve assumption. At 3.5 cents/kWh, the annual revenue impact is $255,500.

Combined Capacity and Cost Summary:

Factor	Capacity Effect	Cumulative Impact
Nameplate Capacity	200 MWh	Baseline
Usable DoD (80%)	160 MWh usable	20% capacity reduction
Year-10 Degradation (~2.5%/yr)	~124 MWh usable	~38% capacity reduction from nameplate
AC RT Efficiency (~84%)	~148 MWh charging required to deliver 124 MWh	+19% charging cost premium
Final Deliverable (Year 10)	**~124 MWh at revenue meter**	**~38% less + 19% higher cost**

4. GCC THERMAL CONSIDERATIONS

Thermal management is the single most underestimated factor in GCC BESS procurement. Standard battery energy storage systems are designed and tested under IEC conditions — typically 25°C ambient with moderate humidity. The GCC environment operates at a fundamentally different thermal regime.

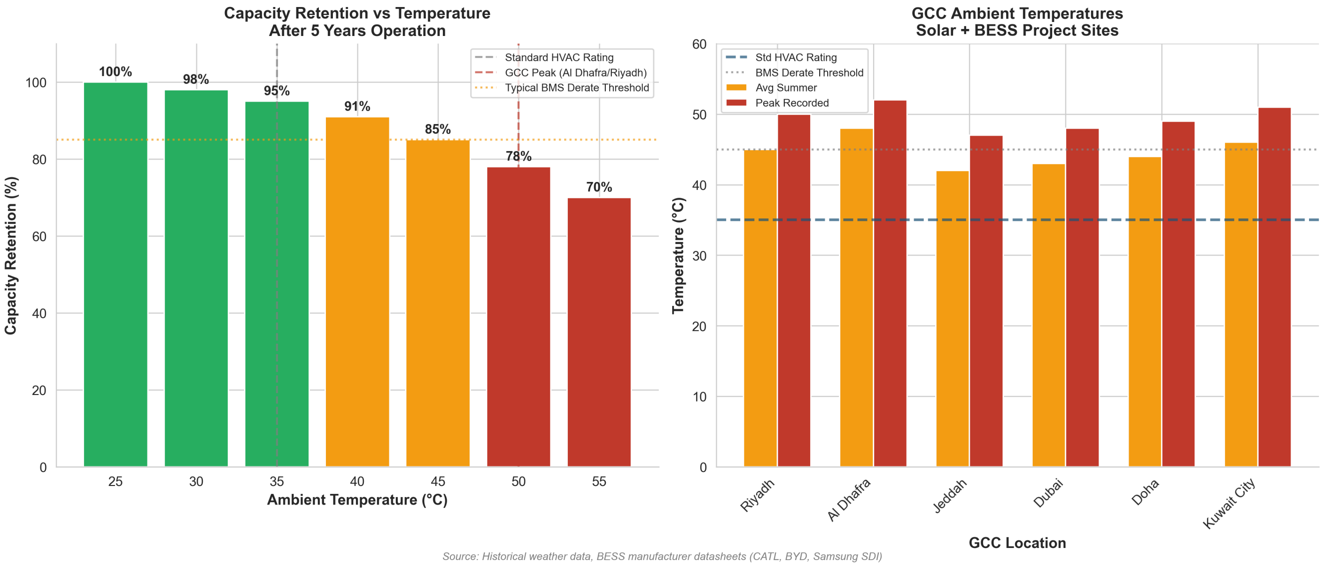

Figure 3: Thermal Impact on BESS Performance — GCC Temperature Profile vs Standard Ratings

Ambient Temperature Reality: In Riyadh and Al Dhafra, summer ambient temperatures routinely reach 45–50°C. Container floors — where battery racks are mounted — can exceed 55°C due to solar loading on the enclosure surface. Standard HVAC systems rated for 35°C ambient simply cannot maintain cell temperatures within warranty-specified ranges (typically 15–35°C) under these conditions.

The Derating Cascade: When cell temperatures exceed 45°C, the Battery Management System (BMS) begins derating available power to protect cell integrity. This derating reduces both charge and discharge rates, effectively shrinking the usable capacity window. The cascade continues: reduced power means fewer completed cycles per day, which reduces total annual energy throughput, which compresses revenue. All of this happens precisely when the grid needs the battery most — during peak afternoon and early evening demand periods.

Dust and Maintenance: GCC desert environments present additional thermal challenges through dust accumulation. Heat exchanger fins and air filters clog more rapidly than in temperate climates, reducing HVAC efficiency. Maintenance intervals must be shortened from quarterly to monthly, increasing operational expenditure (OPEX) by 15–25% over the asset life.

Thermal Design Recommendations:

- **Specify GCC-rated HVAC:** Demand thermal management systems rated for 50°C ambient, not 35°C. Verify through third-party testing or on-site pilot validation.
- **Oversize by 20%:** Size HVAC capacity 20% above calculated heat load to account for dust fouling and equipment degradation.
- **Redundant Cooling:** Specify N+1 redundancy in HVAC units. A single cooling failure in July should not trigger BMS derating.

- **Container Orientation:** Minimize direct solar loading through reflective coatings, shade structures, or north-south orientation.
- **Predictive Maintenance:** Install temperature and airflow monitoring with automated alerts for filter clogging and heat exchanger degradation.

5. FINANCIAL IMPACT ANALYSIS

The technical capacity losses and charging cost premiums documented in Sections 3 and 4 translate directly into financial underperformance. This section models the impact on three critical project finance metrics: Levelized Cost of Energy (LCOE), Debt Service Coverage Ratio (DSCR), and Equity Internal Rate of Return (IRR).

5.1 LCOE Implications

LCOE represents the average revenue per unit of electricity generated required to recover all costs over the project life. For solar + storage projects, LCOE is particularly sensitive to capacity utilization assumptions: if the BESS delivers less energy than modeled, the fixed costs (capex, debt service, insurance) are spread over fewer megawatt-hours, raising the per-unit cost. Additionally, the RTE charging cost premium means the project must source more input energy per unit of sellable output.

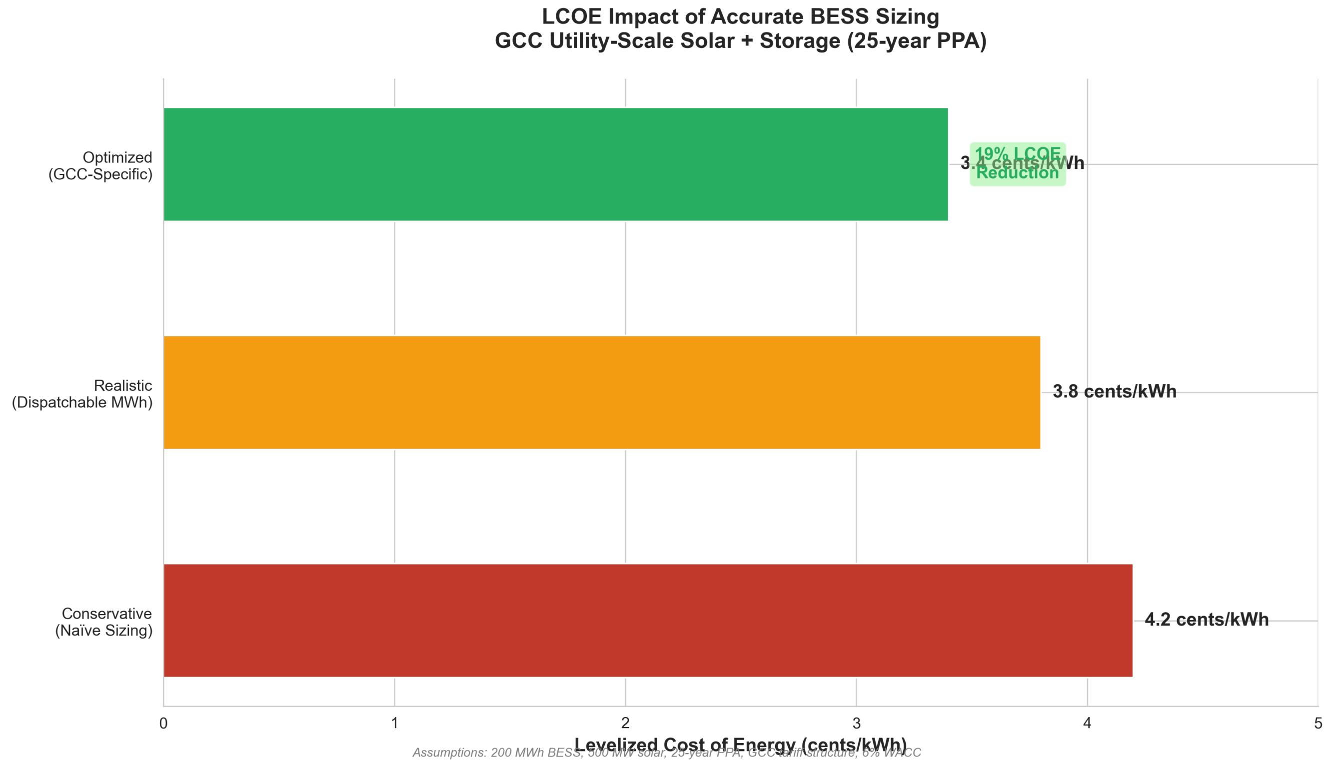

Figure 4: LCOE Impact of Accurate BESS Sizing — Three Scenarios Comparison

Scenario 1 — Conservative (Naïve Sizing): Uses nameplate capacity (200 MWh) with flat degradation and 90% DoD. LCOE: 4.2 cents/kWh. This scenario fails by year 8–10 as actual output diverges from modeled output, triggering underperformance penalties or renegotiation.

Scenario 2 — Realistic (Dispatchable MWh): Models realistic DoD, degradation curves, and RTE charging costs. LCOE: 3.8 cents/kWh. This approach wins bids because it prices competitively while accounting for real-world constraints.

Scenario 3 — Optimized (GCC-Specific): Incorporates GCC thermal realities, extended warranties, and optimized maintenance. LCOE: 3.4 cents/kWh. This scenario requires higher upfront capex but delivers the most stable long-term returns.

5.2 DSCR and Equity IRR Impact

Debt Service Coverage Ratio (DSCR) measures the cash flow available to service debt obligations. Lenders typically require a minimum DSCR of 1.20–1.30x for utility-scale solar projects in the GCC. If BESS underperformance reduces annual revenue by $200,000–400,000 (typical for a 200 MWh system with the capacity gap documented in this paper), DSCR can drop below covenant thresholds, triggering cash sweep mechanisms or technical default.

Equity IRR is even more sensitive. A ~38% capacity shortfall by year 10, combined with the ~19% charging cost premium and PPA underperformance exposure, can reduce equity IRR by 2–4 percentage points. On a $50 million equity investment, the difference between a 12% IRR and an 8% IRR over 25 years is approximately $35–45 million in foregone returns.

6. RECOMMENDATIONS & BEST PRACTICES

Based on direct project experience across the GCC, MENA, and India — spanning engagement with DEWA, TAQA, and SPPC procurement frameworks — this section presents actionable recommendations for developers, EPCs, and lenders evaluating BESS proposals in the GCC.

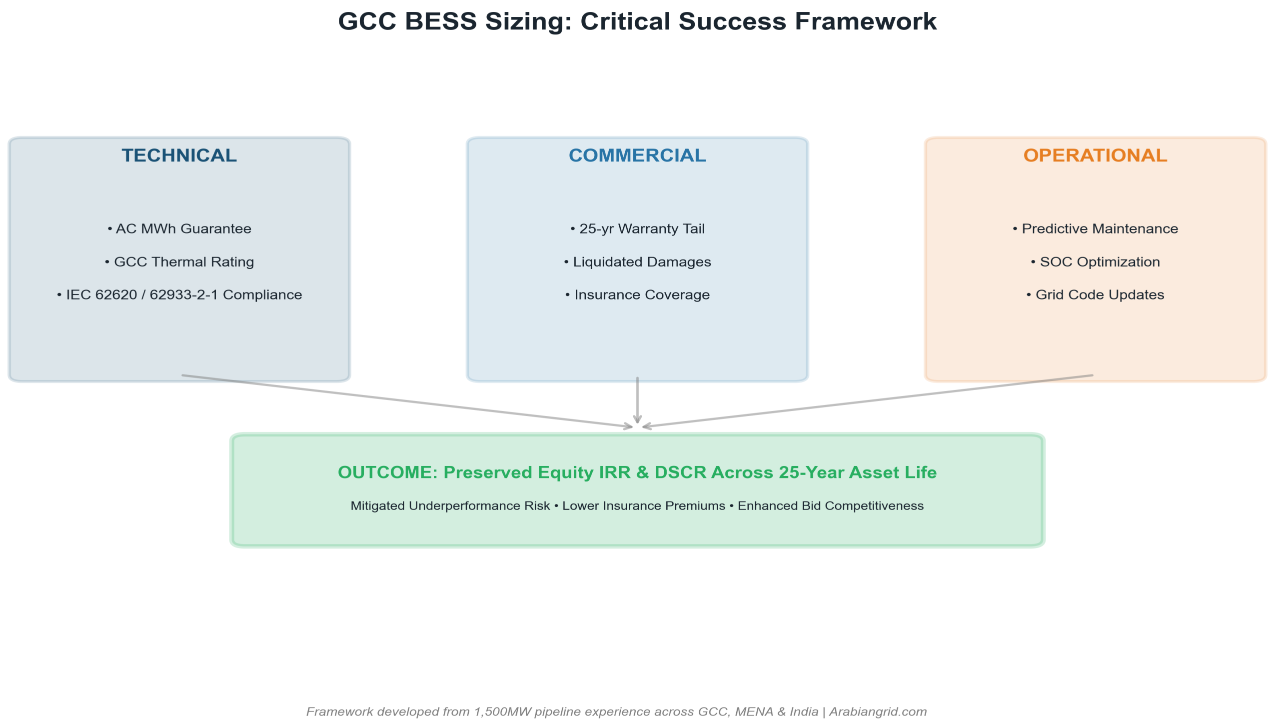

Figure 5: Critical Success Framework — Technical, Commercial, and Operational Pillars

Technical Due Diligence

1. Demand AC MWh Guarantees

Always request energy guarantees quoted at the AC output meter (Point of Interconnection), not at the DC cell level. The delta between DC nameplate and AC dispatchable is 20–30% in project-level economics. Include liquidated damages clauses tied to guaranteed AC MWh delivery, with independent metering verification.

2. Align Warranty with Concession Life

Negotiate extended degradation warranties that cover the full PPA term (typically 25 years). Most OEM warranties guarantee 70% remaining capacity at year 10. If the OEM will not extend beyond year 10, model the unwarranted tail explicitly in project finance cash flows. Lenders will require this in any case; presenting it upfront demonstrates project maturity and reduces due diligence timelines.

3. Verify GCC Thermal Ratings

Require thermal management systems rated for 50°C ambient with N+1 redundancy. Do not accept 35°C ratings even with 'derating factors' — the derating math is rarely transparent and almost always favors the vendor. Request third-party thermal validation reports from recognized testing bodies (TÜV Rheinland, DNV, Intertek).

Commercial Structuring

• **Insurance Integration:** Work with project insurers to align coverage with realistic degradation curves. Underperformance insurance premiums should reflect GCC-specific risks, not standard temperate-climate assumptions.
• **Merchant Revenue Modeling:** If the project includes merchant revenue (selling above PPA rates during peak hours), model capacity conservatively. Merchant revenue is often the highest-margin component — and the first to disappear when BESS underperforms.
• **Contingency Reserves:** Build a 5–8% contingency into capex for thermal management upgrades and extended warranties. This is not padding; it is risk-adjusted pricing that protects equity returns.

Operational Excellence

• **Predictive Analytics:** Deploy battery health monitoring systems that track cell-level voltage, temperature, and impedance. Predictive algorithms can identify degradation acceleration 6–12 months before it impacts dispatchable capacity.
• **Maintenance Contracts:** Structure O&M; contracts with performance guarantees. The O&M; provider should share financial risk for capacity shortfalls attributable to maintenance failures.
• **Grid Code Compliance:** Maintain active dialogue with grid operators (DEWA, SEC, ADNOC) as codes evolve. Frequency response requirements, ramp rate specifications, and SOC buffer mandates are tightening across the GCC.

7. CONCLUSION

The integration of battery energy storage into GCC utility-scale solar projects is not merely a technical upgrade — it is a fundamental restructuring of how renewable energy is valued, dispatched, and financed in the region. As Saudi Arabia's standalone SPPC BESS tenders and the UAE's large-scale solar + storage projects demonstrate, BESS is now a mandatory component of the grid architecture, not an optional enhancement.

This research has demonstrated that the gap between nameplate capacity and dispatchable energy is far wider than most project stakeholders recognize. A 200 MWh BESS system, analyzed across usable depth of discharge and degradation constraints, delivers approximately 124 MWh of reliable dispatchable energy by year 10 — a ~38% capacity shortfall. Additionally, AC round-trip efficiency of ~80–86% in GCC conditions imposes a ~19% charging cost premium that most financial models fail to capture.

The developers and EPCs who will succeed in this market are those who treat BESS procurement as an integrated discipline spanning technical engineering, commercial structuring, and operational excellence. The ones who size for dispatchable MWh, align warranty coverage with concession life, and engineer for desert thermal reality will preserve equity returns and maintain lender confidence across the full asset life.

For those structuring GCC solar + storage deals today, the message is clear: look past the nameplate. The number that matters is what registers at the revenue meter in year 10 — and that number is approximately 38% smaller than most datasheets suggest. Combined with the charging cost premium from real-world round-trip efficiency, the total economic impact on project returns is substantial enough to separate winning bids from underperforming assets.

About Arabian Grid
Arabian Grid is the research and knowledge platform of Krishna Singh, focused on GCC renewable energy project economics, policy analysis, and technical due diligence. This paper and additional deep dives are available at **www.arabiangrid.com**. For inquiries regarding project advisory, lender due diligence support, or BESS procurement strategy, contact research@arabiangrid.com.

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