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FROM DEPENDENCE TO SOVEREIGNTY:

RENEWABLE ENERGY INVESTMENT ROADMAP TOWARDS JUST TRANSITION IN BANGLADESH

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Change Initiative is a Bangladesh-based research and advocacy organization focused on designing practical, nature-smart, and policy-driven solutions for sustainable development. This study presents a comprehensive investment roadmap for a decentralized renewable energy investment in Bangladesh (2026-2040), integrating innovative financial modelling and governance reforms to achieve national energy sovereignty and macroeconomic resilience.

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List of Abbreviations

Abbreviation	Full Form
ADF	Augmented Dickey-Fuller (Unit Root Test)
ARDL	Autoregressive Distributed Lag
BCPP	Bangladesh Climate Prosperity Plan
BDP 2100	Bangladesh Delta Plan 2100
BERC	Bangladesh Energy Regulatory Commission
BESS	Battery Energy Storage System
BPDB	Bangladesh Power Development Board
CAPEX	Capital Expenditure
dMRV	Digital Monitoring, Reporting, and Verification
ECT	Error Correction Term
FDI	Foreign Direct Investment
FPV	Floating Solar Photovoltaic
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GEPI	Generation Electricity Price Index
GWh	Gigawatt-hour
IDCOL	Infrastructure Development Company Limited
IEPMP	Integrated Energy and Power Master Plan
IRR	Internal Rate of Return
LCOE	Levelized Cost of Energy
LDC	Least Developed Country
LNG	Liquefied Natural Gas
MDB	Multilateral Development Bank
MRV	Monitoring, Reporting, and Verification
NDC	Nationally Determined Contributions
OPEX	Operating Expenditure
PPA	Power Purchase Agreement
RE	Renewable Energy
SREDA	Sustainable and Renewable Energy Development Authority
TWh	Terawatt-hour
UECM	Unrestricted Error Correction Model
VPP	Virtual Power Plant

Executive Summary

Bangladesh's transition toward high-middle-income status depends on a national energy system that is no longer tethered to global fuel price volatility. The current reliance on imported gas and coal creates a persistent drain on foreign exchange reserves and exposes the national budget to external inflationary shocks that disrupt long-term planning. This roadmap is motivated by the urgent need to secure a predictable, domestic energy foundation that supports industrial maturity without the land-use conflicts typical of utility-scale projects. By prioritizing decentralized infrastructure, the state can align its development goals with a resilient macroeconomic framework that transforms energy from a fiscal burden into a permanent pillar of national self-sufficiency and economic resilience.

Econometric modeling indicates that the trajectory for national power demand is shifting significantly as the economy matures. Total demand of Bangladesh is forecasted to grow to 157,850 GWh by 2030, eventually reaching 316,500 GWh by 2040. To maintain system stability and meet national climate commitments, the roadmap calculates that the power system must successfully integrate:

- 7,449 MW of renewable energy by 2030.
- 21,514 MW of renewable energy by 2040.

The recommended path follows a decentralized, "Zero-Arable Land" strategy requiring a cumulative investment of $32.82 billion. This strategy avoids the displacement of agricultural soil by utilizing vertical industrial spaces and underutilized water bodies. By adopting the Localized Stability model, the roadmap integrates 21,514 MW of capacity with dedicated storage systems. This ensures that intermittent generation becomes dispatchable during evening peaks, providing a bankable alternative to expensive national grid overhauls. This approach provides a clear technical roadmap for three primary sub-sectors:

- Industrial Rooftop Solar: 12,048 MW.
- Solar Irrigation: 3,442 MW.
- Floating Solar: 1,721 MW.

Mobilizing this capital requires a transition from public-debt-led models to a multi-dimensional financing architecture. The roadmap provides a methodology to redirect capital from planned gas infrastructure toward domestic assets, yielding substantial economic benefits through avoiding technical losses and long-term price stabilization. Furthermore, the framework taps into innovative social and community finance mechanisms. This includes utilizing the vast potential of wealth-redistribution funds to provide debt-free ownership for marginalized communities and issuing dollar-denominated bonds to capture the savings of the global diaspora. By pairing these with carbon market integration and institutional de-risking tools, the roadmap converts renewable energy generation into a high-yield, sovereign-backed asset class that attracts institutional capital while empowering the productive base of the economy through direct asset ownership.

Ultimately, this study demonstrates that energy sovereignty is a measurable outcome of smart resource management and institutional reform. By shifting toward a market-facilitator model, the state can regulate a diverse ecosystem of energy producers while decentralizing the risks inherent in the transition. This roadmap is not merely a technical proposal; it is a strategic necessity for safeguarding the nation’s fiscal health and providing a foundation for community stewardship. Transitioning to a decentralized renewable energy system ensures that Bangladesh remains insulated from global volatility, anchoring its future in a resilient, self-sufficient, and economically strategic power network that fosters localized economic dignity, enhanced industrial competitiveness, and long-term prosperity for the entire population.

Chapter 1

Economic Reality and Energy Sector Landscape of Bangladesh

1.1 Introduction

The economic development trajectory of Bangladesh is currently at a critical juncture, defined by a shift from a period of high-speed growth to one characterized by structural rebalancing and heightened vulnerability to external shocks. As the nation pursues the Government of Bangladesh's target to achieve high-income status by 2041 under the Perspective Plan 2021-2041, the energy sector has emerged as both the primary driver of industrial productivity and a significant source of fiscal instability (Ministry of Power, Energy and Mineral Resources, 2023; Government of Bangladesh, 2020). Recent macroeconomic indicators suggest that the traditional model of energy-intensive growth, fuelled by domestic natural gas and subsidized imports, is no longer sustainable under the prevailing fiscal and monetary conditions (International Monetary Fund, 2026).

Moreover, current geopolitical instability, particularly the escalating Middle East conflicts, poses immediate and medium-term threats to this recovery. Geopolitical tensions involving major suppliers like Qatar and the UAE threaten the global energy supply chain, specifically through the Strait of Hormuz, a chokepoint through which nearly two-thirds of Bangladesh’s LNG supplies passed in 2025 (Energy Tracker Asia, 2026). These disruptions have driven Brent crude prices to spikes of $92 to $119 per barrel, directly inflating the national import bill and putting intense pressure on the exchange rate (Policy Research Institute, 2026).

Following the global energy supply chain volatility and the domestic disruptions of the mid-2024 period, Bangladesh's GDP growth experienced a notable deceleration, falling to 3.7% in the 2024-2025 fiscal year (FY25) from 5.8% in FY23 (International Monetary Fund, 2026). This slowdown was driven by a combination of factors of production delays resulting from social unrest, a tighter monetary policy stance designed to combat persistent inflation, and a significant contraction in both public and private investment (World Bank, 2025). The World Bank projects a gradual recovery, with growth expected to rebound to 4.7% in FY26 and potentially reach 6.3% by FY27, provided that the government implements bold structural reforms in the financial and energy sectors (World Bank, 2025).

A core challenge remains the mobilization of domestic revenue. The tax revenue-to-GDP ratio fell sharply in FY25, exacerbating the fiscal deficit and limiting the government's capacity to fund critical infrastructure and climate adaptation projects (International Monetary Fund, 2026). In this context, the energy sector's heavy reliance on subsidies particularly for imported fossil fuels and liquid-fuel-based peaking plants has become a major macro-financial risk. The rationalization of these subsidies is now viewed by international financial institutions as an essential step toward restoring fiscal discipline and creating space for inclusive development (International Monetary Fund, 2026).

Table 1: Key Economic Indicators of Bangladesh, FY2025-FY2027

Economic Indicator	FY2025 (Actual)	FY2026 (Projected)	FY2027 (Projected)
Real GDP Growth (Annual%)	3.7	4.7	4.7
CPI Inflation (Annual Average %)	10	8.9	6
Tax Revenue (% of GDP)	6.9	7.2	9.3
Central Govt. Overall Balance (% of GDP)	-2.9	-4.3	-4.7
Gross International Reserves (USD Billion)	21.4	30.9	35.8

Source: Compiled from International Monetary Fund (2026) and World Bank (2025) development updates.

The heavy reliance on subsidies has become a major macro-financial risk. For FY2025-26, the power sector has been allocated Tk 370 billion in subsidies, with an additional Tk 90 billion for LNG (IEEFA, 2025). To cope with rising costs, Petrobangla has proposed increasing LNG subsidies to Tk 260 billion (Energy Tracker Asia, 2026). Consequently, a transition toward renewable energy (RE) is a strategic macroeconomic necessity. Recent studies highlight the potential gains of this shift: a single 1MW rooftop solar plant can save the country approximately $0.18 million (Tk 22.4 million) per annum in fuel import bills, while scaling to 2,000MW could save the Bangladesh Power Development Board (BPDB) up to $1 billion annually (IEEFA, 2025).

1.2 Navigating the Energy Trilemma: Balancing Security, Equity, and Sustainability

Bangladesh's energy strategy is governed by the "Energy Trilemma," a framework that seeks to balance three competing objectives: energy security, energy equity (affordability and access), and environmental sustainability. While the nation has made remarkable strides in expanding electricity access, it continues to face profound challenges in the dimensions of security and sustainability (World Energy Council, 2023).

1.2.1 The Risk of Import Dependent Energy Security

The security dimension of the trilemma focuses on a nation's capacity to meet current and future energy demand reliably and to withstand system shocks. Bangladesh's energy security score fell to 40.2 in 2023 ranking 83rd globally in its Energy Trilemma Index, reflecting a high vulnerability due to rapid depletion of local gas and a surge in volatile LNG and coal imports (World Energy Council, 2023; IEEFA, 2025).

The current reliance on imported primary energy for over 60% of power generation creates a vulnerability to geostrategic perturbations and supply chain disruptions (Ministry of Power, Energy and Mineral Resources, 2023). Import costs reached $20 billion in 2024, causing BPDB's operating losses to double and straining foreign exchange reserves (Khan, 2023; Change Initiative, 2026). Currently, fuel shortages render 23% of power plants inoperable, while outages cost the economy 1.5% of GDP annually (World Bank, 2022; Zero Carbon Analytics, 2026; Policy Research Institute, 2026). While oil-fired peaking plants cost twice the grid average, renewables remain underutilized at only 4.59% capacity (IEEFA, 2025; Khan et al., 2023). To mitigate industrial load shedding and fiscal instability, the government prioritizes domestic renewable energy as a zero-fuel-cost strategic necessity (World Bank, 2025; SREDA, 2024).

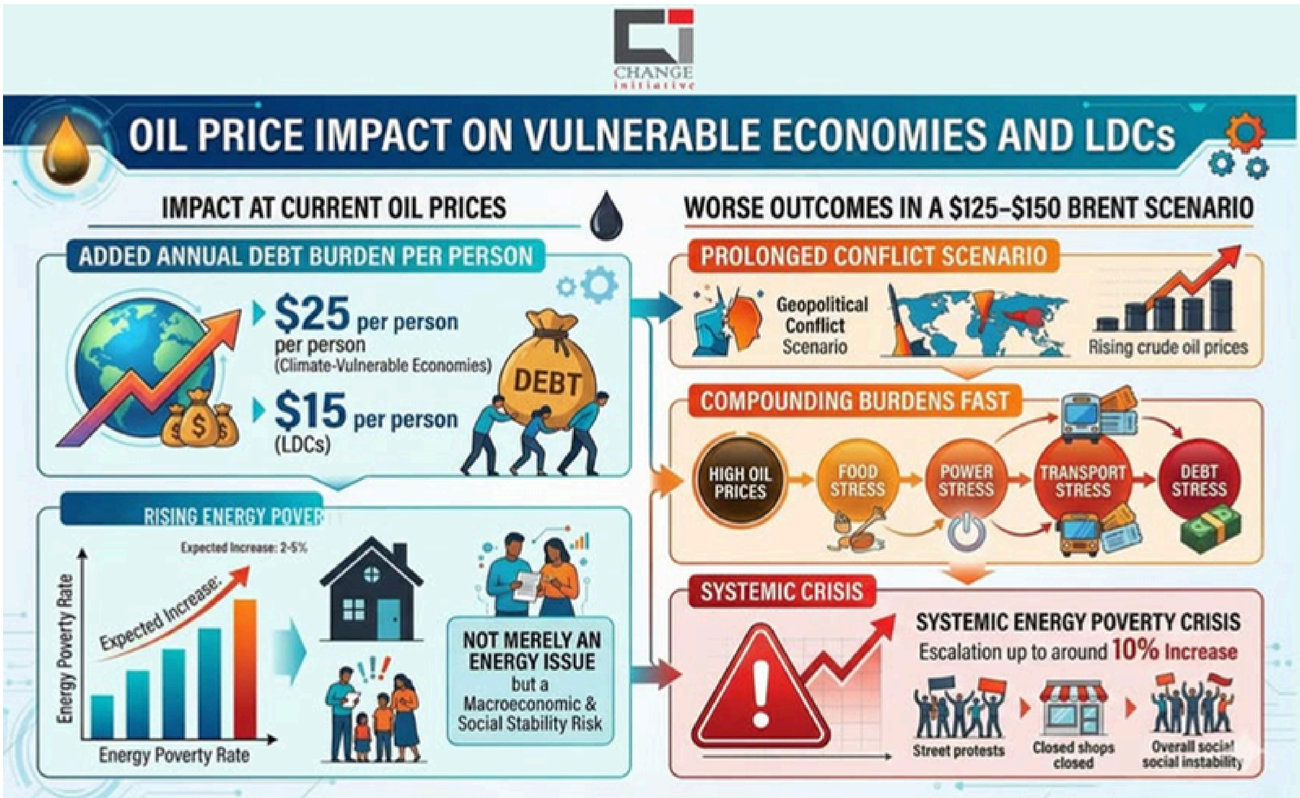
1.2.2 Energy Equity: Access Achieved, Affordability at Risk

Energy equity measures the ability to provide universal access to reliable and affordable energy. Bangladesh is recognized as one of the top improvers globally in this dimension, having achieved nearly 100% electricity access by 2021, a quadrupling of its performance since 2000 (World Energy Council, 2023). However, this success in "access" is increasingly at odds with "affordability."

The high cost of maintaining a surplus generation capacity, much of which relies on expensive liquid fuel, has led to a rising subsidy burden and subsequent tariff hikes. Retail electricity prices were adjusted multiple times between 2023 and 2024 to align with cost-recovery principles (World Bank, 2025). Change initiative analysis shows that utilizing just 10% of BSCIC space for 57 MW of renewable capacity could reduce SME electricity costs by at least 20% via a zero-upfront OPEX model (Khan et al., 2026). The transition to renewable energy offers a pathway to lower long-term generation costs, potentially easing the pressure on both subsidies and consumer tariffs (Sustainable and Renewable Energy Development Authority, 2024).

Change Initiative analysis revealed that if current Middle East-linked oil prices persist, a reasonable lower-bound estimate is an added annual debt-equivalent burden of around $25 per person in climate-vulnerable economies and $15 per person in LDCs, with much worse outcomes under a $125-$150 Brent scenario. For fragile households, that is not a small number. It compounds into food, power, transport, and debt stress fast. Even at current oil prices, energy poverty is predicted to rise noticeably by 2-5%, and under a prolonged conflict scenario it could escalate into a systemic crisis with increases of up to around 10%, making this not merely an energy issue but a significant macroeconomic and social stability risk.

Figure 1: Oil Price Shocks and Their Economic and Social Impacts on Vulnerable Economies and Least Developed Countries (LDCs)



Source: Change Initiative. (March 2026). Internal analysis on oil price impacts.

1.2.3 Environmental Sustainability: Transitioning from Decarbonization to Natural Rights-Led Governance

For Bangladesh, environmental sustainability is an existential priority, yet current frameworks require a shift toward more ambitious, rights-based pathways to address the scale of the crisis. As the 7th most vulnerable nation to climate change, Bangladesh faces an average annual loss of $3 billion from natural hazards, with climate change effects projected to cause a 1.3% reduction in annual GDP growth by 2041 (Asian Development Bank, 2022; Mahmood, 2022). While the nation historically relied on natural gas, the recent four-fold increase in coal's share of power generation; rising from 2% in 2015 to 20% by 2024, threatens to undermine its climate commitments (Climate Analytics, 2024; World Bank, 2022).

The transition to renewable energy (RE) is the primary engine for national decarbonization. According to the Change Initiative (2025) proposal for NDC 3.0, a "Conditional Scenario" involving the deployment of 24,106 MW of renewable capacity could nearly halve power sector emissions to 50.6 MtCO2 by 2030, compared to 108.87 MtCO2 in the Business-As-Usual (BAU) scenario. Furthermore, an "Ideal Scenario" (Net-Zero) could reduce emissions by over 90%, cutting grid emission intensity to just 69 kg/MWh (Change Initiative, 2025). These findings emphasize that decarbonization is technically and economically feasible if renewable energy is frontloaded to displace fossil fuel generation, specifically prioritizing the displacement of oil, then coal, and finally gas (Change Initiative, 2025).

The ND-GAIN Index highlights the severity of this challenge, ranking Bangladesh 174th globally with a score of 35.5 (ND-GAIN, 2023). With a high vulnerability score (0.568) and a low readiness score (0.279), the nation remains the 18th most vulnerable country to climate impacts (ND-GAIN, 2023). These vulnerabilities are often quantified in economic terms, such as the $1 billion lost annually to tropical cyclones or the potential 9% GDP reduction from severe flooding (World Bank, 2022). However, the Natural Rights-Led Governance (NRLG) framework suggests that these figures reflect a deeper crisis: the failure to recognize the biosphere as a governing entity with inherent rights (Change Initiative, 2025).

To align with a 1.5-degree pathway, Bangladesh must move beyond anthropocentric economic planning toward a model where mitigation is viewed as an ethical cornerstone of planetary survival. Under the NRLG framework, renewable energy transition is not merely a technical goal but a means to protect the Right to Life by reducing air pollution-related mortality and advancing Nature Justice by safeguarding ecosystems against temperature rise (Change Initiative, 2025). This holistic approach integrates the "Legal Recognition of Nature's Rights" into national policy, ensuring that energy strategies do not just reduce carbon but actively uphold the rights of all species to exist and regenerate (Change Initiative, 2025; Khan, 2025).

To meet its international commitments, Bangladesh must align its energy policies with the Kunming-Montreal Global Biodiversity Framework (GBF) and integrate natural rights into its National Biodiversity Strategies and Action Plans (NBSAPs). By prioritizing nature-based solutions such as mangrove restoration and wetland protection alongside a massive RE scale-up, the nation can transition from a climate victim to a credible leader in Earth-centric governance (Change Initiative, 2025).

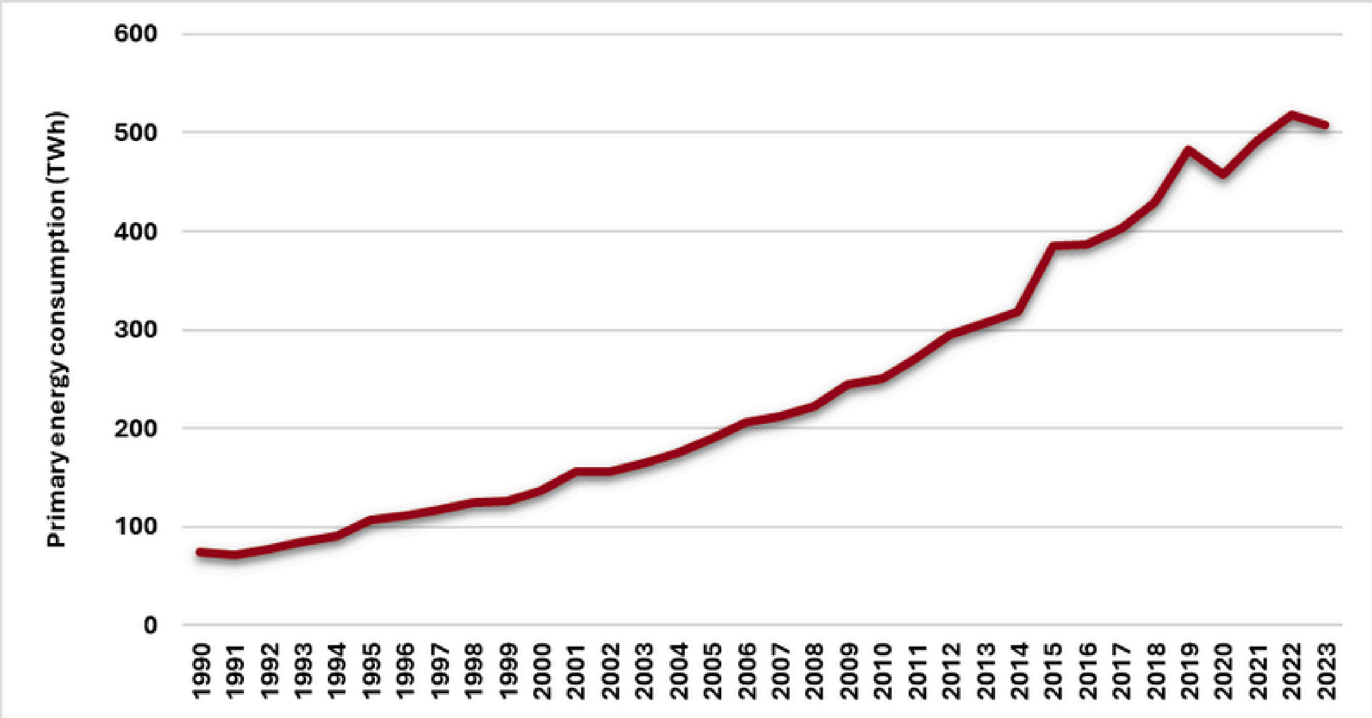
1.3 Energy Sector Landscape in Bangladesh

1.3.1 Energy Demand Growth in Bangladesh

This figure 1 illustrates a nearly sevenfold expansion in primary energy consumption, rising from approximately 75 TWh in 1990 to a peak of ~518 TWh in 2022.

The trajectory signals aggressive industrialization and escalating demand. Analytically, the steady climb is punctuated by a sharp surge between 2014 and 2015 and a brief 2020 contraction, reflecting macroeconomic sensitivity to global disruptions. Economically, the steep slope underscores the massive infrastructure investment required to sustain such growth. The slight 2023 downturn may indicate a pivot toward energy efficiency or a stabilization phase in market development

Figure 2:Primary Energy Consumption in Bangladesh (1990-2022)



Source: Data from Our World in Data, compiled by the author

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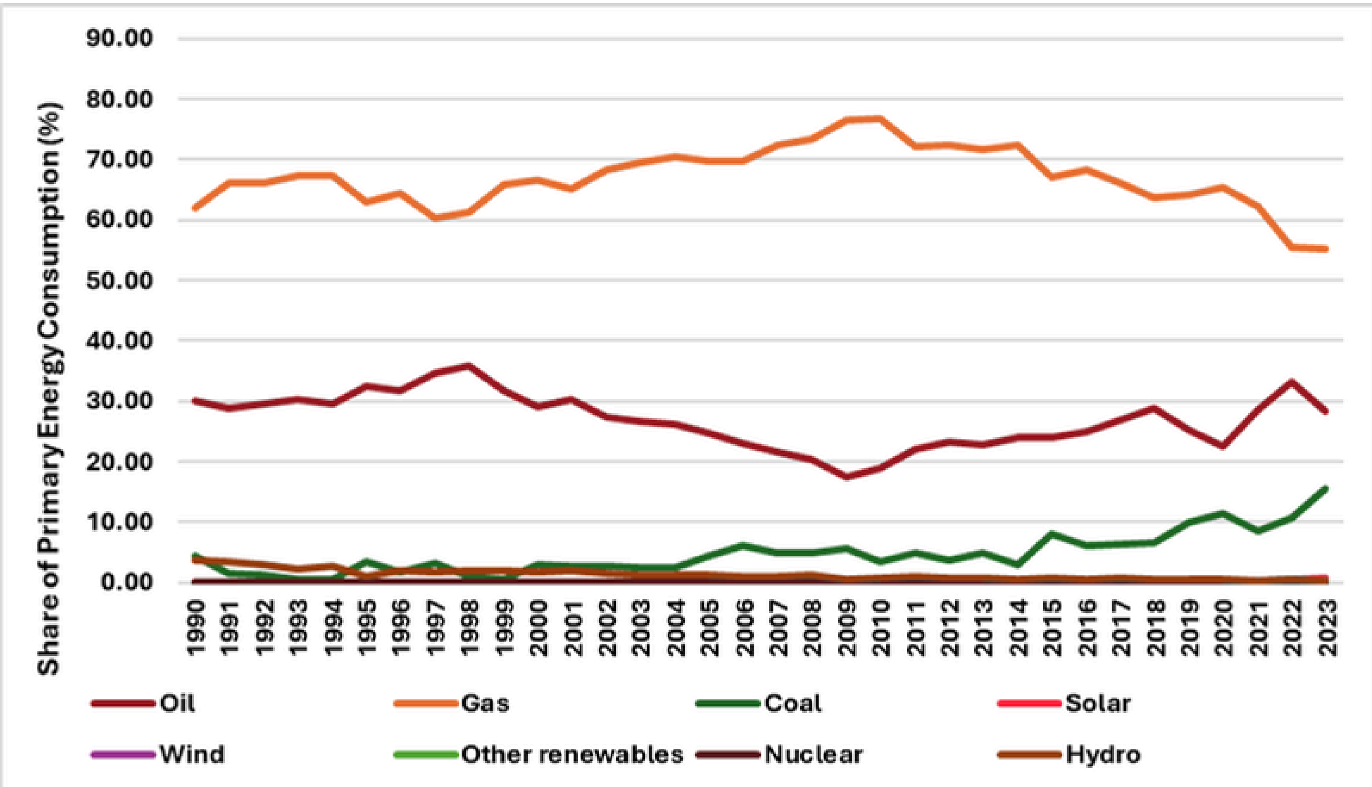
Figure 3: Primary Energy Mix of Bangladesh (1990-2022)



Source: Data from Our World in Data, compiled by the author

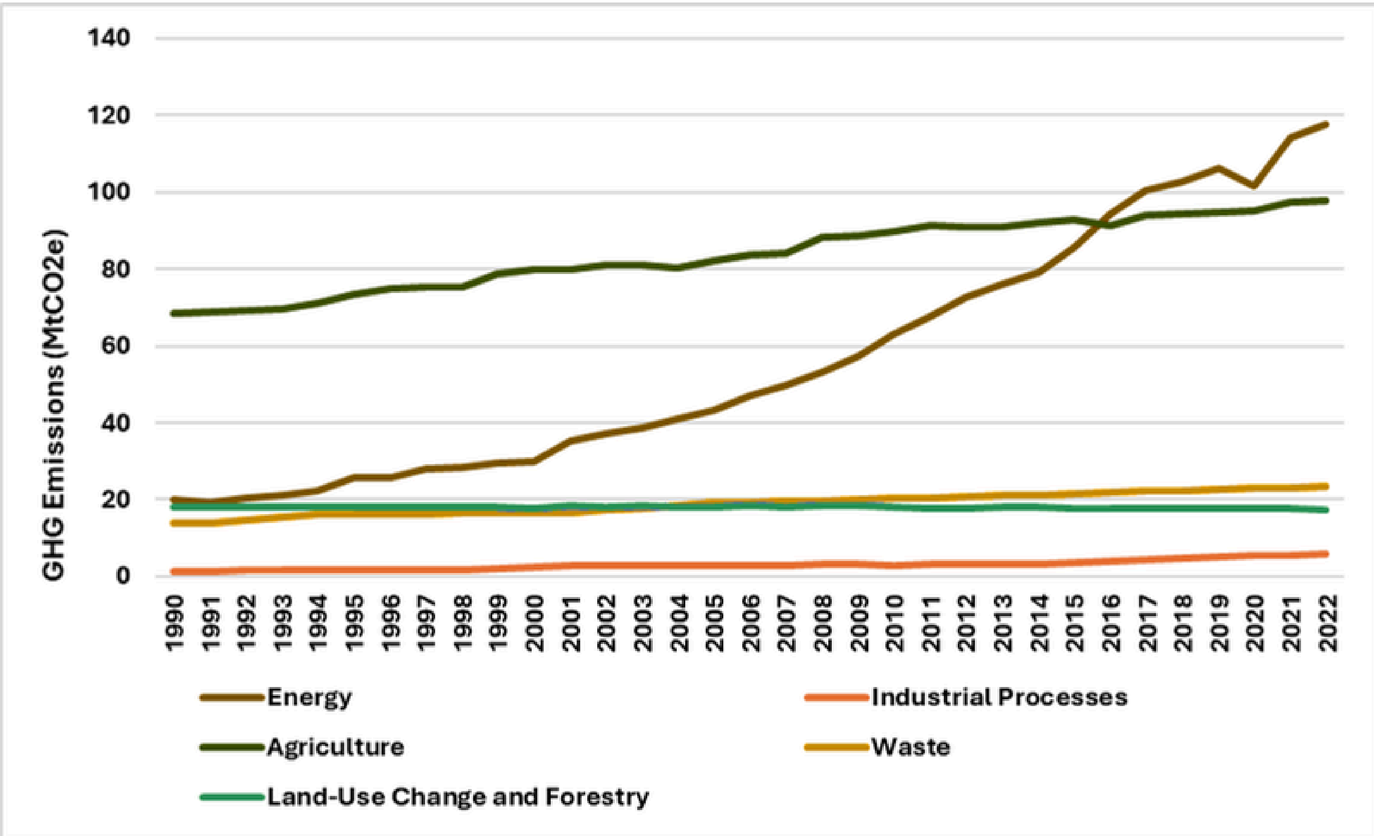
The figure shows a clear long-term shift in the structure of primary energy consumption from 1990 to 2023. It illustrates a fossil-fuel-dependent economy, with Natural Gas dominating despite dropping from a 77% peak in 2010 to 55% in 2023. However, a "regressive" shift is evident as the Coal share quadrupled to ~15.5%, partially offsetting the decline in gas.

Oil remains a volatile secondary pillar at ~28%, while renewables like Solar and Wind stagnate near zero. Economically, this indicates a preference for established, carbon-intensive infrastructure and price-driven fuel switching over capital-intensive green transitions, prioritizing immediate energy security and cost over long-term decarbonization targets.

1.3.2 GHG Emissions Profile

Figure 4 shows a clear structural shift in Bangladesh's emissions profile. Agriculture remained the largest source for most of the period, but energy-sector emissions rose sharply after the mid-2000s and overtook agriculture around 2016.

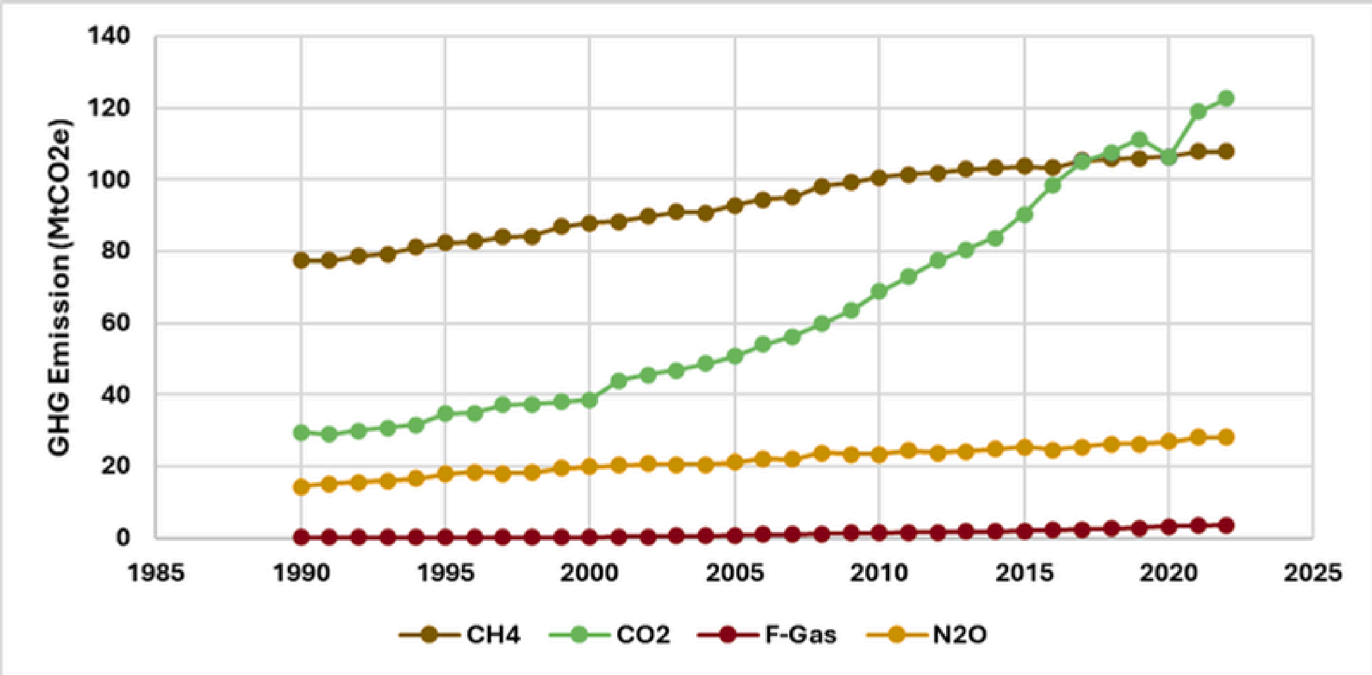
Figure 4: Sectoral GHG Emission of Bangladesh (1990-2022)



Source: Data from Climate Watch, compiled by the author during the research period

By 2022, energy had become the dominant emissions driver, reflecting the growing fossil-fuel intensity of power generation and industrial expansion. Waste and land-use emissions remained relatively stable, while industrial process emissions increased gradually from a low base. Overall, the trend confirms that Bangladesh's decarbonization challenge is now primarily an energy-sector challenge.

Figure 5: Historical GHG Emission by Type (1990-2022)



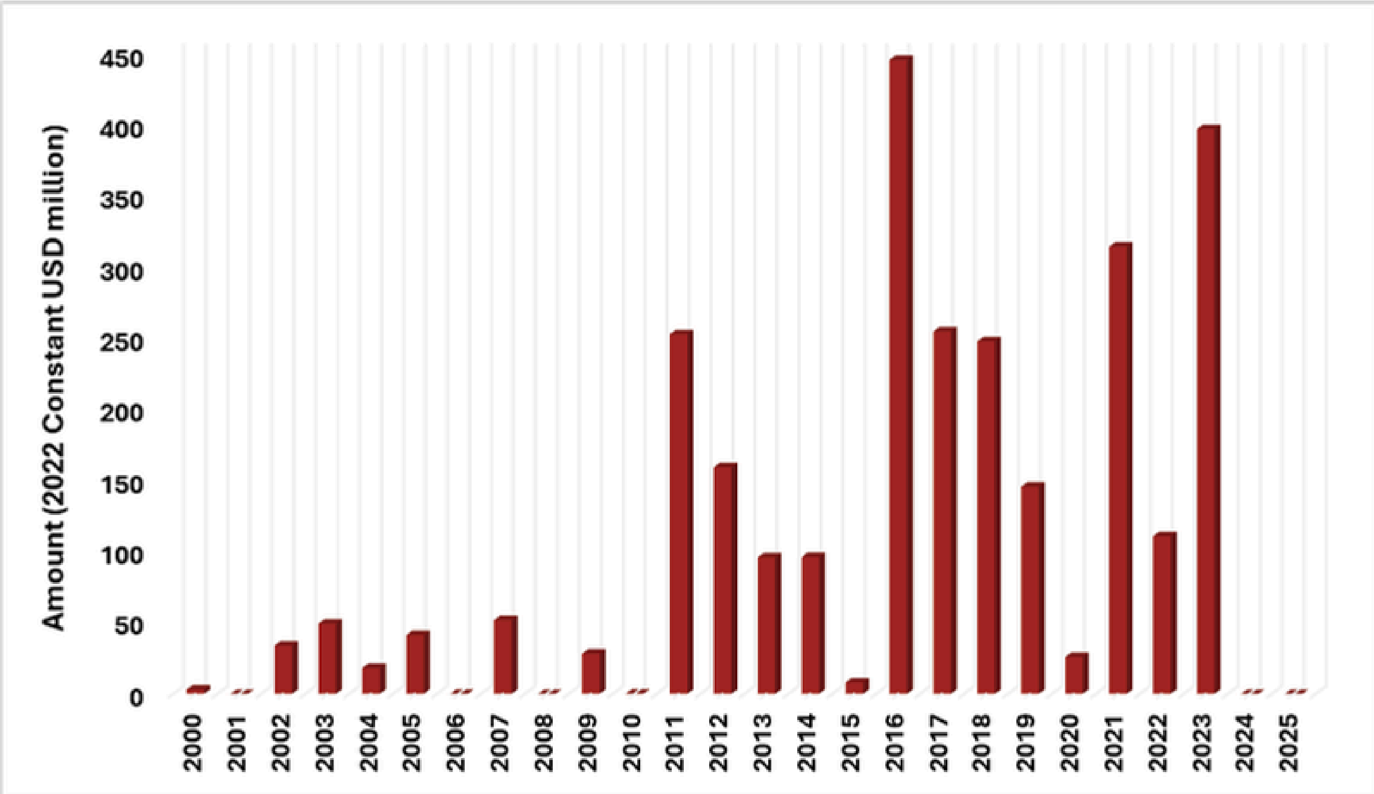
Source: Data from Climate Watch, compiled by the author during the research period.

The graph shows that Bangladesh's emissions growth is increasingly driven by CO_2. While CH_4 remains high and relatively stable, CO_2 emissions have risen sharply since the early 2000s and overtaken CH_4 in recent years. N_2O has increased slowly, while F-gases remain minimal but gradually rising. Overall, the trend confirms that Bangladesh's climate challenge is shifting from agriculture-linked methane dominance toward fossil-fuel-driven CO_2 growth.

1.3.3 Overview of Demand and Gaps in Investment for Renewable Energy Transition

The graph shows that renewable energy investment in Bangladesh has been uneven and episodic, with sharp spikes rather than steady growth.

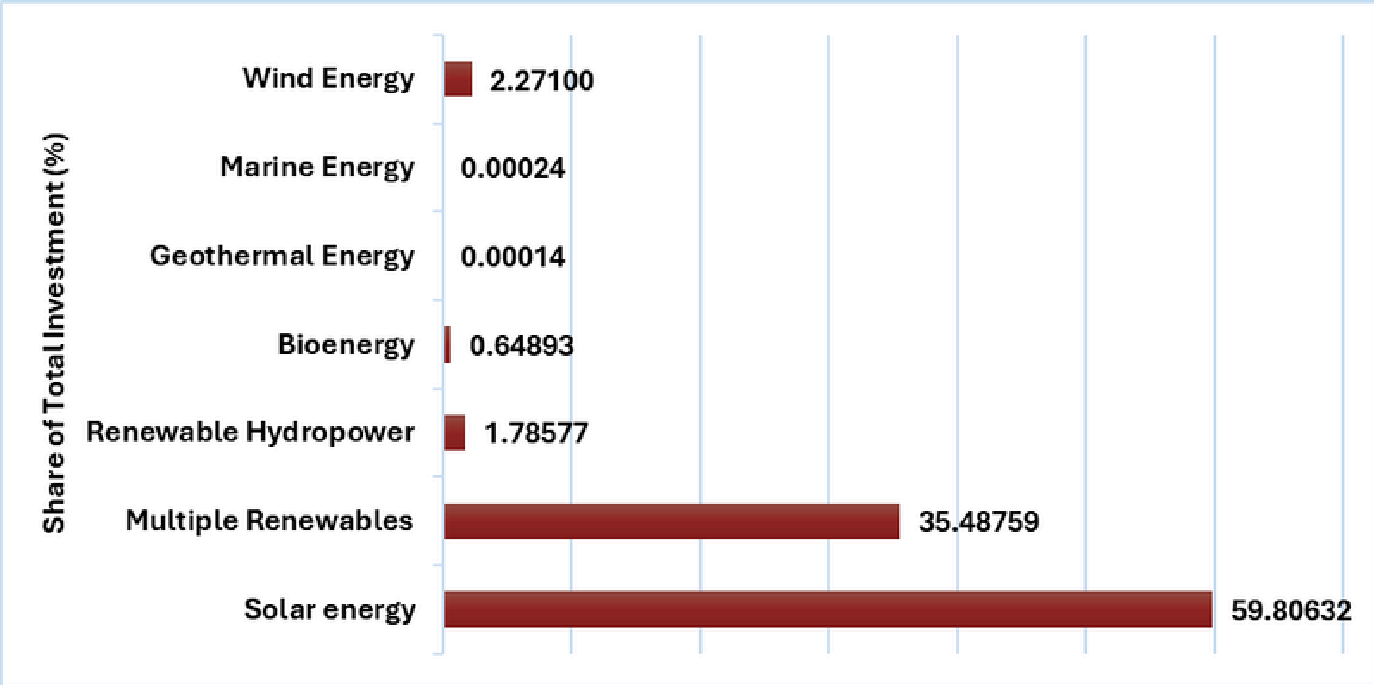
Figure 6: Renewable Energy Investment (2000-2025)



Source: Data from the International Renewable Energy Agency (IRENA), compiled by the author during the research period

Major investment peaks appear in 2011, 2016, 2021, and 2023, while several years show very low or no recorded investment. This reflects a project-driven market rather than a mature investment pipeline. For the roadmap, the key message is clear: Bangladesh does not only need more renewable investment, but it also needs predictable, year-on-year financing backed by stronger project preparation, grid readiness, and bankable procurement.

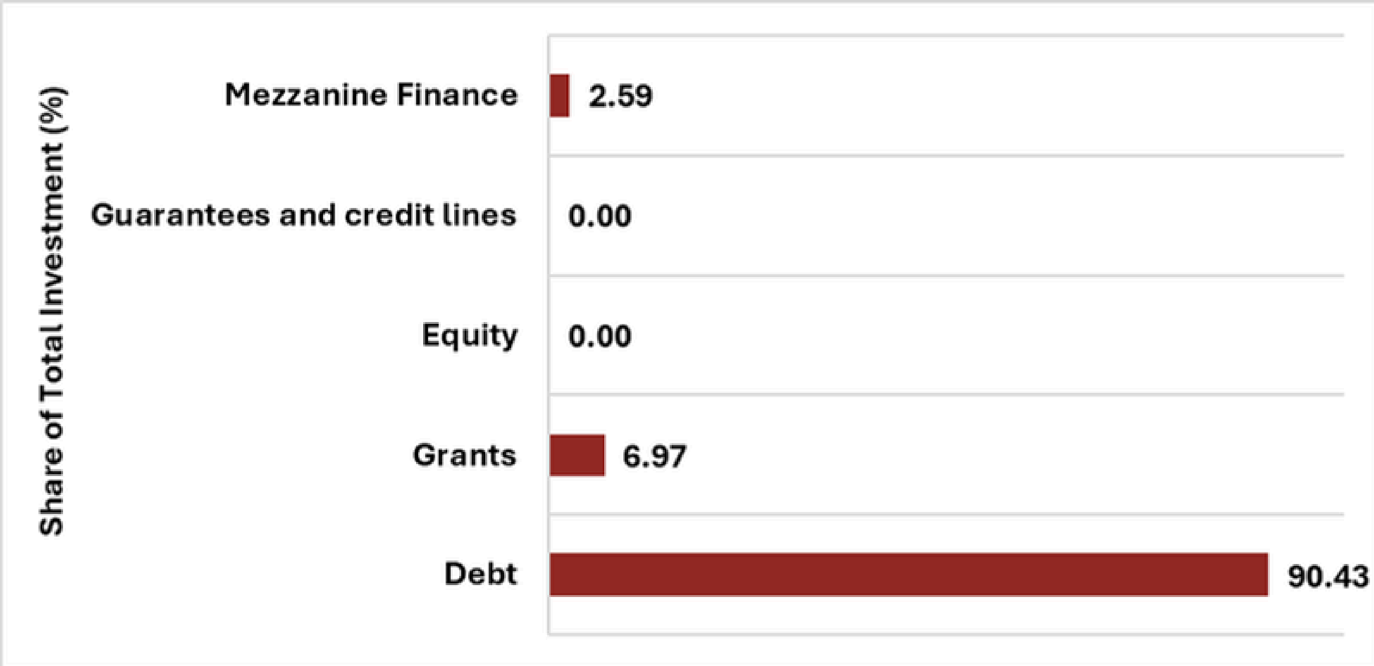
Figure 7: Financing Structure of Renewable Energy Investments in Bangladesh



Source: Data from the International Renewable Energy Agency (IRENA), compiled by the author.

The financing mix for renewable energy in Bangladesh is overwhelmingly debt-based. Debt accounts for 90.43% of total investment, while grants make up only 6.97% and Mezzanine finance 2.59%. Equity, guarantees, and credit lines are virtually absent. This indicates a shallow financing structure where risk is not shared effectively. For scaling renewables, Bangladesh needs more blended finance, guarantees, equity participation, and concessional instruments to reduce investor risk and improve bankability.

Figure 8: Financing Structure of Renewable Energy Investments in Bangladesh (2000-2025)



Source: Data from the International Renewable Energy Agency (IRENA), compiled by the author during the research period

The investment pattern shows that Bangladesh's renewable energy financing is highly concentrated in solar. Solar alone accounts for 59.81% of total investment, followed by multiple-renewable projects at 35.49%. Other technologies receive very limited financing, with wind at 2.27%, hydropower at 1.79%, and bioenergy below 1%. Marine and geothermal energy are almost absent. Overall, Bangladesh's renewable investment portfolio is solar led, but still insufficiently diversified for a resilient long-term transition.

1.4 Problem Statement

Bangladesh's energy transition is held back by a persistent gap between policy ambition and implementation. Despite commitments under the Perspective Plan 2021–2041, the Bangladesh Climate Prosperity Plan, and NDC 3.0, the power system remains heavily dependent on imported fossil fuels. This exposes the economy to external shocks, especially Middle East supply disruptions through the Strait of Hormuz, which threaten nearly two-thirds of Bangladesh's LNG imports from Qatar and Oman (Energy Tracker Asia, 2026). Gas shortages have already left around 23% of power plants inoperable and pushed some export-oriented industries, including textiles, to operate at only 30–40% capacity (Energy Tracker Asia, 2026).

This import-dependent pathway is now fiscally unsustainable. Imported LNG costs nearly 18 times more than domestic gas, with LNG subsidies for FY2025–26 projected to rise from Tk 6,000 crore to Tk 26,000 crore (Energy Tracker Asia, 2026). At the same time, excess fossil-fuel capacity and capacity payments weaken the power sector's financial position and reduce space for renewable energy incentives. Although Bangladesh has major solar potential, including up to 50,000 MW through agrivoltaics, renewables remain marginal, and many existing assets are inactive due to poor maintenance, weak grid integration, and limited oversight (Energy Tracker Asia, 2026). Transmission bottlenecks and energy shortfalls already cost the economy around 1.5% of GDP annually (World Bank, 2022).

The core problem is a combined financing and governance gap. High upfront costs, regulatory uncertainty, land and grid constraints, and limited affordable long-term finance continue to deter private investment. The IEPMP 2023 also risks diluting focus by prioritizing capital-intensive "clean energy" options over faster, decentralized renewable solutions. Without subsidy rationalization, derisking tools, and private capital mobilization, Bangladesh will lack the fiscal space for a resilient transition (World Bank, 2025; IMF, 2026).

Bangladesh therefore, needs a forward-looking renewable energy investment roadmap for 2026–2030 that explains why renewable assets remain underused and identifies bankable technology pathways, financing instruments, and implementation priorities. This is essential for energy security, fiscal stability, and alignment with national and global climate commitments.

1.5 Rationale of the Roadmap

Bangladesh's energy system is increasingly dependent on imported fossil fuels, with over 45% of total energy demand met through imports and, in crisis conditions, up to 95% reliance on external energy sources. This structural dependence exposes the economy to severe price volatility, foreign exchange pressure, and geopolitical disruptions, as evidenced by recent LNG supply shocks that forced power rationing and economic slowdown.

The financial burden of this dependence is escalating rapidly. Bangladesh spent approximately USD 3.88 billion on LNG imports in 2025 alone, while cumulative LNG import expenditure reached around USD 17.6 billion between 2018 and 2025 (Sophie, 2026). This import-driven model is deepening subsidy pressures and contributing to macroeconomic instability.

Despite this high-cost system, the energy mix remains overwhelmingly fossil-fuel dominated. Renewables account for only around 5.4% of electricity generation capacity, far below global benchmarks and national aspirations. In contrast, fossil fuels still dominate more than 90% of the overall energy mix, reinforcing long-term environmental and financial risks (Koons, 2024).

At the same time, domestic gas supply is insufficient to meet demand, with a deficit exceeding 1,300 million cubic feet per day, further increasing reliance on imported LNG (Alam, 2025). This widening supply-demand gap underscores the unsustainability of the current energy pathway.

The import dependence is also structurally embedded across fuel types. Bangladesh imports the majority of its oil, coal, and refined petroleum, including over 6 million metric tons of coal annually, along with large volumes of crude and refined fuels. This exposes the entire energy system not just electricity to global market shocks.

Meanwhile, renewable energy potential remains significantly underutilized. Current clean energy capacity represents only a small fraction of total demand, despite strong solar and wind potential (Tachev, 2024b). The absence of a coherent investment roadmap, policy certainty, and scalable financing mechanisms continues to constrain both domestic and international investment.

This model is not only environmentally unsustainable but financially risky. Continued reliance on debt-financed fossil fuel infrastructure, combined with rising import bills, is increasing the likelihood of Bangladesh falling into a climate and energy debt trap.

A transition to renewable energy is therefore not optional; it is a strategic necessity. However, such a transition must be just and inclusive, ensuring protection for workers, equitable energy access, and community participation. Without this, structural inequalities may deepen.

This study is thus essential to provide a renewable energy investment roadmap that reduces import dependence, stabilizes the economy, mobilizes finance, and enables a just transition. It reframes energy transition not merely as a technological shift, but as a pathway from structural dependence to national energy sovereignty.

1.6 Objectives of the Roadmap

This roadmap primarily aims to develop a comprehensive, evidence-based, and actionable Multi-Year Renewable Energy Investment framework (2026-2040) for Bangladesh to accelerate investment, particularly from the corporate sector, aligning with national targets and NDC commitments.

Specific Objectives:

- To identify and analyze key financial, policy, regulatory, and market barriers & enablers for RE investment, with a specific focus on corporate actors.
- To estimate the future power demand in Bangladesh, both in total and in renewable energy, to meet the renewable energy target by 2040.
- To forecast the required investment in the renewable energy sector in Bangladesh.
- To design specific, actionable policy and regulatory reform recommendations to create a more bankable renewable energy investment environment.

1.7 Scope of the Roadmap

This roadmap focuses on small-scale decentralized renewable energy projects in Bangladesh. Decentralized renewable energy refers to modular, localized solutions placed close to consumption points, reducing transmission losses, lowering grid dependence, and strengthening local energy sovereignty.

The study focuses on renewable options that require lower capital than utility-scale plants, can be deployed faster, and allow wider participation by households, farmers, communities, and small businesses. It covers four areas: solar irrigation pumps to reduce diesel dependence in agriculture; rooftop solar for households, commercial buildings, institutions, and industries; floating solar for land-constrained areas; and off-grid non-solar renewables for location-specific energy solutions.

Within this scope, the roadmap assesses financing needs, investment potential, policy conditions, implementation barriers, and institutional requirements. It also considers how these technologies can improve energy access, resilience, fossil-fuel reduction, and local economic participation.

The study does not focus on large utility-scale projects, major transmission infrastructure, or centralized power expansion. Instead, it prioritizes decentralized renewable investments that can complement national planning while creating a more inclusive and locally rooted energy transition.

Chapter 2

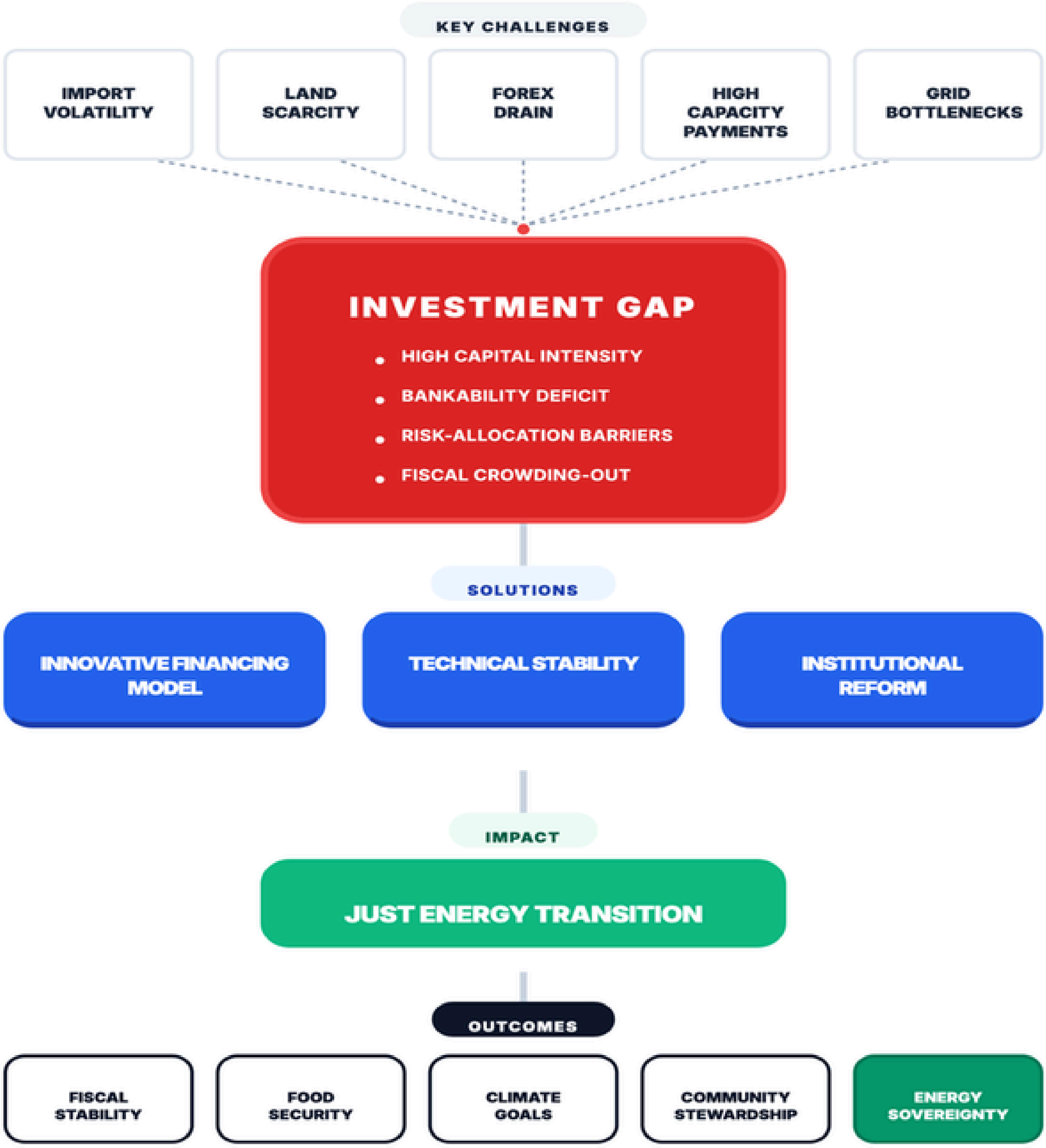
Methodology for Developing the Roadmap

2.1 Conceptual Framework

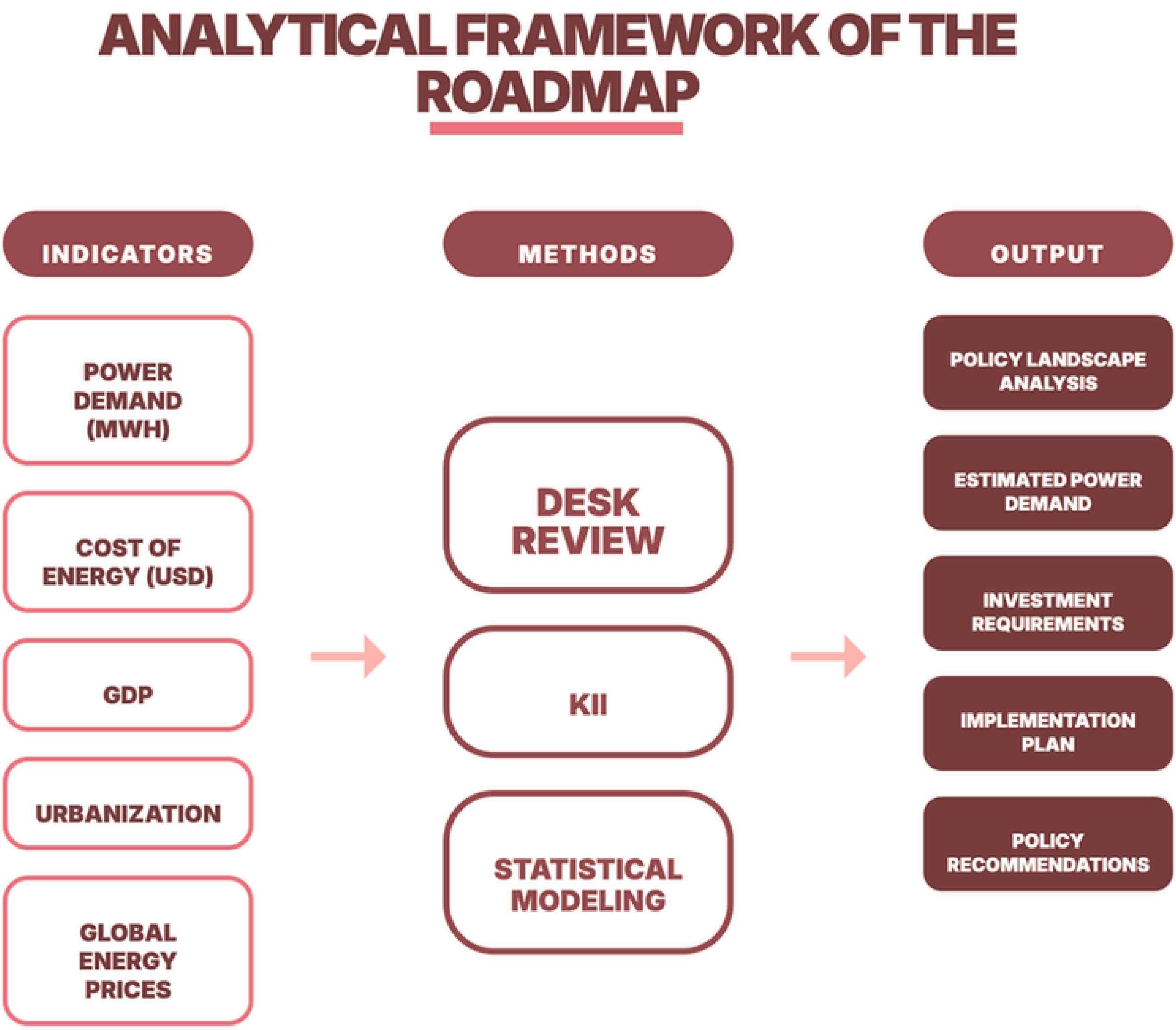
The conceptual framework serves as the logical foundation of this study, mapping the transition from systemic challenges to national energy autonomy. It identifies five primary challenges ranging from import volatility and foreign exchange strain to grid and land limitations that converge into a significant investment gap. This gap is characterized by high capital requirements and limited access to long-term financing, which currently hinders the scaling of renewable infrastructure. To bridge this divide, the roadmap proposes a series of integrated solutions focusing on innovative financing models, technical stability through storage, and institutional reforms that move toward a facilitator-based governance model. By implementing these pathways, the roadmap facilitates a transition that balances economic growth with social equity.

The goal is to produce a self-correcting ecosystem where fiscal stability, food security, and climate targets are met through community stewardship. This progression ensures that energy sovereignty is achieved, transforming the power sector into a domestic asset that safeguards the nation’s long-term prosperity.

CONCEPTUAL FRAMEWORK OF THE ROADMAP



2.2 Analytical Framework



The analytical framework begins with the identification of core indicators, such as power demand, unit costs, and broader economic drivers like urbanization and global price trends. These inputs are processed through a multi-dimensional approach that includes comprehensive desk reviews, key informant interviews, and statistical modelling to ensure that the findings are grounded in both current data and practical reality. The concluding phase of this process generates the primary outputs of the study, including a detailed landscape of the existing policy environment and precise estimates for future demand and investment needs. By connecting these indicators to a phased implementation plan, the framework ensures that the resulting recommendations are technically sound and strategically aligned with the nation's development trajectory.

This roadmap applies a mixed-methods, sequential analytical framework that integrates quantitative modelling with qualitative evidence to produce an investment plan that is not only technically sound but also institutionally and commercially implementable. The quantitative track estimates future energy demand translates demand into capacity requirements, and prices investment needs across scenarios using consistent unit-cost and system-reliability assumptions; the qualitative track then stress-tests those results against on-the-ground constraints and incentives through KIIs, stakeholder mapping and political economy analysis, policy review, and sentiment/text analysis. Together, these two parts ensure the roadmap answers both "how much and by when" (scale, technology mix, investment needs) and "under what governance, risk-allocation, and market conditions" (bankability, coordination, social license, and regulatory feasibility) the required capital can be mobilized and deployed.

2.3 Quantitative Approach

2.3.1 Macro-Econometric Energy Demand Forecasting

To establish a long-term electricity demand trajectory, the roadmap employs an Autoregressive Distributed Lag (ARDL) modelling framework. This method is chosen for its ability to integrate short-term dynamics and long-term equilibrium without the risk of spurious correlations.
Model Specification:

The structural equation for demand estimation is defined as:

$$\ln(E_t) = \beta_0 + \beta_1 \ln(G_t) + \beta_2 \ln(U_t) + \beta_3 \ln(P_t) + \epsilon_t$$

Here,

$E_t = Total\ Electricity\ Demand\ (GWh)$

$G_t = Real\ GDP\ (Current\ USD)$

$U_t = Urbanization\ Rate\ (\%)$

$P_t = Global\ Energy\ Price\ Index\ (GEPI)$

2.3.2 Power System Capacity Dimensioning

Projected energy consumption (GWh) is converted into required generation capacity (MW) using a System Load Factor (LF) of 45%. This conservative factor accounts for tropical climate peak spikes and the high residential-to-industrial ratio in Bangladesh.

Capacity Formula:

$$Capacity\ (MW) = \frac{ForecastedGWh \times 1000}{8760 \times 0.45}$$

2.4 Qualitative Approach

2.4.1 Key Informant Interview

KIIs were conducted with senior decision-makers across the investment chain, like financial institutions, private industry, think tanks, policy leadership, and government governance.

This purposive mix ensures the roadmap captures both “capital-side” and “state-side” constraints, so barriers to bankability and implementation are diagnosed from those who approve, finance, regulate, and execute renewable energy decisions.

Table 2: Profile of Key Informants Interviewed

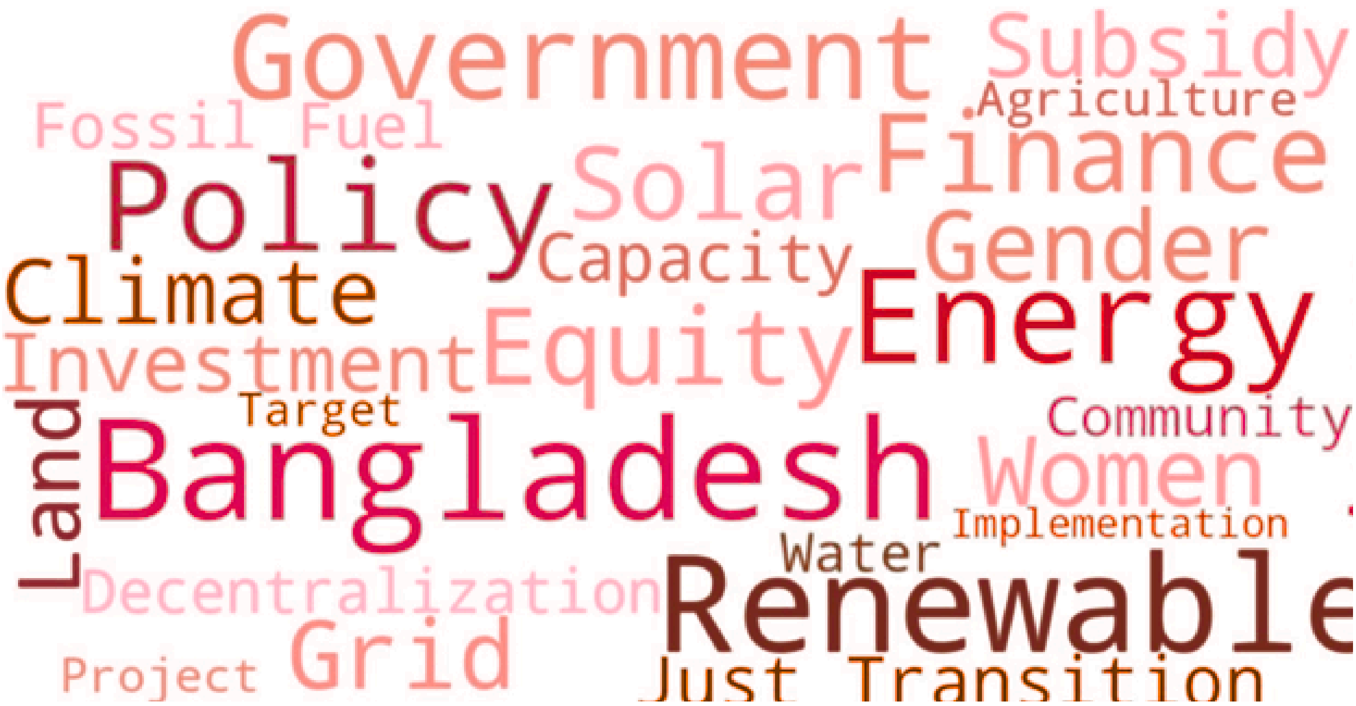
Organization Type	Company Name	Designation
Financial Sector	Brac Bank	Head of Sustainable Finance
	IDCOL	CEO
Private Sector Industry	PRAN-RFL	COO-RE
Think Tank	IEEFA	Lead Energy Analyst
Policy & Think Tank	BIDS	Director General
Government Governance	Ministry of Finance	Deputy Secretary
Renewable Energy Equipment Manufacturer (Solar PV)	LONGi Solar	Senior Sales Manager
Development Partner	UNDP	Resident Representative

Source: Authors' Compilation

2.4.2 Sentiment Analysis

Sentiment analysis is used to quantify the policy narrative and social perception signals that shape investor confidence and reform durability. The study applies thematic text-mining to renewable energy policy discourse to identify what themes dominate (and what is missing), how issues cluster (e.g., finance-equity-decentralization), and whether the discourse is oriented toward delivery levers (procurement, grid readiness, de-risking) versus aspirational targets. This helps anticipate where reforms may face credibility gaps or compliance resistance and informs communication and sequencing choices.

Figure 9: Thematic Landscape of Renewable Energy Policy Discourse



2.4.3 Stakeholder Mapping and Political Economy Analysis

Stakeholder mapping and political-economy analysis are then used to operationalize feasibility. Stakeholders are mapped by influence (decision rights and veto power) and willingness (incentives to support or resist), separating actors who can approve/enable projects from those who can legitimize, monitor, or enforce. Political-economy diagnosis focuses on the binding coordination failures where the constraint is not technology, but misaligned incentives across procurement, grid interconnection, tariff/payment discipline, and risk-sharing and designs coalition pathways (lead agencies, quick wins, and enforcement hooks) to move from policy intent to repeatable, financeable transactions.

2.4.4 Policy Analysis

Policy analysis complements this by reviewing the relevant laws, regulations, plans, and guidelines against investment-critical criteria: clarity of targets and definitions, procurement and standardization, licensing and permitting steps, grid code/interconnection and dispatch rules, tariff and offtake arrangements, dispute resolution, and de-risking provisions. The output is a policy-to-risk translation: each gap is linked to a specific risk premium (cost of capital, tenor shortening, collateralization, or non-bankability) and converted into prioritized reforms by impact and feasibility, the roadmap reads as an execution plan rather than a wish list.

2.5 Limitations of the Roadmap

The fundamental limitation of this roadmap is the dependency on historical time-series data that might be exposed to overestimation biases due to prior reporting inconsistencies. This bias overestimation in the historical data might affect the quantitative estimation in the long term. Moreover, this roadmap exclusively focused on the ‘Zero Arable Land’ mandate which also affected the financing plan and the technology mix in the renewable energy installation framework. Importantly, no global supply-side volatility has been considered that might emerge as a result of possible shocks to the supply chain or changes in technology that can significantly affect the cost and supply of Nature-Smart Energy equipment. Finally, all the calculations and analysis have been limited to existing governmental targets and objectives. The strict implementation of such targets in the mobilization of the transition to renewable energy restricts the roadmap since market-based factors associated with LDC status and credit rating can lead to a faster transformation.

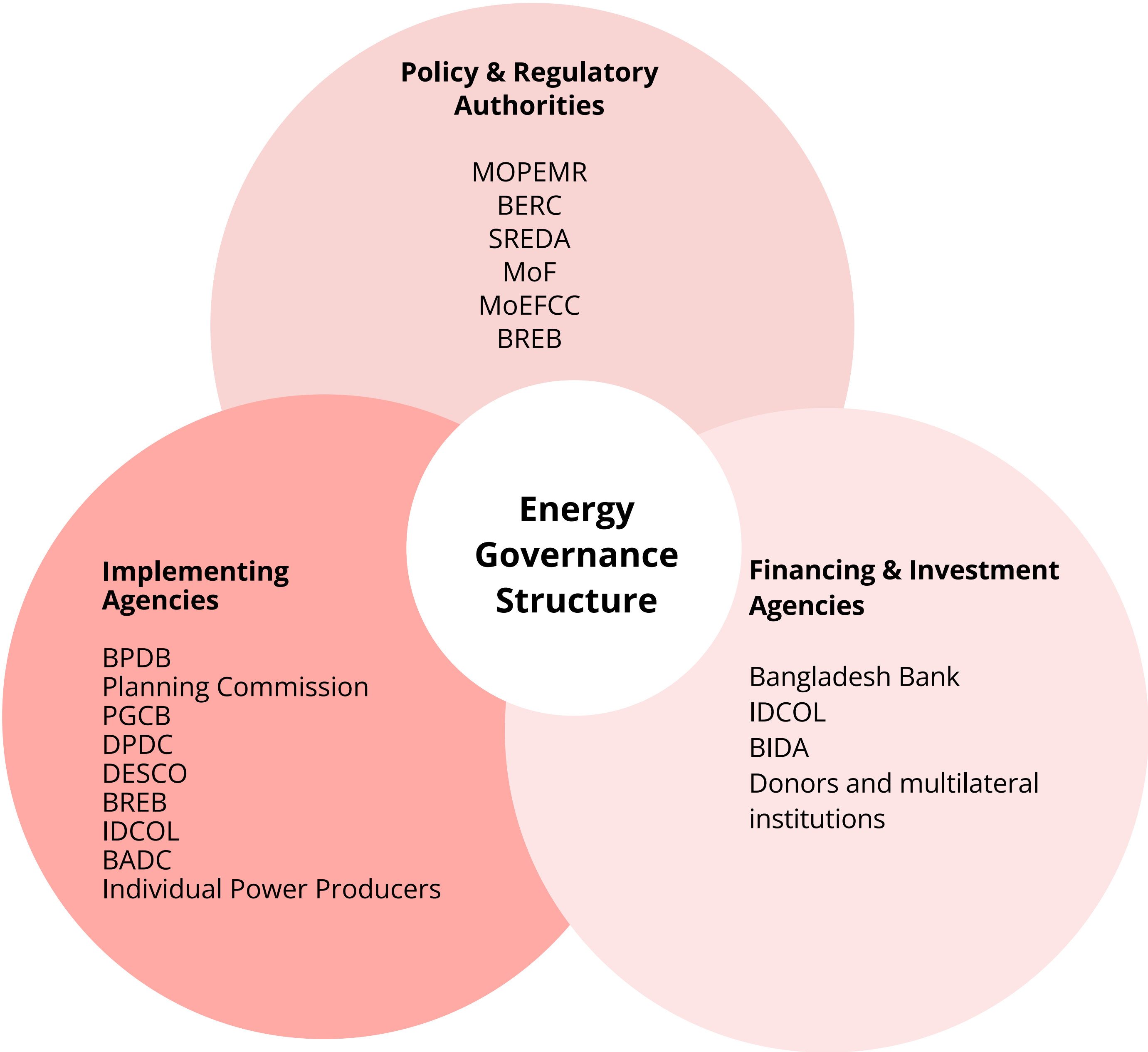
Chapter 3

Governance and Policy Landscape of Energy Sector in Bangladesh

3.1 Energy Governance Structure in Bangladesh

Bangladesh's energy governance structure is a complex interplay of institutions managing both conventional (gas, coal) and renewable sectors, shaped by rapid economic growth and climate commitments. This section evaluates the effectiveness of the current energy governance structure in Bangladesh, highlighting roles and key challenges.

Figure 10: Energy Governance Structure in Bangladesh



Source: Authors' Compilation

3.1.1 Policy and Regulatory Authorities

The Ministry of Power, Energy and Mineral Resources (MPEMR) leads governance, with Power Division overseeing electricity and the Energy and Mineral Resources Division (EMRD) handling hydrocarbons and coal. Bangladesh Energy Regulatory Commission (BERC) is responsible for regulating tariffs and licensing across sectors. Sustainable and Renewable Energy Development Authority (SREDA) coordinates renewables but lacks enforcement power, functioning more as an advisor amid land scarcity and grid constraints.

3.1.2 Implementing Agencies

Implementation translates policies into action but reveals disparities between conventional and renewable pathways. Planning Commission is responsible for aligning national plans such as the Integrated Energy and Power Master Plan (IEPMP) 2023, targeting clean energy adoption, but inconsistencies signaling coal revival often deter investors. Major distribution entities include Dhaka Power Distribution Company (DPDC), Dhaka Electric Supply Company (DESCO), and the Bangladesh Rural Electrification Board (BREB). While a multitude of implementing agencies exist, their fragmented operations often lead to coordination gaps, inefficiencies in resource allocation, and slower renewable uptake.

3.1.3 Financing and Investment Agencies

Bangladesh Bank promotes sustainable finance through several refinance schemes, but utilization is modest due to process frictions and foreign exchange constraints. IDCOL plays a pivotal role by channeling concessional financing from multilateral partners like the World Bank, Asian Development Bank (ADB), Green Climate Fund (GCF), etc. Bangladesh Investment Development Authority (BIDA) facilitates private investment with incentives such as 10-year tax holidays.

3.2 Policy Landscape Shaping Energy Investment in Bangladesh

The following table summarizes the core findings from the analysis of Bangladesh's renewable energy policy evolution (1996 - 2025). It outlines how the institutional framework has "manufactured bankability" while identifying the systemic frictions that must be resolved to unlock the $32.82 billion roadmap.

Table 3: Summary of Energy Policy Landscape in Bangladesh

Policy Dimension	Core Insights & Current Status	Investment & Bankability Implications
Strategic Evolution	Shift from ad-hoc facilitation (1990s) to integrated master plans (IEPMP 2023, NDC 3.0). Renewables are now viewed as macro-stability tools.	Transitions of renewables from "environmental options" to critical hedges against FX volatility and imported fuel price cycles.
Institutional Architecture	Establishment of standardized PPAs, SREDA (2012), and BERC (2003) has created a baseline for "manufactured bankability."	Enables private capital mobilization via established fiscal incentives (tax holidays, duty exemptions) without increasing public debt.
Systemic Frictions	Persistent execution gaps, institutional overlaps (SREDA vs. BPDB), and fossil-centric defaults (capacity payments/stranded assets).	Inflates investment risk premiums; underutilized capacity creates a "fiscal drag" that reduces the state's capacity for new incentives.
Grid & Land Constraints	Severe land scarcity (PP2041) and limited grid absorption (IEPMP 2023) hinder utility-scale expansion.	Shifts the investment priority toward decentralized technologies (solar irrigation, rooftops) which offer better risk-adjusted returns.
Investment Unlocks	Repurposing conditional NDC (NDC 3.0 in 2025) targets as a blended-finance taxonomy; leveraging Article 6 for carbon crediting.	Pairs concessional capital with guarantees to crowd in private lenders; uses "Peak-shaving" logic to justify storage investments.

Source: Authors’ Compilation

Bangladesh's renewable energy policies, spanning from foundational frameworks in the 1990s to ambitious targets in 2025, collectively reflect a strategic evolution toward viewing renewables not merely as environmental imperatives but as critical instruments for energy security, macroeconomic stability, and resilience against imported fuel volatility. The current situation reveals a policy landscape that has matured from ad-hoc private sector facilitation and environmental gatekeeping to integrated master plans and climate commitments, yet renewable penetration remains modest, typically below 6-10% of installed capacity or generation as of 2025 due to persistent execution gaps, grid constraints, and a historical reliance on fossil fuels. Policies like the Private Sector Power Generation Policy (1996, revised 2004) and the Renewable Energy Policy (2008 and 2025) have established bankable contracting precedents, while newer ones such as the Integrated Energy and Power Master Plan (IEPMP 2023) and NDC 3.0 (2025) provide quantified pipelines (e.g., 25% renewable power by 2035, 40% by 2041), but the system still grapples with underutilized capacity, payment arrears, and land scarcity, limiting scale-up despite demonstrated pilots in solar home systems and mini-grids.

The strengths across these policies lie in their institutional and financial de-risking architecture, which as a climate finance expert, shows that Bangladesh has "manufactured bankability" through standardized PPAs, fiscal incentives (tax holidays, duty exemptions), and dedicated entities like SREDA (2012 Act) and BERC Act(2003), enabling private capital mobilization without overburdening public budgets. This is evident in the Bangladesh Climate Prosperity Plan (BCPP) (2022-2041) and BDP 2100 (2018), which normalize blended finance, carbon markets, and green bonds as tools to lower the cost of capital, while emphasizing renewables as hedges against FX risks and subsidy cycles, a macro-stabilization logic that aligns with global climate funds' priorities. Moreover, policies like the Electricity Act (2018) and PSMP 2016 introduce merit-order dispatch and ancillary services, potentially favouring zero-marginal-cost renewables, and the BCCSAP (2009) and Energy Efficiency Master Plan (2016) integrate demand-side measures to enhance system flexibility, revealing an underappreciated synergy where efficiency "buys time" for renewable power integration.

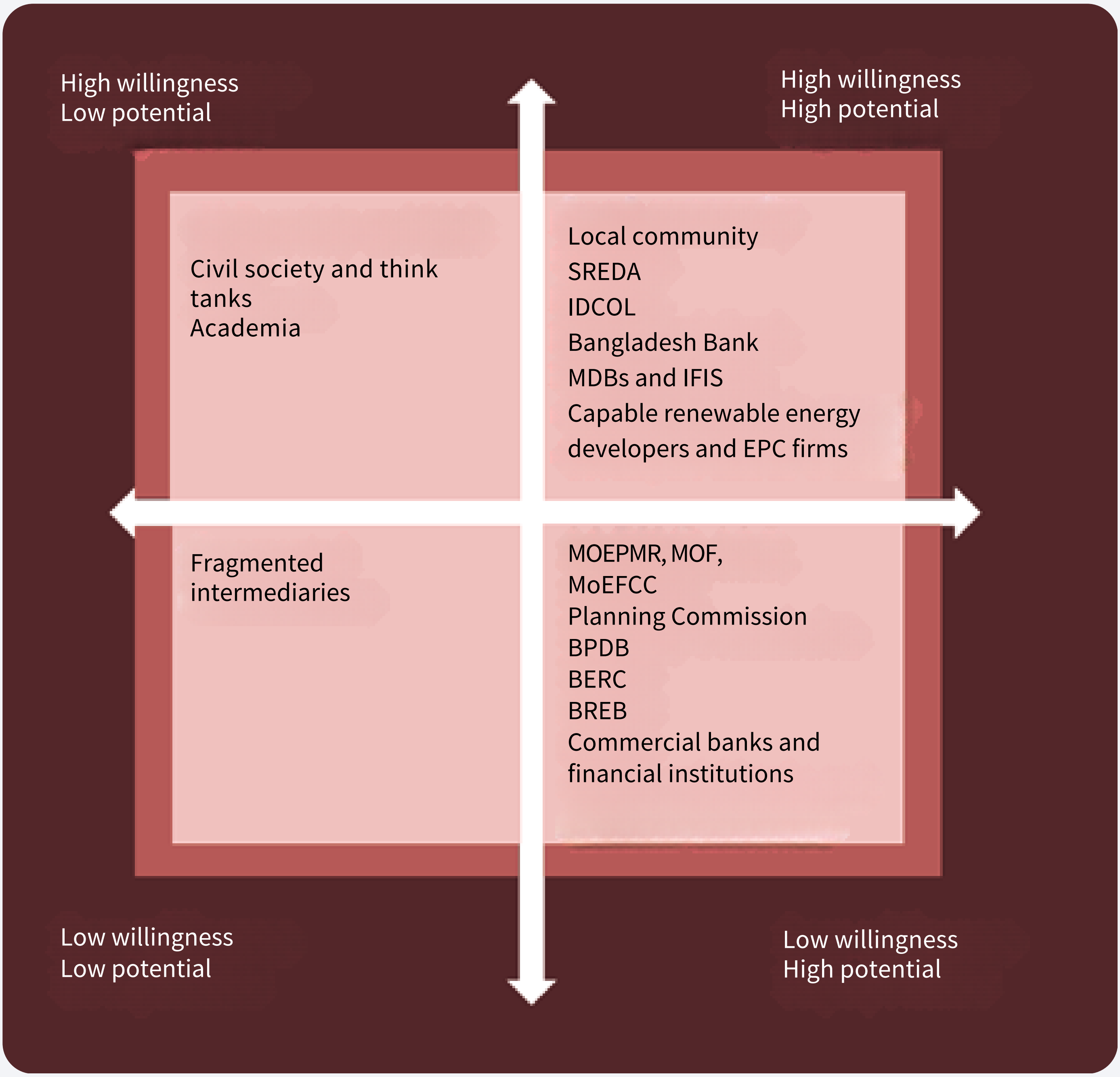
However, bottlenecks persist as systemic frictions that inflate investment risks: many policies, including the Captive Power Plant Guidelines (2007, revised 2019) and Solar Power Development Program (2013), default to fossil-centric models, treating renewables as exceptions rather than defaults, leading to contingent liabilities from capacity payments and stranded assets. It demonstrates the institutional overlaps (e.g., between SREDA, BERC, and BPDB) that cause delays, weak MRV/data systems flagged in NDCs (2021 and 2025), and finance-contingent ambitions where conditional targets (60% in NDC 3.0) depend on external support, exposing vulnerabilities to global funding cycles. Land and grid absorption constraints, noted in IEPMP 2023, further exacerbate development risks, while political-economy issues like subsidy reform resistance hinder tariff discipline needed for investor confidence.

To unlock renewables as energy sovereignty assets, Bangladesh can repurpose these policies into a cohesive investment roadmap by operationalizing de-risking tools: standardize RE hubs with pre-secured land and evacuation (Renewable Energy Policy 2025), fast-track grid codes and storage via the Electricity Act and PSMP, and leverage SREDA's fund for concessional windows that target high-security-impact segments like solar irrigation and mini-grids (Eighth Five Year Plan, BDP 2100). A key hidden insight for climate finance is to treat conditional NDC elements as a blended-finance taxonomy, pairing Article 6 carbon crediting with guarantees to crowd in private lenders, while using BERC's tariff authority and the Energy and Power Research Council (2015) for performance benchmarks that reduce information asymmetry. Ultimately, by aligning procurement with macro-hedging logic e.g., prioritizing diesel-displacement and peak-shaving projects, this policy ecosystem can shift from aspirational targets to financeable pipelines, delivering fiscal savings, reduced import dependence, and enhanced resilience.

3.3 Stakeholders Mapping and Political Economy Analysis

The renewable energy stakeholder environment in Bangladesh presents a complicated combination of power, capability, and interest. While several groups demonstrate high willingness, they are often handicapped by overlapping mandates, and slow inter-agency execution. This implies that renewable energy acceleration is not primarily a technical delivery constraint; it is a political economic coordination problem in which bankability, permitting decisions, and payment credibility are determined by institutional incentives and enforcement capacity across multiple agencies.

Figure 11: Political Economy Mapping of Renewable Energy in Bangladesh



Source: Authors' Compilation

In this roadmap, local communities are positioned at the center stage not only as rights-bearing stewards of land and local ecosystems, but also as prosumers with high willingness and high potential. By giving communities, a direct stake in generation, use, and local oversight, the prosumer approach can reduce project friction, improve payment discipline, and make renewable energy investment more locally legitimate and bankable.

The High willingness- Low potential quadrant includes stakeholders that are aligned with the renewable agenda but cannot unlock investment at the pace and scale required. Civil society, think tanks, and academia sit here: their willingness is high because transition improves resilience and reduces import exposure, but their direct control over procurement and financing terms are limited.

The Low willingness- High potential quadrant contains stakeholders with the most decisive levers over renewable energy but whose willingness is often limited by perceived risks and political tradeoffs. Ministries and agencies responsible for public finance may be cautious because renewable incentives can create short-term fiscal exposure or contingent liabilities; power-sector gatekeepers may deprioritize renewables while regulators can be hesitant when tariff reforms carry inflation optics.

The final quadrant includes actors who neither have strong incentives to advance renewable energy nor possess decisive capacity to unlock investment at scale. Some of these are fragmented intermediaries and small market players with weak capacity and limited balance sheets; others may benefit from opaque processes, discretionary approvals, or short-term arbitrage opportunities that make them structurally resistant to rule-based reform.

Chapter 4

Projected Renewable Energy Demand and Required Investment in Bangladesh (2026-2040)

This roadmap is structured into two distinct phases to manage the national debt burden and allow for technical maturity. Phase 1 (2025 - 2030) that requires an investment of $8.72 Billion. This phase prioritizes the highest-yield industrial rooftops and the most intensive diesel-pumping regions, establishing a "proof-of-concept" for the decentralized model. The objective is to demonstrate technical feasibility and stable returns, thereby lowering the risk premium for international investors.

Phase 2 (2031–2040), which is the "National Scale-Up” phase, requires $24.10 Billion. This phase leverages the technical and financial learnings of Phase 1 to expand decentralized solar into secondary industrial zones and the remaining agricultural clusters. By the start of Phase 2, the costs of BESS and PV components are projected to have decreased significantly, improving the overall internal rate of return (IRR) for the projects. This phased approach ensures that Bangladesh achieves its 30% renewable target through a fiscally responsible and technologically grounded trajectory.

4.1 Renewable Energy Demand in Bangladesh till 2040

Based on the ARDL-UECM analysis, the national power demand is projected to transition from its baseline of approximately 103 TWh to a significantly higher trajectory by 2040. The following table summarizes the long-term growth in the total energy demand and renewable energy demand to meet the 20% and 30% target by 2030 and 2040, respectively. For the detailed and step-by-step calculation of the demand using ARDL model, refer to the annex (1).

Table 4: Energy Demand Forecasting in Bangladesh (2026-2040)

Indicator	2026	2030	2040
Energy Demand (GWh)	110,610	146,825	282,696
Peak Load Capacity (MW)	28,059	37,246	71,713
Renewable Penetration (%)	-	20.00%	30.00%
Total RE Required (MW)	**1,200**	**7,449**	**21,514**
	(Base)	(Phase 1 Target)	(Phase 2 Target)

Source: Authors' Compilation

4.2 Scenario Analysis for Renewable Energy Investment Need

This table separates the roadmap into what investors immediately recognize as the "plant cost" (renewable generation) versus the less visible but decisive "system cost" (storage and grid integration). The key point is that generation investment is fixed across all scenarios: in every case, Bangladesh needs $5.94B by 2030 and $19.03B by 2040 for RE generation, totalling $24.97B. So, the scenarios are not debating how much renewable capacity to build; they are debating whether the roadmap prices the enabling infrastructure needed to make that capacity deliver reliable electricity.

Table 5: Scenario Analysis for Renewable Energy Investment Need

Investment Phase	Category	Scenario 1: Full-Spectrum	Scenario 2: Generation Only	Scenario 3: Battery Energy Storage System
Phase 1: 2026-2030	RE Generation (Solar/Wind)	$5.94 Billion	$5.94 Billion	$5.94 Billion
(Target: 7,449 MW)	Storage & Grid Integration	$2.64 Billion	$0.00	$1.75 Billion
---	Sub-Total (Phase 1)	$8.58 Billion	$5.94 Billion	$7.69 Billion
---	---	---	---	---
Phase 2: 2031-2040	RE Generation (Solar/Wind)	$19.03 Billion	$19.03 Billion	$19.03 Billion
(Target: 21,514 MW)	Storage & Grid Integration	$9.91 Billion	$0.00	$6.10 Billion
---	Sub-Total (Phase 2)	$28.94 Billion	$19.03 Billion	$25.13 Billion
---	---	---	---	---
TOTAL ROADMAP	Generation + System	$37.52 Billion	$24.97 Billion	$32.82 Billion
	Avg. Annual Need	**$2.50 Billion/Yr**	**$1.66 Billion/Yr**	**$2.18 Billion/Yr**

Source: Authors' Compilation

The difference sits entirely in Storage & Grid Integration. In the Full-Spectrum scenario, the roadmap explicitly includes these costs to be $2.64B by 2030 and $9.91B by 2040, raising the total to $37.52B. In the Private-Battery scenario, some flexibility is expected to be financed and deployed through private investment, so integration needs fall to $1.75B by 2030 and $6.10B by 2040, bringing the total to $32.82B. In the Gen-Only scenario, integration is shown as $0, so the total remains $24.97B but this should be read as unpriced, not "unneeded." The power system still requires balancing, dispatchability, and grid readiness; the cost is simply shifted outside the roadmap (to later public spending, operational inefficiencies, or reliability losses).

The phase split is also instructive. Phase 2 (2030-2040) is where the financing and execution challenge concentrates: generation scales up sharply, but integration scales even more because higher renewable penetration increases the need for flexibility and grid absorption. This is why the investment gap is not only about building more MW; it is about ensuring those MW become usable energy rather than paper capacity vulnerable to curtailment, congestion, and payment stress.

Finally, the “Avg. Annual Need” row translates these choices into a financing narrative. Full-Spectrum requires about $2.50B/year, Private-Battery about $2.18B/year, and Gen-Only about $1.66B/year. The apparent “cheapness” of Gen-Only is therefore a balance-sheet illusion: it lowers the visible capital ask by excluding the system component that determines deliverability and investor confidence. The Private-Battery pathway reads as a pragmatic middle option still acknowledging system stability needs but reducing fiscal pressure by crowding in private capital for flexibility.

4.3 Scenario Comparison

Table 6: Comparative Scenario and Investment Need for Renewable Energy

Investment Phase	Scenario 1: Full-Spectrum	Scenario 2: Generation Only	Scenario 3: Battery Energy Storage System
Phase 1 (2030)	$8.58 Billion	$5.94 Billion	**$7.69 Billion**
Phase 2 (2040)	$28.94 Billion	$19.03 Billion	**$25.13 Billion**
TOTAL (2026-2040)	**$37.52 Billion**	**$24.97 Billion**	**$32.82 Billion**

Scenario 1: Comprehensive National Grid Modernization

Scenario 1 represents a high-capital intensity path, totaling $37.52 Billion. This configuration integrates the decentralized renewable fleet with a comprehensive modernization of the national smart-grid and centralized utility-scale storage facilities. While this path provides the highest theoretical level of system reliability, it entails significant pressure on the public exchequer. It assumes a state-led modernization of the entire transmission and distribution network to allow for the seamless integration of renewable resources.

This configuration maintains a high degree of centralized oversight. While technically robust, the associated fiscal burden and reliance on sovereign debt may create implementation bottlenecks. Nonetheless, Scenario 1 serves as a critical benchmark for evaluating the total systemic cost of a fully modernized, high-reliability national grid.

Scenario 2: Generation-Focused Capacity Expansion

Scenario 2 represents the most capital-conservative approach, totaling $24.97 Billion. This framework prioritizes the rapid installation of decentralized generation assets while if the existing grid infrastructure can accommodate the increased renewable penetration without significant immediate upgrades or dedicated storage investments. By eliminating the expenditures associated with BESS and grid modernization, Scenario 2 offers the lowest direct capital requirement per megawatt of installed capacity.

However, this scenario presents substantial long-term technical and economic risks. Without the "Stability Premium" provided by BESS, the grid remains highly vulnerable to the variability of solar output. During peak solar production hours, the system may experience over-voltage conditions, while the lack of storage ensures that the renewable fleet cannot contribute to the critical evening peak. From a bankability perspective, Scenario 2 may struggle to attract risk-averse institutional capital, as the probability of technical curtailment and system instability increases. It serves as a cautionary model, illustrating that prioritizing lower initial CAPEX can lead to higher total system costs and reduced reliability in the long run.

Scenario 3: Optimized Private-Sector Battery Integration

Scenario 3 represents the recommended strategic pathway, requiring a total investment of $32.82 Billion. This scenario seeks an optimal equilibrium between capital efficiency and system reliability by mandating that decentralized generation projects-specifically in the industrial and irrigation sectors-incorporate site-specific battery storage. This approach shifts the burden of grid stability from the state to the private developers and industrial prosumers, utilizing a "Behind-the-Meter" storage model.

By allocating $7.85 Billion to localized BESS, Scenario 3 ensures that decentralized energy becomes a dispatchable asset, capable of firming up the evening peak. This scenario is particularly attractive to Multilateral Development Banks (MDBs) as it creates a distributed network of resilient nodes rather than a fragile, centralized system. Furthermore, it allows the state to preserve its sovereign debt capacity, as the majority of the investment can be mobilized through private-sector financing mechanisms, supported by appropriate fiscal incentives and net-metering regulations.

4.4 Decentralized Renewable Energy Capacity Targets (MW)

This table 11 presents the allocation of decentralized renewable energy (RE) capacity targets by technology for 2030 and 2040, consistent with the Zero-Arable Land principle.

Table 7: Renewable Energy Capacity Allocation-Land Impact Matrix

Technology Sub-Sector	Share of Solar	Target 2030 (MW)	Target 2040 (MW)	Land Impact
Total RE Target (MW)	100%	7,449	21,514	-
I. SOLAR (Decentralized)	(80%)	5,959	17,211	ZERO Arable Land
Rooftop Solar	*(70%)*	*4,171*	*12,048*	Uses existing factory/home roofs.
Solar Irrigation	*(20%)*	*1,192*	*3,442*	Uses existing agricultural plots.
Floating Solar	*(10%)*	*596*	*1,721*	Uses ponds/reservoirs/Kaptai lake.
II. NON-SOLAR	(20%)	1,490	4,303	Focus on coastal belts.

Source: Authors' Compilation

A total renewable energy target of 7,449 MW by 2030 and 21,514 MW by 2040 is first divided into solar (80%) and non-solar (20%) components. The solar portion is further re-allocated across decentralized sub-sectors based on land-use efficiency and deployment feasibility. Specifically, 70% of solar capacity is assigned to rooftop solar, leveraging existing industrial and residential rooftops; 20% to solar irrigation, integrated within existing agricultural plots; and 10% to floating solar, utilizing ponds, reservoirs, and large water bodies such as Kaptai Lake. Together, these solar technologies comply with a zero net impact on arable land.

The remaining 20% non-solar capacity is allocated to wind and biomass, consistent with the existing baseline, with wind development concentrated along coastal belts where land-use conflicts are minimal. Overall, the allocation ensures that renewable energy expansion is achieved through distributed, land-efficient technologies, while maintaining a balanced technology mix and minimizing pressure on agricultural land.

4.5 Discussion on Energy Governance and Socio-Economic Transformation

The transition to a decentralized, renewable-led energy system necessitates a fundamental restructuring of energy governance in Bangladesh. This roadmap transcends simple capacity targets, proposing a shift that redefines the state’s role, protects fundamental resource rights, and secures long-term macroeconomic resilience.

4.5.1 Redefining Governance: From Monopoly to Market Facilitator

The traditional “Command and Control" model - where the state serves as the sole off-taker and primary generator - has reached its fiscal and technical limits. The mounting burden of capacity payments for underutilized fossil-fuel plants, combined with the extreme volatility of global LNG markets, has created a rigid system that is both economically unsustainable and prone to supply shocks. Our analysis supports a transition toward a Market-Facilitator model of governance. In this decentralized framework, the state’s role shifts from a monopoly provider to a regulator of a diverse ecosystem of energy producers. By empowering industrial prosumers and agrarian energy hubs, the state effectively decentralizes the operational and financial risks of the energy transition. This fosters "Energy Autonomy," where localized nodes of production and storage reduce the systemic impact of centralized grid failures, providing a resilient foundation for a 21st-century economy.

4.5.2 The No-Land Mandate and Agricultural Integrity

A defining feature of this roadmap is the explicit exclusion of utility-scale renewable energy in favor of a decentralized approach. In conventional planning, land use is often treated as a secondary environmental impact; however, in Bangladesh - the world's most densely populated non-city-state - land is a finite strategic asset inextricably linked to food security. By prioritizing industrial rooftops and aquatic infrastructure, we preserve nearly 60,000 acres of prime agricultural soil. This "Zero-Arable Land" mandate ensures that the transition to renewable energy does not violate the fundamental requirement for food sovereignty. From a research perspective, this creates a unique model for land-constrained nations, demonstrating that renewable targets can be achieved through innovative spatial planning and the integration of generation assets into the existing built environment rather than through land displacement.

4.5.3 The Sovereignty Dividend: Macroeconomic Stability

The $32.82 billion investment requirement must be evaluated against the "avoided costs" of the status quo. Bangladesh's current trajectory relies on imported fossil fuels, creating a perpetual drain on foreign exchange reserves. By transitioning to a renewable-led system, the nation effectively swaps variable operational expenditures (fuel imports) for fixed domestic capital assets. This "Economic Sovereignty Dividend" provides long-term stability, shielding the Central Bank from currency devaluations and inflationary fuel price spikes. Every gigawatt of decentralized capacity installed acts as a hedge against global volatility, allowing for more predictable fiscal planning and ensuring that energy wealth remains within the domestic economy rather than being exported to fuel-producing nations.

4.5.4 Mitigating Variability via the Virtual Power Plant (VPP)

The discussion surrounding renewable energy is often dominated by concerns regarding intermittency. Our findings suggest that this is an investment problem solvable through the "Stability Premium." By distributing battery storage at the point of generation rather than at centralized substations, the roadmap creates a Virtual Power Plant (VPP) architecture. In this model, thousands of decentralized nodes balance the grid in concert; localized BESS units absorb excess energy during the day and discharge it during the evening peak. This decentralized storage is inherently more resilient than centralized systems; failure in a single node does not jeopardize the entire grid. Economically, this reduces the total system cost by minimizing the requirement for expensive, gas-fired "spinning reserves."

4.5.5 Socio-Economic Inclusion and Institutional Reform

The roadmap's focus on solar irrigation transforms 1.34 million pumps into "Agrarian Energy Hubs." This empowers rural populations to participate in the modern energy economy, supporting local processing and digital connectivity. Rather than being passive recipients of state power, rural communities become active stakeholders. However, achieving this requires dismantling legacy institutional barriers. Fragmented oversight must give way to Regulatory Harmonization, centered on a "Single-Window" clearing house for decentralized projects. Fiscal policy must also align with technical needs, providing targeted incentives and duty exemptions for BESS components to lower the cost of private capital. Ultimately, the 2040 vision represents a move toward energy autonomy - shielding the national power system from global volatility and providing a replicable model for land-constrained emerging economies.

Chapter 5

Investment Mobilization: Strategic and Innovative Financing

The implementation of the decentralized renewable energy roadmap requires a total capital mobilization of $32.82 Billion through 2040. Meeting this requirement necessitates a transition from traditional sovereign debt models toward a sophisticated, multi-dimensional financing architecture. This chapter delineates the strategic sources of capital, the institutional mechanisms for fund mobilization, and the structural frameworks required to ensure that each instrument is both bankable and practically viable within the contemporary macroeconomic context of Bangladesh.

5.1 Sovereign and Institutional Capital Mobilization

The mobilization of large-scale capital requires instruments that align national policy outcomes with global institutional mandates. This involves utilizing sustainability-linked debt and tapping into the strategic liquidity pools of the Gulf Cooperation Council (GCC) sovereign wealth funds.

5.1.1 Sustainability-Linked Bonds (SLB) and Performance Accountability

To bridge the initial financing gap, the state can issue "Climate Prosperity" Sustainability-Linked Bonds. Unlike conventional bonds, the cost of borrowing for an SLB is tied to the achievement of specific renewable energy targets. For instance, the coupon rate remains stable if the nation reaches its target of 20% renewable energy by 2030, but "steps up" by a pre-defined basis point penalty if the targets are missed. This mechanism transforms policy commitments into a financial obligation, increasing credibility among global ESG investors and Multilateral Development Banks (MDBs).

5.1.2 Strategic Alignment with GCC Capital

The liquidity pools of GCC sovereign wealth funds, such as Saudi Arabia's Public Investment Fund (PIF/ACWA Power) and Abu Dhabi's Mubadala/Masdar, offer a critical pathway for utility-scale decentralized investment. These entities prioritize the "Develop-Invest-Operate-Optimize" model, which fits the 2040 roadmap's requirement for high-reliability infrastructure. To attract this capital, the roadmap leverages the Merchant Power Model, allowing developers to build facilities and sell electricity directly to industrial consumers via the grid, bypassing the liquidity constraints of the state utility. Combined with Shariah-compliant insurance from the Islamic Corporation for the Insurance of Investment and Export Credit (ICIEC), this creates a bankable environment for institutional Gulf capital.

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5.2 Fiscal Policy and Regulatory Reorientation

A fundamental shift in fiscal policy is required to redirect capital from fossil-fuel-intensive expenditures toward renewable energy infrastructure. This reorientation utilizes both the rechanneling of existing capital and the implementation of regulatory levies.

5.2.1 Rechanneling LNG Capital

Empirical research indicates that for every $1 USD redirected from planned LNG infrastructure and fuel imports toward decentralized renewable energy, a total systemic economic benefit of $17 USD is generated. This is achieved by reducing an $8 USD loss - stemming from fuel subsidies, foreign exchange leakage, and technical transmission losses - and generating a $9 USD gain through domestic value creation and energy price stability (see Annex for details). By capping future LNG expansion and rechanneling those funds into a National Renewable Energy Fund, the state provides the low-interest liquidity needed for Phase 1 implementation.

5.2.2 Fossil Fuel Sunset Fees and Revenue Recycling

To gradually shift industrial incentives, a phased "Sunset Fee" can be applied to fossil-fuel-based power consumption. Designed as a Pigouvian-style correction, this fee is administratively simple: a line item on gas bills that increases over three phases. Crucially, any industrial unit that installs rooftop renewable energy or enters a corporate PPA becomes exempt from the fee. The revenue generated is recycled specifically into industrial zone grid upgrades, ensuring that current fossil-fuel activity finances the infrastructure needed for the transition.

5.3 Social and Community-Led Finance

To ensure energy sovereignty at the grassroots level, the roadmap utilizes social finance instruments that move away from consumption-based relief toward productive asset ownership.

5.3.1 The Zakat Solar Fund

With an estimated potential of $17 Billion USD in 2024, Zakat can be transformed from temporary relief into a tool for energy autonomy. The "Productive Zakat" model utilizes the principle of Tamlik (transfer of ownership) to provide Zakat-eligible communities with debt-free equity in renewable energy assets, such as solar irrigation pumps or mini-grids. Rather than being passive beneficiaries, households become shareholders in a productive asset that reduces energy costs and generates recurring dividend income.

5.3.2 Cooperative Equity and Community Stewardship

To address the "tragedy of the commons" in rural assets, the roadmap promotes a cooperative equity model for solar irrigation. These associations are structured as legal entities where farmers own "water shares." By utilizing a blended mix of 40% grants, 40% loans, and 20% farmer equity, the cooperative ensures long-term maintenance is an economic interest rather than a social obligation. Grid-integration during the off-season creates a second revenue stream that services the debt and funds dividends, making the model self-sustaining and resilient.

5.4 Macroeconomic Risk Management and Diaspora Capital

Currency volatility and short debt tenors are primary barriers to bankability. The roadmap addresses these through specialized risk-allocation instruments and the mobilization of diaspora savings.

5.4.1 FX Hedging and Local-Currency Refinancing

Currency fluctuations repeatedly destabilize otherwise viable projects. A dedicated "Currency Hedging Facility," potentially hosted by the Central Bank, can offer standardized hedging products to renewable energy projects. Furthermore, a local-currency refinancing facility allows commissioned projects to swap short-term high-interest debt for long-tenor local currency loans, reducing rollover risk and improving the debt service coverage ratio (DSCR).

5.4.2 Remittance-Backed "Probashi" Diaspora Bonds

Bangladesh possesses a 10-million-strong global workforce. The "Probashi" Green Diaspora Bond is a dollar-denominated instrument that allows migrants to invest their savings directly into national renewable energy infrastructure. By ring-fencing these proceeds into a Green Infrastructure Escrow Account, the bond ensures that funds are used exclusively for capital assets. Non-financial incentives, such as "Green CIP" status for investors, provide additional motivation for uptake, strategically linking diaspora success with national energy independence.

5.4.3 Community Carbon Cooperatives and Digital MRV

To monetize environmental outcomes at the smallholder level, the roadmap utilizes Community Carbon Cooperatives. These cooperatives aggregate thousands of micro-actions - such as improved irrigation or residue management - into a single carbon-credit program. By utilizing Digital Monitoring, Reporting, and Verification (dMRV) through mobile applications and geo-tagged data, the cooperative reduces transaction costs, allowing farmers to access international carbon revenue as a seasonal bonus to increase agricultural productivity.

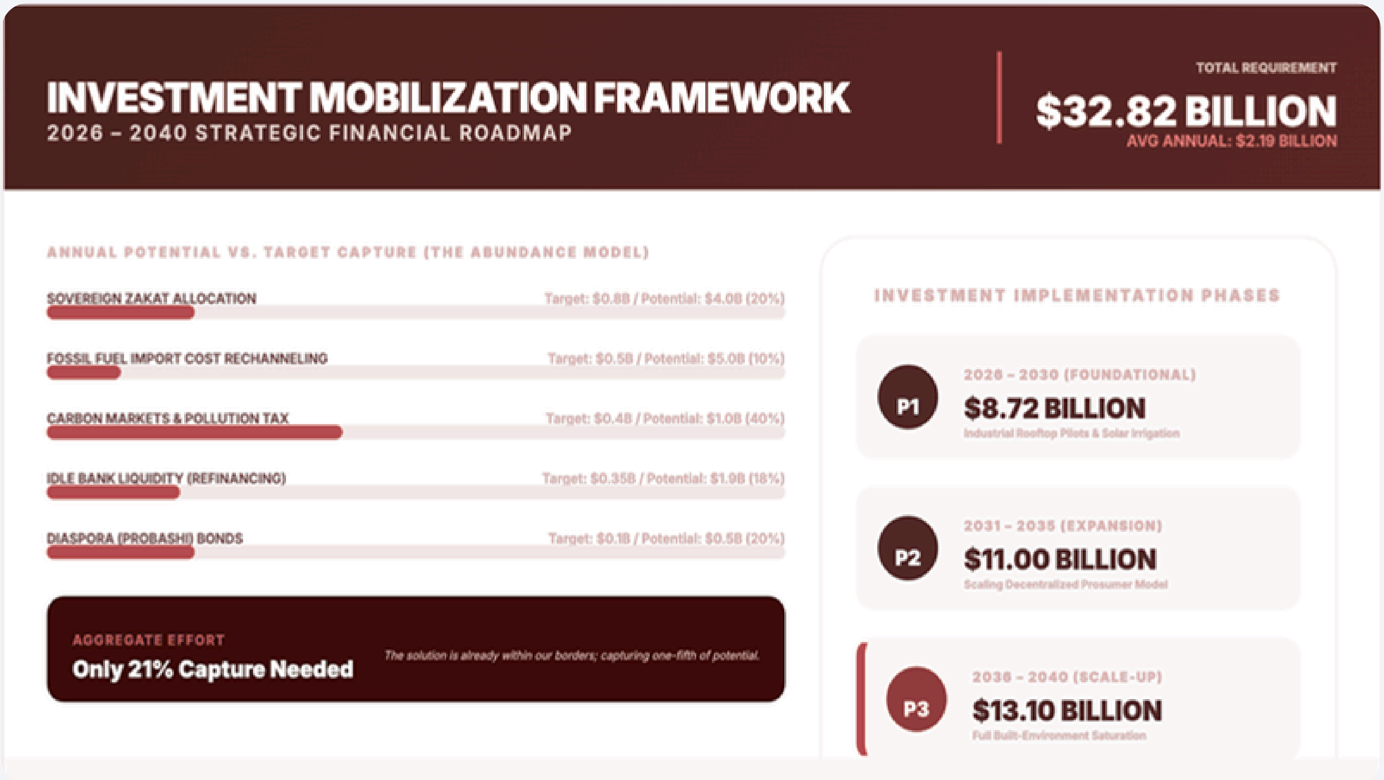
5.5 Institutional De-risking: PCGs and First-Loss Window

The finance gap in Bangladesh is often a result of a lack of risk-sharing for segments where collateral is weak. To crowd in domestic commercial banks, the roadmap proposes a Partial Credit Guarantee (PCG) combined with a first-loss blended finance window. Hosted by a public financial intermediary like IDCOL, this facility absorbs initial defaults up to a certain cap, significantly reducing the expected credit loss for commercial lenders. This converts hesitant bank liquidity into longer-tenor lending for renewable energy segments that currently sit outside traditional comfort zones.

5.6 Investment Mobilization Framework

This roadmap recommends a total $32.82 billion investment for the transition to energy sovereignty, averaging $2.19 billion annually. This framework replaces a $5 billion annual foreign exchange drain with permanent domestic assets. By capturing just 21% of identified internal and innovative potential, Bangladesh can shift from a debt-heavy import model to a debt-free prosumer architecture (see Annex 4 for details).

Primary mobilization channels include Sovereign Zakat Allocation ($4B annual potential), Idle Bank Liquidity ($9.5B total), and the rechanneling of fossil fuel import costs. This strategy leverages a 1:17 sovereignty multiplier, where every $1 invested saves $8 in systemic losses and generates $9 in new economic value. Execution centers on a "Zero-Arable Land" strategy, utilizing industrial rooftops and solar irrigation to eliminate $2.5 billion in annual capacity payments. This is a calculated shift from recurring resource bleeding to high-yield sovereign infrastructure.



5.6.1 Strategic Solutions to Accelerate Renewable Energy Investment in Bangladesh

Bangladesh can accelerate renewable energy investment without exposing the national budget to costly sovereign guarantees. Instead of placing taxpayer resources behind private power contracts, the Government can mobilize domestic and international capital through targeted risk-sharing instruments, concessional finance, competitive auctions, and innovative financing mechanisms.

This approach will reduce contingent liabilities and future debt burdens, improve sovereign creditworthiness, attract private investment at lower cost, strengthen energy sovereignty; and accelerate achievement of the 10,000 MW solar target.

Chapter 6

Summary Findings and Way Forward

The transition to a renewable-led energy system in Bangladesh is a strategic macroeconomic necessity to enhance energy security and reduce import bill volatility. This section synthesizes the core lessons from the investment roadmap and provides a granular, sector-specific execution framework to achieve energy sovereignty by 2040.

6.1 Summary Findings: Macroeconomic and Sectoral Insights

The roadmap identifies critical bottlenecks and opportunities across the energy landscape:

- **Generic Macro-Dynamics:** Electricity demand is highly elastic, with a 1% GDP growth corresponding to a 1.22% increase in load, necessitating front-loaded investment to avoid economic suppression.
- **The Financing Realism:** The current RE investment landscape is 90.43% debt-led, revealing a critical absence of risk capital and equity, which limits the scale of repeatable project pipelines.
- **Rooftop Solar:** Industrial prosumers in the RMG and textile sectors see RE not just as a cost-saver, but as an ESG competitive differentiator for global market access.
- **Solar Irrigation:** Transitioning from diesel-based systems is a fiscal imperative, as it substitutes high-cost fuel imports and subsidies with domestic capital assets.
- **Floating Solar:** Aquatic PV offers a 5–10% efficiency gain due to thermal regulation while simultaneously reducing water evaporation in reservoirs.

6.2 Way Forward: Strategic and Sector-Specific Actions

To mobilize the $32.82 billion required, the roadmap proposes the following implementation pathways:

Generic Policy and Finance

- **Reward Foreign Investors:** Implement "Merchant Power" models to allow developers to sell directly to industrial clusters, bypassing state payment backlogs and ensuring bankability.
- **Incentivize Global Capital:** Provide 10-year full corporate tax exemptions for projects commissioned before 2030 and establish a "Currency Hedging Facility" to mitigate FX risks for international portfolios.
- **De-risking Instruments:** Utilize Partial Credit Guarantees and first-loss blended finance to lower the risk premium for commercial lenders.

Sectoral Execution Pathways

- **Industrial Rooftop Solar:** Standardize corporate Power Purchase Agreements (PPAs) and "Lease-to-Own" models to transform factory roofs into a $13.79 billion bankable asset class.
- **Solar Irrigation:** Deploy cooperative equity models where 1.34 million diesel pumps are transitioned to solar energy hubs, allowing farmers to earn dividend income from grid sales during off seasons.
- **Floating Solar PV:** Prioritize FPV on Kaptai Lake and industrial water bodies to reach a 1,721 MW capacity vision by 2040 without encroaching on productive land.
- **Community Off-Grid & Land Policy:** While the roadmap adheres to a "Zero Arable Land" principle for utility-scale solar, it permits strategic, minimal land allocation for community-led off-grid projects. This nuanced approach ensures that remote char villages and localized energy nodes can achieve energy access through community stewardship models.

Technical and Stability Mandates

- **The Stability Premium:** Mandate the integration of site-specific Battery Energy Storage Systems (BESS) for industrial and irrigation projects to firm up the evening peak and ensure grid reliability.
- **Institutional Reform:** Establish a "Renewable Energy Clearing House" as a single-window interface to harmonize regulatory approvals and reduce transaction costs for developers.

6.2.1 Key Policy Actions

A. FISCAL REFORM (COST REDUCTION)

- Duty drawback / tax exemption on solar equipment (panels, batteries, inverters)
- Redirect fossil fuel subsidies from affluent users
- Introduce carbon tax → fund renewable expansion

B. LOW-COST FINANCING (3-4% INTEREST REGIME)

- Cap interest rates at 3-4% for solar investments (CAPEX + OPEX)
- Subsidize bank cost of capital use
- CSR funds of banks & financial institutions
- Bangladesh Bank green refinancing
- Establish credit guarantee facility

C. DIASPORA FINANCING (PROBASHI SOLAR BOND)

- Issue $100 denomination bonds
- Target: 15 million diaspora → $1.5 billion mobilizations
- Managed via international financial hubs e.g. Singapore
- Direct channel to renewable projects

D. PROSUMER MARKET REFORM: ENACT PROSUMER ACT BY JUNE 2025

- Allow households & SMEs to sell surplus electricity locally
- Enable peer-to-peer energy trading
- Deploy smart metering for settlement

E. TAX INCENTIVES (OFF-GRID SOLAR ≤10 MW)

- 10-year tax holiday for mini-grids and decentralized community solar.
- Revenue offset through carbon tax proceeds.

6.3 An Illustrative Financial Model for a 10,000 MW Solar Acceleration Program

Bangladesh's journey toward energy sovereignty is often viewed through the lens of a long-term, 21,000 MW roadmap, yet a focused 10,000 MW solar acceleration reveals a more immediate, high-stakes narrative of economic transformation. This scenario is not merely a technical exercise; it is an $8 billion investment in a permanent sovereign asset, blended across utility-scale farms and decentralized industrial rooftops at an average cost of $0.8 million per MW.

The process begins with the harvest of 15.8 TWh of annual electricity, which translates into a recurring $1.1 billion revenue stream-replacing the volatile expense of imported fuel with stable, domestic wealth. However, the plot reveals a familiar bottleneck: the cost of capital. At market interest rates of 12%, the project's Internal Rate of Return (IRR) remains a stagnant 8–10%. The narrative shifts when financing is restructured to a 3 - 4% concessional model, which rockets the IRR to 18%, making the transition both bankable and irresistible for private equity.

To achieve this without burdening the public treasury, the architecture draws from four untapped reservoirs. First, the state "stops the bleeding" by redirecting 30% of existing fossil-fuel subsidies, unlocking $360 million annually for interest-rate buy-downs. Second, a modest $10/ton carbon tax on the power sector generates $950 million-enough to modernize the national grid and seed the solar subsidy fund. Third, the global diaspora is invited as a primary partner; 10 million Bangladeshis abroad investing just $100 each through remittance-linked "Probashi" bonds can mobilize $1 billion in low-cost capital. Finally, domestic banking CSR pools are utilized to bridge interest gaps, potentially leveraging $5 billion in private investment.

The impact reaches the very heart of the economy through a thriving prosumer market. Over 4,000 MW of rooftop solar allows SMEs to become energy self-sufficient, slashing electricity bills by up to 40% and generating $800 million in annual industrial savings.

The resolution of this 10,000 MW case is purely macroeconomic. At full scale, it eliminates $2 billion in annual fuel import costs, reduces CO_2 emissions by 16 million tons, and creates over 500,000 high-skilled jobs. This case study proves that the barrier to energy independence is not a shortage of capital, but a misalignment of policy. By choosing to prioritize domestic infrastructure over recurring fossil-fuel debt, Bangladesh can transform a "leaking bucket" of resource drain into a high-yield sovereign dividend.

Chapter 7

Conclusion

The Renewable Energy Investment Roadmap establishes that the transition to a decentralized, renewable-led energy system is no longer an environmental elective but a strategic macroeconomic necessity for Bangladesh. As the nation navigates a critical juncture of structural rebalancing and heightened vulnerability to external shocks, energy sovereignty provides the primary hedge against global commodity volatility and fiscal instability.

The empirical foundation of this roadmap, grounded in the ARDL modelling framework, confirms that energy demand is irreversibly tied to Bangladesh's economic maturity. With a high-income elasticity of 1.22 and an urbanization elasticity of 2.21, the power system must prepare for a 7.3% annual increase in load to support a 6% GDP growth trajectory. Failure to proactively front-load this capacity would result in suppressed demand, acting as a direct brake on national development.

A central achievement of this roadmap is the validation of the "No-Land" Decentralized Strategy. By prioritizing industrial rooftops, solar irrigation, and floating solar, Bangladesh can achieve a total renewable energy target of 21,514 MW by 2040 with zero net impact on arable land. This ensures that the energy transition reinforces rather than violates the strategic imperative of food security. Specifically, the transition of 1.34 million diesel-operated irrigation pumps and the utilization of underutilized RMG factory roofs represent the most efficient pathways for large-scale integration.

Financially, the roadmap delineates a $32.82 billion requirement through 2040. The recommended Scenario 3 (Optimized Private-Battery Integration) acknowledges that the "Stability Premium", the inclusion of $7.85 billion in Battery Energy Storage Systems (BESS) is essential to convert intermittent solar into dispatchable energy. This approach de-risks the portfolio for institutional investors and preserves sovereign debt capacity by shifting the burden of grid stability to private-sector prosumers.

To mobilize this capital, Bangladesh must pivot from traditional sovereign debt toward an innovative, multi-dimensional financing architecture. This includes:

- **Social and Diaspora Finance:** Leveraging the $17 billion Zakat potential as a debt-free equity instrument and issuing "Probashi" Diaspora Bonds to link expatriate savings with national infrastructure.
- **Fiscal Rechannelling:** Implementing the "Fuel-Swap" strategy, where redirecting capital from LNG imports to domestic renewables yields a 1:17 investment-to-return ratio.
- **Global Strategic Alignment:** Attracting GCC liquidity through Merchant Power models and IsDB consortium financing to bridge the financing gap.

Finally, the 2040 vision transforms the Bangladeshi energy landscape from a centralized, fossil-fuel-dependent system into a resilient network of distributed nodes. By aligning procurement with macro-hedging logic and operationalizing de-risking tools, Bangladesh can deliver fiscal savings, reduced import dependence, and enhanced economic resilience. This roadmap provides the bankable, evidence-based trajectory required to secure a sustainable and sovereign energy future.

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Annexes

Annex 1: Statistical Assumptions and Step-by-Step Estimation

Annex 1.1: Decentralized Renewable Energy Strategy

The Zero-Arable Land mandate guides the strategy toward decentralized renewable technologies that utilize existing infrastructure or non-productive spaces, minimizing pressure on agricultural land while scaling clean energy capacity.

Table 8:Decentralized Renewable Energy Technology Mix and Capacity Projections

Technology Sub-Sector	Share of RE	2030 Target (MW)	2040 Vision (MW)
Industrial Rooftop Solar	56%	4,171 MW	12,048 MW
Solar Irrigation Pumps	16%	1,192 MW	3,442 MW
Floating Solar PV	8%	596 MW	1,721 MW
Non-Solar (Wind/Bio/Waste)	20%	1,490 MW	4,303 MW

Annex 1.2 Financial Investment Modelling

Investment requirements are modelled across three scenarios to evaluate system reliability.
Capital Expenditure (CAPEX) Assumptions (at $1 equivalent to BDT 122):

·Rooftop Solar: $0.85M / MW
·Solar Irrigation: $1.15M / MW
·Wind (Coastal): $1.35M / MW
·Battery Storage (BESS): $350 / kWh (4-hour duration)

Financial Investment Modelling estimates the capital investment required to implement the proposed decentralized renewable energy strategy. Investment needs are calculated under three scenarios to assess financial feasibility and system reliability. The modelling applies standardized CAPEX assumptions (in constant current USD prices) for each technology type, for instance, rooftop solar, solar irrigation, coastal wind, and battery energy storage systems (BESS). These unit cost assumptions are multiplied by the capacity targets identified in Phase III to estimate total investment requirements and to evaluate the role of storage in supporting system flexibility and reliability.

Annex 1.3 Model Reliability & Diagnostics

To ensure the robustness of the 2040 forecasting, the model passed a diagnostic suite for parameter stability and residual normality.

·Normality (Jarque-Bera): Passed (Normal residuals).
·Autocorrelation (Breusch-Godfrey): Passed (No serial correlation).
·Heteroskedasticity (Breusch-Pagan): Passed (Homoskedastic errors).
·Stability (CUSUM): Parameters verified as stable.

To ensure that the roadmap's energy demand projections provide a robust and credible basis for the planned USD 32.82 billion in investments, the macro-econometric model was subjected to comprehensive diagnostic testing. The Jarque–Bera test confirmed the normality of the residuals indicating that the model's errors follow a Gaussian distribution and are free from systematic bias or specification errors.

Furthermore, the model successfully passed tests for serial correlation and heteroskedasticity , demonstrating that residuals are both independent and stable over time. Together, these results serve as a rigorous quality-assurance benchmark, reinforcing the statistical integrity of the long-term projections. By meeting these technical standards, the roadmap elevates its energy transition strategy to a bankable, evidence-based framework, ensuring that the pursuit of energy sovereignty rests on a mathematically sound and dependable analytical foundation.

Annex 1.4 Variable Description

Table 9: Description of the Variables

Category	Assumption	Rationale
Macroeconomic	**GDP Growth (2025-2030)**	Conservative estimate for post-LDC graduation phase.
	GDP Growth (2031-2040)	Structural stabilization and industrial maturity.
	Urbanization Rate	Targets for modern smart cities and industrial migration.
Econometric	**Income Elasticity**	1% GDP growth creates a 1.22% increase in energy demand.
(ARDL Model)	**Urbanization Elasticity**	The primary driver reflects high intensity of urban living.
	Price Elasticity	Demand is inelastic; grid electricity is an essential good.
	Correction Speed	57% of any supply/demand shock is corrected within 1 year.

Source: Authors' Compilation

This variable description table outlines the factors considered in estimating the power demand and the investment needed. In developing the model, this roadmap also considered several assumptions related to technology mix and financial modelling. See Annex 1 for detailed assumptions for modelling energy demand and investment need.

Table 10: Calculation Assumptions for Energy Demand and Investment Need

Category	Assumption Type	Assumption Value	Rationale for Assumption
Technical	System Load Factor	45%	Reflects evening peak spikes; provides a safety buffer.
	Renewable Tech Split	80% Solar / 20% Non-Solar	2025 Policy alignment; land-efficient mix.
	Storage Needs (BESS)	4-Hour Backup	For 20% of variable solar capacity to ensure stability.
Financial	Solar PV CAPEX	$0.85M - $0.75M / MW	Includes Rooftop, Floating, and Utility averages.
(USD 2025)???	Wind Power CAPEX	$1.35M / MW	Coastal onshore aggregation.
	BESS CAPEX	$350 / kWh	Fully installed containerized lithium-ion systems.
	Grid Integration	15% of Generation	CAPEX for substations and smart transmission lines.

Source: Authors' Compilation

Annex 1.5 Statistical Validation & Elasticities

Prior to estimation, all variables are tested using Augmented Dickey-Fuller (ADF) tests. While levels were non-stationary, all variables became stationary at the First Difference (I(1)), validating the use of the ARDL Bounds Test for forecasting power demand in Bangladesh.

Table 11: Summary of Statistical Properties of the Estimation Model

Annex 1.5 Statistical Validation & Elasticities

Prior to estimation, all variables are tested using Augmented Dickey-Fuller (ADF) tests. While levels were non-stationary, all variables became stationary at the First Difference (I(1)), validating the use of the ARDL Bounds Test for forecasting power demand in Bangladesh.

Table 11: Summary of Statistical Properties of the Estimation Model

Parameter	Coefficient	Standard Error	Interpretation
GDP (B1)	**1.22**	(0.045)	1% GDP growth corresponds to 1.22% demand growth.
Urbanization (B2)	**2.21**	(0.120)	High intensity of urban energy consumption.
Energy Price (B3)	**-0.08**	(0.012)	Highly inelastic; limited consumption response to price.
Speed of Adjustment (α)	**-0.57**	(0.080)	57% recover from shocks within one year.

Source: Authors' Compilation

Annex 1A: Econometric Model Specification

1.Augmented Dicky Fuller Test (ADF)

$$\Delta y_t = \alpha + \beta_t + \Upsilon y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

2.Autoregressive Distributed Lag (ARDL)

$$\Delta Y_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta y_{t-i} + \sum_{i=o}^{q} \beta_2 \Delta x_{t-i} + \lambda_1 Y_{t-1} + \lambda_2 X_{t-1} + \mu_t \qquad (2)$$

3. Error Correction Model (ECM)

$$\Delta Y_t = \alpha + \sum_{i=1}^{p} \Upsilon_i \Delta Y_{t-i} + \sum_{j=0}^{p} \delta_j \Delta X_{t-j} + \varphi ECT_{t-1} + \varepsilon_t \qquad (3)$$

Annex 1A: Econometric Model Specification

(All Equations for ADF, ARDL, and ECM will be inserted here as equation function)

Annex 1B: Econometric Model Diagnostics and Elasticities

The forecasting framework utilizes an Autoregressive Distributed Lag (ARDL) approach to identify the long-run cointegrating relationship between electricity demand (E_t), Real GDP (G_t), Urbanization (U_t), and the Global Energy Price Index (P_t).

Annex 1B.1 Unit Root Analysis (ADF)

Prior to estimation, the stationarity of all series was verified using the Augmented Dickey-Fuller (ADF) test. Results confirm that the variables are integrated of order $I(1)$, a necessary condition for the ARDL Bounds Test.

Variable	Level (p-value)	Δ (p-value)	Decision
$ln(E_t)$	0.7932	0.0001*	Stationary at $I(1)$
$ln(G_t)$	0.9914	0.0000*	Stationary at $I(1)$
$ln(U_t)$	0.5742	0.0012*	Stationary at $I(1)$
$ln(P_t)$	0.4681	0.0000*	Stationary at $I(1)$

Annex 1B.2 Cointegration and Error Correction (ECM)

The ARDL Bounds Test identifies a stable, long-term equilibrium. The Error Correction Term (ECT) quantifies the speed at which the system returns to this equilibrium following a macroeconomic shock.

Test	Statistic	Bound I(0)	Bound I(1)	Conclusion
F-Bounds Test	8.845	3.23 (5%)	4.35 (5%)	Cointegration Validated
Speed of Adj. (ECT_{t-1})	-0.571	-	-	57% Annual Recovery

Annex 1B.3 Long-Run Coefficients

The estimated elasticities represent the structural growth parameters for the 2040 forecast.

Regressor	Elasticity	Standard Error	t-Statistic	P-Value
Income ($ln G_t$)	1.221	0.045	27.13	0
Urbanization ($ln U_t$)	2.214	0.12	18.45	0
Price ($ln P_t$)	-0.082	0.012	-6.83	0

Annex 1C: Physical Capacity and RE Target Modeling

This section converts econometric demand forecasts into required installed capacity (MW) based on a conservative system Load Factor (LF) of 45% and the RE Policy 2025 penetration targets.

Annex 1C.1. Capacity Requirements (2025–2040)

Metric	2025 (Base)	2030 (Target)	2040 (Vision)
Energy Demand (GWh)	110,610	146,825	282,696
Peak Load Capacity (MW)	28,059	37,246	71,713
Renewable Penetration (%)	-	20.00%	30.00%
Total RE Required (MW)	1,200	7,449	21,514

Annex 1C.2. Decentralized Technology Allocation

Under the "Zero-Arable Land" mandate, solar capacity is entirely decentralized.

Technology Sub-Sector	Share (%)	2030 (MW)	2040 (MW)
Industrial Rooftop Solar	56%	4,171	12,048
Solar Irrigation Pumps	16%	1,192	3,442
Floating Solar PV	8%	596	1,721
Non-Solar (Wind/Bio/Waste)	20%	1,490	4,303

Annex 1D: Investment and CAPEX Framework

The financial model utilizes Scenario 3 (Localized Stability) as the baseline for the $32.82 billion requirement, assuming decentralized BESS for grid stability.

Annex 1D.1. Unit Cost Assumptions (at Current USD Price for 2025)

- Solar PV (Rooftop/Avg): $0.85 Million / MW
- Solar Irrigation: $1.15 Million / MW
- Non-Solar (Wind): $1.35 Million / MW
- Battery Storage (BESS): $350 / kWh (4-hour discharge capacity)

Annex 1D.2. Phased Investment Roadmap (USD Billions)

Component	Phase 1 (Till 2030)	Phase 2 (Till 2040)	Total Roadmap
Solar Generation	$5.28	$10.79	$16.07
Non-Solar Generation	$1.69	$7.21	$8.90
Battery Storage (BESS)	$1.75	$6.10	$7.85
Total Phase CAPEX	$8.72	$24.10	$32.82

Annex 1E: Model Reliability Tests

The model was subjected to a diagnostic suite to ensure parameter stability and normality.

Test Type	Metric	Result	Decision
Normality	Jarque-Bera	1.14 (0.56)	Normal Residuals
Autocorrelation	Breusch-Godfrey	0.45 (0.64)	No Serial Correlation
Heteroskedasticity	Breusch-Pagan	1.02 (0.42)	Homoskedastic Errors
Stability	CUSUM / CUSUMsq	Passed	Parameters Stable

Annex 2: Detailed Discussion on the Statistical Output

A1: Determinants and Dynamics of Power Demand Growth

The empirical analysis of the demand model using the Autoregressive Distributed Lag (ARDL) model confirms that electricity consumption is intrinsically tied to the structural transformation of the Bangladesh economy. The Bounds Test (F-statistic: 8.84) verifies a robust long-run equilibrium, suggesting that energy policy must be proactive rather than reactive. By utilizing an Unrestricted Error Correction Model (UECM), we have bypassed the limitations of traditional OLS, ensuring that our projections account for the non-stationary nature of macroeconomic variables while capturing the speed at which the system returns to its long-term growth path.

Regressor	Elasticity	Standard Error	t-Statistic	P-Value
ln(GDPt)	1.221	0.045	27.13	0
ln(URBt)	2.214	0.12	18.45	0
ln(PRICEt)	-0.082	0.012	-6.83	0

Here, GDP denotes the gross domestic product, URB denotes the rate of urbanization (as% of total population), and PRICE denotes the Global Energy Price Index. Additionally, ln denotes natural logarithm and t denotes time.

A1.1 The Income-Demand Nexus: Elasticity and Economic Maturity

The long-run Income Elasticity of 1.22 is a critical indicator of Bangladesh's current development stage. In emerging economies, energy demand typically grows faster than GDP as industrialization intensifies. Our analysis suggests that as Bangladesh nears LDC graduation and transitions toward higher-value industrial output-moving from basic textiles to complex manufacturing-the "energy-intensity" of our wealth creation will rise. This necessitates a front-loaded investment strategy that anticipates demand rather than trailing it.

We observe that at this elasticity level, every 1% of GDP growth intensifies the demand for power by 1.22%. This relationship is not merely a historical artifact but a projection of future industrial needs. If Bangladesh maintains a 6% GDP growth rate, the power system must be prepared for a 7.3% annual increase in load. Failing to provide this capacity results in suppressed demand, which acts as a brake on economic potential. This coefficient signals to investors that the ceiling for energy consumption in Bangladesh is still far off, making power infrastructure a high-yield, long-term asset class.

A1.2 Urbanization as the Primary Driver: Demographic Energy Intensity

The high Urbanization Elasticity (2.21) identifies the rural-to-urban shift as the single most significant pressure point for the grid. Urbanization in Bangladesh is not just about population movement; it is about the transition from low-intensity biomass use to high-intensity electricity-dependent lifestyles. The high-rise residential growth in Dhaka and Chittagong, combined with the proliferation of air conditioning and digital infrastructure, creates a non-linear spike in demand.

From a governance perspective, this suggests that energy security is most effectively addressed where demand is concentrated-in industrial clusters and urban centers. By deploying decentralized, site-specific generation, the system meets the user at the point of consumption. This is economically intuitive: it bypasses the massive transmission losses (currently averaging 8-10%) and the logistical complexities associated with centralized plants located in remote areas. A decentralized model respects the existing urban footprint, utilizing "vertical space" (rooftops) rather than consuming horizontal agricultural land.

A1.3 Systemic Resilience and Error Correction

The Error Correction Term (ECT) of -0.57 implies that the system possesses a natural "reversion to mean," where 57% of any exogenous shock is absorbed within a single year. This indicates that while the Bangladesh energy market is subject to short-term volatility-such as global fuel price spikes or pandemics-it has a strong internal mechanism to return to its long-term growth path.

For Multilateral Development Banks (MDBs) and institutional investors, this ECT value is a proxy for sovereign reliability. It suggests that even in periods of fiscal tightening, the fundamental drivers of energy demand remain tethered to the real economy. This high speed of adjustment provides a stable, predictable foundation for long-term power purchase agreements (PPAs) and ESG-linked financing, as it assures stakeholders that the underlying demand fundamentals are resilient and self-correcting.

A2: The "No-Land" Decentralized Strategy: Technical and Economic Rationale

A2.1 Industrial Rooftop Solar: The Transition to Decentralized Generation

A primary pillar of this roadmap involves the strategic transition of Bangladesh's industrial sectors from passive consumption to active decentralized generation. With an estimated technical potential of 12,048 MW by 2040, industrial rooftop solar represents the most efficient pathway for large-scale renewable integration. The Ready-Made Garment (RMG) and textile sectors, which contribute over 80% of national export earnings, possess significant underutilized rooftop area within Export Processing Zones (EPZs) and private industrial parks.

This strategy offers an optimized economic paradigm for both private entities and state utilities. For industrial operators, on-site solar generation serves as a long-term hedge against the volatility of grid tariffs and fossil fuel price fluctuations. Given that global fashion brands increasingly mandate Environmental, Social, and Governance (ESG) compliance and carbon-neutral supply chains, rooftop solar serves as a critical competitive differentiator for securing market access in high-value jurisdictions. For the utility sector, decentralized generation reduces the demand on an overextended national grid, thereby mitigating technical transmission losses and deferring the capital expenditure required for high-voltage infrastructure upgrades.

This model enhances energy autonomy within the productive sectors. By localizing power generation at the point of use, industrial units achieve a higher degree of self-sufficiency, insulating domestic manufacturing from the volatility of global liquefied natural gas (LNG) markets. This decentralization democratizes the energy landscape, enabling capital-intensive industries to optimize operational expenditures and reallocate savings toward technological advancement and labor productivity.

A2.2 Solar Irrigation: Enhancing Agricultural Resilience

Agriculture remains a fundamental component of the Bangladeshi economy, though it currently relies heavily on carbon-intensive and fiscally burdensome diesel-based irrigation. This roadmap proposes the systematic transition of 1.34 million diesel-operated irrigation pumps to solar-photovoltaic (PV) systems, unlocking 3,442 MW of decentralized capacity by 2040.

The rationale for this transition is based in fiscal sustainability and resource optimization. The state currently allocates substantial foreign exchange reserves to fuel imports, which are subsequently subsidized to maintain agricultural affordability. Solar irrigation mitigates these fiscal imbalances. By substituting variable operational costs with fixed capital assets, the framework provides the agrarian sector with predictable, near-zero marginal cost water resources. This directly reinforces the socio-economic security of the farming community and national food stability.

Furthermore, solar irrigation arrays can function as decentralized rural energy nodes. During non-irrigation periods, these systems can provide surplus energy to local markets, cold storage facilities, and essential service centers. This integrated resource management approach ensures that the rural population becomes an active stakeholder in the national energy transition, fostering a synergistic relationship between food production and energy generation.

A2.3 Floating Solar: Optimizing Aquatic Infrastructure

In light of acute land scarcity, water bodies represent a significant yet underutilized frontier for photovoltaic deployment. The roadmap allocates 1,721 MW to floating solar PV (FPV), primarily utilizing the Kaptai Lake reservoir and large-scale industrial water storage facilities. Technical analysis indicates that FPV offers distinct advantages over land-based counterparts: the natural thermal regulation provided by the water body increases panel efficiency by 5–10%, while the coverage effectively reduces evaporative losses-a critical factor for reservoir management and industrial process water conservation.

FPV represents the highest level of land-use optimization within this framework. By utilizing existing aquatic infrastructure to generate power, the roadmap ensures that energy infrastructure development does not infringe upon agricultural land or the rights of landless populations. While initial capital requirements for FPV remain higher than rooftop configurations, the dual benefit of enhanced energy yield and resource conservation positions it as a strategic necessity for a climate-resilient 2040 energy vision.

Annex 3: Analysis on Sovereignty Multiplier

Annex 3A: Economic Gain on Renewable Energy Investment

Component	Value (Per $1 Invested)	Strategic Category	Description
Initial Capital	**$1.00**	**Baseline Investment**	The unit of capital utilized for decentralized renewable infrastructure.
Saved Losses	**$8.00**	**Resource Bleeding Reduction**	Reclaimed fiscal space from the cessation of capacity payments, fossil fuel subsidies, and high-cost fuel imports.
Economic Gains	**$9.00**	**Value Creation**	Direct and indirect GDP growth generated through domestic energy production, carbon market revenues, and increased industrial productivity.
Net Systemic Gain	**$17.00**	**Total Sovereignty Dividend**	The cumulative economic benefit realized for the nation per unit of investment.

Annex 3A.1. Calculation of Annual Saved Losses ($6.52B Identified)

The analysis identifies $8.00 in losses saved for every $1 invested. At maturity, the primary recurring fiscal recoveries are:

- **Capacity Payments:** $2.50 billion/year saved by transitioning from passive consumption to a decentralized prosumer model.
- **Fossil Fuel Subsidies:** $3.10 billion/year reclaimed from high-emission sectors and redirected toward social safety nets.
- **Carbon Market Revenue:** $925 million/year generated through Article 6 trading and domestic carbon levies.
- **Note:** Remaining values in the $8.00 factor are attributed to avoided spot-market fuel import volatility.

Annex 3A.2. Calculation of Total Economic Gain ($557.94B)

The cumulative GDP potential of $557.94 billion is derived by applying the $9.00 Value Creation factor to the total mobilization target over the 15-year horizon.

- **Formula:** Total Gain = (Total Investment $32.82B / Value Creation Factor 9)

Annex 3B: Forecasted Economic Gain and Phasing Analysis

The economic gains are phased to reflect the transition from the initial de-risking stage to full market scaling.

Table B.1: Average Annual Economic Returns

Period	Phase Description	Average Annual Return (USD)
Phase 1 (2026–2030)	Preparation & De-risking	**$26.15 Billion / year**
Phase 2 (2031–2040)	Market Scaling & Equity	**$42.72 Billion / year**
OVERALL (2026–2040)	**15-Year Horizon**	**$37.20 Billion / year**

Table B.2: Total Average Returns by Phase

Phase	Total Potential Gain (Cumulative)	Logic
Phase 1 Total	**$130.75 Billion**	Focus on MDB-backed pilots and regulatory de-risking.
Phase 2 Total	**$427.20 Billion**	High-velocity private equity and carbon market scaling.
CUMULATIVE TOTAL	**$557.95 Billion**	**Full Sovereignty Dividend Realization.**

Annex 3C: Summary of Fiscal Relief (At 2040 Maturity)

Budget Line Item	Annual Recovery (USD)	Strategic Impact
Capacity Payments	$2.50 Billion	Permanent elimination of non-productive debt.
Fuel Subsidies	$3.10 Billion	Fiscal space reclaimed for productive sectors.
Carbon Revenues	$0.925 Billion	Direct new sovereign revenue stream.
TOTAL ANNUAL RELIEF	**$6.525 Billion**	**Direct recurring benefit to the national exchequer.**

Annex 4: Investment Mobilization Framework

Annex 4A. Annual Investment Mobilization Portfolio

The "Abundance Model" identifies that the required annual investment of $2.19 billion is only 17.2% of the total identified annual potential of $12.75 billion.

Financing Source	Total Annual Potential (USD)	Target for RE Roadmap (USD)	Mobilization Effort
Sovereign Zakat Allocation	$4.00 Billion	$0.80 Billion	20%
Import Cost Rechanneling	$5.00 Billion	$0.50 Billion	10%
Carbon Markets & Tax	$1.00 Billion	$0.40 Billion	40%
Idle Bank Liquidity	$1.90 Billion*	$0.35 Billion	18%
Diaspora (Probashi) Bonds	$0.50 Billion	$0.10 Billion	20%
Multilateral (IMF RSF/MDBs)	$0.35 Billion	$0.04 Billion	11%
TOTAL	**$12.75 Billion**	**$2.19 Billion**	**~17.2% Avg.**

***Based on BDT 1.14 Trillion (~$9.5B) in idle funds distributed over the first 5-year phase.**

Annex 4B: Detailed Discussion on Illustrative Financial Model for a 10,000 MW Solar Acceleration Program

While the roadmap covers a wider decentralized renewable portfolio, the following illustrative model is used to demonstrate how the financing architecture performs under a large-scale solar deployment case. This section presents an illustrative financial model for a 10,000 MW solar program in Bangladesh. The purpose is not to replace the broader 2040 investment model set out in earlier chapters, but to show how a focused solar scale-up can be structured using the same strategic logic of low-cost capital, fiscal reallocation, diaspora finance, distributed market participation, and targeted public de-risking that underpins this roadmap. This makes the financing framework more concrete by linking it directly to expected revenue generation, return profiles, subsidy recycling, and macroeconomic gains.

- **Core Investment Assumptions** The model assumes a total solar deployment of 10,000 MW (10 GW) under conditions considered realistic for Bangladesh. Average capital expenditure is taken as $0.75 million per MW for utility-scale solar and $0.9 million per MW for rooftop or distributed systems, yielding a blended average of $0.8 million per MW. On that basis, the total investment required is estimated at approximately $8 billion. This framing is consistent with the roadmap's broader emphasis on combining utility-linked and decentralized solar pathways rather than relying on a single project archetype.
- **Generation and Revenue Potential** Using a capacity factor of 18%, the annual electricity output from a 10,000 MW solar portfolio is estimated as follows: 10,000 MW × 8,760 × 18% = 15.8 TWh per year Assuming a conservative average tariff of $0.07 per kWh, annual revenue is estimated at:

- **15.8 TWh × $0.07 = $1.1 billion per year** This result is strategically important for the roadmap's argument. It shows that even under conservative tariff assumptions, solar at scale can generate a large and recurring domestic revenue stream while simultaneously reducing exposure to imported fuel volatility. In other words, the transition is not only a climate measure; it is a durable income-generating infrastructure shift.

- **Operating Cost, Payback, and Return Profile**

Operating expenditure is assumed at 1.5% of CAPEX, which translates into annual O&M costs of:

- **approximately $120 million per year**

This yields a net annual cash flow of:

- $1.1 billion – $0.12 billion = approximately $980 million per year
- On that basis, the simple payback period is:
- $8 billion / $0.98 billion = approximately 8-9 years

The Internal Rate of Return (IRR), however, varies sharply by financing conditions. Under current financing conditions, where borrowing costs are assumed at 10–12%, the estimated IRR is only 8–10%, indicating a weak investment profile. By contrast, under a concessional or policy-supported financing structure with 3-4% financing, the estimated IRR rises to 14–18%, making the program significantly more attractive. The strategic implication is clear: the cost of capital is the decisive factor. This is fully consistent with the report's existing argument that the core barrier is not the technical viability of solar, but the structure of financing and risk allocation surrounding it.

- **Subsidy Reallocation as a Solar Finance Mechanism**

The current fossil-fuel burden remains large. Under the model, the annual fossil import bill for LNG and oil is assumed at $8–10 billion, while implicit subsidies and capacity charges are estimated at $1–1.5 billion per year. If 30% of fossil subsidies are redirected to a dedicated solar fund, the available annual fiscal space becomes:

- **$1.2 billion × 30% = approximately $360 million per year**

This reallocation could be used to finance interest subsidies in the 3-4% range, rooftop solar incentives, and credit guarantees. The strategic value of this approach is that it does not require a wholly new fiscal burden; rather, it improves the productivity of public expenditure by shifting support away from recurrent fossil inefficiencies and toward domestic capital formation. This logic closely complements the roadmap's existing discussion on rechannelling LNG capital and recycling fossil-linked revenues into renewable infrastructure.

- **Carbon Tax Revenue Model**

A second financing channel can emerge from carbon pricing. Under a conservative carbon tax of $10 per ton of CO_2, and using an emissions base of 95 million tons within a power-sector range of 90-100 million tons of CO_2 per year, the model estimates annual public revenue of:

- 95 million tons × $10 = $950 million per year
- The proposed allocation is as follows:
- Solar subsidy fund: $500 million
- Grid modernization: $300 million
- Nature protection and pollution reduction: $200 million

This distribution is strategically useful because it links decarbonization with system modernization and environmental co-benefits rather than treating carbon pricing as a narrow fiscal instrument. Under this model, carbon tax revenue alone can fully finance the core public support architecture required for solar transition. This also fits the chapter's broader narrative that regulatory reform and fiscal restructuring can reduce investment friction without deepening sovereign debt dependence.

- **Probashi Bond Mobilization**

Diaspora capital represents another major source of lower-cost financing. The model assumes 10 million diaspora participants investing $100 each, which yields:

$1 billion in mobilization
At an interest rate of 3-4%, this capital would be materially cheaper than commercial borrowing. The funds could be directed toward floating solar, rooftop aggregation, and storage systems. Beyond capital mobilization, this mechanism has an important macroeconomic role: it reduces pressure on foreign exchange reserves and stabilizes import financing for solar equipment. This is strongly aligned with the report's existing treatment of remittance-backed "Probashi" diaspora bonds as a strategic instrument for linking national energy independence with overseas Bangladeshi savings.

- **CSR-Based Interest Subsidy**

The model also identifies a role for the domestic financial sector through CSR-supported interest-rate reduction. Using an estimated annual banking-sector CSR pool of $150–200 million, these funds could be used to subsidize the difference between a market lending rate of 10% and a target renewable energy financing rate of 4%, leaving a 6% interest gap. Under this structure, CSR resources combined with carbon tax revenue can cover the concessionally needed to reduce financing costs. The result would be the unlocking of $3-5 billion in private investment leverage. This is highly consistent with the report's de-risking logic, especially where concessional support is used not to replace private capital, but to make it investable at scale.

- **ProSumer Market Value**

The distributed market case is also substantial. For 4,000-4,500 MW of rooftop solar, assuming an average system size of 50 kW for SMEs, the model estimates electricity cost savings of 30-40%. At economy-wide scale, this generates $500 million-$800 million in annual SME savings, while also reducing grid demand and lowering overall system losses. This is important because the roadmap repeatedly emphasizes that distributed renewable energy is not only a generation strategy; it is also an industrial competitiveness strategy. In Bangladesh's case, prosumer solar can strengthen SMEs directly by reducing energy costs and improving resilience to tariff and fuel-price volatility.

- Tax Holiday Cost versus Gain

For off-grid solar projects of 10 MW or less, the model estimates the cost of a tax holiday at approximately $50-80 million per year. However, this revenue loss is considered negligible when offset against carbon tax proceeds, amounting to less than 10% of that revenue source. The net effect is therefore assessed as strongly positive due to gains in rural electrification and diesel reduction. This aligns well with the report's broader emphasis on decentralized and locally anchored transition pathways, especially in segments where conventional grid extension remains costly or inefficient.

- **Aggregate Macroeconomic Impact**

At full scale, the model projects a set of major macroeconomic gains. These include fuel import savings of $1.5-2 billion per year, CO_2 reduction of 14-16 million tons per year, SME cost reduction of 30-50%, job creation of more than 500,000, and strong improvement in foreign exchange stability. Taken together, these outcomes reinforce one of the central findings of this roadmap: the principal barrier to accelerated solar deployment is not the absence of capital in the economy, but the misalignment of policy, incentives, and risk-sharing mechanisms. Solar scale-up, in this sense, is less a question of resource scarcity than of public-financial prioritization and institutional coordination.

Bangladesh does not face a fundamental shortage of financial resources for large-scale solar development. Instead, the primary challenge lies in a structurally embedded allocation pattern that prioritizes higher-cost and inefficient fossil-fuel–based investments. A well-designed financing architecture combining subsidy reallocation, carbon-based revenue mechanisms, mobilization of diaspora capital, CSR-supported interest rate reduction, and reforms to enable a functional prosumer market can make a 10,000 MW solar program financially viable without imposing an equivalent additional burden on the public budget. The binding constraint is therefore misaligned policy and institutional priorities rather than the availability of financing.

- **Probashi Bond Mobilization**

Diaspora capital represents another major source of lower-cost financing. The model assumes 10 million diaspora participants investing $100 each, which yields:

$1 billion in mobilization
At an interest rate of 3-4%, this capital would be materially cheaper than commercial borrowing. The funds could be directed toward floating solar, rooftop aggregation, and storage systems. Beyond capital mobilization, this mechanism has an important macroeconomic role: it reduces pressure on foreign exchange reserves and stabilizes import financing for solar equipment. This is strongly aligned with the report's existing treatment of remittance-backed "Probashi" diaspora bonds as a strategic instrument for linking national energy independence with overseas Bangladeshi savings.

- **CSR-Based Interest Subsidy**

The model also identifies a role for the domestic financial sector through CSR-supported interest-rate reduction. Using an estimated annual banking-sector CSR pool of $150–200 million, these funds could be used to subsidize the difference between a market lending rate of 10% and a target renewable energy financing rate of 4%, leaving a 6% interest gap. Under this structure, CSR resources combined with carbon tax revenue can cover the concessionally needed to reduce financing costs. The result would be the unlocking of $3-5 billion in private investment leverage. This is highly consistent with the report's de-risking logic, especially where concessional support is used not to replace private capital, but to make it investable at scale.

- **ProSumer Market Value**

The distributed market case is also substantial. For 4,000-4,500 MW of rooftop solar, assuming an average system size of 50 kW for SMEs, the model estimates electricity cost savings of 30-40%. At economy-wide scale, this generates $500 million-$800 million in annual SME savings, while also reducing grid demand and lowering overall system losses. This is important because the roadmap repeatedly emphasizes that distributed renewable energy is not only a generation strategy; it is also an industrial competitiveness strategy. In Bangladesh's case, prosumer solar can strengthen SMEs directly by reducing energy costs and improving resilience to tariff and fuel-price volatility.

- **Tax Holiday Cost versus Gain**

For off-grid solar projects of 10 MW or less, the model estimates the cost of a tax holiday at approximately $50-80 million per year. However, this revenue loss is considered negligible when offset against carbon tax proceeds, amounting to less than 10% of that revenue source. The net effect is therefore assessed as strongly positive due to gains in rural electrification and diesel reduction. This aligns well with the report's broader emphasis on decentralized and locally anchored transition pathways, especially in segments where conventional grid extension remains costly or inefficient.

- **Aggregate Macroeconomic Impact**

At full scale, the model projects a set of major macroeconomic gains. These include fuel import savings of $1.5-2 billion per year, CO_2 reduction of 14-16 million tons per year, SME cost reduction of 30-50%, job creation of more than 500,000, and strong improvement in foreign exchange stability. Taken together, these outcomes reinforce one of the central findings of this roadmap: the principal barrier to accelerated solar deployment is not the absence of capital in the economy, but the misalignment of policy, incentives, and risk-sharing mechanisms. Solar scale-up, in this sense, is less a question of resource scarcity than of public-financial prioritization and institutional coordination.

Bangladesh does not face a fundamental shortage of financial resources for large-scale solar development. Instead, the primary challenge lies in a structurally embedded allocation pattern that prioritizes higher-cost and inefficient fossil-fuel–based investments. A well-designed financing architecture combining subsidy reallocation, carbon-based revenue mechanisms, mobilization of diaspora capital, CSR-supported interest rate reduction, and reforms to enable a functional prosumer market can make a 10,000 MW solar program financially viable without imposing an equivalent additional burden on the public budget. The binding constraint is therefore misaligned policy and institutional priorities rather than the availability of financing.

CHANGE initiative

From Dependence to Sovereignty:
Renewable Energy Investment Roadmap
Towards Just Transition in Bangladesh