WHO PAYS FOR THE ENERGY TRANSITION?

A decision framework for fair costs, reliable power, fiscal durability and measurable results

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24 September 2026

Research and policy white paper | Global scope | Evidence reviewed through 24 September 2026

Scope and independence

This paper advances an independent analytical framework. It does not represent a dispatch model, tariff filing or investment recommendation for a specific country. Local decisions require current local engineering, legal, fiscal, market and social evidence.

Contents

Headings are exported as PDF bookmarks for direct navigation.

How to use this paper

This white paper is designed for decisions in which technology, finance, public policy and social outcomes interact. It should be read as a sequence. Start with the service need. Then define the system boundary and counterfactual. Build the full cost and payer ledger. Test affordability, reliability, access, fiscal durability and climate performance. Stress the preferred pathway. Record dissent and the conditions attached to approval. The appendices convert those principles into review files and operating controls.

The framework is intentionally technology-neutral. It does not treat a low generation cost, a low emissions rate, a low tariff, a high renewable share or a large investment total as sufficient evidence by itself. Each metric answers only part of the decision. A project that performs strongly on cost but fails during stressed hours needs additional resources. A project that performs strongly on reliability but creates an unaffordable fiscal guarantee needs redesign. A project that lowers annual emissions while imposing unresolved land or access harm needs a remedy and a governance response.

For boards and senior officials, the most useful pages are the Executive summary, Integrated decision model, Worked illustrations, Recommendations and implementation, Appendix N independent challenge checklist, Appendix O executive decision sheet and the Source audit matrix. Technical teams should use the remaining appendices to build the supporting file. Regulators and finance ministries should focus on utility solvency, tariff incidence, guarantees, foreign exchange, cost of capital and the annual correction cycle. Community and workforce teams should use the land, grievance, remedy and workforce sections before design choices narrow.

Decision rule

Do not approve an option because one metric is attractive. Approve a complete service package after its material costs, risks, distributional effects and performance conditions are visible, stressed and assigned to accountable owners.

Publication assurance and scrutiny standard

This edition separates institutional evidence from the author's proposed framework. Quantitative global claims are attributed to the underlying organisations and retain their date, scope and definition. Global averages are used as context unless the text explicitly states otherwise. The paper does not convert scenario outcomes into observed facts. It does not use a global cost benchmark as a country tariff. It does not treat an explicit fiscal subsidy estimate as the same concept as an implicit external-cost estimate. These distinctions are central to the audit standard.

The research cut-off is 24 September 2026. The reference base prioritises primary institutional sources from the IEA, IRENA, IMF, World Bank, OECD, IPCC, UNEP, UNFCCC, IFC and ILO. Current 2026 sources are used where available for investment, electricity systems, access, critical minerals and fiscal conditions. Older sources are retained where they provide a relevant methodology, such as power-sector cost recovery or procurement design. A live project should refresh all market, policy and financial inputs before approval.

The publication file is designed for traceability. Major claims have numbered references. The Source audit matrix identifies the evidence class of selected high-value claims. The appendices define the minimum project appraisal file, scenario register, reliability method, fiscal-risk treatment, procurement audit, grievance controls, data assurance and monitoring thresholds. The framework requires preservation of original forecasts so later reviewers can compare promises with observed results and distinguish forecast error from a change in method.

Independent scrutiny remains necessary. A country application should subject the technical model, contracts, fiscal exposure, distribution analysis and climate accounting to specialist review. The independent reviewer should search for assumptions that reverse the recommendation and should record unresolved dissent. No publication-quality global paper replaces local legal authority, system studies, engineering design, environmental and social due diligence, audited utility data or consultation with affected people.

Evidence snapshot

The figures below are global indicators used to establish context. They are not substitutes for local appraisal values.

Signal	Latest evidence used in this edition	Decision implication
Energy investment	USD 3.4tn total in 2026; about USD 2.2tn in clean-energy categories [1]	Capital is scaling, but allocation and financing conditions differ sharply by market.
Grids	Annual grid investment needs to rise about 50% from roughly USD 400bn by 2030 [4]	Network delivery is a central constraint, not a secondary add-on.
Generation costs	2025 global averages: solar PV USD 44/MWh; onshore wind USD 33/MWh [3]	Plant cost must be separated from delivered system cost.
Access	655m people still lacked electricity access in the latest SDG7 update [6]	Transition success includes effective, affordable service.
Utilities	About 40% of utilities in the World Bank developing-country sample covered operating and debt-service costs [14]	Utility solvency is a precondition for durable investment.
Renewable buildout	About 4,600 GW renewable capacity growth forecast over 2025-2030 [25]	Integration, queues, flexibility and supply chains rise in importance.
Data centres	Electricity use projected to reach about 945 TWh by 2030 in IEA base case [24]	Large-load planning must be locational and scenario-based.
Critical minerals	High refining concentration and expanding trade restrictions remain material [21]	Supply-chain resilience belongs in project risk analysis.

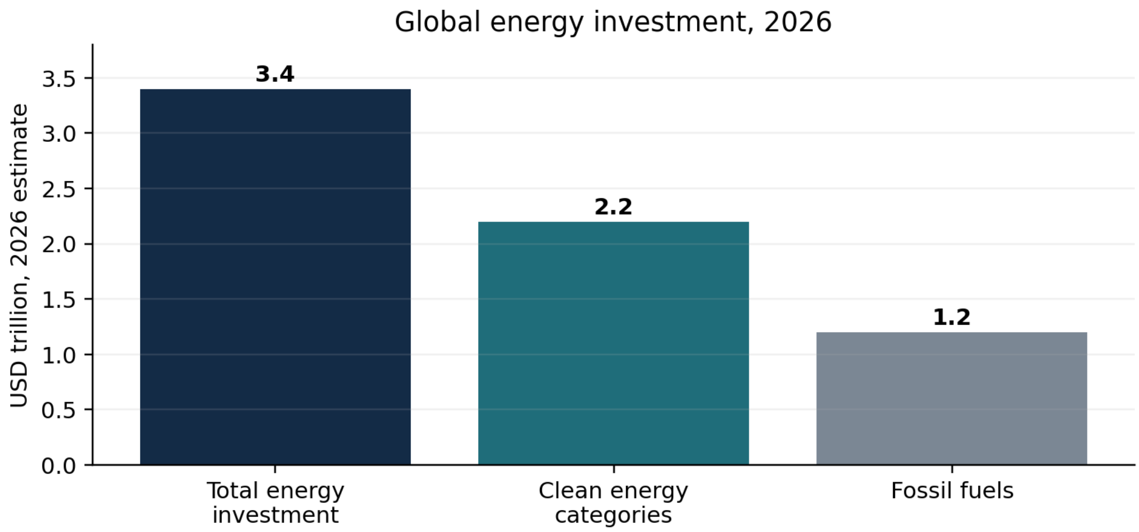

Figure 1. Global energy investment, 2026 estimate. Source: IEA [1].

Executive summary

The energy transition is often presented as a choice between technologies. For decision makers, the more consequential choice is how to provide reliable energy service, who finances the infrastructure, who bears the downside risks and how the benefits are distributed. A low price for generation does not establish a low delivered cost. A public subsidy does not eliminate a cost. An emissions reduction claim does not establish that households have dependable access.

The 2026 evidence strengthens the case for a service-first approach. Global energy investment is estimated at USD 3.4 trillion in 2026, with about USD 2.2 trillion directed to renewables, nuclear, grids, storage, low-emissions fuels, efficiency and electrification [1]. Yet the capital mix is only one part of the transition. IEA estimates that annual grid investment must rise by roughly 50% from around USD 400 billion by 2030 to meet expected electricity demand [4]. The gap between generation spending and network spending explains why low-cost generation does not automatically produce low-cost, reliable electricity at the meter.

The distribution problem is equally material. Tracking SDG7 reports 655 million people without electricity access, including more than 560 million in Sub-Saharan Africa [6]. At the same time, the World Bank reports that only about 40% of utilities in its developing-country sample cover operating and debt-service costs [14]. A transition that expands generation while weakening the utility, raising arrears or leaving vulnerable customers unable to use the service is incomplete. The approval question therefore needs to cover access, bill burden, utility cash flow, fiscal exposure and reliability together.

Technology economics have improved, but headline generation costs remain an incomplete decision metric. IRENA reports 2025 global average levelised costs of USD 44/MWh for solar PV and USD 33/MWh for onshore wind, while offshore wind averaged USD 78/MWh [3]. Those values are useful benchmarks, not retail tariffs. They exclude many location-specific costs and values such as network reinforcement, congestion, reserves, curtailment, taxes, financing conditions, backup, land and the timing of generation. The paper therefore distinguishes plant economics from delivered service economics.

A second change is the speed of demand and system transformation. Renewables are forecast to add about 4,600 GW of capacity from 2025 to 2030, with solar PV accounting for close to four-fifths of the increase [25]. Data-centre electricity consumption is projected to more than double from 2024 to around 945 TWh by 2030 in the IEA base case [24]. Battery storage added 108 GW globally in 2025 [11]. These trends increase the value of coordinated planning. Generation, grids, storage, demand response, firm capacity and customer protection must be evaluated as a portfolio rather than as isolated assets.

Five mandatory approval tests

1. Affordability across households and firms. 2. Reliability through stressed hours. 3. Effective access and service quality. 4. Fiscal and utility durability. 5. Verified climate performance against a documented counterfactual.

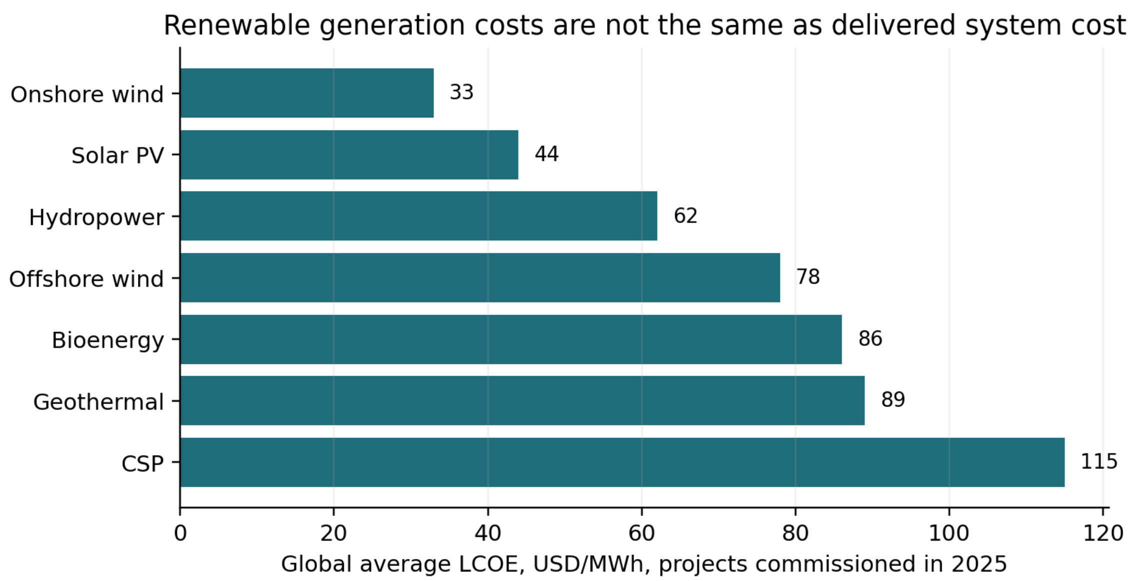

Figure 2. Global average renewable generation costs for projects commissioned in 2025. Source: IRENA [3]. These values are not delivered retail tariffs.

The International Energy Agency estimates total energy investment at USD 3.4 trillion in 2026, of which about USD 2.2 trillion goes to clean energy categories [1]. Its electricity analysis also identifies grid investment as a constraint, with annual expenditure needing to rise by about 50% from roughly USD 400 billion by 2030 under its demand outlook [4]. These are global estimates, not a project appraisal for any country. IRENA reports global average generation costs of USD 44/MWh for solar PV and USD 33/MWh for onshore wind in 2025 [3]. The cost of financing and integrating these technologies varies materially by location.

This paper proposes five tests for each pathway: affordability across households and firms; reliability through stressed hours; effective access; fiscal durability; and verified climate performance. It joins these tests to a full cost ledger and a scenario register. Every material project should disclose who pays if construction is late, demand disappoints, a currency falls, fuel prices spike or an extreme event damages assets.

The central recommendation is to approve complete service packages on the basis of comparable, independently reviewed outcomes. Contracting should allocate risks to those able to manage them. Protection for vulnerable households should exist before prices change. Utilities must fund maintenance. Public reports should retain the original forecast alongside observed performance and revisions.

Test	Decision evidence
Affordability	Bills and total energy spending by income group and firm type.
Reliability	Hourly adequacy, outages, resilience and restoration.
Access	Sustained service quality, connection and use.
Fiscal durability	Cash outlays, utility gap, debt and contingent liabilities.
Climate	Measured system emissions against a documented counterfactual.

This is a decision framework, not a claim that one technology or policy suits every country. The report sets out methods and stress tests. Local approval still requires local data, legal review, engineering studies and meaningful engagement with affected people.

Research question and scope

The question is: how should a country allocate the costs and risks of an energy transition while delivering dependable, affordable service and measurable emissions reductions? The unit of analysis is the complete pathway from supply through network and end use. The relevant payers are households, businesses, utilities, taxpayers, investors, international partners and future users.

The paper uses a broad definition of payment. Payment includes direct bills and taxes, but also foregone public revenue, utility losses, guarantees, foreign-exchange exposure, land and livelihood costs, pollution damages, transition support, maintenance backlogs and risks shifted to future users. The purpose is not to force every impact into a single monetary number. It is to prevent important burdens from disappearing because they sit outside the project company or outside the first year of a tariff.

The relevant comparison is between complete pathways that deliver a stated service. A generation option with low energy cost but insufficient output in stressed hours should not be compared directly with a dispatchable option without adding the resources needed to reach the same reliability standard. The same principle applies to access. A connection programme should be judged against sustained, affordable service, not connection count alone. This equal-service rule is the foundation for the cost, risk and distribution analysis that follows.

This paper addresses electricity and connected uses in cooking and transport. It treats climate mitigation, adaptation, energy security and distribution as related decision criteria. It does not assume that every energy technology belongs in every system. The analysis is global and comparative. No country-specific financial return, tariff or avoided-emissions figure is calculated.

Method

First, distinguish observed values, institutional estimates, modeled scenarios and the author's recommendations. Second, establish a common service standard, counterfactual, time horizon and currency for comparing options. Third, draw a payer ledger across investment, operations, social protection and contingent obligations. Fourth, stress the plan under plausible disruptions. Fifth, verify distributional and environmental outcomes with independent data. The method draws on IEA, IRENA, IMF and IPCC publications listed in the references [1-9, 11].

Evidence is treated in four classes. Observed data describe measured outcomes. Institutional estimates use defined methods to infer values not directly observed. Scenarios show conditional futures under stated assumptions.

Recommendations in this paper are normative proposals. Each class answers a different question. Mixing them weakens accountability, particularly when a scenario is reported as a forecast or a global average is used as a local appraisal value.

The paper also uses an adversarial review step. For each preferred pathway, the reviewer asks what omitted assumption would be most likely to reverse the ranking. The challenge should cover construction delay, lower demand, higher demand, exchange-rate depreciation, interest-rate changes, fuel-price movements, drought or extreme heat, transmission delay, equipment failure, lower technology performance and delayed social-protection delivery. Where data do not support a probability, the analysis uses transparent severity cases and break-even values rather than false precision.

The IEA World Energy Outlook scenarios are conditional explorations, not predictions [2]. IRENA global cost averages are not site-specific delivered tariffs [3]. IMF explicit subsidy estimates represent fiscal spending, while implicit estimates also include unpriced damages; they are not interchangeable budget funds [7]. These distinctions govern every comparison in the paper.

For audit purposes, classify each important claim as observed, estimated, scenario-based or proposed. Keep its source, geographic boundary, period and assumptions beside the claim. This classification prevents a modeled outcome from being reported as a measured result.

The paper does not contain field interviews, an original econometric estimate or a national system dispatch model. Its recommendations should be tested locally before a government, utility or investor makes a capital commitment. The accompanying source register identifies the basis for global factual claims.

1. The public interest and the evidence

A defensible transition begins with a measurable service obligation. The same project may lower emissions, raise short-run bills, reduce import exposure and create a fiscal guarantee. These effects need a common baseline and a transparent decision standard. Global data are valuable for context, but local system conditions determine investment choices.

1. The Case

The transition is a financing and service problem, not merely a generation substitution. Every pathway transfers costs through tariffs, taxes, capital markets, fuel purchases and environmental impacts. A comparison must track these transfers across time. The payer map should be traced twice: once at project approval and again after financing, tariff and tax rules operate. A government-funded connection may still raise bills through later maintenance. A privately financed plant may still expose the treasury through a guarantee. Trace each path to the final household, firm or taxpayer.

Establish one public ledger covering electricity, cooking, transport and productive energy use. Evaluate complete service packages at the same reliability and access standard. Test whether a seemingly cheap project becomes expensive when connection, backup, financing and maintenance are included. Recalculate with a delayed grid connection.

Publish the ledger, baseline, service standard and distribution of costs. Label benefits that are modeled rather than received in cash. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA 2026 investment and IPCC AR6 [1, 5].

2. Evidence Hierarchy Global averages explain direction and scale, but they cannot determine a local tariff. Country data, hourly demand, equipment specifications and contract terms take priority for project approval. Institutional estimates often refer to different years and boundaries. Independent reviewers should record why a source is applicable. A global technology average is useful as a reasonableness check, yet a local bid with different financing and network needs should take precedence. Preserve the rejected estimate and the reason for rejection so a future reviewer can reconstruct the choice.

Use a claim register with source, date, geography, definition and confidence level. Separate observed data, estimates, scenarios, assumptions and recommendations. Remove a major source or change an assumption and see whether the recommendation survives. Seek independent replication for material results.

Publish versioned datasets, calculation files and a correction log. Never present a scenario as a forecast. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA World Energy Outlook scenarios [2].

3. System Boundaries

A plant-gate cost omits transmission, firm capacity, balancing, storage, losses and end-of-life obligations. The same technology can serve different roles across power systems. Compare options at the meter, rather than the generator fence. A lower-cost generator that requires extra firm capacity or a new line needs those costs included. Conversely, flexible demand or efficiency may reduce the required line size. Model interactions before ranking isolated technologies.

Define a common boundary from generation through delivery to final use. Compare options that supply the same hourly load and quality of service. Include an extended low-output period and an equipment outage. Test import availability and correlated failures.

Show delivered cost, expected unserved energy, peak capacity margin and lifecycle emissions under each option. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IRENA costs and IEA Electricity 2026 [3, 4].

4. Baseline And Counterfactual Savings are calculated against an alternative that would otherwise occur. A misleading baseline can inflate fuel savings, emissions reductions and claims of additional investment. The counterfactual should reflect planned maintenance and plausible regulation. If an old unit would close for safety reasons, crediting a new project with decades of displaced operation exaggerates its contribution. State what replaces the unit in the no-project case and test a second reasonable alternative.

Record the existing asset fleet, planned retirements, demand growth and policy commitments before assessing new projects. Use a reasonable counterfactual, not an obsolete plant assumed to operate indefinitely. Compare results against more than one credible baseline, including demand efficiency and continued maintenance of existing assets.

Publish assumptions, data year, treatment of imports and changes from the previous baseline. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 and IEA 2026 [1, 5].

5. Energy Access

A household connection does not guarantee dependable, affordable service. Productive users need sufficient power quality and predictable operating hours. Access indicators should distinguish connection, availability and effective use. An access programme should specify the service tier its connection delivers. A light and phone charger are valuable, yet they cannot support refrigeration or a workshop. Count an upgraded connection separately from a new one and verify that payment terms permit sustained use after the introductory period.

Prioritise unserved settlements and critical facilities. Compare grid, mini-grid and stand-alone options at the same service target, including upkeep and payment collection. Test low uptake, high connection charges, equipment breakdown and weak utility revenue. Protect continuity when a pilot operator exits.

Track newly served people, hours available, affordability, voltage quality and operating businesses. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: SDG 7 2026 update [6].

6. Affordability Measurement Average tariffs conceal the burden on households with little income and high essential energy need. Electricity alone omits cooking fuel and transport, while one month can miss seasonal pressure. Affordability also depends on volatility. A household might manage an average bill but fail during a high-use cooling month or a sudden income loss. Report the distribution of monthly burdens, not only annual means. Check whether delayed assistance forces households to borrow or self-disconnect.

Report total energy spending as a share of disposable income by decile or the finest defensible grouping. Add connection fees, arrears and service quality. Model tariff increases, inflation, a household income shock and failed compensation delivery. Test urban and rural households separately.

Publish distributional tables, survey limitations and appeal outcomes. Avoid claims of fairness based solely on an average bill. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IMF subsidies and IPCC equity [5, 7].

7. Reliability Standard

Reliability has several dimensions: adequacy, frequency of outages, duration, power quality and restoration after a major event. Annual energy balance cannot prove peak-hour adequacy. Peak risk often occurs in hours with the least operating flexibility. Reserve calculations should include scheduled maintenance, forced outages and transmission constraints. A system that meets annual demand on paper can still impose high social costs during a small number of unserved peak hours.

Set a public service standard and model hourly supply across representative and extreme years. Preserve reserve and maintenance margins. Test simultaneous generator failure, low renewable output and an unavailable import line. Include repair lead times.

Report outage duration, interruption frequency, unserved energy, reserve margin and critical-facility restoration. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA Electricity 2026 [4].

2. Households, budgets and finance

The phrase who pays is an accounting and distribution question. The payer at financial close differs from the ultimate payer after tariffs, taxes and risk transfers. This chapter follows cash and contingent obligations through households, utilities, government and investors. It also distinguishes an economic resource cost from a transfer within society.

8. The Full Cost Ledger

The full cost ledger should be reconciled across four views. The project view captures capital expenditure, operating cost, financing and contractual revenue. The utility view adds network reinforcement, losses, balancing, reserves, purchased power, collections and stranded assets. The fiscal view adds grants, tax expenditure, guarantees, state-owned enterprise support and debt. The household and firm view records bills, connection charges, backup costs, transport or cooking substitution and the economic cost of outages. A cost shifted from one view to another has not disappeared.

Financing deserves separate treatment because it changes the delivered price of capital-intensive technologies. OECD analysis finds that a high cost of capital can materially suppress clean-energy investment, with the problem acute in developing economies and newer technologies [15]. The IEA and IFC likewise note that typical utility-scale solar financing costs in key emerging economies have often been two or three times those in advanced economies or China [8]. Better project preparation, credible offtakers, enforceable contracts, predictable regulation, risk-sharing instruments and deeper local capital markets therefore affect consumer cost as directly as equipment prices.

Contingent obligations belong in the ledger even when no cash leaves the treasury at financial close. Guarantees, termination payments, minimum-revenue commitments and foreign-exchange protection can reduce investor risk and financing cost, but they transfer downside exposure to public balance sheets. OECD work on guarantees stresses targeted use of risk-mitigation instruments in emerging markets [16]. Every guarantee should identify the risk it addresses, its maximum exposure, trigger, beneficiary, fee, budget treatment and exit condition.

Upfront construction is only one part of lifetime cost. Interest, foreign exchange, curtailment, backup, land, social measures and disposal can shift between parties without appearing in a headline price. Use the same price year and currency for every ledger entry. Record whether taxes are genuine social costs or transfers within the country. Present public and private cash flows separately from economic resource costs. Without these distinctions, a single total can double count or conceal distribution.

Assign each cost to a payer, year, currency and accounting category: direct cash, private capital, tax expenditure, utility obligation or contingent liability. Reprice contracts for inflation, interest rates and exchange rates. Include overruns and earlier-than-planned replacement.

Publish a reconciliation from project cash flows to consumer bills and public accounts. State what remains uncertain. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA investment and IMF fiscal analysis [1, 7].

9. Household Tariffs

Tariffs must fund efficient service while preserving essential access. A freeze without a budget transfer can erode maintenance, increase utility arrears and eventually worsen service for the same households it seeks to protect. Tariff design should avoid penalising low-income families with many members merely because their essential consumption crosses a low-volume block. Simulate bills for realistic occupancy and appliance profiles. A funded direct transfer may be more precise than a broad tariff discount where eligibility systems function well.

Define a cost-recovery path with targeted protection. Review fixed fees, lifeline blocks, prepaid terms and disconnection practice. Model low consumption, high occupancy, seasonal income and delayed benefit payments. Examine who misses eligibility registers.

Publish bill examples for several household types and the funding source for each concession. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IMF distributional analysis [7].

10. Subsidy Reform

Subsidy analysis should distinguish three issues: protection of vulnerable users, fiscal affordability and price signals. The IMF's 2025 update estimates explicit fossil-fuel subsidies at about USD 725 billion in 2024 and reports that the poorest fifth of households receives only a small share of the benefit from broad fuel subsidies [34]. The precise distribution varies by country, but the global result illustrates a recurring weakness of untargeted price suppression: higher-consuming households and firms often capture more of the transfer in absolute terms.

The 2026 energy shock also demonstrates the risk of temporary relief becoming an open-ended fiscal commitment. IMF tracking found widespread use of producer subsidies, excise cuts, price caps and administrative interventions, while warning that many measures lacked clear expiration dates or fiscal-cost estimates [17]. A credible reform package should define the protected population before prices change, fund the transfer mechanism, test delivery systems, set an expiry or review date, and publish the net fiscal effect. If administrative capacity is weak, the transition schedule should reflect that constraint rather than assume perfect compensation.

Explicit fiscal support differs from implicit estimates of unpriced pollution and climate harm. Both matter for policy, but they cannot be treated as identical funds available for new spending. Announce reform only after testing payment rails and a grievance channel. Compensation promised on paper offers little protection if its arrival lags the fuel bill. Keep a transparent record of excluded households and the temporary measures used to prevent loss of essential service.

Inventory every subsidy and beneficiary. Deliver targeted cash or near-cash protection before changing prices, where administrative capacity permits. Test payment-system failure, fuel-price spikes, transport pass-through and political reversal. Maintain a temporary emergency rule with a defined expiry.

Report savings actually realised, compensation delivered, coverage gaps and changes in energy poverty. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IMF Fossil Fuel Subsidies [7].

11. Public Budget

Treasury exposure includes direct spending, tax concessions, borrowing, capital injections and commitments to state utilities. Fiscal space varies by country and by stage of the economic cycle. Capital budgets and operating budgets should be reviewed together. A government may fund a new line but leave the utility without crews and spares to operate it. Show annual service costs throughout the asset life and the source of each appropriation before authorising construction.

Compare projects against competing public priorities and debt limits. Disclose multiyear cash requirements and contingent claims. Test lower revenues, weaker currency and higher refinancing rates together. Identify spending that can be deferred without compromising safety.

Publish annual budget and medium-term exposure tables, with reconciliation to actual payments. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IMF and IEA financing [7, 8].

12. Guarantees

A government guarantee can lower financing cost while placing a large loss on the public if the contract fails. Its face value, trigger and duration matter more than the absence of an immediate cash payment. Maximum guarantee exposure is not the same as expected loss. Both matter. Present a stress case with simultaneous claims, since projects may fail together under a currency or utility crisis. State whether legislative or treasury approval is required when the ceiling rises.

Cap and register guarantees, price their risk and require approval outside the project sponsor. Include termination and currency obligations. Model an early termination, utility default and exchange-rate depreciation. Test correlated claims from several projects.

Publish maximum exposure, expected exposure range, beneficiary and annual changes. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA finance and IMF fiscal principles [8].

13. Utility Solvency

Utility financial viability is a transition variable, not a separate accounting matter. The World Bank's review of more than 180 utilities in over 90 countries found only about 40% able to cover operating and debt-service costs [14]. Persistent under-recovery, high technical and commercial losses, weak collections and poor planning increase the cost of capital and delay maintenance. A utility asked to sign long-term power contracts without a credible revenue path can become the channel through which apparently private investment turns into public arrears.

Tariff reform should therefore be paired with operational reform. The regulator should separate efficient costs from avoidable losses, define service standards, require audited performance and protect essential consumption through targeted mechanisms. Cost recovery does not mean passing every inefficiency to customers. World Bank work on power-sector viability distinguishes financial, fiscal and economic perspectives on cost recovery and notes that the reference cost itself matters [27]. The practical goal is an efficient revenue requirement, transparent subsidy funding and service accountability.

A utility may face rising demand and investment needs while collecting too little to maintain existing assets. Technical and commercial losses complicate any new financing plan. Utility reform should start with a measured loss baseline. Technical losses require network investment, while commercial losses may require metering, billing and governance changes. Avoid assigning all shortfalls to customers before identifying avoidable inefficiency and the cost of remedy.

Pair tariff decisions with audited accounts, loss-reduction targets, collections safeguards and transparent public service compensation. Test reduced

collections, wholesale price increases and a delayed tariff review. Quantify arrears through the supply chain.

Report audited losses, receivables, cash coverage and maintenance backlog. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA financing and grids [4, 8].

14. Private Risk

Investors should bear construction and operating risks they control. Transferring all downside to customers or the treasury weakens discipline and distorts bid comparisons. Contract discipline depends on credible enforcement. A performance penalty that cannot be collected after contractor insolvency offers weak protection. Consider security, parent support or staged payments, but price those protections in the tender comparison rather than assuming they are free.

Assign each risk to its best manager. Set measurable availability, completion and performance obligations with enforceable remedies. Test contractor insolvency, output shortfall and dispute resolution. Compare public outcomes after step-in or termination.

Publish a risk-allocation matrix and material contract clauses. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA financing [8].

15. Concessional Capital Low-cost finance can address genuine barriers, but an indiscriminate subsidy may fund investments that would proceed without it. Additionality and local market development should guide allocation. Concessional resources should address a documented barrier. A grant for early grid studies has a different purpose from a tariff subsidy. Evaluate additionality against a credible market counterfactual and measure whether the concession helped establish a repeatable financing route.

Target early-stage preparation, access, grids or risk that private lenders cannot efficiently bear. Set a sunset and disclose grant-equivalent support. Compare mobilised investment with and without the concession. Test a withdrawal of donor support.

Report subsidy per beneficiary, private capital mobilised and service outcomes, not only commitments. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA financing [8].

16. Cost Of Capital Debt and equity costs shape electricity prices, especially for capital-intensive technologies. Currency mismatch and unreliable payment can outweigh equipment-price gains. The financing case should distinguish nominal and real rates and identify inflation assumptions. A lower initial interest rate may be offset by shorter tenor, fees or foreign-currency exposure. Compare the complete debt schedule and refinancing risk, not a single quoted percentage.

Improve contract enforceability, utility credit, permitting and domestic capital markets before assuming low discount rates. Use realistic financing offers in bids. Refinance at higher rates, lose a credit enhancement and devalue local currency. Test debt-service coverage.

Publish weighted cost of capital, tenor, currency and sensitivity range without exposing protected personal data. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA financing [8].

17. Foreign Exchange

Imported equipment and foreign-currency debt expose local tariffs and budgets to depreciation. Foreign-currency indexation shifts that exposure toward consumers unless hedged or absorbed elsewhere. Local currency revenues paired with foreign debt create a transfer of exchange risk. A lender may offer a lower nominal rate because households or government absorb devaluation through indexation. Show the full distribution of outcomes under both hedged and unhedged structures.

Match revenues and liabilities where feasible. Disclose indexation, reserve accounts and who pays for hedging. Model gradual depreciation and a sudden step change while demand weakens. Include debt maturity concentration.

Publish currency exposure by payer and the resulting bill and fiscal ranges. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA financing [8].

3. Procurement and the physical system

The price of one asset cannot stand in for the cost of dependable supply. Procurement rules, contract terms, lines, storage, dispatchable resources and imports interact. A sound comparison holds service quality constant and asks which portfolio meets it under difficult conditions.

18. Procurement Design

Competitive procurement works best when the government or utility has prepared the project before asking the market to price it. Site control, network studies, permits, standardized contracts, transparent bid criteria and credible offtaker arrangements reduce uncertainty and bid premiums. IFC's Scaling Solar experience illustrates the value of a repeatable package rather than a one-off tender [28]. The principle extends beyond solar: competition is strongest when bidders price the same service, the same risk allocation and the same information set.

Price alone should not determine award where delivery risk differs. The evaluation should examine completion security, indexation, curtailment rules, availability obligations, degradation guarantees, local-currency exposure, change-in-law provisions, termination compensation and the cumulative fiscal effect of amendments. Any post-award change large enough to alter the competitive ranking should trigger a documented public-interest review. Contract management after award deserves the same governance attention as the tender itself.

A low bid can conceal escalation, take-or-pay commitments or weak delivery guarantees. Competition requires comparable scope and publicly stated evaluation criteria. Bid scoring should specify how uncertain benefits and risks are valued. A bidder's optimistic generation estimate should be replaced with the same independent weather assumptions used for competitors. Keep the evaluation record sufficient for an auditor to reproduce the ranking.

Tender complete service requirements, disclose bid adjustments and independent evaluation, and screen conflicts of interest. Test the winning offer against delayed completion, lower output, curtailment and termination. Compare its risk-adjusted cost with the next bid.

Publish award rationale, contract duration and key public obligations. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA investment [1].

19. Contract Disclosure

Commercial confidentiality may protect narrow proprietary details, yet the public needs visibility into price adjustment, minimum payment and termination exposure. Renegotiation can alter the public deal after competition has ended. Publish material amendments with the original terms and explain why alternatives were rejected. A series of small amendments may have a large cumulative effect, so aggregate the cost over the contract life.

Adopt a standard disclosure schedule before tender. State the exact legal basis for each redaction and an expiry where appropriate. Ask whether an auditor can reconstruct public liabilities from released documents. Test dispute and renegotiation procedures.

Publish material terms, amendments and a change log. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: Author's governance framework [10].

20. Grid Planning Generation additions depend on lines, substations, operational visibility and skilled crews. IEA Electricity 2026 estimates that annual grid investment must rise by about 50% from roughly USD 400 billion by 2030 to meet projected demand [4]. Grid investment should consider both new lines and better use of existing assets. Connection queues can contain speculative projects. Transparent queue management, operational upgrades and targeted reinforcement may release capacity faster than a large new corridor in some systems.

Plan network capacity and generation together, with staged connection milestones and maintenance resources. Model permitting delay, transformer shortage and load growth in a different location than forecast.

Track connection queues, project completion, congestion, losses and outage restoration. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA Electricity 2026 [4].

21. Storage

Storage economics depend on the service purchased. A battery paid for frequency response is not equivalent to a battery expected to cover a multi-day energy deficit. IEA reports that utility-scale battery project costs fell sharply in 2024 and that global battery additions reached 108 GW in 2025 [13, 11]. The trend strengthens the role of batteries in short-duration flexibility, but duration, state of charge, temperature, degradation and competing market commitments determine dependable capacity during a stress event.

Procurement should state the required service in operational terms: MW, MWh, minimum duration, response time, availability window, cycle requirement, degradation allowance, reserve obligation and end-of-life performance. The financial model should include augmentation or replacement, fire safety, insurance, controls and disposal. A battery with a low quoted capital cost but weak availability guarantees or an unrealistic cycling assumption can create a false saving. Reliability models should use usable capacity, not nameplate capacity alone.

Storage provides services that depend on duration, cycling, degradation and the time of system need. A battery's nameplate capacity is not a guarantee of multi-day adequacy. Storage economics depend on the value of each service hour. Count charging energy, losses and replacement in the cost. Avoid selling the same reserved capacity to multiple services at the same time unless the dispatch plan demonstrates compatibility under stress.

Procure defined services such as frequency response, peak shifting or reserves. Model replacement and fire safety costs. Test prolonged low renewable output, high cycling, heat and accelerated degradation. Include charging constraints.

Report verified usable capacity, availability, cycle count and service delivered at critical hours. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA electricity and IRENA costs [3, 4].

22. Dispatchable Capacity A system needs resources available during stressed hours. The relevant value of a dispatchable plant depends on fuel security, availability, emissions and its interaction with variable supply. Firm capacity should be credited based on dependable output at the hours of system need. Nameplate output and average annual utilisation are weak substitutes. Dispatchable resources also need a verified fuel plan and maintenance reserve to deliver their claimed security value.

Retain or procure capacity only after comparing demand response, imports, storage and firm generation on a consistent service basis. Test fuel interruption, start failure, simultaneous maintenance and extended peak periods.

Publish dependable capacity, utilisation, emissions and total standby costs. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA Electricity 2026 [4].

23. Import Dependence Electricity or fuel imports may lower cost in normal periods while exposing users to external prices, transport disruption and neighbouring shortages. A diversification claim must consider correlated regional events. Import diversity requires attention to shared bottlenecks. Two suppliers routed through one port or interconnection may fail together. Maintain a map of physical dependencies, contract flexibility and realistic restoration periods under regional emergencies.

Evaluate supplier concentration, contract flexibility, storage and physical interconnection capacity. Model a shipping interruption, regional drought or simultaneous grid stress across borders.

Track import concentration, days of cover and the cost of alternative supply. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA energy security [9].

24. Demand Efficiency Reducing waste may defer generation and network investment, yet savings depend on uptake, rebound and equipment performance. Efficiency is not an unlimited or zero-cost resource. Efficiency savings should be measured against a baseline adjusted for weather and production. A fall in electricity use caused by factory closure is not

an efficiency gain. Verification protocols should also account for equipment that would have been purchased without support.

Compare verified efficiency programmes with supply options at matched service levels. Protect low-income access to efficient equipment. Test lower adoption, higher cooling demand and rebound in use. Verify persistence across several years.

Publish measured kWh and peak reductions net of programme cost and free riders. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 and IEA WEO [2, 5].

4. Demand and different economies

National averages do not describe the energy needs of a workshop, an island grid, a remote community or a mineral producer. The burdens and options differ. This chapter turns the common framework into questions suited to varied users and resource positions.

25. Industry And Large Loads

Large new loads have become a planning issue in their own right. IEA estimates data centres used around 415 TWh in 2024 and projects consumption to rise to about 945 TWh by 2030 in its base case [24]. The global share remains modest, but local effects can be large because facilities cluster geographically and seek high reliability. Mines, smelters, hydrogen projects, desalination plants and electrified industrial heat can create similar local step changes in load.

A large-load connection agreement should allocate the cost of dedicated and shared network assets, define security requirements, address project cancellation and identify flexibility value. The system planner should model a high-growth case and a cancellation case. If the asset is built for one customer, smaller users should not silently carry the full stranded cost if the project is delayed or abandoned. Where the customer offers interruptibility, onsite generation, storage or reactive-power support, the contract should value those services transparently.

Mines, factories and data centres can change local peak demand and network economics quickly. A favourable tariff for a large user may transfer costs to smaller customers. Large users should receive a price that reflects the assets built for them and any benefits they provide through flexible demand. If public funds build dedicated capacity, identify the public benefit. Protect smaller users against stranded costs if the large project stops early.

Require transparent connection studies, dedicated asset payments and demand flexibility terms. Test project cancellation after network construction and higher-than-forecast load.

Report load forecasts, reserved capacity, contributions and residual public exposure. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA 2026 demand [1, 4].

26. Small Firms Small enterprises often face both higher effective energy costs and costly outages. Tariff analysis should capture lost production, backup fuel and equipment damage. For small businesses, continuity may be worth more than a modest tariff cut. Survey backup-generator spending, damaged stock and lost hours. A programme claiming business benefits should report these outcomes alongside electricity prices, with sample limitations clearly stated.

Include small-business representatives in consultation. Provide clear connection service standards and predictable tariffs. Test an outage-heavy season and a tariff increase alongside a sales decline.

Publish sector-level bill examples, outage costs and connection times. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: Author's distributional framework [10].

27. Cooking Fuels

The transition extends beyond electricity. Households need safe, affordable cooking arrangements compatible with local infrastructure, preferences and supply chains. Cooking transitions should avoid counting an appliance distribution as sustained adoption. Users may retain several fuels because of cost, reliability or food preferences. Track actual use over time, including whether modern fuel supply reaches remote households consistently.

Include cooking energy in affordability surveys and programme design. Compare equipment, fuel, ventilation and maintenance together. Test fuel scarcity, appliance failure and a price shock. Check whether households revert to more harmful fuels.

Measure sustained use, total household expenditure and health-relevant exposure where feasible. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: SDG 7 2026 [6].

28. Transport Electrification shifts energy costs from fuel purchases toward vehicles, chargers and power networks. Benefits differ by driving patterns and access to finance. Transport analysis should separate new vehicle buyers from households dependent on public transport. Charger placement, vehicle financing and electricity tariff design affect who benefits. Compare public funds for charging with alternatives that improve mobility for people unable to purchase a vehicle.

Compare vehicle lifetime cost and charging availability across income groups. Avoid allocating public charging costs solely to non-users without justification. Test weak vehicle uptake, peak-hour charging and battery replacement.

Report transport cost by user group, charger uptime and grid cost allocation. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA WEO and IPCC AR6 [2, 5].

29. Rural And Remote Service

Distance raises connection and maintenance cost. A uniform national tariff may require explicit cross-subsidy or budget support to reach remote users. Remote-area programmes should include spare parts and a trained repair network in the initial budget. A low-cost installation followed by months of outage provides poor value. Procurement should define service availability and consequences when the operator fails to maintain equipment.

Choose grid, mini-grid or stand-alone supply through lifecycle service comparison. Assign a provider responsible for repairs and replacement. Test transport disruption, technician shortages and weak payment collection.

Track hours of service, repair time, household burden and subsidy per connection. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: SDG 7 and IEA finance [6, 8].

30. Island Systems Small grids have limited reserve and strong exposure to imported fuel, storms and equipment lead times. Variable generation may offer fuel savings while requiring careful stability design. On an island, resilience and affordability interact. A storm can damage generation, storage and fuel logistics at once. Diversification may reduce one exposure while creating another through specialised components. Test restoration sequences for hospitals, water and communications first.

Model frequency, inertia, storage and critical-load restoration alongside energy economics. Test a storm that damages generation and port access simultaneously. Include spare-part availability.

Publish island-specific reliability, fuel use and recovery times. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA electricity and energy security [4, 9].

31. Fossil Exporters An energy-exporting state may face revenue volatility while investing in domestic low-emission supply. The fiscal case differs from that of an importer. Export revenue is an uncertain source for fixed long-term obligations. Model a price downturn that lasts longer than a typical reserve fund. Keep domestic electricity planning grounded in realistic fiscal buffers and transparent annual appropriations.

Separate export revenue assumptions from domestic service planning. Build fiscal buffers and avoid pledging uncertain future revenue to fixed payments. Test a prolonged price fall and a faster change in external demand.

Publish budget breakeven assumptions and stranded-asset exposure. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA WEO scenarios [2].

32. Mineral Producers Transition equipment raises demand for minerals, but local extraction also creates land, water, labour and closure obligations. Gross export value is an incomplete measure of national benefit. Mineral revenues should be assessed net of infrastructure, environmental oversight and closure obligations. Local processing proposals need a verified power, water and market case. A licence alone does not prove that downstream value or jobs will materialise.

Apply transparent licensing, environmental safeguards, local capacity planning and funded closure provisions. Test commodity price collapse, processing delay and community opposition.

Report public revenue, verified jobs, environmental compliance and closure security. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 and IEA WEO [2, 5].

5. People, environment and performance

Energy projects alter work, land, pollution and exposure to climate hazards. Emissions should be measured against a credible counterfactual. A project also needs social legitimacy and sustained technical performance. Distributional and environmental issues are part of its approval case.

33. Land And Rights

Generation and network assets require land. Project benefits do not remove the need for lawful tenure, informed engagement and remedy for adverse effects. Land alternatives should be compared before a preferred route or site becomes politically fixed. Record livelihoods as well as formal title. A compensation payment does not automatically restore a community's access to water, transport or culturally significant places.

Map rights and livelihood impacts before site selection. Document alternatives and compensation terms. Test a disputed title, delayed consent process and irreversible habitat harm.

Publish consultation records, grievances, remedies and independently checked commitments. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 equity [5].

34. Workforce Transition New jobs may differ in place, pay, timing and skill from jobs lost elsewhere. A national net job count can hide concentrated harm. Retraining is an input, not the outcome. Track whether people obtain comparable work and whether families can bridge the period between jobs. A transition with dispersed new positions may require relocation support or local economic development beyond classroom instruction.

Map affected occupations and set funded retraining, placement and income support before closure. Test slow local hiring and training that leads to no job offer.

Track placement, wages and retention by affected group rather than training enrolment alone. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 [5].

35. Health And Pollution

Air quality and health effects may be material, but attributing them to one project requires a defensible baseline and exposure method. Health benefits depend on where emissions fall and where people live. A national reduction may coexist with a local hotspot near backup generation or industrial demand. Monitoring should reflect exposure pathways and avoid overstating causality from limited measurements.

Assess local pollution alongside carbon outcomes. Prioritise communities bearing existing burdens. Test alternative fuel and plant dispatch patterns, including backup operation during a crisis.

Disclose emissions factors, monitoring locations, uncertainty and affected population. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 [5].

36. Climate Resilience A lower-carbon asset still faces physical climate hazards. Flood, heat, wildfire and coastal exposure affect reliability and insurance costs. Resilience investment should be compared against the cost of interruption and recovery. A higher initial design cost may protect service over decades. Record uncertain hazard projections as ranges and avoid assuming historical extremes represent the maximum future risk.

Screen assets for present and plausible future hazard ranges, then fund design, redundancy and emergency response. Test a compound event that damages generation, roads and communications together.

Report expected restoration time, critical service continuity and resilience spending. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 synthesis [5].

37. Emissions Accounting

Climate performance requires a defined counterfactual and boundary. Global policy remains off track relative to the Paris temperature goals. UNEP's 2025 Emissions Gap Report estimates warming of roughly 2.8 degrees C under current policies and 2.3-2.5 degrees C under full implementation of available NDCs, subject to the report's assumptions and policy set [19]. The result reinforces the need for faster emissions reductions, but it does not determine the emissions value of a particular power project.

Project claims should use time-matched system effects where feasible. A renewable generator displaces the marginal mix at the hours it produces, not the annual average mix in every case. Storage can shift energy from low-emission to high-emission hours or the reverse. Transmission can enable cleaner generation while also increasing total trade.

Electrification moves emissions from end use to the power system. The accounting method should state treatment of imports, lifecycle emissions, curtailment, methane, construction and asset retirement. Report both gross project output and net system effect.

Installed renewable capacity is not avoided emissions. Actual output, curtailment, displaced generation and lifecycle boundaries determine the result. Emissions claims should report gross system emissions as well as any project-level avoided estimate. A renewable plant might displace different generators at different hours. Imported electricity also needs a consistent boundary to prevent shifting emissions outside the accounting area.

State the baseline, grid factor, time matching and emissions scope. Reconcile modeled reductions with measured operations. Test changes in dispatch, demand and imports that alter the displaced source.

Publish annual generation, fuel use, emissions and uncertainty. Correct earlier claims when the baseline changes. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 and IEA review [5, 11].

38. Methane And Fuel Chains Gas-fired options depend on upstream emissions, leakage, transport and plant efficiency. Boundaries that stop at the power station understate lifecycle effects. Methane assumptions should identify the supply chain and time horizon used. Treat estimates with uncertainty bands when direct measurements are absent. Compare the same lifecycle boundary for all options so an upstream omission does not make one fuel appear cleaner by definition.

Specify upstream assumptions and compare credible ranges. Avoid presenting uncertain leakage estimates as site measurements. Test higher methane leakage and lower plant utilisation.

Report data provenance, measurement plan and lifecycle sensitivity. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 [5].

39. Technology Performance

Manufacturer specifications and models are not field results. Site heat, dust, humidity, maintenance and operating practice affect performance. Acceptance tests should occur under relevant operating conditions. A short commissioning demonstration does not prove sustained performance. Retain measurement rights and access to raw operating data after handover, with practical remedies if warranties or support lapse.

Require acceptance testing, warranties, spare parts and independent output measurement. Test lower capacity factors, degradation and a contractor exit.

Publish measured availability and corrective actions against guaranteed values. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IRENA and author framework [3, 10].

40. Supply Chains

Supply-chain security now affects schedule, cost and strategic autonomy. IEA reports that the average share of the leading refiner across key energy minerals remains high and that export controls have widened since 2023 [21]. Grids face separate constraints in transformers, cables and specialist labour [4]. The appropriate response is not indiscriminate stockpiling. It is a criticality analysis that identifies components whose failure or delay stops service, their lead times, substitute specifications, supplier concentration and inventory economics.

Procurement should distinguish commercial concentration from national-security risk. Dual sourcing, framework agreements, standardised equipment, local maintenance capability, strategic spares and recycling can improve resilience. Local manufacturing should be assessed against scale, cost, quality and export potential. For equipment with rapid technology change, excessive inventory can become obsolete. The risk register should therefore link each supply-chain measure to a specific failure mode and review it as markets evolve.

Long lead times for transformers, turbines and controls can delay whole systems. Single suppliers create repair and cybersecurity exposure. Supply-chain resilience has a carrying cost. A stockpile of critical spares is justified where its cost is lower than the expected cost of long outages. Document compatibility, storage life and who owns the inventory if the operating contract ends.

Map critical components, alternatives and stock levels. Align procurement schedules with commissioning dependencies. Test a two-year component delay or failure of the sole vendor.

Publish delivery milestones and critical spares coverage. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA grid analysis [4].

6. Delivery, resilience and assurance

Commitments fail through delays, weak data, poor controls and an inability to revise a flawed plan. Accountability requires named owners, thresholds, independent review and public correction. This chapter specifies the operating discipline needed after the press release and contract signing.

41. Cyber And Control

Digital control supports a complex grid but introduces operational risk. Data integrity and access controls are part of reliability, especially when remote systems manage dispatch. Digital resilience should include safe manual operating modes. Independent backups are useful only if staff train on them. Test detection and restoration across utility, vendor and telecommunications boundaries, with a record of gaps closed after each exercise.

Define independent backup operation, segmentation, incident response and vendor responsibilities. Test loss of communications and corrupted meter or dispatch data.

Report recovery exercises, outages attributable to control failures and audit closure. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: Author's resilience framework [10].

42. Project Delays

Delayed assets create fuel costs, financing charges and the need to keep older units operating. The party paying for delay must be visible before contract signature. Project schedules should reflect permitting, land access and manufacturing constraints. An aggressive completion date can produce misleading comparisons if its failure costs sit outside the bid. Require a credible critical path and a funded bridge plan.

Set milestones, independent certification and realistic contingency budgets. Model late generation, late transmission and both together. Identify bridge supply and its funding.

Report planned versus actual dates, claims and revised consumer impact. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA investment [1].

43. Fiscal Crisis

A fiscal stress test should model the interaction between energy prices, exchange rates, interest rates and public revenue. The 2026 energy shock prompted many governments to introduce price controls, producer subsidies and tax relief while debt-service burdens were already high [17]. These measures can protect households in the short term, but broad support becomes expensive if it persists. A transition plan that depends on permanent fiscal transfers should show the funding source under a recession or commodity-price shock, not only under the central case.

The treasury test should include direct capital grants, state-owned utility support, tax concessions, guarantees, foreign-exchange protection, public lending and termination exposure. It should also show the budget effect of the protection package for vulnerable users. Where the state is a fossil-fuel exporter, a low-price scenario can reduce the revenue available to finance fixed transition commitments. Where the state is an importer, a high-price scenario can increase both subsidy pressure and inflation. The most useful output is a multi-year cash and contingent-liability table linked to explicit trigger actions.

High debt service or reduced revenue can force choices between energy support and other essential services. A transition plan that relies on indefinite subsidy is fragile. Fiscal triage should distinguish a project delay from a cancellation that creates termination liabilities. During a crisis, maintain critical existing assets before starting discretionary additions. State the legal and budget consequences of each reprioritisation choice.

Rank commitments by safety, essential access and verified value. Establish a transparent method to pause or resize projects. Test recession, currency pressure and energy price increases in the same year.

Publish fiscal stress ranges, spending priorities and explicit protection for essential service. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IMF fiscal analysis [7].

44. Social Trust

Social legitimacy depends on process and distribution. IPCC assessments identify affordability, access, participation, distributional effects and respect for affected groups as dimensions of energy justice and a just transition [31, 32]. These concepts are broad. For project governance they should be translated into observable commitments: who received information, which alternatives were open, how concerns changed design, what compensation or remedy exists, and which groups experience higher bills, land impacts or employment loss.

Consultation should begin before the preferred site, route or tariff is effectively fixed. Decision makers should distinguish disagreement from process failure. A project does not require unanimity, but it needs a record showing material concerns were heard, assessed and answered. Grievance systems should have timelines, appeal routes and remedy authority. Public reporting should include unresolved cases and recurring themes. Where benefits are promised, such as jobs or community services, commitments should have budgets, owners, delivery dates and verification.

People judge a transition by bills, service and whether commitments are honoured. Consultation after terms are fixed provides little scope to correct mistakes. Trust depends on correcting an inaccurate public claim promptly. Publish what changed in the forecast, who approved the earlier statement and whether households receive remedy. Credible uncertainty bands are preferable to promises of exact future savings.

Publish understandable bill examples and hold engagement before procurement and siting decisions are locked. Test a gap between promised savings and observed bills. Require a public explanation and corrective plan.

Record participation, unresolved concerns, grievance response and published changes. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IPCC AR6 equity [5].

45. Data Governance Energy data may sit across utilities, ministries, investors and regulators. Inconsistent definitions make scrutiny impossible and can distort forecasts. Data governance should define the unit of measure and reporting period for every metric. A generation figure in MWh cannot be compared directly with installed MW. Reconcile readings across source meters, billing systems and public releases before publication.

Name a steward for every indicator and publish metadata, revision dates and methods. Protect personal records. Reconcile billing, metering and generation totals. Investigate unexplained discrepancies.

Publish a data dictionary and audit trail with confidence ratings. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA data practice [11].

46. Independent Review

A project sponsor's model is useful but not independent assurance. Material assumptions need challenge by specialists outside the approving team. Independent review should not end with a certificate. Publish the scope, limitations, unresolved findings and management action. Reviewers need access to underlying contracts and models, with a process for protected material and a public summary of material exposure.

Commission technical, fiscal, social and environmental review with disclosed mandates and conflicts. Have reviewers reproduce the base case and at least three downside cases.

Publish findings, management responses and deadlines for unresolved issues. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: Author's assurance framework [10].

47. Decision Thresholds

A dashboard without a decision rule may reveal a problem too late. Thresholds should connect indicators to named actions and accountable officers. Decision triggers should be operational, not vague. For example, a reserve shortfall should lead to a named procurement or demand-response action by a date. The authority to act and funding source must exist before the trigger is breached.

Set triggers for tariff support, reserve procurement, contract renegotiation and project pause before the event. Run tabletop exercises for simultaneous reliability and fiscal stress.

Report trigger breaches, actions taken and time to resolution. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: Author's governance framework [10].

48. Annual Review

Costs, technology and demand change. A fixed plan should be revised through a predictable process that preserves investor confidence and public accountability. Annual reporting should keep the original forecast visible alongside revisions. Otherwise, an agency can appear accurate by changing the baseline each year. Reconcile what changed because of external conditions, model error, delivery performance and policy choice.

Conduct a yearly review and a deeper reassessment after material shocks. Preserve version histories. Compare original forecasts against observed results and explain deviations, not only revised projections.

Publish scorecards, contract changes, updated scenarios and unresolved risks. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: IEA scenarios and author framework [2, 10].

49. Country Application

No global ranking determines the best national technology mix. Resource endowment, utility finances, geography, institutions and public priorities differ. National application should include legal and administrative capacity. A sophisticated market design that a regulator cannot enforce may perform worse than a simpler rule with credible implementation. Set a staged programme and fund the institutions responsible for oversight.

Use the common five tests but set thresholds through national evidence and consultation. Commission a local model before approving material spending. Compare a high-fuel, high-debt, high-growth and climate-hazard case with the base plan.

Publish country assumptions and the distribution of results across groups. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: All institutional sources [1-9].

50. Final Accountability The central question is whether a complete package delivers dependable service, preserves essential access, withstands adverse events and reduces emissions without hiding liabilities. Final approval should record conditional findings, dissent and missing evidence. A project with a good central case may be unacceptable if its downside threatens essential service or public finances. The record should explain why its chosen risk level is acceptable to the people who pay.

Approve projects only when the full ledger, scenario register, risk allocation and monitoring plan are available. Challenge the recommendation from the perspective of a low-income household, utility, treasury, investor and future user.

Record the decision, dissent, evidence gaps, conditions and review date. The reviewer should trace the consequence back to its payer and record a response if a threshold is breached. Evidence basis: Author's synthesis [10].

7. Integrated decision model

The preceding topics are connected. A proposed solar-plus-storage investment, for example, changes fuel use and peak supply, but its net value depends on battery duration, grid constraints, financing terms and the generation it displaces at specific hours. The same investment can look favourable under annual energy accounting and fail a multi-day reliability test. The decision model therefore evaluates a portfolio, not an individual technology.

The model is designed to stop one attractive metric from dominating the decision. A pathway advances only after it passes five gates: equal service, full cost and payer visibility, distributional protection, resilience under compound stress and verifiable climate performance. Failure at a gate does not always mean rejection. It may lead to redesign, a contract condition, phased investment or a requirement for better evidence. The decision record should state which response was chosen.

Scoring systems should be used with restraint. A weighted score can hide a critical weakness if strong performance in one area offsets a non-negotiable failure elsewhere. Reliability for a hospital, legal land rights or an unaffordable fiscal guarantee may need hard thresholds rather than weights. The framework therefore combines thresholds with comparative metrics. The preferred option should remain intelligible without a proprietary model: readers should be able to see the major trade-offs, the assumptions that drive the ranking and the point at which the decision changes.

Step 1: Define equal service

Set annual and hourly demand, essential service, outage limits, access targets, asset life and emissions boundary. Record whether the plan must cover a drought year, a critical hospital load or a rapid industrial expansion. Options that deliver different standards must be normalised or reported separately.

Step 2: Calculate the payer ledger

For each pathway, identify capital and financing cost, fuel and operating cost, network reinforcement, reserve or backup, social protection, taxes and guarantees. Present the stream by year and payer. Use one price year and show nominal and real comparisons. Transfer payments such as taxes should be reported separately from resource costs to avoid double counting.

Step 3: Model the distribution Translate tariffs, taxes and service quality into representative households and firms. Show deciles where survey evidence supports them, and disclose who is absent from administrative data. Include connection fees, cooking fuels, transport, self-generation and outage losses where material.

Step 4: Stress the system

Run fuel-price up and down cases, high and low demand, currency and interest shocks, project delay, prolonged low renewable output, equipment failure, fiscal squeeze and extreme weather. Test combinations rather than only independent one-at-a-time changes. A conclusion that reverses under modest input changes needs a conditional recommendation.

Step 5: Decide and monitor

Approve only after an independent review of material assumptions and a public record of the accepted trade-offs. Define triggers for additional reserve, targeted assistance, contract remedies or programme pause. Report observed performance against the original forecast every year.

Output	Minimum question
Cost comparison	Do pathways deliver equal service across the same time horizon?
Payer map	Which group bears each cost and downside risk?
Stress results	What fails first under compound shocks?
Decision record	Why was this trade-off accepted and who signed it?
Correction rule	What evidence triggers revision, and by when?

8. Worked illustrations

The examples below are qualitative thought experiments. They use no invented country figures. Their purpose is to show how a decision changes when a cost or risk omitted from a headline comparison is restored.

A useful worked illustration should preserve uncertainty rather than invent precision. For each archetype below, the decision team should build a central case, downside cases and a break-even table. The purpose is to identify which assumptions deserve the most diligence. If a 5% change in construction cost does not change the ranking but a six-month grid delay does, management attention belongs on the grid interface. If the result turns on the discount rate, financing structure deserves deeper review. If household affordability fails under a modest tariff increase, protection design belongs inside the project rather than after it.

The same discipline applies to technology neutrality. Renewables, storage, efficiency, networks, nuclear, fossil generation, imports and emerging technologies should be compared against the service required and the policy objectives. Some options face technology-specific risks. CCUS, for example, involves complex project interfaces and financing challenges even as investment has grown [30]. The framework does not assume inclusion or exclusion. It asks whether the package is deliverable, financeable, reliable, socially legitimate and consistent with the stated emissions pathway.

Illustration A: a diesel-reliant remote industrial site

The proposed package combines solar generation, storage and existing dispatchable equipment. The initial case emphasises avoided fuel purchases. The complete case also includes storage degradation, maintenance, land, controls, spares, finance and a multi-day low-output period. The owner should compare actual fuel logs before and after commissioning, adjusted for production and weather. Emissions claims need the displaced generation profile and relevant fuel factors. If the battery protects only a short peak, it should not be credited with full outage resilience. The contract should assign performance and replacement obligations explicitly.

The decision can favour the hybrid design without implying universal self-sufficiency. The approval record should specify the residual fuel requirement, the bridge supply if commissioning slips and the party carrying currency exposure on imported components. Public claims should separate projected and verified results. This illustration is generic and does not assert AGM operational figures.

Illustration B: household tariff reform A utility needs revenue for repairs and network expansion. A uniform tariff increase may improve its accounts while leaving a low-income household with unaffordable essential service. The government should test several occupancy and consumption profiles, provide a funded targeted transfer before the increase, and check the payment mechanism in practice. A freeze with no budget compensation would also be tested because it can deepen utility arrears and outages.

The decision record should compare the cost of compensation with the reliability benefit of restored maintenance. It should report who misses eligibility, how appeals work and how quickly assistance arrives. The reform succeeds only if essential access, utility performance and fiscal funding hold together.

Illustration C: a new large electricity user

A major industrial user asks for a large connection and a low long-term tariff. The network must be reinforced before the plant starts. The appraisal should compare user payments with the full dedicated cost and examine whether smaller customers inherit a stranded asset if the plant closes. Flexible demand may create system value, but the flexibility needs enforceable dispatch terms and compensation rules.

A stress case assumes that the user delays operations after the line is completed. The contract should specify capacity charges, security and the conditions for releasing reserved capacity. Public disclosure should show the residual exposure without divulging proprietary production information.

9. Recommendations and implementation

The framework supports a sequenced programme rather than a single global technology prescription. Governments and utilities should start with a trustworthy baseline and essential service standard. They should then select investment packages through comparable system studies, disclose public exposure and establish household protection before price changes.

Implementation should begin with a 90-day evidence reset. The utility, regulator and finance ministry should reconcile demand, losses, outages, tariffs, arrears, fuel use, contractual obligations and current investment commitments. The result should be a single baseline with a data dictionary and named owners. Major discrepancies should be resolved before launching new procurement. This first stage often produces more value than adding another high-level target because it reveals where the system is already carrying hidden cost or reliability risk.

The next stage is a portfolio and financing plan. Generation, network, flexibility, access and efficiency investments should share one demand forecast and stress cases. The financing plan should show local and foreign currency, public and private sources, concessional support, guarantee exposure and the customer or taxpayer ultimately funding each item. UNFCCC's 2025 NDC synthesis shows that countries reporting quantified needs expect a mix of domestic, international, public and private finance, with substantial stated needs in the energy sector [20]. The report covers a limited set of NDCs and should not be treated as a global total, but it illustrates the financing architecture governments are considering.

Finally, the plan should establish an annual correction cycle. Actual demand, costs, outages, construction progress, emissions and distributional effects should be compared with the original approval case. Changes in method should not erase the earlier series. Material deviation should trigger a defined response such as rebidding, tariff adjustment, additional protection, accelerated network work or cancellation of a weak project. A transition plan gains credibility when it shows how it will correct itself.

Period	Action	Accountable evidence
0-6 months	**Baseline, data dictionary, service standard and risk**	**Published assumptions and audited**
register.	utility position.	
6-18 months	**Portfolio study, consultation, procurement and**	**Independent review and disclosed**
funded protection.	contract summary.	
Each year	**Report outcomes and run updated compound**	**Original forecast, actual values and**
stress tests.	correction log.	

The five mandatory approval gates are: equal service comparison; full cost and payer ledger; household and firm distribution; compound scenario test; and independent assurance with a monitoring plan. A missing gate should delay a material commitment or become a clearly disclosed condition precedent. Decision makers should publish dissent and unresolved gaps, not only the preferred option.

Implementation requires skills and institutional capacity. A complex tariff design that a regulator cannot enforce will perform poorly. A data system that cannot reconcile meters and bills will make verification weak. Budget for training, maintenance and oversight alongside physical infrastructure.

10. Limitations and conclusion

This paper cannot determine a country-specific optimum. Its global numbers have distinct definitions and years. Institutional scenarios are conditional. Generation cost averages exclude local integration and financing. A complete appraisal needs engineering, economic, legal, social and environmental work with local data. The paper offers a transparent procedure for that work, not a substitute for it.

No global framework removes the need for local engineering, legal, fiscal and social analysis. Data quality differs across systems. The value of reliability depends on customer type and outage duration. Financing terms change rapidly. Technology costs and supply chains move. Climate hazards evolve. Some impacts, including biodiversity, cultural values and distributional justice, resist reduction to one monetary figure. The framework therefore emphasises transparent boundaries, separate metrics and decision records rather than a universal score.

The evidence through 24 September 2026 supports a disciplined central proposition. The energy transition is advancing at scale, but the binding constraints increasingly sit in networks, finance, institutions, utilities, supply chains, workforce and social delivery as much as in generation technology [1, 4, 12, 14, 21, 22]. Good decisions expose these constraints early. They compare equal service, trace every material cost and risk to a payer, protect vulnerable users before reform, test compound shocks and publish enough evidence for an independent reviewer to reproduce the logic.

The central answer is that every transition cost is paid by someone, now or later. Good policy makes those payments visible and tests the service obtained in return. Households need affordable essential energy. Firms need predictable service and fair charges. Utilities need revenue and controls sufficient to maintain assets. Treasuries need limited and disclosed exposure. Investors need clear, enforceable contracts while retaining risks they control. Future generations need both lower environmental harm and durable infrastructure.

Approve complete service packages. Set measurable thresholds. Protect vulnerable users before reform. Model adverse combinations. Verify reported outcomes and correct the plan when results differ from forecasts. These requirements provide a more credible basis for transition decisions than either a technology slogan or a single headline cost.

Appendix A. Minimum project appraisal file

Decision statement Project scope, alternatives, service standard, decision maker, approval conditions and rationale. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

Baseline and data

Demand by hour, current reliability, access, tariffs, utility finances, fuel use, emissions and source dates. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

System study

Generation, network, reserves, imports, storage, maintenance and extreme conditions for each option. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

Economic and financial model Price year, currency, discount rate, capex, opex, taxes, debt, guarantees and sensitivity ranges. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

Distribution analysis Representative household and firm burdens, service effects, access, labour and geographic differences. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

Environmental and social record Emissions boundary, land, water, biodiversity, rights, engagement, grievances and closure duties. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

Risk and contract record Risk owner, limits, security, change clauses, delay remedies, termination and public disclosure. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

Verification plan

Data owners, baseline retention, independent review, public indicators and correction triggers. The file should state the source and reviewer for each material assumption, identify gaps, and retain a dated version for later comparison.

Appendix B. Scenario register template

Each row in a working register should contain a scenario definition, baseline input, stressed input or range, probability treatment, direct effect, second-order effect, payer, contract clause, responsible officer, trigger and response. Where probability cannot be estimated credibly, use a transparent range rather than a fabricated point estimate.

Scenario	Combined exposure to test	Response owner
Fuel and currency	Imported fuel rises as currency depreciates.	Treasury, utility and tariff regulator.
Demand and delay	Load grows while a line is late.	System operator and project sponsor.
Weather and outage	Low renewable output coincides with equipment failure.	System operator and emergency authority.
Fiscal and social	Revenue falls as household bills rise.	Finance and social protection agencies.
Hazard and logistics	Storm damages assets and blocks access to spares.	Utility and civil protection.

The register should show correlation and duration. A one-day supply event and a six-week interruption require different remedies. It should also state whether a project remains acceptable under the combined shock or needs a revised design.

Appendix C. Claims and source audit

The following checks are required before publication or use in a financing decision. A statement about investment is not a statement about final consumer cost. A generation-cost average is not a delivered tariff. Nameplate capacity is not annual generation or firm capacity. An avoided-emissions estimate requires a baseline. A subsidy estimate is not automatically an available budget. A scenario is not a forecast.

No internal AGM project data appear in this report. A later case study should use only figures authorised for public disclosure and should distinguish targets from measured results. The published edition date is 24 September 2026. Later editions should refresh figures against current primary sources.

Appendix D. Levelised and delivered cost A levelised cost of electricity divides the present value of a plant's lifetime costs by the present value of its generation.

It is useful for comparing generation technologies under consistent assumptions. It does not by itself price electricity at a customer meter. A delivered comparison must add network, losses, balancing, firm capacity and any storage required to meet the specified service standard. The analysis should account for curtailment and avoid counting energy that the system cannot absorb as a benefit.

Use the same real or nominal discounting convention in numerator and denominator. State commissioning year, asset life, residual value, fuel, maintenance, degradation, tax treatment and capacity factor. A higher discount rate has a larger effect on capital-intensive assets. A model that combines one project's low-cost finance with another's high-cost finance without explanation will produce a misleading ranking. Provide a sensitivity table across plausible local financing and output values.

A system comparison should calculate both expected total cost and the cost of meeting stressed hours. One option may provide inexpensive annual energy while requiring a separate reliability asset. The alternative may have a higher energy price but supply valuable peak capacity. Assess the combined portfolios. Where costs fall on different institutions, reconcile the economic total with actual tariffs, utility accounts and budget payments.

Calculation	Required boundary
Plant generation cost	Capital, financing, fuel, operation and actual usable output.
Delivered service cost	Plant plus grid, losses, balancing, reserves and access.
Fiscal exposure	Budget cash plus guarantees and state-utility obligations.

Appendix E. Affordability distribution

Define the unit of analysis before calculating burden: person, household or customer account. An account can serve multiple households, while an informal settlement may have no formal account. Use survey data to estimate disposable income and energy expenditure. Disaggregate results by income, geography, household size and other relevant vulnerability measures, subject to data quality and privacy. Report coverage gaps instead of assuming that unobserved households resemble observed customers.

A tariff change can affect people directly through electricity and indirectly through food, transport or business prices. The model should separate these channels. Include fixed charges, connection cost, prepaid fees, arrears and seasonal variation. Test whether a lifeline threshold serves larger low-income families adequately. Where household microdata are not available, use representative cases with explicitly stated limitations rather than inventing precise decile outcomes.

For compensation, compare entitlement with actual delivery. A transfer credited after a bill is due may not prevent disconnection. Track payment failures, appeals, excluded households and the fiscal cost of administration. An equity assessment should also compare the quality of service received; a lower bill paired with frequent outages may still leave a household worse off. Publish the minimum essential service assumption and consult affected groups on its adequacy.

Indicator	Interpretation limit
Energy burden	Income data and seasonal use may be uncertain.
Disconnection	Low disconnection can conceal self-rationing.
Compensation coverage	Eligibility is not proof of timely receipt.

Appendix F. Reliability modelling

Build an hourly demand and supply representation with weather-linked renewable output, scheduled maintenance, forced outage assumptions, storage state of charge, imports and network limits. Annual generation divided by annual demand is not a reliability result. A credible model should estimate the magnitude and timing of unmet load under multiple weather years and relevant equipment failures. The service standard should distinguish ordinary operations from rare emergency conditions.

Storage should be modeled through power, energy, efficiency, charging opportunities and degradation. Dispatchable resources should receive an availability value supported by maintenance and fuel logistics. Imports should reflect physical capacity and the risk of concurrent shortage in neighbouring systems. Demand response should be credited only where customers have an enforceable arrangement and the ability to respond during the relevant hours.

Validate the model against historical dispatch, outages and fuel consumption. Run a prolonged low-output period, a high-heat demand episode, a line failure and a compound event. Report expected unserved energy and the worst credible service interruption separately. Since model outputs depend strongly on uncertain forced-outage rates and weather correlations, publish those inputs and independent review findings.

Input	Validation
Hourly load	Reconcile meter totals and peak records.
Renewable output	Use relevant site or regional weather profiles.
Forced outage	Compare historical asset performance.
Import availability	Check agreements and neighbouring stress.

Appendix G. Public finance and guarantees A treasury assessment should include capital grants, operating support, tax expenditures, borrowing, guarantees, indemnities and state-owned enterprise obligations.

Show annual cash and a separate schedule of contingent exposure. The maximum contractual obligation is not the same as its expected loss, yet both should appear in the decision record. An apparently private project can have material public risk through minimum revenue, currency or termination clauses.

Stress public accounts under lower revenue, higher interest rates, currency depreciation and simultaneous calls on several guarantees. Test whether compensation for vulnerable users remains funded when a fiscal shock arrives. If a policy relies on utility under-recovery, show the resulting maintenance, arrears and recapitalisation effects. Do not describe a future environmental benefit as cash that can meet a bond coupon.

The approval file should state who authorised each obligation, its ceiling, term, trigger and annual reporting process. Independent fiscal review should reconcile the project model with budget and debt documents. Public disclosure should permit citizens and legislators to understand the scale of exposure while respecting narrow, justified commercial protections. Material amendments should update the register and the original appraisal.

Exposure	Public record
Direct spending	Annual and total appropriations.
Guarantee	Ceiling, trigger, beneficiary and expiry.
Utility obligation	Payment floor, tariff gap and arrears.

Appendix H. Emissions and counterfactuals A project-level reduction is the difference between emissions in a defined counterfactual and emissions with the project, for a specified time period and boundary.

The counterfactual should include plausible retirements, efficiency changes and policy commitments. The calculation should use actual output rather than installed capacity. Where renewable generation is curtailed or replaces another low-emission resource, avoided emissions differ from a simple annual average grid factor.

Define direct fuel combustion, purchased electricity and material upstream sources. Use appropriate fuel quantities and factors. Show how imports are treated. A plant that reduces local emissions but shifts generation to a neighbouring grid should not be described as eliminating the full burden. Lifecycle construction and equipment effects may be material to a comparative study and should be included under a consistent boundary.

Report a range when displacement is uncertain. Keep forecast reductions separate from verified annual results. Reconcile meter readings, fuel records and operational logs. An independent reviewer should reproduce the calculation and examine changes in demand or production that affect the comparison. If the baseline changes, retain the old series and publish a bridge explaining the revision.

Claim	Evidence required
Capacity installed	Commissioning certificate and nameplate.
Energy generated	Metered MWh with period and losses.
Fuel displaced	Adjusted counterfactual and actual fuel logs.
Emissions avoided	Boundary, factors, displacement and uncertainty.

Appendix I. Procurement and contract audit

Before tender, define the service to be purchased and the risks that each bidder will bear. Publish evaluation criteria and weighting. Require bidders to use common assumptions for demand, weather, fuel and interconnection where possible.

Separate differences in technology performance from differences caused by inconsistent bid scope. An independent evaluator should test whether the preferred bid remains preferred after realistic adjustments for delay and output.

After award, review indexation, foreign currency, minimum payments, curtailment, change in law, force majeure, termination, step-in rights and dispute resolution. Assign a public cost to the relevant downside cases. Performance guarantees should be collectible and backed by credible security. A nominal penalty offers little protection if the contracting entity has no assets when a claim arises.

Maintain a procurement record of conflicts, clarifications, scoring, deviations and approval. Disclose material public terms and every later amendment. Compare the renegotiated lifetime cost with the original award. If the deal changes enough to reverse the competitive ranking, document the legal and public-interest rationale for retaining it. Contract transparency is a continuing obligation, not an award-day exercise.

Stage	Audit question
Tender	Did every bidder price the same service?
Award	Is the ranking reproducible?
Operation	Do payments match verified performance?
Amendment	What cumulative public cost changed?

Appendix J. Engagement and remedies

Map groups affected by bills, land use, workforce change and service outcomes. Consultation should begin while route, site and tariff alternatives remain open. Record the information provided, languages used, time allowed and how feedback changed the proposal. A meeting count does not demonstrate meaningful influence. Project proponents should address the concerns of people who lack formal title or regular customer accounts.

Create accessible grievance channels with an acknowledgement period, investigation process, appeal route and remedy authority. Protect people from retaliation and avoid making a technical expert the sole arbiter of livelihood impacts. Report unresolved grievances and the time taken to close them. Social commitments should appear in the project budget and contract, with a named owner after commissioning.

For displaced workers, compare replacement opportunities by location, pay and required skill. Fund transition support before employment ends. Track job placement and retention rather than course attendance alone. For land and environmental impacts, verify restoration or compensation outcomes over time. Public legitimacy grows from a record of decisions and remedy, not a claim that everyone agreed.

Stage	Minimum proof
Design	Alternatives and responses to affected groups.
Construction	Complaints, remedies and monitoring.
Operation	Service, livelihood and workforce outcomes.

Appendix K. Data and assurance protocol

A publishable indicator needs a definition, unit, period, geographic boundary, source system, owner, quality check and revision rule. Maintain a data dictionary across utility, regulator and ministry reporting. Reconcile generation, purchased power, sales and losses. Explain legitimate differences between billing and physical energy because meter dates and boundaries can vary. Protect personal and commercially sensitive records while providing aggregated evidence for public review.

Separate management calculations from independent assurance. A reviewer should test a sample of source records, recalculate material metrics and inspect control weaknesses. Its report should state scope and limitations, not only a pass label. The decision maker should publish a management response with actions and dates. Unresolved limitations must travel with subsequent public claims.

A correction protocol should preserve earlier figures, identify the error or changed assumption and display a bridge to the revised value. Quietly replacing a baseline frustrates scrutiny. Track revisions to tariffs, emissions and reliability models in a version register. Keep a consistent annual series so readers can distinguish a true improvement from a change in method.

Data item	Minimum control
Meter reading	Reconciliation and exception handling.
Model assumption	Owner, source and version.
Public claim	Reviewer and limitation statement.

Appendix L. Decision minutes and dissent

The final decision record should describe the proposal, alternatives, accepted service standard, payer ledger, most material risks and the reasons the selected option is preferred. Include a map of where the preferred option performs worse than alternatives. A balanced decision can still proceed, but decision makers must explain why the trade-off is acceptable and who bears the cost.

Record dissent in substance. An engineer may dispute a reserve margin, a fiscal reviewer may object to a guarantee, or a community representative may identify a livelihood effect. Each concern should have a disposition: resolved with evidence, addressed through a condition, or accepted with a stated reason. This record helps future oversight distinguish an unforeseen problem from a known risk that was ignored.

Set conditions precedent before signing where crucial evidence remains incomplete. Name the official with authority to confirm completion. Define the monitoring cadence and the thresholds that trigger reconsideration. Publish a non-confidential summary and retain the full file for audit. The minutes should be clear enough for a later administration to understand the original decision without reconstructing private conversations.

Field	Required entry
Choice	Preferred pathway and rejected alternatives.
Trade-off	Distribution, reliability, fiscal and climate effects.
Dissent	Concern, evidence and disposition.
Review	Owner, date and trigger.

Appendix M. Stress testing protocol

A stress test is not a prediction of the most likely future. It asks whether a plan continues to deliver essential service under a defined disturbance and what action limits harm. Start with one-at-a-time sensitivities to find influential variables. Then test compound cases, because currency, imported fuel prices, fiscal revenue and household income may move together. State duration as well as magnitude.

The register should distinguish reversible harm from irreversible consequences. A tariff increase can be compensated later, while a prolonged outage to a hospital may cause immediate loss. Test the time between detecting a threshold breach and implementing a remedy. A response that depends on procuring equipment with an eighteen-month lead time will not resolve next week's shortfall.

For each case, report the change in bill, fiscal outlay, unserved energy, emissions and affected groups. Identify the contract and officer responsible. Avoid assigning probabilities without a defensible empirical basis. When probabilities are unavailable, use transparent severity categories and show break-even values at which the preferred option changes. Preserve the stressed model and review it after real events.

Test class	Example
Market	Fuel spike with exchange-rate depreciation.
System	Peak load with generator and import failure.
Delivery	Grid delay with growing industrial demand.
Social	Household income fall and compensation delay.

Appendix N. Independent challenge checklist

An independent challenge should be designed to find a decision-changing weakness rather than to restate the project team's work. The reviewer should receive the same data pack used for approval, including the original models and contracts. The reviewer should identify the five assumptions with the greatest effect on affordability, reliability, fiscal exposure and emissions, then test plausible adverse values. Any material data gap should be reported as a decision risk rather than filled silently with a convenient assumption.

The challenge should cover technical adequacy, economic and financial assumptions, procurement integrity, legal obligations, distributional effects, climate accounting and delivery readiness. The reviewer should also compare the preferred option with at least one credible alternative and a delay case. If the preferred option survives only because the alternative was specified to a lower service standard, the comparison should be rebuilt.

A final challenge memorandum should separate fatal issues, conditions precedent, monitoring conditions and residual risks accepted by the decision maker. Management should respond to every material finding. Acceptance of a risk is a governance decision and should name the person or body with authority to accept it. Independent review adds value only when it can change the decision or the conditions attached to it.

Challenge domain	Minimum test
Service equivalence	Same load, access and reliability standard across options.
Technical	Stressed-hour adequacy, network dependency, degradation and failure modes.
Financial	Capex, financing, FX, inflation, schedule and revenue sensitivities.
Fiscal	Cash outlays, guarantees, SOE support and termination exposure.
Distribution	Bills, access, firms, land, workers and geographic effects.
Climate	Counterfactual, timing, lifecycle boundary and measurement plan.
Governance	Procurement integrity, conflicts, disclosure, dissent and correction triggers.

Appendix O. Executive decision sheet

The executive decision sheet is a two-page summary drawn from the full appraisal, not a substitute for it. It should state the service need, preferred pathway, alternatives, capital and lifetime cost range, payer map, tariff or bill effect, fiscal exposure, reliability outcome, emissions outcome, access effect, land and workforce implications, critical dependencies, top five downside cases and the conditions required before signature.

The sheet should show the break-even assumptions most likely to reverse the decision. It should also identify unresolved dissent. A red status should be used for any missing legal authority, unfunded social protection, unmodelled critical reliability risk, uncapped fiscal guarantee or unresolved land issue. Amber items should have a named owner and deadline. Green should mean evidence is complete enough for the relevant decision stage, not that the project has no risk.

The final signature block should record approval date, decision authority, independent reviewer, next formal review date and the events that trigger early reconsideration. The original signed sheet should remain in the public or audit file so later revisions can be compared with the decision that was made.

Field	Executive entry
Service need	Demand, access, reliability and timing.
Preferred pathway	Scope, capacity and delivery dates.
Cost and payer	Lifetime range, bill effect and fiscal exposure.
Top risks	Five decision-changing assumptions and mitigations.
Conditions	Items required before contract or financial close.
Review	Owner, date and early-reconsideration triggers.

Appendix P. Source notes and evidence taxonomy

Global institutional sources in this paper provide context and method. They do not replace local data. IEA investment, electricity, critical-mineral, employment and technology reports use their own definitions, scenario frameworks and reporting periods. IRENA generation-cost values are global averages for projects commissioned in a given year and should not be used as a local delivered tariff. IMF subsidy estimates distinguish explicit fiscal support from broader implicit underpricing of externalities. World Bank utility findings describe sampled utilities and sector studies rather than every utility worldwide.

For each cited global statistic, a country application should record whether the statistic is being used as a comparator, an input or a methodological reference. Comparator use is descriptive. Input use requires evidence that the value is suitable for the local case. Methodological use adopts the analytical approach while supplying local values. This taxonomy reduces the risk of importing a global number into a local model without justification.

The evidence cut-off for this edition is 24 September 2026. Later data, policy changes or market developments should be incorporated through a dated revision rather than silently replacing this edition. URLs in the reference list are provided for verification. Where a cited page is updated over time, the decision file should retain a copy or archive record of the version used for a material approval.

Appendix Q. Affordability and distribution methodology

Affordability should be measured with more than an average tariff. The core household metric is total essential energy spending as a share of disposable resources, evaluated across income groups and household types. Electricity, cooking fuel and essential transport should be considered together where reforms move costs between fuels. A household that receives cheaper electricity but loses a cooking subsidy may face a higher total burden. The analysis should therefore build representative household profiles from expenditure surveys, billing records and service-use data, then show both absolute bills and burden ratios.

Distribution analysis should separate fixed charges, volumetric charges, taxes, levies, connection costs and arrears. Fixed charges often weigh more heavily on low-use customers, while volumetric subsidies often deliver larger absolute benefits to high-use customers. The model should test lifeline blocks, targeted transfers, social tariffs, connection grants and energy-efficiency support. Each instrument should identify eligibility, administrative cost, exclusion error, inclusion error, delivery lag and funding source. Protection is incomplete if a household qualifies on paper but receives support after disconnection or debt accumulation.

Affordability analysis for firms should distinguish micro and small businesses from large industrial users. Small firms often pay a higher effective price when outages force diesel backup, spoil inventory or reduce operating hours. Large users may receive negotiated tariffs while creating dedicated network costs. The appraisal should report bill effects, outage costs, connection charges and any cross-subsidy by firm type. For essential public services, such as hospitals and water systems, the analysis should show operating-budget impacts and backup requirements.

The stress tests should include income loss, inflation, tariff reform, compensation delay, higher consumption during extreme heat and a period of poor service. The decision threshold should be defined before approval. Examples include a maximum share of vulnerable households exceeding a burden threshold, a disconnection-rate trigger or a minimum transfer coverage rate. The purpose is not to select one universal affordability threshold. It is to make the chosen threshold explicit, measurable and linked to a funded response.

Public reporting should show distribution tables before and after protection, not only the average tariff. It should also disclose which users fund the protection. A subsidy funded from general taxation has a different incidence from one funded through an electricity levy. The evaluation should retain survey limitations, informal-income uncertainty and differences between billed consumption and actual energy use. Where data are weak, the approval should require improved measurement rather than imply precision the evidence does not support.

Appendix R. Reliability, adequacy and resilience methodology

Reliability analysis should begin with a clear service standard. Resource adequacy asks whether enough dependable capacity and energy are available to meet demand under defined conditions. Operational reliability asks whether the system can withstand disturbances and remain stable. Resilience asks how the system prepares for, absorbs and recovers from severe events. These concepts overlap but should not be collapsed into one reserve-margin number. The appraisal should identify which dimension each investment improves and the evidence used to value the improvement.

An hourly adequacy model should use chronological demand and resource profiles where variable generation, storage or energy-limited resources are material. The model should represent forced outages, maintenance, imports, hydrology, fuel constraints, storage state of charge, demand response and transmission limits. Solar and wind should use weather-correlated profiles rather than average capacity factors alone. Storage should be modeled with power, energy, efficiency, duration, degradation and charging constraints. Imports should be derated when neighboring systems face correlated stress.

A central case is not enough. The model should test peak demand above forecast, lower renewable output, drought, thermal derating during heat, a major unit outage, transmission failure, fuel disruption and delayed new capacity. Compound cases are more useful than isolated sensitivities where risks are correlated. For example, extreme heat can raise demand while reducing thermal efficiency, stressing transformers and lowering hydropower availability. The output should show unserved energy, loss-of-load metrics, outage duration, restoration time and critical-load performance where data permit.

Resilience planning should identify critical facilities, black-start capability, communications, spare equipment, mutual-aid arrangements, emergency fuel and restoration logistics. The value of redundancy should be judged against the consequence of failure. A remote community, mine or island may rationally carry more backup than a strongly interconnected system. The analysis should also identify common-mode failures, where two resources that appear independent rely on the same substation, fuel route, communications network or weather pattern.

The reliability file should preserve assumptions and calibration. Historical outages provide evidence but do not define the future if load, climate, generation mix or network topology changes. Scenario results should therefore be presented as conditional. The decision record should state the reliability standard accepted by the authority, the cost of meeting a tighter standard and the groups exposed if the standard is missed. This makes reliability an explicit public-service choice rather than an implicit engineering assumption.

Appendix S. Public finance, guarantees and contingent liabilities

The fiscal appraisal should consolidate direct expenditure and contingent exposure across ministries, state-owned enterprises and public lenders. Direct items include grants, equity injections, tax expenditures, interest subsidies, social-protection payments, network funding and decommissioning costs. Contingent items include guarantees, minimum-revenue commitments, termination compensation, foreign-exchange protection, liquidity facilities and obligations that arise if a utility cannot honor a power-purchase contract. The same exposure should not be omitted because it sits in a state-owned company rather than the central budget.

Each guarantee should have a policy purpose and a priced risk. The file should state the beneficiary, covered event, cap, duration, currency, recovery rights, fee and trigger process. The analysis should estimate expected exposure where defensible and always report maximum contractual exposure. Correlation matters. A portfolio of guarantees can fail together during currency depreciation, recession, drought or an energy-price shock. Stress tests should therefore examine portfolio exposure rather than one contract at a time.

Foreign-exchange risk deserves explicit treatment in systems with local-currency revenue and imported equipment or hard-currency debt. The appraisal should show the share of cost and debt denominated in foreign currency, indexation rules, hedging terms and the payer if the local currency depreciates. A sovereign guarantee of currency convertibility or tariff indexation can lower financing cost while transferring macroeconomic risk to customers or taxpayers. The decision maker should compare this transfer with alternatives such as local-currency finance, partial hedging, reserve accounts or blended finance.

Fiscal space should be tested over the full commitment period. A grant funded in the construction year may be manageable while a twenty-year guarantee creates exposure across several budget cycles. The model should include interest-rate shocks, lower tax revenue, higher social-protection needs and support to a financially weak utility. For hydrocarbon exporters, lower commodity revenue should be included. For importers, high fuel prices and currency depreciation can create simultaneous pressure on subsidy budgets and electricity costs.

The public report should include a fiscal risk statement for major energy commitments. It should reconcile approved exposure with actual cash calls each year and explain material changes. Guarantees that no longer address a market failure should expire rather than become permanent entitlements. Where concessional finance reduces project cost, the report should distinguish the benefit to the project from the economic cost of scarce concessional capital and state why this use ranks above competing public priorities.

Appendix T. Procurement and contract forensic audit

A forensic procurement review should reconstruct the transaction from planning through operation. The first question is whether the tender reflected a genuine service need supported by system planning. The second is whether bidders received the same information and priced the same scope. The third is whether the award ranking is reproducible from published criteria and evaluation records. The fourth is whether later amendments altered price, risk or scope enough to undermine the competitive result.

The pre-tender file should include demand and system studies, site and land status, network connection requirements, environmental and social obligations, permits, revenue model, draft contract, risk allocation and evaluation method. Material uncertainty should be identified rather than hidden in bidder assumptions. If bidders price different grid responsibilities or different fuel, curtailment or land risks, the lowest nominal bid is not necessarily the lowest public cost.

The contract audit should focus on clauses that move economic value after the headline price. These include escalation, indexation, minimum offtake, deemed generation, curtailment compensation, availability bonuses and penalties, change in law, force majeure, refinancing gains, termination payments, foreign-exchange adjustment, tax treatment, step-in rights and dispute resolution. The reviewer should model a small number of realistic contract scenarios and reconcile them to the project model and public fiscal exposure.

Post-award governance should track cumulative amendments. A sequence of individually small changes can produce a material transfer. Each amendment should state cause, value, legal authority, effect on competition and whether the change would have altered the original ranking. Emergency or sole-source procurement should document the urgency, alternatives considered, price benchmark and plan to return to competition. Conflict-of-interest declarations should cover advisers, evaluators, decision makers and beneficial ownership where legally available.

Operational contract management should verify performance before payment. Metering, availability, output, outages, fuel quality, construction milestones and service-level metrics should have defined evidence and dispute procedures. The contract manager should maintain a payment register and compare actual outcomes with the bid model. At the end of each year, the authority should publish a non-confidential summary of material performance, amendments and public exposure. Procurement integrity does not end when the contract is signed.

Appendix U. Climate, lifecycle emissions and counterfactual protocol

A defensible emissions claim begins with the decision counterfactual. The baseline should describe what generation, fuel use, imports, efficiency or demand would occur without the project. A counterfactual based only on the current fleet may be wrong if a retirement, new interconnector or committed plant is already expected. The baseline should therefore include committed changes and use at least one alternative reasonable case when uncertainty is material.

For power projects, annual average grid intensity is a simple metric but can misstate marginal impact when production is concentrated in particular hours. Where data allow, hourly or seasonal marginal analysis is preferable. Storage requires special treatment because charging and discharging occur at different times. A storage project can reduce emissions if it shifts low-emission energy to high-emission hours, but the opposite is also possible. Transmission can alter dispatch across regions. Electrification shifts emissions from vehicles, boilers or cooking appliances into the power system and should be evaluated on a lifecycle or well-to-use basis suited to the decision.

Lifecycle boundaries should identify construction materials, fuel production and transport, methane leakage where relevant, operating emissions, equipment replacement and end-of-life treatment. The level of detail should be proportionate to the decision. Material sources deserve measured or well-supported factors. Immaterial sources may use standard factors with a documented rationale. Avoided emissions should not be counted twice across generators, corporate buyers and national inventories where the accounting frameworks differ.

Climate adaptation and mitigation should also be separated. A resilient grid investment may have limited direct emissions reduction but large adaptation value. A low-emission project can still be physically vulnerable to flood, heat or drought. The project file should therefore report emissions performance and climate-resilience performance as distinct outcomes. Any carbon price or social cost used in economic appraisal should identify the value, currency year, escalation rule and whether it represents a policy price, market price or analytical shadow price.

Verification should compare forecast emissions with observed operational data and an updated counterfactual. The original forecast should remain visible. If the system mix changes, the project may deliver a different emissions effect than expected even when physical output matches plan. Public claims should state the boundary, period, method and uncertainty. Where credits or certificates are issued, the accounting rules of the relevant standard should be disclosed separately from the broader system-impact analysis.

Appendix V. Utility financial recovery and performance compact

A utility recovery plan should combine revenue adequacy with operational accountability. Raising tariffs without improving collections, losses, procurement or service can transfer inefficiency to customers. Holding tariffs below efficient cost without a funded subsidy can create arrears and maintenance failure. The recovery compact should therefore establish a multi-year revenue path, service targets, loss reduction, collection improvement, capital priorities, debt management and a transparent subsidy mechanism for protected users.

The baseline should reconcile energy purchased or generated, energy sent out, energy billed, cash collected and technical losses. Commercial losses should be separated from technical losses where data permit. Receivables should be aged and major public-sector arrears identified. The utility should publish audited accounts, debt-service obligations, power-purchase commitments, foreign-currency exposure and maintenance backlog. The regulator should identify which costs are efficient and which performance gaps remain management responsibilities.

Tariff design should provide predictable adjustment rather than repeated crisis increases. Automatic formulas can reduce political delay but need safeguards for extraordinary shocks and data errors. Fuel or power-purchase pass-through should be transparent. Capital investment should enter the revenue requirement only when used and useful under the applicable regulatory framework. Service quality penalties or incentives should be material enough to affect management behavior without threatening financial stability.

Operational improvement should focus on a small set of measurable drivers: feeder and transformer losses, meter coverage, billing accuracy, collection rate, outage frequency and duration, connection time, theft, procurement cost, staffing productivity and maintenance completion. Digital investment should be linked to a business problem. A new billing or meter platform has little value if data governance, exception handling and field operations remain weak.

Government support should be conditional on the compact. Equity injections, debt restructuring or guarantees should have milestones and disclosure. Social tariffs should be funded transparently rather than financed through hidden utility arrears. The annual review should explain whether performance gains reduced the revenue requirement or improved service. The objective is a utility able to finance efficient maintenance and investment while delivering affordable, accountable service.

Appendix W. Institutional maturity model and implementation controls

Transition plans often fail because institutional ambition exceeds delivery capacity. A maturity assessment should rate the planning, regulatory, utility, procurement, fiscal, data, social and assurance functions needed for the proposed programme. The rating should be evidence-based and linked to the complexity of the next investment stage. A country does not need perfect institutions before investing, but project design should reflect the controls that exist rather than those assumed on paper.

At the foundational level, authorities need a reconciled baseline, legal mandates, basic financial reporting, standard procurement records, system operating data and a public complaints route. At the developing level, institutions add integrated planning, transparent tariff methods, competitive procurement, contract management, risk registers, targeted protection and regular performance publication. At the advanced level, institutions support probabilistic adequacy analysis, dynamic grid planning, sophisticated market design, portfolio risk management, digital assurance and independent evaluation.

Each major project should include an institutional dependency map. A battery procurement may depend on grid-code updates and dispatch rules. A private generator may depend on utility creditworthiness and tariff collection. A tariff reform may depend on a social registry and payment system. A new interconnector may depend on regional dispatch and settlement rules. If a dependency is not ready, the project should include a funded workstream, a condition precedent or a phased design that limits exposure until the institution matures.

Implementation controls should use stage gates. Concept approval confirms the service need and alternatives. Development approval confirms site, studies, consultation and preliminary economics. Procurement approval confirms tender readiness and fiscal authority. Contract approval confirms risk allocation and protection. Financial close confirms funding and conditions precedent. Commissioning confirms technical acceptance and operational readiness. Postimplementation review compares actual results with the original case. Skipping a gate should require a documented exception with an owner and deadline.

The maturity model should be updated annually. Institutional strengthening should have observable outputs, such as audited accounts issued on time, shorter connection queues, lower losses, completed procurement audits, improved complaint closure or more accurate outage data. Training hours alone are not an outcome. The central discipline is to match the pace and complexity of investment to the ability of institutions to plan, contract, operate, regulate, protect users and correct errors.

Appendix X. Scenario register and compound stress-testing design

A scenario register should distinguish forecasts from decision tests. The central planning case records the organisation's best current estimate of demand, costs, schedules and operating conditions. Sensitivities vary one assumption at a time to identify which variables drive the result. Stress scenarios combine variables that can move together during adverse events. Strategic scenarios describe materially different structural futures, such as rapid industrialisation, slower demand, a fuel-supply disruption, accelerated electrification or a different technology pathway. Each type serves a different purpose and should be labelled accordingly.

The register should include demand, peak shape, fuel prices, carbon or policy prices where relevant, exchange rates, interest rates, inflation, construction cost, schedule, renewable output, hydrology, thermal availability, storage degradation, imports, network completion, customer collections and social-protection delivery. Not every variable needs a wide range. The range should reflect historical variation, contract exposure, engineering uncertainty or a stated policy test. Where evidence is weak, use a transparent severe-but-plausible case rather than an invented probability distribution.

Compound cases should reflect causal links. A currency shock can raise imported fuel, equipment and debt-service costs while increasing inflation and weakening household income. Drought can lower hydropower, increase thermal use and raise fuel imports. Extreme heat can raise cooling load while derating generation and network equipment. A major industrial project can raise demand at the same time as a transmission project slips. These combinations often reveal vulnerabilities hidden by one-at-a-time analysis.

Each scenario should report the same outputs: delivered cost, household and firm bill effect, utility cash effect, fiscal cash and contingent exposure, unserved energy or service shortfall, emissions, access effect and the groups bearing the largest burden. The model should identify the first threshold breached and the management response. If the response takes longer than the stress event, it should not be treated as an immediate mitigation. The scenario register should therefore include response lead time and responsible owner.

Break-even analysis is often more useful than a single probability. The team should calculate the fuel price, exchange rate, capacity factor, delay, financing cost or demand level at which the preferred option loses its advantage. A narrow break-even range signals a fragile decision and a need for flexibility in contract or phasing. A wide range provides confidence without claiming certainty. The register should be updated when new evidence arrives and should preserve the original approval scenarios for later accountability.

Appendix Y. Financing architecture and cost-of-capital diagnostic

The financing diagnostic should begin with cash-flow risk rather than with a preferred financing instrument. Capital-intensive energy projects are sensitive to interest rates, tenor, refinancing risk and required equity returns. The project team should identify which risks raise the cost of capital: construction, offtaker credit, currency, convertibility, political or regulatory change, resource uncertainty, technology performance, merchant price exposure, land, permitting and grid connection. Each proposed financing intervention should address a named risk rather than subsidise returns without diagnosis.

The base financing table should show debt and equity shares, currencies, interest rate or expected return, tenor, grace period, amortisation, fees, reserve accounts, hedging, security package and refinancing assumptions. The model should state whether financing costs are nominal or real and keep the inflation basis consistent with the operating model. For public projects, the analysis should separate the government's borrowing cost from the economic opportunity cost of using scarce public balance sheet capacity. For private projects, the tariff model should show which financing assumptions are passed through to customers.

Concessional capital, guarantees and blended structures should be tested for additionality. The question is what market failure prevents an otherwise valuable project from proceeding on reasonable terms. A guarantee that lowers cost while covering a risk already controlled by the sponsor creates weak incentives. A well-targeted guarantee can address political, offtaker or currency risk that private parties cannot efficiently manage. The decision file should compare the amount of public or concessional capital committed with the private capital mobilised, while avoiding simple leverage ratios that ignore risk quality and development impact.

Local-currency finance can reduce currency mismatch but may carry higher nominal rates or shorter tenor. Foreign-currency finance may look cheaper before depreciation. The comparison should model both. Hedging costs should be included rather than treated as external. Where full hedging is unavailable, the contract should state who carries residual currency risk. A tariff indexed to foreign currency shifts risk to customers. A sovereign guarantee shifts risk to taxpayers. A reserve account shifts cost into the project. None is costless.

The financing plan should be resilient to delay and refinancing. Construction delays increase interest during construction and can push repayment into a weaker operating period. Refinancing assumptions should not be counted as savings unless credible. The project should also show debt-service coverage under downside cases and the effect of lower collections or curtailment. A financing structure is strong when the project remains serviceable under plausible stress without relying on repeated emergency public support.

Appendix Z. Land, rights, grievance and remedy protocol

Land and rights management should begin during alternatives analysis. The project team should map legal title, customary use, livelihoods, access routes, cultural sites, biodiversity constraints and existing infrastructure before a preferred site or corridor becomes fixed. The objective is to compare avoidable impacts, not only to compensate after design. The record should distinguish owners, occupants, users and groups whose livelihoods depend on common resources. Lack of formal title does not mean lack of material impact.

Engagement should provide information early enough to influence decisions. The project should record the alternatives presented, languages and formats used, attendance, material concerns and the design or mitigation changes that followed. Meeting counts are weak evidence if participants had no meaningful choice or information. Where technical studies affect people directly, summaries should explain the practical consequence rather than rely only on specialist reports. Sensitive information and personal data should be protected while the process remains auditable.

Compensation and livelihood restoration should use transparent eligibility, valuation and appeal rules. Cash compensation alone may not restore income where land, access, customers or natural resources support livelihoods. The plan should therefore identify restoration measures, delivery timing and monitoring indicators. Resettlement or relocation, where unavoidable, should be completed before displacement and should include service continuity. Construction contractors should operate under the same commitments as the project owner.

The grievance mechanism should provide multiple access channels, acknowledgement times, investigation steps, escalation and appeal. It should allow confidential complaints and protect against retaliation. Cases should be categorised so recurring problems become management information. The authority should track open cases, average closure time, overdue cases, remedies delivered and complainant satisfaction where appropriate. A grievance should not be closed merely because the company issued a response if the agreed remedy remains outstanding.

The board or public authority should receive a periodic summary of high-severity and recurring grievances, land disputes and unfulfilled commitments. Independent review is appropriate for major or contested impacts. The decision file should state which issues remain unresolved at financial close or construction start and who has authority to determine whether work proceeds. Social risk becomes more costly when treated as a communications problem after construction has already limited the available alternatives.

Appendix AA. Cybersecurity, operational technology and data governance

Modern power systems increasingly depend on digital control, communications, smart meters, remote equipment and third-party software. Cybersecurity should therefore be treated as an operational reliability issue. The asset inventory should identify critical operational technology, data flows, remote access, vendor connections, backup systems and dependencies on telecoms or cloud services. Protection priorities should follow consequence. A compromise of a billing portal differs from a compromise of protection relays or dispatch control, even though both require security.

Access should follow least privilege, with strong authentication for privileged and remote accounts. Networks should be segmented so a business-system compromise does not provide a direct path into operational control. Changes to operational settings should be logged and subject to defined authority. Vendors should have controlled, time-limited access and security obligations that survive the construction phase. Procurement should address patch support, software end-of-life, vulnerability disclosure and access to configuration data.

Resilience requires more than prevention. The operator should maintain offline or independently protected backups for critical configurations and data, test restoration and retain manual or degraded operating procedures where feasible. Incident response should define technical command, executive escalation, regulator notification, evidence preservation and public communication. Exercises should test loss of communications, corrupted telemetry, ransomware in business systems and compromised vendor credentials. Lessons should feed back into design and training.

Data governance supports both security and accountability. Meter, outage, dispatch, billing, contract and emissions data should have owners, definitions, retention rules and quality controls. Access to personal data should be restricted while aggregated operational evidence remains available for oversight. Models should record input versions and changes. A dashboard without a controlled source system can create false confidence. Material public indicators should be reproducible from source records and should include a correction process.

Cyber and data controls should be proportionate to system size but not ignored in small or remote systems. A single unsupported controller, shared password or untested backup can create a common point of failure. The annual assurance programme should review high-risk assets, vendor access, backup tests, incident closure and critical vulnerabilities. The objective is safe, recoverable operation, not a compliance certificate detached from actual system risk.

Appendix AB. Monitoring scorecard, thresholds and correction rules

Monitoring should connect the original decision to observed results. The scorecard should contain a limited number of indicators across service, affordability, finance, delivery, social outcomes and climate performance. Each indicator needs a definition, source, frequency, owner, target, alert threshold and response. Indicators should be selected because management will act when they move, not because data are easy to collect. A long dashboard with no decision rules is reporting, not control.

Service indicators include peak demand, reserve adequacy, outage frequency and duration, critical-load interruptions, connection time, voltage quality and restoration performance. Financial indicators include collections, receivables, losses, debt-service coverage, maintenance backlog, project cost and guarantee exposure. Affordability indicators include representative bills, burden ratios for protected groups, arrears, disconnections and compensation delivery. Delivery indicators include schedule variance, milestone completion, procurement actions and unresolved interface risks.

Social and environmental indicators should track grievances, remedy completion, land commitments, workforce outcomes, local service commitments and material environmental conditions. Climate indicators should report actual generation or energy savings, fuel displacement, emissions under the stated method and material changes to the counterfactual. The scorecard should keep forecasts and actual values side by side. A target should not be rewritten after underperformance without a visible explanation and approval.

Thresholds should be linked to graduated responses. An early-warning threshold triggers investigation and preparation. A control threshold triggers a defined management action. A stop or reconsideration threshold triggers executive or regulatory review. Examples include sustained reliability deterioration, a fiscal guarantee approaching a cap, a compensation programme missing coverage targets, a project delay that changes the least-cost plan or an emissions result materially below the approval case. The response owner and deadline should be preassigned.

The annual review should explain deviations, actions and whether the preferred pathway still ranks above alternatives. It should also retire indicators that no longer affect decisions and add new ones when system conditions change. Independent assurance should test a sample of source records and recalculations for the most material indicators. The scorecard becomes credible when poor results lead to visible correction, not when every indicator is presented as successful.

Appendix AC. Demand forecast, elasticity and adoption uncertainty

Demand forecasts should be treated as distributions rather than single numbers. A base case should separate underlying economic activity, population, industrial projects, appliance ownership, electrification, efficiency, distributed generation and price response. Each driver should have an owner, an evidence source, a review date and a stated uncertainty range. The forecast should distinguish energy consumption from peak demand because the two respond differently to weather, operating schedules, customer behavior and technology adoption. Where data are weak, the model should present explicit low, central and high cases instead of hiding uncertainty inside a single growth rate.

Large projects deserve separate treatment. Mines, data centers, processing plants, ports, irrigation systems and new industrial loads can change both annual energy and hourly system shape. The appraisal file should record committed projects, probable projects and speculative projects separately, with commissioning dates and ramp-up assumptions. Demand that depends on another public project should be linked to that dependency. A delayed industrial project should trigger an automatic re-run of capacity, revenue and tariff scenarios so the system does not build ahead of demand without understanding who carries the cost.

Price elasticity should be applied with caution. Short-run household response may be constrained by appliance stock, climate and the absence of substitutes, while commercial and industrial users may have greater flexibility or self-generation options. The model should therefore use customer-class-specific assumptions and should show the effect of tariff reform, efficiency standards and distributed energy on both utility sales and peak demand. Where historical elasticities come from another country, the transfer should be disclosed and sensitivity tested rather than treated as local evidence.

Forecast governance matters as much as the forecast. An annual refresh should compare actual demand, peak load, new connections, losses, distributed generation and major customer commissioning against the prior forecast. Material misses should be explained and carried into the next planning cycle. The decision record should state which investment choices are robust across the range and which depend on a narrow demand outcome. This converts forecasting from a prediction exercise into a disciplined mechanism for avoiding stranded assets, underbuilt networks and unexpected tariff pressure.

Appendix AD. Grid reinforcement, congestion and interconnection protocol

Generation economics cannot be separated from the network that moves electricity to customers. Every material generation or storage proposal should include an interconnection study covering thermal limits, voltage, stability, fault level, protection, reactive power, curtailment risk and the timing of upstream reinforcement. The study should identify which network works are required for connection, which are required for reliable operation at higher output, and which would have been needed even without the project. This distinction prevents unrelated grid expenditure from being assigned selectively to one technology or hidden from the delivered-cost comparison.

Congestion should be modeled chronologically. Annual energy balances often miss hours when local generation exceeds export capability or when demand centers cannot receive remote supply. A credible study should test representative operating conditions, planned outages, high renewable output, low demand, high demand, major contingency events and restoration states. Where curtailment is expected, the appraisal should show who bears the lost-energy risk under the contract and whether the compensation mechanism creates incentives to build generation faster than the network can absorb it.

Interconnection queues and connection agreements should use transparent readiness criteria. Projects with secure land, permits, financing, equipment plans and credible schedules should not be treated as equivalent to speculative applications. Milestones should include study completion, security posting, design approval, construction readiness and commercial operation. Capacity reservations should expire or reduce when milestones are missed, subject to fair extension rules for delays outside the developer's control. The objective is to protect scarce network capacity from indefinite reservation while preserving bankability for projects that are genuinely advancing.

Network reinforcement decisions should use options analysis. Reconductoring, dynamic line rating, reactive support, transformer upgrades, storage, demand response, topology changes and new lines may solve different parts of the same constraint. The least-cost answer should be tested against resilience, construction time, land access, maintainability and future expansion. The final record should explain the constraint, the alternatives considered, the reason for selection, the cost allocation and the trigger for the next reinforcement stage. This creates an auditable link between system need and capital expenditure.

Appendix AE. Storage sizing, duration and replacement economics

Storage should be appraised by the service required rather than by megawatts and megawatt-hours alone. The study should define the operating problem first, such as frequency response, ramp management, peak capacity, renewable shifting, outage support, black start or network deferral. Each service has different requirements for power, duration, response time, state of charge, cycling and availability. A design optimized for one service should not be assumed to provide another service at full value at the same time. The dispatch model should enforce those operational constraints explicitly.

Sizing should use chronological simulations that capture the sequence of charging and discharging opportunities. Average-day analysis can overstate performance because difficult periods may occur after several hours or days of adverse conditions. The model should test seasonal patterns, prolonged low renewable output, high demand, forced outages and transmission constraints. It should report unserved energy, reserve shortfalls, curtailment, cycles, depth of discharge and state-of-charge distribution. Where storage is credited with firm capacity, the accreditation method and reliability standard should be disclosed.

Lifecycle economics should include degradation, augmentation, auxiliary consumption, warranty limits, replacement timing, insurance, fire protection, software and end-of-life obligations. A low initial equipment price is not enough. The financial model should show usable capacity over time and the cost of maintaining the contracted service through the full term. If augmentation is assumed, its timing, quantity, price and financing should be visible. If recycling or residual value is credited, the basis should be conservative and separated from core project economics.

The contract should align payment with the service customers need. Availability payments, energy arbitrage revenue, ancillary-service revenue and capacity value should not be double counted. Performance tests should verify power, usable energy, response, efficiency and availability under defined conditions. Repeated underperformance should lead to cure obligations, payment reduction or replacement. A public decision should also compare storage with transmission, flexible generation, demand response and operational reform so the selected solution reflects the system problem rather than a preference for a particular asset class.

Appendix AF. Dispatchable capacity, reserve and adequacy options

Adequacy planning should begin with the reliability outcome to be protected, not with a predetermined technology. The model should represent hourly or sub-hourly demand, variable generation, hydro conditions where relevant, generator forced outages, planned maintenance, transmission limits, imports, demand response and storage. It should test many weather and outage combinations because a system that looks sufficient in an average year may fail during correlated stress. The result should report the frequency, duration and magnitude of shortfalls, not only a reserve-margin percentage.

Dispatchable resources differ in start time, minimum stable output, ramp rate, fuel dependence, maintenance requirements, emissions, water use and black-start capability. Capacity comparisons should therefore include operational suitability as well as capital cost. A low-cost unit that cannot start quickly or obtain fuel during a disruption may provide less resilience than its nameplate rating suggests. Conversely, an expensive peaking resource may have high insurance value if used rarely but available during critical hours. The appraisal should disclose the service each asset is expected to provide.

Fuel security should be tested as a system risk. The plan should examine delivery routes, storage days, supplier concentration, currency exposure, contract flexibility and the consequence of a disrupted terminal, pipeline, road or port. Dual-fuel capability should receive value only where the alternate fuel is physically available, permitted, stored and tested. Where domestic fuels are involved, production, processing and transport assumptions should be reconciled with realistic commissioning schedules. Emergency fuel arrangements should be documented before they are counted as resilience.

Procurement should preserve optionality when the demand and technology outlook are uncertain. Modular additions, shorter construction periods, staged commitments and convertible sites can reduce the cost of forecast error. The decision record should show the cost of being early, the cost of being late, and the conditions under which the next block of capacity will be authorized. This stage-gated approach helps prevent overbuilding while ensuring enough lead time for resources that are necessary for reliability.

Appendix AG. Tariff reform and vulnerable-customer protection

Tariff reform should separate the revenue requirement from the distribution of that requirement across customers. The first step is to determine the efficient cost of service, including prudent operating expenditure, maintenance, losses, depreciation, financing, taxes and required investment. The second step is to decide how costs are recovered through fixed charges, energy charges, demand charges, time-varying rates, connection fees and public funding. Policy choices about cross-subsidy should be explicit so the financial position of the utility is not obscured by tariff design.

Affordability analysis should use household-level or income-group data where possible. Average bills can conceal severe burdens for low-income customers with different household size, appliance stock, climate exposure or housing efficiency. The analysis should test bill impacts across consumption bands and income groups and should identify customers who depend on electricity for essential medical or accessibility needs. Protection should be designed before a major tariff change takes effect, with clear eligibility, funding and review rules.

Targeted protection is generally more transparent when it appears as a defined benefit rather than an unfunded obligation on the utility. Options include lifeline blocks, bill credits, social tariffs, connection support, arrears plans and direct transfers. Each instrument should be tested for coverage, exclusion error, administrative burden, fraud risk, work incentives and fiscal cost. Broad subsidies should disclose who receives the largest monetary benefit and whether the mechanism weakens incentives for efficiency or distributed generation.

A reform package should include service obligations and a public performance compact. Customers are more likely to accept higher charges when reliability, connection times, outage communication, billing accuracy and complaint resolution improve in parallel. The utility should publish measurable indicators and a timetable. If expected efficiency savings fail to materialize, the shortfall should not automatically pass through to customers without review. Tariff reform becomes more durable when price, protection, utility performance and accountability move together.

Appendix AH. Foreign exchange, sovereign risk and cost-of-capital stress test

Energy infrastructure often combines local-currency revenue with foreign-currency debt, imported equipment or fuel. The appraisal should map every material currency exposure across construction, operations, debt service and maintenance. A base case should show the assumed exchange rate, inflation, interest rate and hedge structure, then stress each variable separately and in combination. The objective is to identify the point at which tariff requirements, public support or project liquidity become difficult, rather than to assume a stable macroeconomic path.

Cost of capital should be decomposed into observable components where possible. The model should distinguish the risk-free benchmark, country risk, credit spread, tenor, currency, fees, reserve accounts, political-risk cover, guarantees and equity return. Concessional finance should be shown separately from commercial finance so decision makers understand the value and scarcity of the subsidy embedded in the financing structure. A low headline interest rate may still produce a high all-in cost when fees, hedging and short tenor are included.

Government support should be valued as an exposure even when no cash leaves the budget at financial close. Guarantees, termination payments, minimum-revenue clauses, convertibility undertakings and fuel-payment support can transfer risk to the public balance sheet. The fiscal register should record the beneficiary, maximum exposure, trigger, probability range where estimable, mitigation and reporting owner. Scenario testing should include a depreciation event combined with project underperformance or lower demand because these risks can reinforce one another.

Financing comparisons should use the same service and risk allocation. A public loan, sovereign guarantee or concessional facility should not be compared with private finance as though the structures carry identical public risk. The decision record should show the project's weighted cost of capital, the public contingent exposure, the expected tariff effect and the refinancing assumptions. A refinancing gain should not be treated as guaranteed. The project should remain viable under a credible downside case without relying on future capital-market conditions that have not been secured.

Appendix AI. Workforce, local content and transition capability plan

A credible transition plan should identify the occupations and capabilities needed to build, operate, maintain and regulate the future system. The workforce model should distinguish temporary construction labor from long-term technical roles, utility operations, system planning, cybersecurity, environmental management, finance, procurement and emergency response. Skills gaps should be mapped against the project schedule because training that arrives after commissioning does not reduce execution risk. The plan should specify which skills require formal certification, supervised experience or manufacturer authorization.

Local-content objectives should be tied to capability and competitiveness rather than headline percentages alone. The procurement plan should classify packages that local firms can supply now, packages that become feasible with targeted development, and packages where international supply remains necessary for safety, warranty or scale. Supplier-development support should focus on quality systems, HSE performance, financial controls, bid preparation, logistics and technical standards. Progress should be measured through qualified suppliers, contract performance and sustained capability, not only expenditure booked locally.

Labor-transition measures should identify workers and communities exposed to declining technologies or changing operating models. The response may include retraining, recognition of prior learning, redeployment, income support, mobility assistance and local economic development. Programs should start early enough for people to make informed choices. Eligibility, duration and funding should be published. Outcomes should track completion, placement, retention and earnings where lawful and feasible, while protecting personal information.

Capability planning also applies to public institutions. Regulators, ministries, utilities, system operators and emergency services need staff who understand new contract structures, power-system behavior, digital risks, environmental obligations and financial exposures. Training should be linked to real responsibilities and institutional succession, not isolated workshops. The decision file should identify critical roles, backup coverage and the consequence of vacancies. A transition is more resilient when the institutions responsible for oversight are strengthened at the same pace as the assets they supervise.

Appendix AJ. Supply chain, critical minerals and equipment resilience

Supply-chain appraisal should identify components whose failure or delay can determine the project schedule or system availability. Transformers, switchgear, inverters, protection equipment, cables, turbines, control systems, batteries, specialized semiconductors and spare parts often have different lead times and supplier structures. The project should maintain a critical-item register with supplier, country of origin, manufacturing slot, logistics route, quality hold points, warranty, substitutes and latest required delivery date. The register should be updated through construction and early operation.

Supplier concentration should be tested at several levels. A project may have multiple vendors whose key subcomponents come from the same factory, mineral-processing region or software provider. The review should therefore look beyond the contracting entity to important tier-two and tier-three dependencies where information is available. Alternative suppliers should be assessed for technical compatibility, certification, intellectual property restrictions and redesign cost. Dual sourcing has value only when the alternative has been qualified before disruption occurs.

Critical-mineral exposure should be evaluated where material to batteries, motors, electronics and network equipment. The purpose is not to predict commodity prices precisely. It is to understand concentration, substitution options, recycling pathways, inventory needs and contract mechanisms. Procurement teams should avoid locking the project into unnecessary specifications that restrict substitutes without improving performance or safety. Long-term agreements should balance price security with flexibility if technology or material markets change.

Resilience planning should include spares and repair strategy after commissioning. A low-cost procurement that leaves the operator dependent on overseas repair for a single critical board or control module may create large outage risk. The asset-management plan should classify critical spares, storage conditions, shelf life, test intervals and replenishment triggers. Cybersecurity support, firmware access and vendor continuity should form part of supplier due diligence. The full decision should compare purchase price with lifecycle availability and recovery time.

Appendix AK. Project governance, stage gates and change control

Large transition projects should pass defined stage gates before additional public or corporate capital is committed. A typical sequence includes strategic need, option selection, feasibility, procurement authorization, financial close, notice to proceed, mechanical completion, commissioning and operational acceptance. Each gate should have mandatory evidence, a named decision authority and unresolved issues that are either closed or explicitly accepted. Gate approval should not rely on presentation quality. It should rely on the completeness and reliability of the decision record.

Governance should separate project advocacy from independent challenge. The sponsor is responsible for developing the business case and delivering the project. Finance, legal, engineering, environmental, procurement and risk functions should review assumptions within their mandates. For material projects, an independent reviewer should test the model, major contracts, schedule and system need. Dissent should be recorded with the final decision so later reviewers can distinguish a risk that was unknown from a risk that was understood and accepted.

Change control should focus on cumulative impact. A sequence of individually small scope changes, contract amendments or schedule extensions can materially alter the original economics. The project should maintain a baseline for cost, schedule, output, risk allocation and expected service, then record every approved change against that baseline. Thresholds should trigger escalation when cumulative cost, delay, performance reduction or contingent exposure exceeds the authority of the current decision level. Benefits should be revalidated when the project moves materially away from its approved basis.

Post-completion review should compare the final asset with the approved business case. The review should cover capital cost, schedule, output, reliability, operating cost, tariff effect, environmental performance, local-content outcomes, claims and unresolved liabilities. Lessons should be assigned to future standards or procurement templates rather than filed as narrative only. Good governance does not eliminate forecast error. It creates a traceable process for recognizing error early, correcting course and learning before the next investment decision.

Appendix AL. Independent assurance, audit trail and publication controls

Independent assurance should be proportionate to the decision risk. A small reversible pilot does not need the same review as a long-term power-purchase agreement, sovereign guarantee or major transmission program. The assurance plan should identify the claims most capable of changing the decision, then assign the right reviewer to each. Engineering assumptions should be tested by relevant technical specialists, financial models by finance specialists, legal obligations by counsel, environmental claims by competent practitioners, and data lineage by reviewers who can reproduce the calculation.

The audit trail should preserve source data, model versions, assumptions, approvals and changes. Public summaries may simplify the material, but the underlying record should show where each material number came from and who approved its use. Spreadsheet controls should include version management, protected formulas where appropriate, independent checks and reconciliation to source systems. When a model is updated, the prior approved version should remain recoverable. This protects institutional memory when staff, advisers or governments change.

Publication controls should distinguish observed facts, modeled estimates, scenarios, targets and recommendations. Citations should support the specific claim beside them and should prefer primary or authoritative sources where available. Dates and units should be explicit. A global benchmark should not be presented as a local forecast without adjustment. Charts should preserve scale integrity, identify the measurement period and disclose material exclusions. If evidence is uncertain or contested, the document should state the limitation rather than imply precision that the source does not support.

Before release, the final document should pass content, legal and visual checks. Content review should test internal consistency, arithmetic, citations and claim classification. Legal review should address confidential information, contractual restrictions and regulated disclosures where relevant. Visual review should check page flow, tables, figures, links, fonts, headings and accessibility. The publication record should retain the approved file, review date and owner. This closes the chain from analysis to decision to public accountability and makes later scrutiny easier to answer with evidence rather than reconstruction.

Appendix AM. Distributed energy, customer generation and flexible demand

Distributed energy should be incorporated into system planning as a forecastable resource with uncertain behavior, not treated as invisible load reduction. The planner should estimate rooftop solar, behind-the-meter storage, efficient appliances, electric vehicles, controllable industrial loads and other customer resources by class and location. Adoption assumptions should reflect economics, financing access, interconnection rules, roof or site suitability and customer turnover. The model should distinguish installed capacity from dependable contribution at system peak and should account for the possibility that customer generation changes the timing rather than the total amount of network stress.

Tariff design and interconnection policy should preserve fair cost recovery while rewarding services that reduce system cost. Export compensation, demand charges, fixed charges and time-varying prices should be tested for their effect on utility revenue, customer adoption and network investment. Flexible demand should receive value only where response can be measured, called when needed and sustained for the required period. Programs should define baseline methods, notification rules, performance verification and penalties for non-delivery. The planning model should avoid counting the same flexibility both as reduced demand and as a separate capacity resource.

Distribution networks require visibility as customer resources grow. Utilities should identify feeders where reverse power flow, voltage variation, protection coordination or transformer loading may constrain adoption. Hosting-capacity studies, targeted monitoring and streamlined interconnection can reduce delay while protecting safety. Where network upgrades are needed, the cost-allocation rule should be published in advance. The objective is to integrate customer investment into system planning without transferring hidden costs or creating avoidable barriers to participation.

Appendix AN. Water, land and climate-resilience interface

Energy projects depend on land, water and climate conditions that may change over the asset life. The appraisal should identify water withdrawal, discharge, cooling demand, flood exposure, drainage, erosion, wildfire, extreme heat, wind, salt exposure and access-road vulnerability where relevant. Historical averages should not be the only basis for design. The project should test credible future conditions and define which design standards, safety margins and operating restrictions are being used. Where uncertainty is high, adaptation pathways should allow later reinforcement without requiring a complete redesign.

Land assessment should include competing uses, ecological sensitivity, community access, cultural values, future expansion and the cumulative footprint of associated infrastructure. A generation site, transmission corridor, substation, road and water system may create impacts that are individually small but significant in combination. Alternatives should compare footprint, constructability, access and restoration requirements. Land agreements and permits should align with the expected asset life, decommissioning period and any future repowering option.

Resilience expenditure should be tied to a defined failure mode and avoided consequence. Raising equipment, improving drainage, hardening structures, adding redundant communications or relocating critical controls may have different cost-effectiveness depending on the hazard. The decision file should state the hazard, threshold, consequence, adaptation measure and residual risk. Emergency plans should be coordinated with local authorities and neighboring infrastructure where failure could affect communities beyond the project boundary.

Appendix AO. Decommissioning, repowering and end-of-life funding

End-of-life obligations should be considered at approval rather than deferred until the asset is near retirement. The project should identify dismantling, waste handling, hazardous materials, recycling, site restoration, transmission or pipeline removal, foundation treatment and long-term monitoring obligations. Cost estimates should state the price basis, timing, escalation and residual-value assumptions. Salvage revenue should be separated from gross closure cost so the obligation is visible even if commodity or recycling markets weaken.

Funding mechanisms should match the risk that the responsible entity may no longer have sufficient resources when closure occurs. Options include funded reserves, bonds, guarantees, insurance, parent support or regulated recovery mechanisms. The chosen structure should be reviewed periodically as costs, ownership and asset condition change. Repowering should not automatically cancel existing closure obligations. The project should show which infrastructure will be reused, which will be removed and how the new asset changes the timing and amount of the original liability.

A decommissioning plan should include data preservation and ownership transfer. Drawings, equipment records, contamination data, land agreements and monitoring results may be needed decades after commissioning. The operator should maintain records in formats that remain accessible and should define handover requirements if the asset is sold. Closure performance should be verified against measurable criteria and unresolved obligations should remain visible until formally discharged.

Appendix AP. High-load customers and large connection requests

Large new customers can materially change generation, network and tariff requirements. Connection appraisal should therefore test the customer's demand profile, ramp-up schedule, power quality needs, flexibility, backup arrangements and creditworthiness. A single peak-demand number is insufficient. The utility should understand hourly shape, seasonal behavior, sensitivity to price and the consequence of delayed commissioning. Where the load is associated with a project under development, evidence of financing, permits and construction progress should support the probability assigned to the forecast.

Cost allocation should distinguish customer-specific facilities from shared network reinforcement. The connection agreement should define deposits, security, construction milestones, energization conditions, curtailment rights and the treatment of stranded investment if the customer delays or cancels. Large loads should not impose material unrecovered costs on existing customers without an explicit policy decision. At the same time, connection rules should recognize the wider economic value of new industrial activity and allow transparent public support where government chooses to provide it.

Flexibility can reduce system cost if it is technically and contractually dependable. Data centers, mines, industrial plants and other large users may offer load shifting, interruptibility, on-site generation or storage. The system operator should value those services under defined conditions and verify delivery. Critical loads that cannot curtail should be modeled accordingly. The final decision should state the network works required, the timing risk, the security provided and the effect on other customers under both successful and delayed project scenarios.

Appendix AQ. Regional interconnection and cross-border power trade

Cross-border electricity trade should be appraised as both an economic opportunity and a dependency. The analysis should identify transmission capacity, losses, congestion, market rules, settlement currency, scheduling rights, reserve sharing and emergency support. Import availability should be tested during regional stress, not assumed from average surplus. A neighboring system may face the same drought, heat event, fuel disruption or peak-demand period. Firm capacity value should therefore reflect contractual priority and correlated risk.

Commercial arrangements should address price formation, transmission charges, imbalance settlement, curtailment, force majeure, currency convertibility and dispute resolution. Governments should understand whether public guarantees or sovereign undertakings are embedded in the trade structure. The appraisal should compare imported energy with domestic alternatives using the same delivered-cost boundary and reliability standard. Strategic value may justify diversification, but the decision should state how much dependence on one corridor, market or counterparty is acceptable.

Interconnection can also improve resilience by sharing reserves, balancing variable generation and diversifying resource portfolios. These benefits require compatible technical standards, operating protocols, telemetry, cybersecurity and restoration procedures. Joint exercises should test emergency communication and islanding or resynchronization where relevant. Expansion should proceed through staged commitments so later capacity is added when utilization, reliability benefits and regional market development justify the next investment.

Appendix AR. Emergency preparedness, black start and system restoration

Reliability planning should include the ability to recover after a major disturbance, not only the probability of avoiding one. The system should maintain a restoration plan that identifies black-start resources, energization paths, critical substations, communication channels, fuel requirements and priority loads. The plan should account for the possibility that telecommunications, transport or fuel infrastructure is also disrupted. Roles between generators, utilities, system operators, emergency services and government should be clear before an event occurs.

Black-start capability should be demonstrated through testing rather than assumed from equipment specifications. Tests should confirm starting energy, auxiliary loads, synchronization, ramping and the ability to energize the intended network path. Batteries and inverter-based resources may provide useful restoration services, but the operating strategy should define state-of-charge requirements and control modes. Conventional units should confirm fuel availability and starting reliability after extended outages. Test findings should update procedures and maintenance priorities.

Exercises should include severe but plausible scenarios, including loss of a major station, widespread network damage, cyber disruption, storm impact or fuel interruption. After-action reviews should record communication failures, unavailable equipment, procedural gaps and recovery times. Corrective actions should have owners and deadlines. Restoration readiness is a continuing operating obligation, not a one-time commissioning test.

Appendix AS. Physical climate risk and adaptation pathway

Physical climate risk should be assessed at the asset and system level. The review should identify hazards relevant to the location and asset type, including flood, heat, drought, wind, wildfire, landslide, coastal exposure and changing hydrology. Hazard information should be paired with asset vulnerability and consequence. A high hazard does not automatically imply high project risk if design, location or redundancy reduces exposure. Conversely, a moderate hazard may become material where failure affects a critical node with no substitute.

Adaptation decisions should consider timing. Some measures are economical at initial construction, while others can be triggered later if monitored conditions cross a threshold. The plan should define signposts such as observed flood level, temperature exceedance, erosion rate or water availability and identify the action linked to each signpost. This avoids both underinvestment and premature expenditure. Design choices should preserve future options where uncertainty remains large.

System-level adaptation should examine common-mode failure. Multiple assets designed independently may rely on the same road, substation, river crossing, communications network or cooling-water source. The resilience review should map those shared dependencies and test simultaneous disruption. Investment priorities should reflect consequence, recovery time and the availability of alternatives. Adaptation performance should be reviewed after major events and as hazard information improves.

Appendix AT. Public communication, transparency and decision accountability

Major energy decisions affect bills, public finances, land use, reliability and long-term infrastructure choices. Communication should therefore begin with the decision being made, the alternatives considered and the evidence used. Public material should separate confirmed facts from forecasts and should explain uncertainty in language that does not imply false precision. Where commercial confidentiality limits disclosure, the authority should still publish the decision logic, material public exposures and the method used to test value for money.

Consultation should be designed to improve the decision rather than to validate a predetermined outcome. Stakeholders should receive enough information and time to comment on issues that affect them, and the final record should show how material concerns were addressed. Technical disagreement should not be reduced to a popularity contest. Decision makers should distinguish evidence, values and distributional choices, then state where judgment was required. This makes disagreement more transparent and easier to revisit when circumstances change.

Accountability continues after approval. Progress reports should compare cost, schedule, service outcomes, tariff impacts and major risks against the approved baseline. Material deviations should be explained with corrective action and updated forecasts. Public reporting should avoid selectively presenting favorable indicators while omitting failed assumptions. A consistent reporting framework improves trust because stakeholders can see not only what the project achieved, but also where expectations changed and how decision makers responded.

Source audit matrix

This matrix identifies the basis for selected high-value claims. The classification prevents observed data, estimates and scenarios from being presented as the same kind of evidence.

Claim used in paper	Class	Source
Global energy investment reaches USD 3.4tn in 2026; about USD 2.2tn clean-energy categories	Institutional estimate	IEA [1]
Annual grid investment needs to rise about 50% from roughly USD 400bn by 2030	Scenario-linked system estimate	IEA [4]
2025 global average LCOE: solar PV USD 44/MWh, onshore wind USD 33/MWh	Observed project database aggregate	IRENA [3]
655m people still lack electricity access	Institutional access estimate	SDG7 custodians [6]
About 40% of sampled developing-country utilities cover operating and debt-service costs	Cross-country study finding	World Bank [14]
Battery storage additions reached 108 GW in 2025	Institutional market estimate	IEA [11]
Renewable employment estimated at 16.6m in 2024	Institutional employment estimate	IRENA/ILO [22]
Data-centre electricity consumption reaches about 945 TWh by 2030 in base case	Scenario projection	IEA [24]
Current policies imply about 2.8 C warming this century in EGR 2025 assessment	Scenario assessment	UNEP [19]
Critical-mineral refining remains highly concentrated	Market and supply-chain analysis	IEA [21]

Glossary of decision terms

Term	Working definition
Affordability	The relationship between energy-service cost and the resources of a household or firm, assessed across user groups rather than by average price alone.
Adequacy	The ability of available resources and networks to meet demand under defined conditions.
Availability	The share of time or specified periods in which an asset is capable of delivering its contracted service.
Baseline	The documented starting condition against which change is measured.
Break-even value	The value of an assumption at which the preferred decision changes.
Capacity factor	Actual energy output over a period divided by the output that would occur at continuous full rated power.
Contingent liability	A potential public or corporate obligation that becomes payable if a specified event occurs.
Cost of capital	The required return or financing cost associated with debt and equity, reflecting risk and market conditions.
Counterfactual	The credible alternative state of the system expected without the proposed action.
Curtailment	A reduction in potential generation or load due to system, market or operational constraints.
Deemed generation	Contractual energy treated as delivered for payment purposes under specified circumstances even when physical generation is curtailed or unavailable to the buyer.
Delivered cost	The cost of providing usable energy service at the point of consumption, including relevant network, balancing, reliability and financing effects.
Demand response	A change in electricity consumption in response to prices, incentives or system instructions.
Distributional analysis	Assessment of how costs, benefits and risks differ across income groups, firms, locations or other affected groups.
Effective access	Sustained ability to obtain and afford a useful quality of energy service, not connection status alone.
Explicit subsidy	A fiscal transfer or underpricing that creates a direct budgetary or public-enterprise cost under the relevant accounting definition.
Firm capacity	Capacity expected to be available during system stress, based on the applicable adequacy method.
Foreign-exchange risk	Exposure to changes in currency value where revenues, costs, debt or contracts use different currencies.
Full cost ledger	A structured record of direct, financing, network, fiscal, social and contingent costs with the payer and timing identified.
Guarantee	A commitment by one party to meet specified obligations if another party fails or a defined event occurs.
Implicit subsidy	An analytical estimate of underpricing relative to a broader benchmark that may include environmental or other external costs. It is not the same as a direct budget transfer.

Term	Working definition
Levelised cost of electricity	Discounted lifetime cost of generation divided by discounted lifetime electricity output under a defined methodology.
Load	Electricity demand at a point in time or over a period.
Losses	Energy entering a network but not billed to end users, comprising technical losses and, where applicable, commercial losses.
Marginal emissions	The emissions change associated with an incremental change in generation or demand, which can differ from the average grid emissions rate.
Offtaker	The buyer contractually committed to purchase power or another energy product.
Payer map	A trace of which households, firms, utilities, investors or public bodies ultimately bear each material cost or downside risk.
Reliability	The ability of the system to provide service within defined adequacy and operational standards.
Resilience	The ability to prepare for, absorb, recover from and adapt to severe disruptions.
Scenario	A conditional set of assumptions used to examine a possible future, not necessarily a prediction.
Service standard	The defined quantity, quality, access and reliability outcome used to compare alternatives.
Social protection	Targeted policies or transfers intended to protect vulnerable people from unacceptable welfare loss during reform or shocks.
Stress test	An analysis of system or financial performance under a defined adverse condition or combination of conditions.
Stranded cost	A cost associated with an asset or commitment that is no longer fully recoverable or useful under changed conditions.
System boundary	The set of assets, costs, emissions and services included in an analysis.
Utility solvency	The ability of a utility to meet operating, maintenance, debt and contractual obligations on a durable basis.
Weighted average cost of capital	A weighted measure of the required return on debt and equity used in financial appraisal.

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Publication note

This edition is designed for policy, board and executive scrutiny. The proposed decision framework is an original synthesis. Quantitative claims attributed to institutions retain their source definitions and should be refreshed before use in a live investment or policy decision.