

Keep the Panels or Rebuild? Value Creation in GCC Solar Repowering

A decision-date framework for operating evidence, incremental value and controlled execution

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Abstract

An operating solar asset's repowering decision depends on measured recoverable loss, the condition of retained infrastructure and the cash available under its remaining operating rights. This paper reviews eighteen primary technical, institutional and official sources within their stated scope. It develops a proposed evidence-to-intervention ledger and connects it to a reproducible hypothetical owner-cash model for continuation, targeted revamping, selective module replacement and full repowering.

With a fictional twelve-year remaining contract, USD 35/MWh cash price and 8% real discount rate, targeted revamping produces incremental net present value of USD 0.590 million against continuation. Selective replacement and full repowering produce incremental values of negative USD 6.573 million and negative USD 23.878 million. The calculation includes construction disruption, equipment and removal expenditure, operating costs, renewal, restricted reserve cash and final closure. These are calculated scenario outcomes; they are not actual plant observations, tariffs or investment recommendations.

Six proposed operating matrices, ten numerical exhibits and five figures connect the comparison to procurement, permissions, execution and acquisition pricing. The synthetic monthly energy screen cannot establish hourly dispatch, actual clipping or a bankable yield. All production and financial inputs are fictional. A consequential project decision requires the asset's own measurements, engineering review, contractual analysis, quotations, approvals and committed funding.

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1. A decision over the remaining operating window

The owner of an operating solar plant faces a linked technical and capital-allocation question: how much expenditure is justified by the cash that can be earned during the remaining usable and contracted operating window? A lower-priced replacement module is one input to that question. The decision also depends on recoverable loss, the condition of retained equipment, the capacity and timing of paid export, construction disruption and the rights that survive a change in configuration.

This paper develops a decision-date comparison for continued operation, targeted revamping, selective replacement and full repowering. It combines an original evidence-to-intervention ledger with a reproducible hypothetical owner-cash model and proposed execution controls. Its contribution is the reconciliation of scope, energy, rights and funding across alternatives. The model treats the existing connection and site as retained infrastructure, with no invented separate revenue for owning them. It assigns no value to an unapproved contract extension or uncontracted new service.

The GCC framing concerns operating environments and transaction interfaces that an actual regional asset team would need to examine. This paper identifies no named plant as a repowering candidate and establishes no GCC-wide degradation, repowering age, financing term or regulatory permission. International technical sources support the investigation within their scope. Each actual project would require its own measurements, engineering review, agreement analysis and applicable-authority confirmation.

The analytical sequence begins with the existing loss and the credible continuation strategy. It then qualifies the proposed system, reconciles export to payment, reviews rights and equipment retirement, and compares scoped interventions. Acquisition pricing, the numerical illustration and the execution matrices connect that evidence to a board decision. All financial and production inputs in the worked example are fictional and serve solely to demonstrate the method.

2. Reconstruct the loss before choosing the intervention

The first analytical product should be a loss attribution that an independent engineer can challenge. IEA PVPS analytical-monitoring research and NREL's operation and maintenance guide provide methods and practices for evaluating operating performance. They establish no particular plant's recoverable loss. [18,4] Begin with revenue-meter energy and reconcile it to inverter measurements, irradiance, temperature, scheduled and unscheduled outages, cleaning events and documented grid restrictions. Maintain the original time stamps and quality flags. A spreadsheet that reconciles annual totals while silently discarding hours with missing measurements can give an intervention credit for changes in the observation set. Record how each exclusion affects the estimated energy recovery.

Separate the populations used for diagnosis. Compare strings or blocks of similar age, orientation, equipment and exposure. A healthy reference block can provide information about local operating conditions; its suitability requires checking instrument calibration and the actual equipment configuration. Preserve unusual results and explain why a cohort is included in the replacement scope. A plant-wide average can conceal a small, expensive failure population and can also spread that population's replacement cost across equipment that remains useful.

Create a decision ledger for each proposed improvement. The ledger should identify the measured symptom, proposed cause, competing explanation, diagnostic test, intervention cost and observable completion criterion. An inverter alarm, for example, may require examination of the electrical system and environmental conditions before a replacement decision. The financial model should use the recoverable energy supported by that investigation. It should retain an explicit unresolved category for losses that cannot yet be attributed.

The proposed control is a reconciliation of evidence and action. An operating-loss category becomes an investment input only after the owner states which intervention changes it, during

which period and at what cost. The same recovered kilowatt-hour should enter the valuation once. If a cleaning programme and module replacement both claim to recover the same historical loss, the alternatives must be compared on a common cleaned or uncleaned baseline. This ledger makes the technical challenge visible at the capital committee, including the possibility that a narrower repair answers the measured problem.

3. Establish a defensible retained-plant counterfactual

The retained-plant case is the owner's economically available continuation strategy at the decision date. NLR's PV Lifetime Project report and IEA PVPS research on degradation and failure modes offer evidence about the populations and technologies they study. Neither source determines the remaining life of the asset being valued here. [5,6] Build the case from the current plant condition, remaining contractual term and a funded maintenance plan. Include corrective work, expected component replacements, insurance, monitoring, cleaning, land and connection obligations, and closure expenditure. Historic construction expenditure belongs outside the incremental comparison when it cannot be changed by today's decision. An unpaid obligation that survives a change in equipment remains a future cash requirement.

Define how the counterfactual responds to evidence. Where an inverter fleet has a documented support problem, continuation may require spares, replacement or a reserve for further investigation. Giving the continuation case indefinite free operation would favour it artificially. Assigning every uncertain failure immediately to continuation while assuming perfect new equipment would favour repowering. Use comparable evidence standards and disclose the asymmetry when an option has shorter field experience or a different service arrangement.

Use a maintenance-and-energy bridge to connect the existing operating record to the forecast. Identify the energy already lost at the decision date, the loss recoverable through approved maintenance, the residual condition after that work and the assumptions about subsequent deterioration. Preserve separate lines for grid restrictions and owner-controlled availability. Payment treatment should follow the actual agreement; a physical reduction in export does not establish its revenue consequence without the relevant settlement rules.

This paper proposes a continuation dossier that can be refreshed with a small set of dated records: the last accepted energy reconciliation, critical component condition, confirmed service support, remaining contract rights and the next unavoidable capital event. That dossier is valuable even if no repowering takes place. It gives an acquirer a basis for reviewing the price of existing cash flow and gives an owner a credible alternative to a supplier's upgrade proposal. The illustrative model later in the paper stipulates its continuation inputs; an actual transaction would need the dossier before those inputs could become decision evidence.

4. Design a climate-specific investigation

IEA PVPS provides separate operation and maintenance guidance for different climate settings, including hot and dry conditions. Its 2025 climate-design report also discusses interactions between mitigation measures and the need for further field evidence. These sources support a site-specific investigation; they establish no degradation rate, cleaning benefit or replacement age for an individual GCC plant. The owner should identify which recorded exposures matter at the asset under review. [16,2]

Build an exposure map with the technical advisers. Useful investigation categories include ambient and equipment temperature, dust characteristics, cleaning method and frequency, humidity or salinity where relevant, drainage, wind exposure and records of extreme events. Record when those conditions were measured, which equipment population they represent and whether the measurement spans the period used in the forecast. A climatic label alone leaves the investment team without a testable explanation for an observed loss.

Specify paired tests for recoverable and persistent losses. IEA PVPS's soiling report examines measurement and mitigation, while its extreme-weather report discusses retaining baseline and inspection evidence. These are investigation resources; they establish no loss percentage or damage finding for a particular plant. [3,17] A controlled cleaning comparison should record the condition before and after work, the elapsed time, weather conditions, measurements and any cleaning-related damage. Component investigations should identify sample selection and the basis for extending findings to the larger population. The owner needs both the potential recovery and the uncertainty around how widely that recovery applies. A replacement quotation should not erase the cost of establishing that uncertainty.

Adapt the execution plan to the exposure mechanism. The proposed procurement schedule should request evidence for the actual operating environment and maintenance method, including the permitted cleaning procedure and material compatibility. Where the chosen intervention changes the maintenance method, include training, monitoring, access and continuing consumables in its cash case. Where a risk remains unresolved, assign a further test or explicit contingency with a responsible owner. This framework turns environmental information into design choices, expenditures and acceptance records that can be checked during the operating period.

5. Qualify the replacement as a system configuration

Evaluate the complete proposed electrical and mechanical configuration. The design review should trace module characteristics, string arrangement, inverter operating range, cabling, connectors, protection, mounting, earthing and the high-voltage interface. Larger nameplate output changes the design question; its usable contribution depends on the rest of the system and the conditions under which it operates. A procurement comparison based solely on price per installed watt leaves several interfaces outside the decision.

Create a configuration-controlled technical schedule. Each retained component should have an identified condition assessment and permitted operating envelope. Each replacement should have a specified product revision, evidence package and compatibility review. The public scope of IEC 61215-1:2021 states that its results are not a quantitative prediction of module lifetime; this paper makes no claim to have inspected the paid full standard or a product certificate. [9] Log the assumptions used when records are missing. The review should identify whether the proposed arrangement can be tested before a large order and which findings would require redesign. A small demonstration can reduce uncertainty only for the configuration and operating conditions it actually represents.

Assign responsibility for interfaces explicitly. A module supplier, inverter supplier, installer, existing operator and owner's engineer may each have a narrow scope. The owner should request a written allocation of responsibility for integrated performance, commissioning, warranty administration and remediation. Where no party accepts an interface obligation, retain the corresponding cost and risk in the owner's case. Contract review should establish the actual

remedy and the party expected to fund it; an analytical reserve creates no third-party recovery right.

Keep technical acceptance and economic acceptance connected through a defined sequence. The technical team should document design conformity, safe installation, test results and unresolved defects. The finance team should reconcile the final scope, expenditure, downtime and initial operating evidence to the approved case. A change that remains technically acceptable can still alter the capital conclusion through extra cost or reduced paid energy. The proposed configuration ledger therefore includes both the engineering approval and a cash-model revision record. Its purpose is to keep the investment decision attached to the plant that is actually delivered.

6. Translate additional equipment into paid export

The energy case needs a clear chain from equipment to revenue: available resource, conversion and operating losses, the plant's export capability, accepted delivery and payment. System Advisor Model documentation treats system design, losses and inverter behaviour as modelling inputs. Its published methodology can help define a technical study, but a simplified financial illustration cannot replace a validated plant model with the appropriate time resolution. [7,8]

An owner should request paired estimates of unconstrained generation and export at the settlement boundary. Keep technical conversion limits, grid instructions and contract restrictions identifiable. A forecast with additional DC equipment can produce more energy at some times while encountering unchanged export limits at other times. The relevant comparison concerns the timing and amount of usable output. Annual energy alone cannot show whether an intervention recovers shoulder-period output or merely increases an already constrained peak.

The financial team should state the paid-energy rule in the same units and time periods as the technical model. Confirm the settlement point, deductions, losses, availability definitions and treatment of outages or instructions under the actual contract. If the commercial arrangement changes during repowering, value that change separately from the equipment intervention. Where approval is pending, maintain the existing-rights case and show the proposed change as a conditional alternative with its own cost and timing.

The numerical example in this paper uses a deliberately synthetic monthly export-window screen. It makes cap and outage arithmetic reproducible while exposing the limited resolution of the calculation. That screen contains no hourly weather, inverter-temperature curve or actual dispatch record. It therefore supplies no measured clipping estimate, engineering export assessment or bankable yield. Before a real commitment, the owner would need a validated technical production study, confirmation of contractual delivery rights and a reconciliation of both studies to the valuation. The synthetic screen is a way to examine decision sensitivity while those requirements remain open.

7. Resolve the rights attached to the operating asset

Repowering changes an operating configuration with existing counterparties. Review the actual project agreements for the scope of permitted work and the process for obtaining required approvals. The rights review should cover the offtake arrangement, land, connection, operating permissions, financing, security, insurance and supplier remedies. This paper asserts no standard

GCC right to increase capacity, extend a PPA, retain an existing tariff or change technology without consent.

Use the current signed documents as the base. DEWA's distributed-generation connection conditions and the Abu Dhabi Department of Energy's plant-specific Dhafrah licence illustrate distinct, bounded regulatory instruments. EWEC's Al Dhafra project page describes that particular project. None of these public sources establishes another asset's repowering consent, tariff or extension rights. [12,13,14] A summary can help the committee navigate agreements, but material rights should link to the relevant instrument, clause, amendment and approval record. For each option, distinguish work that the existing documents permit, work requiring a request, and work whose economic terms remain unresolved. Record the date and dependencies of any request.

Translate the rights register into model constraints. A fixed expiry date limits the period available to recover new capital. A construction window can affect downtime. A revised export limit can affect paid energy. An approved insurance or security condition can affect cost and financing. Model the consequence of each verified condition once, and keep unapproved benefits outside the existing-rights case. This makes a consent delay visible as a shorter operating window and additional expenditure where those consequences actually apply.

For a transaction, specify who bears the unresolved rights risk at signing and at completion. The parties might consider a condition, a bounded undertaking, a price mechanism or a separate later investment decision, subject to their legal advice and negotiation. The valuation should identify which assumptions the proposed mechanism addresses and which remain with the buyer or owner. The resulting diligence schedule supports an informed negotiation; it supplies neither legal enforceability nor assurance that a counterparty will accept the proposed route.

8. Price removal and the destination of retired equipment

Equipment removed during an upgrade remains part of the project's cash and responsibility boundary. Inventory the population to be removed, its condition, ownership and proposed destination. Separate the cost of isolation, dismantling, packing, transport, storage, testing and final treatment. Establish the applicable jurisdictional requirements with qualified advisers and the relevant authorities. A net disposal line should retain a gross-cost reconciliation so that a speculative recovery cannot conceal an unfunded obligation.

IEA PVPS research on second-life modules addresses performance and reliability questions for reuse; its recycling report addresses a separate treatment route. Neither source certifies a particular removed population, establishes a buyer, or determines the applicable local waste classification. [1,10] UAE Federal Law No. 12 of 2018 provides a national integrated-waste-management framework; its existence does not determine the treatment or permissions for this fictional asset. [15] An actual reuse proposal needs the relevant tests, evidence of condition, a responsible destination and the terms under which equipment changes hands. The investment committee should request that package before recognising recovery proceeds in its base case.

Design the physical flow before committing to a large removal programme. Identify work areas, handling routes, temporary storage limits, segregation of damaged equipment and the records that link each cohort to a destination. The operating plant and contractors need an agreed allocation of responsibilities. Where removed modules will be held while a claim is examined, include the

associated storage and handling assumptions and obtain advice on preserving evidence. Those requirements can change the construction sequence and the cash needed before completion.

The illustrative valuation assumes an explicit removal and disposal cost and no equipment-sale income. That boundary allows the repowering comparison to proceed without assuming a secondary buyer. A verified sale or reuse route could be added as a separate cash case, using the actual quantity, price, costs, collection conditions and timing. Remaining closure obligations also need review when equipment is replaced mid-life. The owner should explain which obligation is settled during the upgrade and which survives to final retirement, so that the model captures each activity at the relevant date without charging it twice.

9. Keep the intervention set narrow enough to compare

Construct an option set around the diagnosed problem. The retained-plant route includes funded continuation. A targeted revamp addresses a defined component or operating constraint. Selective module replacement changes an identified part of the DC field. Full repowering replaces a broader configuration with its associated design, approval, construction and removal requirements. Give each route a written scope and a common measurement boundary before comparing returns.

Define the exclusions as carefully as the included work. IRENA's generation-cost report concerns the projects and periods in its dataset; an aggregate cost measure is not a firm quotation for replacing an operating plant's configuration. [11] An inverter-only quotation may leave transformers, controls or protection changes with the owner. A full DC quotation may rely on retained structures whose condition remains open. Selective replacement can require additional engineering and inventory administration. Convert those interfaces into owner costs or explicit unpriced items. An option with unresolved scope should have an investment range and an evidence requirement; a precise supplier price alone does not close the owner's total-cost case.

Storage, new control services and a contract extension can be evaluated as additional decisions. Keep their capital, operating, rights and revenue assumptions visible. This paper's numerical comparison excludes storage and new-service income so that the effect of the solar intervention can be traced. A later combined case should reconcile shared costs, timing and export capacity, including which expenditure is genuinely avoided by joint execution. Without that reconciliation, adding projects can create attractive headline value through overlapping benefits.

The proposed option discipline has a practical procurement consequence. Ask bidders to identify the loss they address, the components they retain, the cost boundary, the construction exposure and the evidence by which completion is judged. Compare those responses to continuation and to narrower interventions using the same date, term and cash conventions. The next section extends that discipline to acquisition pricing before the numerical case quantifies it. An owner can then choose between investigation, a bounded pilot, commitment or continued operation with an explicit record of what supports the choice.

10. Purchase existing cash flow and repowering optionality separately

An acquirer should prepare two linked valuation records. The first concerns the current operating asset under its existing rights, obligations and condition. The second concerns a future intervention that requires further capital and may require approvals. State the assumptions shared

by both records. A seller's expectation of an upgrade benefit does not establish the buyer's ability to execute it, its cost or the price at which the benefit should be acquired.

Reconcile the proposed upgrade to the acquisition model. If the seller's forecast already includes higher energy or lower maintenance, the buyer should identify the investment and downtime that enable those outcomes. The capital must enter the case at the appropriate date, with the contractual period available for recovery. If the buyer pays for the upgraded cash flow in the purchase price and also treats the same improvement as a new independent source of value creation, the investment memorandum overstates the incremental opportunity.

Use diligence questions that expose the dependency. Request the retained-plant model, the measured loss diagnosis, the proposed configuration, the all-in intervention budget and the consent schedule. Ask which items are contracted, which are quotations and which remain author or management assumptions. Price mechanisms and conditions can be considered with the transaction advisers, but their effect should be tested against the specific uncertainty they address. A general promise to cooperate leaves the model's timing and cash exposure unresolved.

The proposed buyer screen reports operating value, incremental intervention NPV, peak funding requirement and unresolved conditions side by side. It establishes no actual acquisition price or investment recommendation. Its commercial use is to explain where consideration is being paid for existing performance, where capital will be spent after completion and what evidence could justify recognising additional optionality. The buyer can then negotiate and stage commitments using a transparent cash boundary.

11. Define the remaining-contract investment boundary

The worked example compares four choices for an existing solar facility at a single decision date. Every numerical input is fictional. The purpose is to identify the assumptions that can change the spending decision, with no claim about achieved GCC performance, market equipment prices or an actual power purchase agreement. The plant has a stipulated 100 MWac export interface and twelve years remaining under an assumed unchanged contract. Its existing land, connection and switchyard remain available to every option within this scenario. Their original construction expenditure and current book values are excluded as sunk amounts. Any new works required to use them belong in an actual investment budget. No separate receipt is created for infrastructure already present.

The retain case starts with 120 MWp of DC capacity, a stipulated annual specific yield of 1,750 kWh/kWp before the separately modeled losses, annual degradation of 0.65% and annual operating expenditure of USD 1.8 million. An inverter revamp retains that DC capacity, assumes specific yield of 1,840, degradation of 0.50% and operating expenditure of USD 1.5 million. Selective module replacement increases assumed DC capacity to 135 MWp, with specific yield of 1,810, degradation of 0.45% and operating expenditure of USD 1.45 million. Full repowering uses 160 MWp, specific yield of 1,820, degradation of 0.35% and operating expenditure of USD 1.3 million. These are package-level financial assumptions. In particular, the revamp degradation rate does not assert that replacing inverters physically restores module condition.

Equipment investment occurs immediately in the base case: USD 6 million for revamp, USD 18 million for selective replacement and USD 42 million for full repowering. Separate removal and disposal spending is USD 0.25 million, USD 1.2 million and USD 3 million respectively. There

is no recovery credit for removed equipment. An actual appraisal would require inspection, ownership, waste-handling and resale evidence before adding one. The option-input exhibit records the capacity, yield and recurring-cost differences. The monthly exhibit then shows how installation affects saleable energy in the first year, when the new equipment's nominal rating alone provides an incomplete cash forecast.

All cash is expressed in real USD million unless a different unit is stated. Electricity receipts use the same fictional USD 35/MWh for every option, collected at each year end. Time-zero capital is undiscounted; later cash uses an 8% annual real discount rate. Taxes, inflation, debt, receivables, subsidies and contract renegotiation are excluded. A USD 4 million closure payment occurs at the end of the remaining contract in every case. There is no salvage, extension or post-expiry operation in the base valuation. This common stop is a chosen contractual scenario boundary. It is not an assertion that all equipment becomes physically unusable then. An actual residual opportunity requires a separately supported right, cost and revenue case.

Public sources accessed 9 October 2026. Model inputs, calculated examples and proposed decision records are author-created illustrations. The repowering scenarios are hypothetical. Their generation, cost, timing and revenue assumptions require asset-specific technical and contractual verification. They establish no actual permission to modify an asset, collect additional revenue or obtain financing. The model horizon, cash boundaries and residual treatment are stated with the calculations. Calculated table values use up to three decimal places with round-half-up; calendar years are shown as integers. Floating-point noise is removed at twelve decimal places before display rounding. Calculations retain their underlying precision.

Table 1. Fictional option inputs and common export boundary

Option	DC MWp	Yield kWh/kWp	Capex USDm	O&M USDm/year	Degradation %
Retain	120.000	1,750.000	0.000	1.8	0.650
Inverter revamp	120.000	1,840.000	6.000	1.5	0.500
Selective modules	135.000	1,810.000	18.000	1.45	0.450
Full repower	160.000	1,820.000	42.000	1.3	0.350

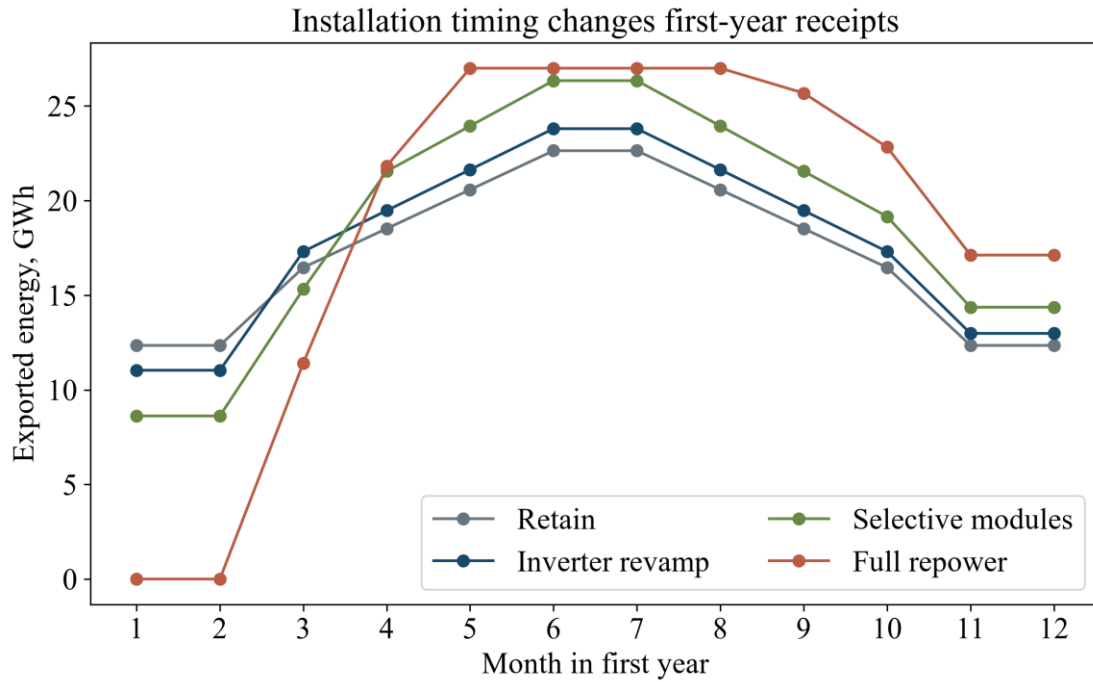
All inputs fictional. Common 100 MWac interface, synthetic 3000-hour annual export window, 98% ordinary availability, USD 35/MWh cash receipt and 12-year remaining contract. Capex excludes separately stated removal and reserve cash.

Table 2. First-year monthly exported energy

Month	Retain MWh	Revamp MWh	Selective MWh	Full MWh
1	12,348.000	11,035.584	8,620.668	0.000
2	12,348.000	11,035.584	8,620.668	0.000
3	16,464.000	17,310.720	15,325.632	11,415.040
4	18,522.000	19,474.560	21,551.670	21,831.264
5	20,580.000	21,638.400	23,946.300	27,000.000
6	22,638.000	23,802.240	26,340.930	27,000.000
7	22,638.000	23,802.240	26,340.930	27,000.000
8	20,580.000	21,638.400	23,946.300	27,000.000
9	18,522.000	19,474.560	21,551.670	25,683.840
10	16,464.000	17,310.720	19,157.040	22,830.080
11	12,348.000	12,983.040	14,367.780	17,122.560
12	12,348.000	12,983.040	14,367.780	17,122.560

Monthly weights are synthetic bookkeeping, not hourly dispatch or measured clipping. Installation availability is applied before the monthly energy cap. All upgrade work starts at the decision date.

Figure 1. Installation timing changes first-year exported energy



All inputs fictional. Monthly energy and outage fractions are synthetic; the calculation supplies no hourly dispatch, engineering acceptance or actual GCC tariff evidence.

12. Translate installation and renewal into exported energy

The energy calculation first allocates annual pre-loss output across twelve synthetic monthly weights. Those weights are 6%, 6%, 8%, 9%, 10%, 11%, 11%, 10%, 9%, 8%, 6% and 6%. Both MWp multiplied by kWh/kWp and MW multiplied by hours produce MWh after the corresponding unit conversion. Ordinary operating availability is stipulated at 98%. This factor excludes the installation and renewal outages modeled separately. The specific-yield assumption represents the remaining package performance before these explicit factors and the synthetic export cap; there is no additional unrecorded performance benefit from the shared switchyard.

Each month's energy cap equals 100 MW multiplied by its allocated share of 3,000 annual export-window hours. The hour shares are 8%, 8%, 8%, 8%, 9%, 9%, 9%, 9%, 9%, 8%, 8% and 7%. Export is the smaller of this cap and energy remaining after ordinary availability and the applicable outage fractions. This construction is synthetic monthly bookkeeping. It cannot reproduce actual hourly dispatch, irradiance coincidence, instantaneous inverter clipping or a grid operator's curtailment instructions. A positive result under it leaves those engineering and contractual matters unresolved. The different monthly energy and window profiles deliberately expose a constraint that a simple annual generation multiplier could miss.

The base installation fractions are explicit. Revamp retains 85% of otherwise available production in January and February, then 100%. Selective replacement retains 60%, 60% and 80% in the first three months, then 100%. Full repowering retains zero in January and February, 50% in March, 85% in April and 100% thereafter. These fractions describe the whole modeled plant's accepted energy during the intervention. They do not establish an actual construction sequence, access permission or outage agreement. Revenue is calculated from the resulting export once; no second foregone-revenue expense is deducted.

The first-year export result is 205,800 MWh for retain, 212,489.088 for revamp, 224,137.368 for selective replacement and 224,005.344 for full repowering. The larger rebuild produces slightly less first-year export than selective replacement because its installation interruption is longer. Its synthetic cap removes a further 11,857.920 MWh after the other first-year losses. The generation-reconciliation exhibit exposes each deduction, while the first figure shows its calendar position. In the second year the full-repower output rises to 271,344.820 MWh under the model assumptions.

Later renewal spending also carries an energy effect. Retain incurs USD 5 million in year six and loses half of otherwise available June production. Each upgrade incurs its stipulated renewal in year eight: USD 2 million for revamp or selective replacement and USD 2.5 million for full repowering, with June production unavailable. Degradation continues through these events; there is no assumed performance reset. The annual energy exhibit and second figure show the resulting interruptions. Treating renewal cash and renewal downtime together avoids presenting a smooth generation curve alongside an incomplete maintenance budget.

Table 3. Annual exported energy on the common calendar

Year	Retain MWh	Revamp MWh	Selective MWh	Full MWh
1	205,800.000	212,489.088	224,137.368	224,005.344
2	204,462.300	215,302.080	238,385.417	271,344.820
3	203,133.295	214,225.570	237,312.682	270,857.113
4	201,812.929	213,154.442	236,244.775	270,371.113
5	200,501.145	212,088.670	235,181.674	269,886.814
6	188,242.003	211,028.226	234,123.356	269,404.211
7	197,903.101	209,973.085	233,069.801	268,923.296
8	196,616.731	185,941.665	206,498.678	241,444.064
9	195,338.722	207,878.604	230,976.892	267,966.510
10	194,069.020	206,839.211	229,937.496	267,490.627
11	192,807.572	205,805.014	228,902.778	267,016.410
12	191,554.322	204,775.989	227,872.715	266,543.853

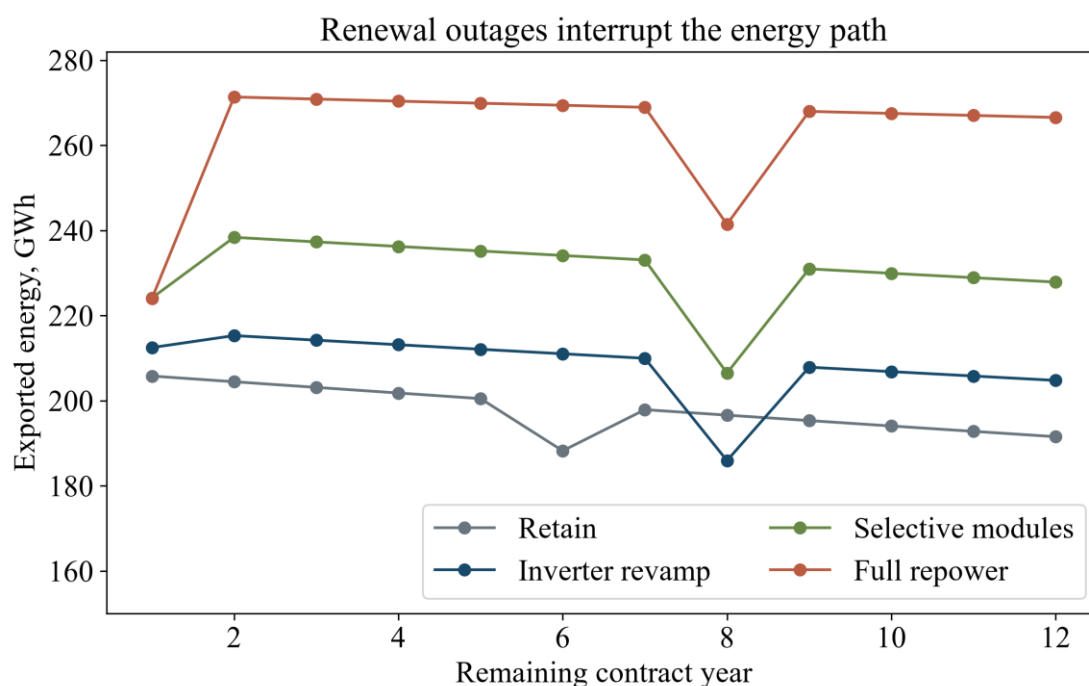
Ordinary availability excludes separately modeled installation and renewal downtime. June renewal occurs in year 6 for retain and year 8 for upgrade options. No contract extension is assumed.

Table 4. First-year generation reconciliation

Option	Raw MWh	Ordinary loss	Installation loss	Cap loss	Export MWh
Retain	210,000.000	4,200.000	0.000	0.000	205,800.000
Inverter revamp	220,800.000	4,416.000	3,894.912	0.000	212,489.088
Selective modules	244,350.000	4,887.000	15,325.632	0.000	224,137.368
Full repower	291,200.000	5,824.000	49,512.736	11,857.920	224,005.344

All energy columns MWh. There is no year 1 renewal outage. Export equals raw less the three listed losses. Synthetic cap loss cannot be interpreted as a physical hourly clipping estimate.

Figure 2. Installation, degradation and renewal on the fixed contract calendar



Fictional monthly energy aggregated annually. Ordinary availability excludes separately modeled work outages. The synthetic monthly export cap is not a measured hourly clipping or curtailment model.

13. Reconcile project value, restricted cash and incremental funding

The decision compares each intervention's discounted project cash with the retain case. The retained facility itself has a calculated project NPV of USD 34.147 million within this limited perimeter. That amount is the present value of its remaining operating receipts after the modeled costs and closure. It is neither a new construction return nor an independently appraised acquisition price. All historical funding and any existing debt claims are outside the account. An acquisition or refinancing analysis would need an additional bridge from these project flows to the rights and obligations actually transferred.

Revamp has project NPV of USD 34.737 million, giving incremental value of USD 0.590 million. Selective replacement has project NPV of USD 27.574 million and incremental value of negative USD 6.573 million. Full repowering has project NPV of USD 10.269 million and incremental value of negative USD 23.878 million. The discounted decomposition shows why a positive total project value can accompany an unattractive replacement decision: the existing facility already produces cash without the immediate replacement expenditure. The incremental-value figure preserves retain as the zero comparison. The relevant question is whether the extra receipts and changed costs justify the new commitment within the assumed remaining term.

The owner also places cash in a hypothetical restricted service account at the investment date: USD 0.5 million for revamp, USD 1 million for selective replacement and USD 2 million for full repowering. Assumed owner-paid warranty-related service costs in year three are USD 0.15 million, USD 0.3 million and USD 0.6 million. These are financial diagnostics, with no asserted supplier coverage, claim probability or actual warranty adequacy. Claims draw the reserve first; any excess would require unrestricted cash. The remaining balance is released in year five under the base assumption. A shorter-contract scenario releases it at the earlier modeled end; legal permission for such release remains hypothetical.

Reserve contributions are transfers into restricted cash, while service payments are actual expenditure. The total project account deducts the service cost once. The liquid project account instead records the contribution, any claim amount exceeding the reserve and the permitted release. The difference between total and liquid annual cash equals the change in restricted cash. Their discounted values differ because the reserve is unavailable for operating use before release. The no-release sensitivity leaves USD 0.35 million, USD 0.7 million and USD 1.4 million locked at the horizon. Later claims and any actual release conditions require their own contractual assessment.

A separate dedicated incremental funding ledger starts with zero cash, retains positive differences from retain and calls additional cash whenever its balance would otherwise become negative. Base required support is USD 6.750 million, USD 20.200 million and USD 47.000 million for the three interventions. These are timely uncommitted funding requirements. The ledger supplies no evidence that existing plant cash can be distributed or redirected, and no lender advance is assumed. Its annual netting cannot establish intrayear liquidity. The project-flow NPV values cash when generated; the retained-cash ledger does not calculate a sponsor distribution return. Actual financing needs monthly payment terms, reserve restrictions and the authority to use existing receipts.

Table 5. Discounted cash-flow decomposition

Option	Revenue PV	O&M PV	Capital/removal PV	Other net uses PV	Project NPV
Retain	52.451	13.565	0.000	4.739	34.147
Inverter revamp	55.221	11.304	6.250	2.931	34.737
Selective modules	60.894	10.927	19.200	3.193	27.574
Full repower	69.052	9.797	45.000	3.986	10.269

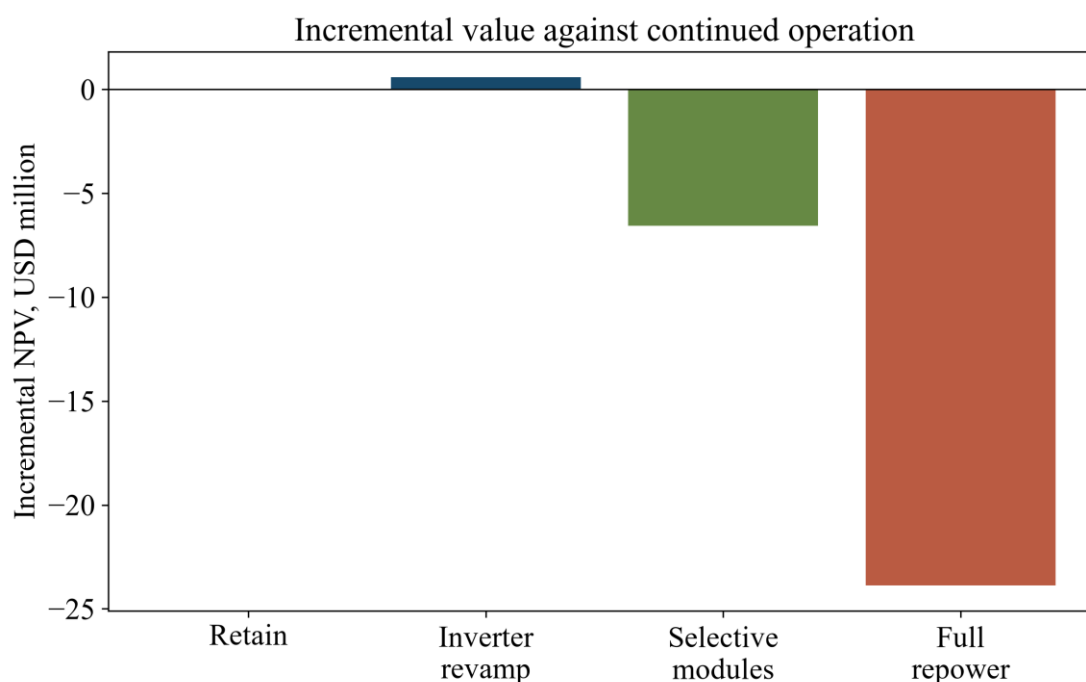
USD million at 8%. Other uses include renewal, actual claims, closure and the timing effect of reserve restriction/release. Shared existing land, grid and switchyard have no new purchase cost or standalone revenue in this decision perimeter.

Table 6. Incremental value and dedicated funding

Option	Incremental NPV	Initial cash use	Funding required	Ending incremental cash	Terminal reserve
Retain	0.000	0.000	0.000	0.000	0.000
Inverter revamp	0.590	6.750	6.750	11.404	0.000
Selective modules	-6.573	20.200	20.200	21.564	0.000
Full repower	-23.878	47.000	47.000	37.305	0.000

USD million relative to retain. Dedicated incremental cash is retained and timely uncommitted support covers deficits. This is not an actual financing commitment or a sponsor-distribution NPV. Whole-plant operating cash is not automatically available to finance the change.

Figure 3. Incremental value relative to retaining the existing plant



Fictional USD million at 8% real discount and USD 35/MWh cash price. Historical expenditure is excluded. Restricted reserve timing is included; no debt or sponsor-distribution return is calculated.

14. Identify the price and capital limits that change the decision

The break-even exhibit varies the same electricity price across all four options while preserving every other assumption. This creates a transparent boundary for incremental value against retain. Revamp requires approximately USD 27.547/MWh, selective replacement USD 62.248/MWh and full repowering USD 85.340/MWh to reach zero incremental NPV. These are calculated sensitivities, with no claim that the existing buyer must accept a higher tariff. The full-repower threshold lies outside the displayed USD 15 to USD 65/MWh sensitivity range. Its value is obtained from the exact linear cash relationship, not from a forecast of future market prices.

The mechanism is the present value of additional exported MWh. At the base discount rate, those incremental quantities are approximately 79,162.513 MWh for revamp, 241,223.295 MWh for selective replacement and 474,325.197 MWh for full repowering. Each additional dollar per MWh changes incremental NPV by that discounted quantity divided by one million. The price figure traces this relationship. The common-price assumption also changes retain's receipts, so the incremental calculation captures only the energy difference. Applying the higher price solely to the new equipment would introduce a separate contract assumption requiring explicit justification.

An alternative boundary holds the USD 35/MWh price constant and solves for maximum immediate equipment expenditure. Revamp can support USD 6.590 million against its stipulated USD 6 million. Selective replacement can support USD 11.427 million against USD 18 million. Full repowering can support USD 18.122 million against USD 42 million. The boundary excludes the separately modeled removal and restricted reserve amounts, which remain fixed. The revamp margin above assumed equipment cost is therefore only about USD 0.590 million. A revised scope or an omitted interface cost of similar present value can remove the apparent benefit.

The sensitivity grid illustrates this exposure without assigning probabilities. A 25% equipment-cost increase changes revamp incremental NPV to negative USD 0.910 million. A 25% reduction increases it to USD 2.090 million, while selective and full replacement remain negative under their corresponding reductions. At USD 65/MWh, selective replacement becomes positive at USD 0.664 million, although revamp remains the more valuable incremental intervention at USD 2.965 million. Separate one-variable thresholds establish comparisons with retain; they do not automatically identify the preferred option among all mutually exclusive packages.

Remaining contract duration matters through the actual cash calendar. With four years remaining, revamp incremental NPV is negative USD 4.357 million; with eight years, it is negative USD 0.752 million. These are alternative initial contract assumptions with their own fixed closure dates. They confer no right to extend the twelve-year base contract. Raising the discount rate from 8% to 10% also moves revamp incremental value slightly below zero, to negative USD 0.100 million. The investment committee therefore needs a documented price, scope and remaining-term case before treating a narrow calculated margin as a spending authority.

Table 7. Decision break-even boundaries

Option	Incremental PV MWh	Break-even USD/MWh	Maximum equipment capex USDm	Assumed capex USDm
Inverter revamp	79,162.513	27.547	6.590	6.000
Selective modules	241,223.295	62.248	11.427	18.000
Full repower	474,325.197	85.340	18.122	42.000

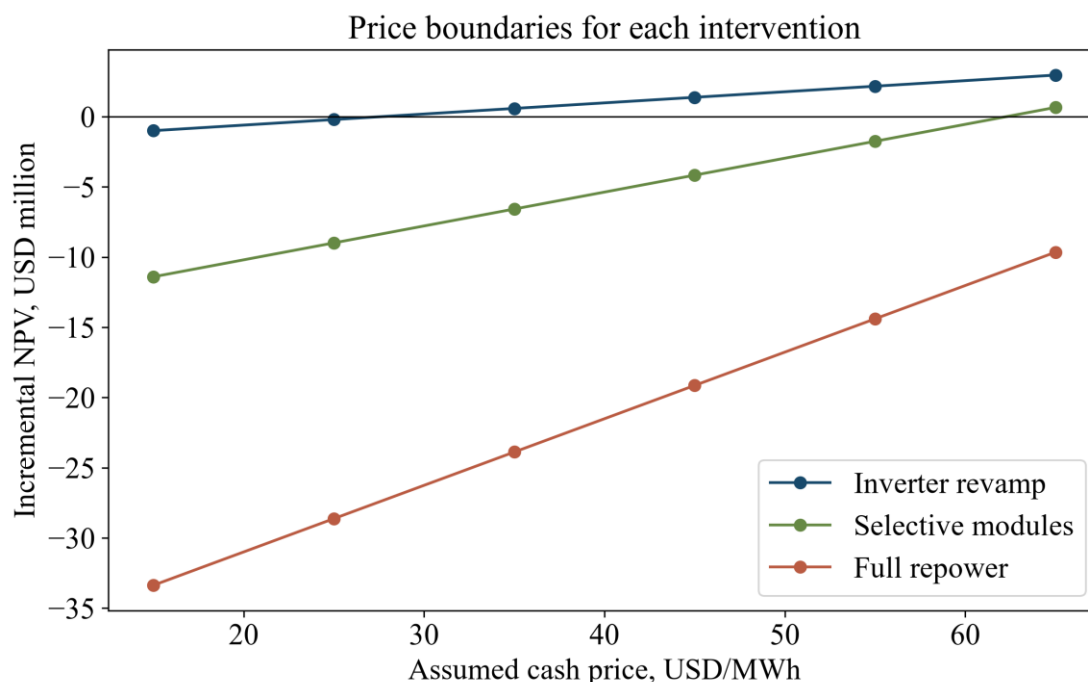
Boundaries equate incremental NPV to zero against retain at 8%, preserving other cash assumptions. Maximum equipment capex excludes separate removal and reserve. Energy price changes apply to all options, with no tariff permission inferred.

Table 8. Price, capital, term and discount sensitivities

Scenario	Revamp incremental NPV	Selective incremental NPV	Full incremental NPV
Base	0.590	-6.573	-23.878
Price 15	-0.993	-11.397	-33.364
Price 25	-0.202	-8.985	-28.621
Price 45	1.382	-4.161	-19.134
Price 55	2.173	-1.748	-14.391
Price 65	2.965	0.664	-9.648
Upgrade capex .75	2.090	-2.073	-13.378
Upgrade capex 1.25	-0.910	-11.073	-34.378
Remaining term 4	-4.357	-15.079	-38.073
Remaining term 8	-0.752	-9.451	-29.390
Discount .06	1.386	-5.040	-21.163
Discount .10	-0.100	-7.891	-26.200

USD million. Term cases are alternative assumed remaining contracts, with closure and reserve release at their stated stop. No automatic extension of the base 12-year term; no scenario probabilities.

Figure 4. Common-price sensitivities for mutually exclusive interventions



Fictional incremental NPV relative to retain, with the same price applied to each option. No price revision right or actual contract extension is inferred. The full-repower break-even price lies above the plotted range.

15. Test delayed installation and coupled downside before commitment

A delayed intervention retains the old equipment until the new installation year. A one-year delay places capital, removal and the initial reserve at the end of year one, with installation in year two. A two-year delay moves those payments to the end of year two and installation to year three. The old plant continues its existing degradation path while waiting. The replacement package then begins its stipulated new performance path, and its renewal, service claim and reserve-release dates move consistently. Expiry remains year twelve. Additional holding expenditure is USD 0.3 million in each waiting year; no separate lost-benefit charge is added.

The delay exhibit produces a useful caution about interpreting direction. Revamp incremental value declines from USD 0.590 million to USD 0.540 million after one year and USD 0.441 million after two. Full repowering remains substantially negative, although its loss becomes smaller as the expensive capital payment is deferred: negative USD 22.983 million and negative USD 22.201 million respectively. This is a conditional discounted-cash result. It provides no measured value of waiting for information and no probability-weighted real option. Revamp's one-year-delayed cumulative export is also slightly higher than its immediate case because performance age and renewal timing change within the common endpoint. The monthly ledger explains that result without imposing a universal rule that every delay must reduce cumulative energy.

The combined downside simultaneously increases equipment capex by 25%, reduces post-change pre-loss energy by 8% and doubles the installation unavailable fraction, with availability floored at zero. Retain remains the same counterfactual. This explicitly stipulated combination yields incremental NPVs of negative USD 5.444 million for revamp, negative USD 16.401 million for selective replacement and negative USD 38.473 million for full repowering. Dedicated incremental funding rises to USD 8.436 million, USD 24.829 million and USD 57.500 million.

Those cash requirements follow the complete dated ledger, including periods when operating differences remain negative. No statistical correlation or likelihood has been estimated.

The final figure compares immediate, delayed, combined-downside and reserve-lock cases on the same incremental basis. Its role is to identify the records that matter before commitment: the permitted work window, actual energy response, complete equipment and interface scope, owner obligations for service events and authority to release restricted cash. A procurement decision can attach evidence conditions to each of these items. The model supplies the financial consequence of the stipulated condition; technical, legal and counterparty evidence must establish whether that condition is available for an actual GCC facility.

The reproducible calculation retains monthly energy and annual cash records for every option and scenario, together with fifty-digit Decimal arithmetic and explicit conservation checks. The checks reconcile raw energy to export, restricted cash to contributions and uses, and incremental funding to retained cash. They are author-calculated identities, with separate independent numerical review required for application. No hourly simulation, field validation, financing commitment or full warranty liability distribution is contained in them. A real decision should replace the synthetic profiles and price with approved technical and contractual inputs, retain the fixed expiry discipline, and disclose every additional right or obligation needed to realise the calculated value.

Table 9. Installation delay and fixed contract expiry

Delay years	Option	Incremental NPV	Funding required	12-year export MWh
0	Inverter revamp	0.590	6.750	2,499,501.644
0	Selective modules	-6.573	20.200	2,762,643.632
0	Full repower	-23.878	47.000	3,155,254.177
1	Inverter revamp	0.540	7.050	2,500,525.654
1	Selective modules	-6.407	20.500	2,740,570.917
1	Full repower	-22.983	47.300	3,094,510.324
2	Inverter revamp	0.441	7.350	2,499,182.940
2	Selective modules	-6.308	20.800	2,716,130.439
2	Full repower	-22.201	47.600	3,031,956.214

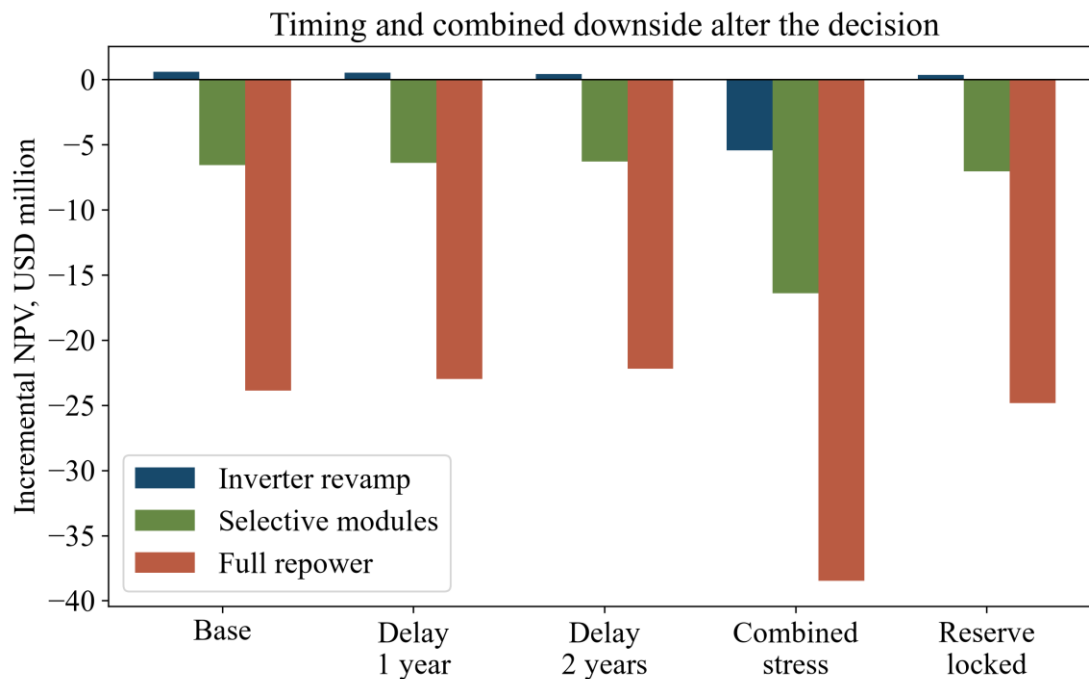
USD million except energy. Capex moves to end-year delay, work starts the following year; old equipment operates before replacement. Holding costs USD 0.3 million/year, fixed expiry year 12, no separate lost-revenue charge.

Table 10. Correlated downside and reserve restriction

Scenario	Option	Incremental NPV	Funding required	Project NPV	Locked reserve
Correlated downside	Inverter revamp	-5.444	8.436	28.703	0.000
Correlated downside	Selective modules	-16.401	24.829	17.745	0.000
Correlated downside	Full repower	-38.473	57.500	-4.327	0.000
Reserve locked	Inverter revamp	0.352	6.750	34.498	0.350
Reserve locked	Selective modules	-7.049	20.200	27.097	0.700
Reserve locked	Full repower	-24.830	47.000	9.316	1.400

USD million. Correlated case combines 25% more equipment capex, 8% lower post-change raw energy and twice the installation unavailable fraction, floored at zero availability. Separate lock case withholds remaining reserve permanently within the valuation boundary; no post-term release value.

Figure 5. Fixed-expiry delay and combined-risk decision cases



Author-stipulated cases with no probabilities. Delays shift uncommitted investment while the old plant operates; expiry stays at year 12. Combined stress changes capital, raw energy and installation downtime together. Reserve-lock cash has no later release value.

16. Establish the rights required for each intervention

A proposed repowering review should begin with a change schedule for the specific operating asset. The schedule would describe the equipment retained, the equipment replaced, the intended outage, any change in installed capacity and the requested operating period. Counsel and the technical team should then examine the actual contracts and permissions against that description. The investor needs a clear account of which conditions already permit the intervention, which require a notice or decision, and which remain unresolved. An existing right to operate should be examined for its application to the proposed alteration. The paper assigns no uniform repowering entitlement across GCC jurisdictions or individual power contracts.

Each approval entry should identify the relevant document, the party authorised to decide, the requested change and the evidence needed for a complete submission. Of particular importance is the relationship between equipment capability, the permitted connection and the product paid for under the offtake arrangement. A modelled increase in available energy requires confirmation that the relevant energy can be delivered, measured and paid for under the actual terms. The review should also examine whether an equipment change affects existing completion obligations, insurance arrangements, warranties or lender conditions. An application in progress should remain a conditional milestone with its associated expenditure and delay exposure visible.

The proposed investment gate should separate preparatory work from commitments that depend on those decisions. A limited survey or design package may be authorised while a major purchase remains conditional. Its approval should state the permitted expenditure and the information it is intended to obtain. Management should identify the cash and contractual consequences if the requested change is refused, delayed or approved with a lower usable capacity. That response belongs in the decision schedule before equipment is ordered. Where the remaining contract term

determines the investment horizon, any extension case should have its own evidence and conditions, with the existing expiry date retained in the unextended case.

In the fictional worked case, the inverter revamp has only USD 0.590 million of incremental net present value over retention. The rights memorandum should therefore identify any consent condition that changes usable output, payment or completion timing before that small advantage supports a commitment. A genuinely additional owner cash cost at time zero consumes the advantage one-for-one when every other cash flow remains fixed. Approximately USD 0.590 million would exhaust it at the displayed precision. A condition changing the outage or revenue calendar requires an exact model rerun; it cannot be represented reliably by subtracting an arbitrary allowance from the reported result.

Table 11. Proposed intervention rights register

Change	Evidence required	Capital condition
Equipment configuration	Applicable permission and change procedure	Release only the authorised scope
Energy delivery and payment	Connection and offtake terms for the revised case	Keep unsupported revenue conditional
Operating period	Existing expiry and any effective extension	Retain the unextended valuation case

Author-proposed diligence controls. No uniform GCC approval, extension or revenue right is asserted.

17. Procure a complete operating interface

The proposed tender should describe the installation as a connected system. A module replacement package would identify the retained structures, electrical equipment, protection, communications and operating processes with which the new equipment must interact. An inverter-led intervention would identify the retained generation field and relevant connection requirements. The purchaser should appoint appropriately qualified technical reviewers to establish the interface requirements and acceptance evidence. A supplier statement about an individual component should be mapped to the exact combined configuration for which the owner seeks acceptance. The tender should make responsibility for each unverified interface explicit.

Bid comparison should use a common scope schedule. Each bidder would state its included engineering, removal, installation, testing, commissioning, documentation, training and continuing support. Exclusions should have a named provider and an allowance supported by a quotation or identified estimate. A low equipment price can accompany substantial owner-supplied work, making the total completion cost dependent on several contracts. The proposed evaluation should show that completion cost alongside the cash payment dates and the consequences of delay. Any output or availability undertaking needs its measurement conditions, exclusions, remedy and responsible counterparty recorded before it is used in the investment case.

Acceptance should be divided into identifiable events. Delivery inspection, installation completion, equipment tests, integrated operation and contractual performance demonstration each serve a stated purpose. The purchaser should define the evidence required for payment and identify the person authorised to accept an exception. A list of minor outstanding work should include completion dates and any retained funds permitted by the agreement. An exception affecting safety, connection compliance or the contracted performance boundary requires its own decision. The committee should understand which payments become due before integrated

operation has been demonstrated and whether the owner has enough liquidity to complete remaining work.

The fictional revamp's maximum equipment capital cost is USD 6.590 million, against assumed equipment expenditure of USD 6.000 million. That ceiling keeps the model's separate removal and reserve assumptions unchanged. A tender evaluation should therefore compare the same equipment scope and identify any additional testing, integration or support charges outside it. A bid below the equipment ceiling can still exhaust the advantage through excluded owner costs. The proposed procurement record would give each exclusion a priced scope and payment date, then rerun the combined case before declaring the tender economically acceptable.

Table 12. Proposed procurement and acceptance interfaces

Interface	Required record	Commercial treatment
New and retained equipment	Approved configuration and compatibility review	Identify responsibility for unresolved interfaces
Completion payment	Defined acceptance event and evidence	Show payments due before integrated operation
Fault investigation	Access to records and investigation process	Retain owner exposure until protection is verified

The actual technical criteria and contractual rights require project-specific engineering and legal review.

18. Phase the works around an executable site plan

A phased intervention should have a site-specific work plan prepared and approved by the responsible professionals. The proposed investment review would ask how the work area is isolated, how retained operations are controlled and how testing and return to service are authorised. Temporary arrangements should be included in the design and operating review. The financial schedule should use the outage pattern supported by that work plan, including the relationship between equipment removal, installation, testing and release. A general assumption of partial operation needs a corresponding physical and operational description before it can support forecast collections.

The owner should request a mobilisation and access schedule covering contractor movements, storage areas, lifting or handling activities and the interfaces with normal operations. Where neighbouring communities, tenants or other site users could be affected, the proposed plan should identify the communication route, responsible contact and procedure for addressing complaints or access conflicts. These are recommended management controls, with actual obligations determined by the applicable project documents and jurisdiction. The committee should receive the associated costs and dependencies. It should also understand which activity may have to stop if an access condition or operating restriction changes.

Removed equipment needs a disposition register from the point it leaves the operating system. The record would identify ownership, condition, test status, storage location, intended destination and the person authorising transfer. Reuse proceeds should depend on evidence of saleability, a permitted destination and a supported collection amount. Items awaiting evaluation should retain that unresolved status in the cash schedule. The disposal or recycling route should identify the service provider, relevant authorisations, transport responsibility and documentary evidence of receipt. Any assumed recovery value should remain separate from the gross removal, testing, handling and treatment costs.

The worked full-repower option produces greater modelled energy while losing USD 23.878 million of incremental value relative to retention. Its assumed equipment capital cost is USD 42.000 million, compared with a conditional maximum of USD 18.122 million. A revised phasing proposal should therefore identify the particular expenditures or energy losses it changes and preserve the model's fixed contractual stop. A contractor's proposal to spread work over more months needs a new outage schedule and payment calendar. The committee should request those inputs and recalculate the option; additional generation alone provides no basis for accepting the original capital commitment.

Table 13. Proposed phased works and disposition controls

Workstream	Decision evidence	Cash consequence
Operating block	Approved isolation, outage and return-to-service plan	Dated lost collections and completion expenditure
Removed equipment	Ownership, condition and destination record	Gross handling cost and conditional recovery
Next block	Actual completion and test results	Cost to continue, change or stop

Proposed management records only. Safety methods, authorisations and permitted destinations must be established for the actual site.

19. Transfer reliability responsibility with the equipment

The proposed reliability handover should reconcile the asset register before and after the intervention. Each retained or replaced component would have a clear identifier, configuration and responsible service party. The operating team should receive the information required to identify faults, obtain approved parts and maintain the system under the applicable instructions. Any temporary operating limitation should have a recorded reason, authorised duration and route to resolution. A financial case that assumes the intervention immediately restores unrestricted operation should be checked against that handover record and the actual acceptance status.

Performance assessment needs a defined comparison boundary. The owner should specify the instruments, data availability, comparison periods and treatment of operating interruptions used to judge the intervention. The modelled generation change should be reconciled with the measured evidence through the agreed method, retaining uncertainty and exclusions. Maintenance activity, environmental conditions, curtailment and measurement changes should be recorded where relevant to interpretation. The purpose is to establish what the available record can support for the particular asset. This proposed procedure supplies no universal improvement factor or proof that a short acceptance period establishes long-term reliability.

Service arrangements should identify who responds to a fault, who authorises remedial work and how the owner funds the response while responsibility is investigated. A warranty receivable requires separate assessment from an immediate repair payment. The forecast should also identify the continuing costs of monitoring, maintenance, spare parts and specialist support. Where the replacement changes the dependency on particular software or service providers, the operating review should examine access and continuity arrangements. An assumed recovery from a contractor should retain its contractual conditions, counterparty exposure and collection timing in the cash assessment.

For the fictional revamp, the USD 0.590 million advantage makes unresolved handover costs decision-relevant. A defect list should identify required remedial work, expected payment dates and any restriction on the output assumed in the valuation. A contractor's promised remedy does

not establish the owner's cash recovery date. The reviewer should preserve gross owner expenditure and conditional contractor recovery separately, avoiding a second deduction for costs already included in the model. Where a defect changes continuing availability, maintenance or renewal needs, the revised operating schedule should be recalculated through the common horizon before the owner accepts the economic handover.

Table 14. Proposed reliability handover register

Item	Handover evidence	Unresolved exposure
Final configuration	Asset register and operating limitations	Restrictions awaiting resolution
Performance assessment	Measurement boundary and exception record	Uncertainty in the claimed improvement
Service response	Responsible party and remedy process	Repair cash before any contingent recovery

No universal performance uplift or reliability period is assumed. The comparison method and continuing obligations remain asset-specific.

20. Reconcile tender value and acquisition price at closing

A tender recommendation should compare each technically admissible option against the same operating baseline and decision date. The owner should reconcile capital scope, generation assumptions, outage, operating costs, removal obligations and remaining contractual life before interpreting the incremental value. The tendered scope should be identifiable in the model so an excluded work package cannot disappear between procurement and approval. Contingencies should state the exposure they address. If two allowances cover the same event, the committee should be shown their relationship and the reason for retaining both. Every additional price deduction should have a defined cash or risk basis.

For an acquisition, the buyer should distinguish the operating asset being purchased from the intervention it may undertake after closing. The purchase agreement needs to identify ownership of the relevant equipment, project rights and outstanding claims, together with any obligations that remain with the seller. The buyer's valuation should state which repowering permissions and contracts are already effective and which depend on future action. A calculated incremental project value does not itself specify an acquisition price or a share-equity payment. Existing financing, cash, liabilities, fees and transaction terms require their own reconciliations.

The proposed closing schedule should identify cash paid to the seller, debt settlements where applicable, transaction costs and cash retained for the planned works. Any assumption that existing project cash is available for repowering needs confirmation of its permitted use. The buyer should also identify deposits or advance payments already made, the rights transferred with them and the amount still needed to complete the intervention. A supplier commitment signed between valuation and closing should be reflected in the updated schedule. The responsible reviewers should verify that the purchase consideration and completion funding together fit the authorised financing plan.

The fictional revamp requires USD 6.750 million of dedicated initial funding: USD 6.000 million of equipment, USD 0.250 million of removal and USD 0.500 million transferred to the stipulated reserve. That requirement is separate from the USD 0.590 million incremental valuation advantage. An acquisition closing memorandum should identify the source of this funding in addition to the seller payment and other closing uses. It should confirm whether any project cash relied upon is actually available for that purpose. The example supplies no leverage assumption

or funding commitment and gives no basis for treating the valuation advantage as cash available at closing.

Table 15. Proposed acquisition and works funding bridge

Closing component	Verification	Decision treatment
Purchased asset and rights	Final scope, obligations and claim ownership	Reconcile purchase consideration separately
Committed intervention	Advance payments and remaining completion cost	Include the full post-closing cash requirement
Changes since valuation	Updated condition, price, outage and approvals	Resolve material differences before commitment

Author-proposed transaction framework. Project value, equity purchase price and available completion funding are separate calculations.

21. Release capital through a continuing decision record

The proposed board approval should identify a specific intervention and the maximum new commitment it permits. It should state which conditions precede the first payment, which precede the outage and which precede the next work block. Management should provide the remaining completion funding requirement at each stage, including costs that continue if the programme pauses. A contingency budget needs a defined approval authority and reporting rule. The committee should retain the option set and the reasons for excluding alternatives so a later material change can be assessed against the original decision.

During execution, the reporting pack should connect physical progress with cash and contractual status. Equipment received, work completed, tests passed, invoices due and collections received are separate observations that require reconciliation. Management should explain deviations through identifiable causes, including discovered asset condition, scope change, delayed approval or a revised outage sequence. The cash forecast should show when the owner must provide additional funds. Expected support that remains unsigned should retain its conditional status. The board should be asked to approve a revised commitment when the work exceeds the authority previously granted.

After return to service, the owner should compare the measured operating record with the case used to justify the intervention. The review should preserve the approved model and identify every subsequent assumption change. It should distinguish the evidence available at approval from information obtained during execution. This provides a useful basis for future asset decisions and accountability for procurement choices. The proposed close-out should retain outstanding claims, restrictions and service obligations until their actual resolution. A completed construction programme can therefore remain subject to specific commercial actions without obscuring its physical status.

The committee's proposed decision in the fictional case should remain narrow: assess whether the revamp's small conditional advantage survives verified procurement, consent and handover requirements, and identify the USD 6.750 million funding source. Full repowering's negative incremental result requires a materially different evidenced case before approval. The committee should retain retention as the comparison and record the exact assumptions supporting any change in its ranking. Further investigation can be authorised with a defined cost ceiling and question to resolve. Its cash cost and any resulting timetable change must enter the next calculation; the investigation itself establishes no improved operating outcome.

Table 16. Proposed staged capital and close-out record

Decision point	Evidence submitted	Approval boundary
Initial release	Rights, scope and funded completion plan	Maximum new commitment
Execution revision	Physical progress, variance and dated cash need	Revised authority where required
Operating close-out	Accepted configuration and unresolved obligations	Continuing actions with named owners

These proposed controls assign no automatic approval or funding commitment. Actual delegated authority and financing conditions must be verified.

22. Test the recommendation against a credible adverse case

An investment committee should ask whether the selected route remains acceptable when related risks move together. A longer construction period can coincide with extra contractor cost and a shorter remaining revenue window. Lower recovered energy can coincide with additional operating expenditure. Evaluate those combinations against the same retained-plant counterfactual and identify the point at which the recommendation changes. A list of independent single-variable sensitivities leaves their joint financing consequence unexplained.

Keep the downside response actionable. The owner should specify which commitments can be deferred, which payments survive a pause and which operations can continue safely. A staged procurement programme has option value only to the extent that the contracts and physical configuration permit staging. Record the actual cancellation, mobilisation, storage and preservation terms when available. An analytical decision to pause does not extinguish a purchase order or restore an already dismantled block.

Reconsideration triggers should refer to evidence that the team can observe. Suitable proposed triggers include a revised firm quotation, a confirmed construction window, a failed compatibility test, a consent condition or a revised energy study. Map each trigger to a responsible review and the affected cash-model lines. Avoid an automatic escalation from an unfavourable test to a broader project without showing how the broader scope answers the underlying finding.

The committee record should preserve the rejected alternatives and the reason for rejection. This supports a later review when prices, condition or rights change. An economically weak full-repower case can remain a useful boundary for supplier negotiation or future monitoring, while a smaller revamp can still require further technical evidence before commitment. The decision process should keep those separate conclusions visible and identify the next evidence-producing action.

23. Use portfolio data without erasing the asset boundary

Portfolio analysis can help prioritise investigations across an owner's operating fleet. Build a common data dictionary for equipment, exposure, loss categories, maintenance actions and cash conventions. Retain the original asset and cohort identifiers so that comparisons remain traceable. A shared taxonomy is particularly useful when operators record similar faults under different work-order codes or when historical data quality varies between plants.

Use analytics to generate reviewable questions. A change in loss behaviour can be flagged for engineering examination, with the relevant measurement window, confidence limits and possible confounding events. Any machine-learning or AI-assisted diagnostic should have an identified training population, validation method and documented limitations. This paper makes no claim

that an algorithm can infer a safe replacement design, a contractual permission or a bankable yield. Those decisions require the appropriate evidence and accountable specialists.

Separate portfolio procurement benefits from plant revenue. A verified framework agreement could change equipment pricing, spare availability or service support; its value would depend on actual terms and quantities. Pooling the purchase does not automatically pool the export rights or remaining PPA term. The investment team should allocate shared costs using a disclosed rule and test whether each plant remains acceptable after that allocation. A portfolio-wide total can otherwise conceal a plant that consumes scarce capital without supporting the chosen return requirement.

The proposed portfolio dashboard therefore has two levels. The first ranks evidence gaps and potential interventions for further work. The second contains the asset-specific approved case and its unresolved conditions. Movement from the first level to the second requires the plant's own technical, contractual and financial review. This keeps screening efficient while preserving the evidence needed for a consequential investment or transaction.

24. Conclusions and the next capital decision

Solar repowering creates a choice over the use of remaining operating rights and new capital. The paper's proposed framework begins with a measured loss diagnosis, a funded continuation case and a configuration-specific intervention. It then reconciles export and payment, construction timing, removal, operating cost and final closure at a common decision date. Current public evidence informs the investigation; project-specific tests, contracts and quotations are still required for an actual commitment.

The hypothetical worked case supplies a reproducible comparison among continuation, a targeted revamp, selective replacement and full repowering. Its calculated values depend on its stated fictional inputs and synthetic energy screen. The investment conclusion should follow the complete incremental cash record and its sensitivities. Additional installed capacity, improved module characteristics or a lower supplier price cannot independently determine that conclusion without the corresponding export, cost and rights boundaries.

The owner can use the proposed evidence and operating matrices to assign the next action. An investigation should answer a specific uncertainty. A pilot should have a defined configuration and acceptance test. A construction commitment should identify all funding required to complete it and the conditions that remain open. Continued operation should retain a funded maintenance and monitoring plan. The framework makes each route auditable without assuming that the most extensive intervention deserves approval.

For an acquisition, the same discipline separates existing operating value from conditional post-completion improvement. For an incumbent owner, it connects technical findings to staged capital decisions and a reconsideration record. In both settings, the useful output is a bounded recommendation with a cash model, supporting evidence, accountable completion conditions and a stated response if that evidence changes.

Frequently Asked Questions

What should trigger a solar repowering investigation?

A proposed investigation should address a defined operating loss, component-support issue or capital event. Reconcile the affected equipment and measured energy to a credible continuation case, then identify which intervention could change the finding. This paper specifies no universal repowering age, degradation threshold or GCC-wide trigger.

How does the hypothetical case rank the interventions?

At the stipulated USD 35/MWh cash price, targeted revamping has incremental NPV of USD 0.590 million. Selective replacement and full repowering have incremental NPV of negative USD 6.573 million and negative USD 23.878 million. Each is compared to the same continuation case over a twelve-year remaining term at an 8% real discount rate. All inputs are fictional; the rankings are conditional calculations.

Does additional installed DC capacity establish paid-energy value?

The owner needs a configuration-specific production study and confirmation of export and settlement rights. This paper's monthly synthetic cap is an illustrative financial screen. It contains no hourly weather or actual dispatch, supplies no engineering clipping estimate and does not establish what a real counterparty will pay.

What does the worked example's restricted reserve represent?

The fictional owner contributes cash at the investment date, pays stipulated service costs from that account and releases the remaining balance on the modelled date. Reserve transfers and actual expenditure are reconciled separately. The scenario establishes no supplier coverage, warranty adequacy or legal permission to release cash; those matters require the actual agreements and asset evidence.

Can removed modules generate recovery proceeds?

A proposed reuse or sale needs documented condition, appropriate testing, a responsible destination and actual commercial and regulatory terms. The worked case assumes removal and disposal costs and no resale income. Verified recovery proceeds could be tested separately with their quantity, costs, collection conditions and timing.

How should an acquirer value a repowering opportunity?

Separate the existing operating case from conditional post-completion improvement. Reconcile any higher energy or reduced maintenance in the seller's forecast to the enabling capital, downtime and permissions. State the funding requirement and unresolved conditions alongside incremental value. The framework establishes no actual purchase price, legal remedy or financing commitment.

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