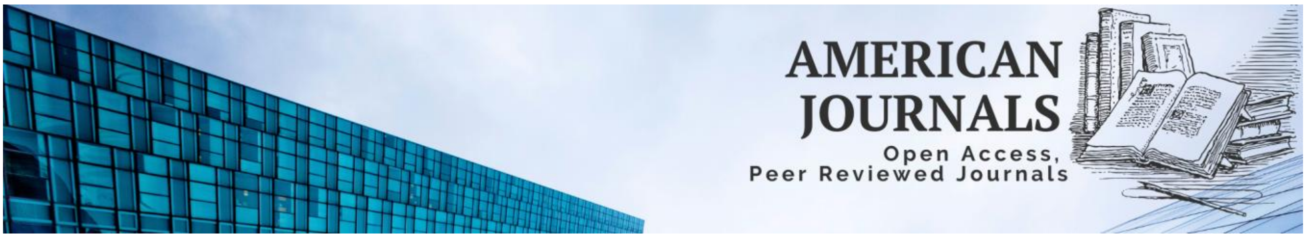


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# A STRATEGIC FRAMEWORK FOR UZBEKISTAN'S TRANSITION TO A GREEN ECONOMY: EXAMINING EXISTING OBSTACLES AND PROSPECTIVE OPPORTUNITIES

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| A B S T R A C T | K E Y W O R D S |
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| In recent years, the economy of New Uzbekistan has experienced sustained growth. Similar to other emerging economies, this expansion has been driven by intensive resource use and the prioritization of industrial development. However, such elevated production levels have imposed adverse environmental consequences. High pollution levels generate significant economic costs—rising healthcare expenditures, declining labor productivity, and increased rates of premature mortality. Consequently, to mitigate ecological damage, optimize resource allocation, and secure genuine economic advancement, Uzbekistan must transition toward a green economy. Moreover, accurately estimating the respective contributions of capital and labor to national output, assessing how environmental quality affects labor efficiency, and forecasting these indicators are indispensable prerequisites for that transition. This article examines the theoretical foundations of sustainable development, reviews international experience, and identifies the obstacles and opportunities that Uzbekistan faces on its path to a green economy. It | Green economy, ecology, sustainable development, Uzbekistan, societal well-being, Kuznets curve, efficiency, natural resources, renewable energy, energy reform, Cobb-Douglas function. |

also presents a current macroeconomic analysis and a forward-looking microeconomic assessment, based on which econometric models are constructed and their parameters estimated.

## Introduction

A stable environmental milieu is recognized as a crucial factor that yields economic gains for every nation. Research indicates that, under conditions of high air quality, workforce productivity can increase by up to 60 percent [5]. However, according to current data, the growth of the global population and sustained economic expansion have continuously intensified the burden on the environment. Over the past century, driven by increases in population and economic activity, the ocean's acidification level has risen by nearly 1.2 times (in 2000 compared to 1900), the rate of tropical forest loss has increased sixfold, and carbon dioxide emissions have grown by 1.5 times. Such climate-related changes, resulting from the rise in global economic activity, may lead to severe consequences in the medium-term perspective [3].

Existing information suggests that, by 2030, economic losses—primarily affecting agriculture—are projected to amount to 1 percent of GDP. Nearly half of these economic losses are associated with habitat degradation due to reductions in water availability and biodiversity, which directly impact agricultural productivity. Climate change also affects labor efficiency and, in Uzbekistan, could reduce the labor supply by 2–5 percentage points [14].

For these reasons, on December 2, 2022, the President of the Republic of Uzbekistan adopted the Decree "On Measures to Increase the Effectiveness of Reforms Aimed at Transitioning the Republic of Uzbekistan to a 'Green' Economy by 2030." Under this decree, and within the framework of Uzbekistan's "Green" Economy Transition Strategy, the following reforms are planned to (1) enhance the efficiency of measures ensuring "green" and inclusive economic growth, (2) expand the use of renewable energy sources, and (3) further promote resource conservation across all sectors of the economy [19]:

- Increase the installed capacity of renewable energy sources to 15 GW and raise their share to more than 30 percent of total electricity generation.
- Improve energy efficiency in the industrial sector by at least 20 percent.
- Reduce energy consumption per unit of GDP by 30 percent—partly through expanded use of renewable energy—and implement the changes necessary to facilitate the transition to a "green" economy.

## LITERATURE REVIEW

In analyzing the literature, we first examined the theoretical foundations of the green economy, its underlying motivations, and its external (positive) effects. According to a group of British researchers, optimizing the use of existing resources, promoting recycling, and limiting the release of harmful substances from industrial enterprises play a central role in generating positive externalities and maximizing social welfare (that is, maximizing the benefits accruing to both consumers and producers). These authors argue that, from an economist's perspective, sustainability is typically interpreted as constant or non-declining consumption (or profit). In contrast, environmental scientists tend to focus more on the sustainability characteristics of the biosphere rather than solely on human well-being.

Thus, even when certain policy decisions appear to economists to achieve Pareto efficiency, environmental scientists may interpret those same decisions as negative externalities [10].

To assess Uzbekistan's current environmental condition, comparisons were drawn between Uzbekistan and other Central Asian countries. In particular, annual trends in ambient $PM_{2.5}$ concentration were analyzed to evaluate changes in air quality over time [8]. To study the relationship between environmental protection expenditures and labor productivity, we reviewed the work of Russian economist Anastasia Vladimirovna Vasilyeva, "Opportunities for Assessing the Environmental Efficiency of Labor at the Level of an Economic Activity." According to Vasilyeva, while financial resources remain the primary determinant of ensuring environmental labor efficiency in absolute terms, it is precisely investment in informational resources within the work environment that provides a comparative advantage across regions [20].

Economist A. Vakhabov asserts that, under conditions of resource scarcity, sustainable economic development can be achieved through "greening" and the use of renewable energy. He identifies three types of policy support for transitioning to a green economy [13]:

Administrative Instruments. These consist of normative-legal constraints that specify the requirements enterprises must follow to avoid environmental harm. These administrative instruments may be enforced through sanctions against individuals or firms that violate environmental regulations. For example, banning certain toxic substances in industrial processes illustrates an administrative instrument.

Economic Instruments. These tools operate through price mechanisms and market relationships to incentivize behavioral changes among economic actors. Economic instruments serve to justify, on economic grounds, the reduction of pollutant emissions by consumers and industrial firms, as well as to encourage the production and adoption of environmentally sustainable technological innovations.

Informational Instruments. Informational support aims to enhance the effectiveness of disseminating knowledge related to forming a "green" economy. Measures under this category include raising public awareness of the importance of conserving water and electricity, providing training on environmental protection, and expanding educational services and other forms of environmental information dissemination.

## METHODOLOGY

To identify the population's decisions regarding environmental issues and the psychological factors influencing them, we employed methods of analysis and synthesis as well as induction and deduction. In constructing the Cobb–Douglas production function, all variables were logarithmically transformed (ln). For macroeconomic analysis, in order to reflect the Kuznets curve, we represented statistical data using a polynomial trend form. Microsoft Excel and R-studio were used for statistical analysis and econometric modeling. Data visualization was accomplished using charts and tables.

## RESULTS

### General Theoretical Analysis

Although there are dozens of motives for transitioning to a green economy, we select three principal variables in order to define clear objectives during analysis. Specifically, there are three primary drivers of the shift toward a green economy:

1. **Social and Ecological Drivers.** The irreversible damage that a "brown" economy inflicts upon flora and fauna, the sudden onset of illnesses among humans, and reductions in life expectancy all demand urgent attention.
2. **Economic Drivers.** Individuals inhaling polluted air over an extended period experience declining work productivity. Consequently, the labor market sees the emergence of a workforce that demands better working conditions. This dynamic, in turn, results in higher labor-hour requirements per unit of output in firms and raises unit production costs.
3. **Resource Depletion.** Fossil fuels—such as oil, natural gas, and coal—exist in finite quantities and will eventually be exhausted. According to researchers at the University of Queensland (Australia), by 2050, reserves of natural gas and oil are projected to decline sharply, leaving coal as the sole conventional fuel source [12]. In such a scenario, any economic actor lacking access to alternative "green" energy sources will either be unable to produce goods and services or will be forced to purchase the remaining conventional fuels at elevated prices.

Although all of the above represent issues that must be addressed at the macroeconomic level, the decline in labor productivity often remains neglected by many economists. Employers may attribute falling productivity to the workforce being "insufficiently skilled or not agile enough," a characterization that can reduce the perceived pool of potential labor resources in the market.

**Microeconomic analysis**

According to a group of Chinese researchers, photovoltaic (solar) panels will become the world's largest single source of energy by 2050, capable of supplying more than 10 trillion kilowatt-hours of electricity per year [2]. In contrast, the depletion trends for other types of energy sources are expected to continue. Therefore, all else being equal, a firm's total variable cost associated with energy inputs will rise over time. In the short run, assume that a firm's cost function is specified as follows:

$$TC = \frac{Q^2}{2} + 5Q + 5000$$

From the function, we can see that the firm's variable costs are equal to Q/2 + 5. If the firm intends to produce 100 units in one month, its cost amounts to 55 arbitrary units. Now, let us examine the cost function under conditions of resource scarcity:

$$TC = Q^2 + 20Q + 5000$$

A firm previously expended 120 monetary units to produce 100 units of output. Over time, variable costs tied to conventional energy inputs increase continuously. Transitioning to renewable energy sources can free firms from this burden, because—in the short run—when energy resources become scarce, a firm must pay more for each additional unit of conventional energy. By contrast, using "green" energy allows the firm to convert a substantial portion of its variable energy costs into fixed costs.

Currently, first-priority electricity consumers pay 1 000 UZS per kilowatt-hour [17]. Suppose a firm that wishes to expand its production must also increase its electricity consumption: to produce 1 000 units of output per day, it uses 100 kWh of electricity. In that case, the firm incurs an energy cost of 100 UZS per unit of output (since 100 kWh × 1 000 UZS/kWh = 100 000 UZS total, divided by 1 000 units). Assuming the enterprise operates 300 days per year (excluding weekends and holidays), its annual electricity expense amounts to 30 000 000 UZS (300 days × 100 kWh/day × 1 000 UZS/kWh). If the firm attempts to raise production beyond this level, surpassing its electricity-consumption quota, it faces higher marginal energy costs—both because of additional tariff surcharges and the law of diminishing marginal productivity, which forces the firm to pay more per unit of conventional energy. By investing in solar panels, however, the enterprise secures an energy source for approximately 25–30 years. For example, installing a 30 kW solar-panel system, which costs roughly USD 28 000, can generate an excess of 100–125 percent of the firm's daily electricity needs [6]. Under these conditions, the firm's annual fixed (amortization) cost averages about 13 000 000 UZS (approximately USD 1 000), and the electricity cost per unit of output falls to roughly 70 UZS when annual output is Q = 180 000 units.

**Macroeconomic analysis**

To determine the country's level of output, to specify the respective roles of capital and labor, and to forecast the production level, the Cobb–Douglas production function is employed. In this research, to examine the effect of environmental conditions on the production function, precisely this model was used:

$$\boldsymbol{Y = AL^{\alpha}K^{\beta}}$$

Here, Y denotes output (production volume), L denotes labor, K denotes capital, A denotes technological progress, α denotes the labor-elasticity coefficient, and β denotes the capital-elasticity coefficient.

According to a UN report, continued environmental damage and ongoing resource depletion are projected to inflict a $2.7 trillion loss on global GDP by 2030 [9]. In addition, air pollution—through increased concentrations of toxic substances — harms human health and reduces worker productivity [4]. To test this theory in the context of Uzbekistan, an econometric model was constructed using statistical data from 2010–2023:

$$Y = 0{,}00004 * K^{0{,}312} * L^{2{,}037}$$

Here, Y denotes the volume of output; L denotes labor; K denotes capital; A denotes technological progress; α is the elasticity coefficient with respect to labor; and β is the elasticity coefficient with respect to capital.

From the model, it can be observed that the sum of the labor and capital elasticity coefficients exceeds 1. Therefore, Uzbekistan's economy exhibits increasing returns to scale. For example, a 2 percent increase in real wage expenditures and real investments in fixed capital raises real GDP by 5.1 percent. Nearly 81 percent of this increase is attributable to expenditures on labor.

**Table 1. The first result with real variables**

| $R^2$ | p-value | F-value | Standart error |
|---|---|---|---|
| 0,987 | p<0,001 (Labour)<br>p=0,12 (Capital) | 0,0002 | 0,058 |

From the table, it can be seen that although the p-value for the capital factor is 0.12, the p-value for the second factor—labor—is below 0.005; the F-statistic is 0.0002 and $R^2$ equals 0.987. Thus, even though the statistical significance of the capital factor is greater than 0.05, the probability that our result is due to chance remains very small. There are two reasons why the p-value for capital exceeds 0.05: first, the number of years observed is limited (the The State Committee of the Republic of Uzbekistan on Statistics began publishing official average wage data only in 2017); second, in some years, the deflator used for investments in fixed capital was substantially higher than the GDP deflator.

Although the model above provides insight into Uzbekistan's current economic situation, the small number of observation years prevents us from optimally analyzing changes in the labor and capital shares of GDP. Therefore, to fully exploit the capabilities of the Cobb–Douglas model, we redefine the L coefficient not by real wage expenditures but by the total number of employed persons in the economy [16]. To observe trends in the elasticity coefficients for labor and capital, we then examined statistical data from the most recent five years.

**Table 2. Cobb–Douglas elasticity temporal evolution**

| Years | Capital Elasticity Coefficient | Labor Elasticity Coefficient | Technological Progress |
|---|---|---|---|
| 2010–2019 | 1,0388 | 5,6081 | 0,0000357 |
| 2010–2020 | 1,1937 | 4,8850 | 0,0000475 |
| 2010–2021 | 1,2673 | 4,7001 | 0,0000364 |
| 2010–2022 | 1,3250 | 4,7371 | 0,0000185 |
| 2010–2023 | 1,3253 | 4,7373 | 0,0000186 |

In our modeling exercise, because the number of observations was twice as large, as expected, the p-values for all factors in every year fell below 0.05 and $R^2$ exceeded 0.97. From the table, we see that although the capital share in GDP grew steadily over the years, the share of employed persons in GDP dropped sharply after 2019. This decline likely reflects the rising role of capital in production and ongoing industrialization. Specifically, during 2010–2019, only 15.6 percent of returns to scale in production were attributable to capital, whereas for 2010–2023 this figure reached 21.8 percent. However, because the technological-progress indicator fell by 92 percent over the same period, the absolute effectiveness of capital utilization declined by 50 percent. Considering that the unemployment rate has also decreased in recent years, one can conclude that the underlying problem lies in worker productivity. Increases in real investment and the absolute size of the labor force, coupled with declining technological progress, suggest that labor productivity has diminished. The fact that the coefficients for LLL (labor) and AAA (technological progress) both fell sharply after 2019 likely stems from the pandemic and disruptions to ecological balance.

**Macroeconomic analysis: Opportunities**

The Kuznets environmental curve describes the hypothesized relationship between environmental-quality indicators and per-capita income. The Environmental Kuznets Curve (EKC) framework is particularly salient for developing countries because it conceptualizes the nonlinear relationship between economic growth and environmental degradation, emphasizing the initial rise in pollution that accompanies industrialization. In early stages of development, resource-intensive activities and lax environmental regulations tend to exacerbate air and water pollution, making the upward segment of the EKC highly relevant. As national income surpasses a critical threshold, increased public demand for environmental quality and the adoption of cleaner technologies typically lead to a decoupling of growth from pollution. For policymakers in developing economies, the EKC provides a heuristic for anticipating when investments in green technologies and stricter environmental standards will yield tangible improvements in ecological outcomes. Finally, understanding the EKC dynamics allows these nations to design transitional policies—such as targeted subsidies for renewable energy and tighter emissions standards—that can shift the peak of environmental degradation to lower levels of income, thus promoting more sustainable development trajectories. In the early stages of economic development, pollutant emissions increase and environmental quality deteriorates [7]. However, once per-capita income reaches a certain threshold (which varies depending on the specific indicator), the relationship reverses [11]. As a result, at higher income levels, economic growth leads to improvements in environmental conditions. According to some media reports, although environmental quality in Tashkent remains unsatisfactory, conditions in other regions have improved year by year [18]. Therefore, to identify positive trends in Uzbekistan, we analyzed statistical indicators from 2017–2023 and constructed a polynomial econometric model.

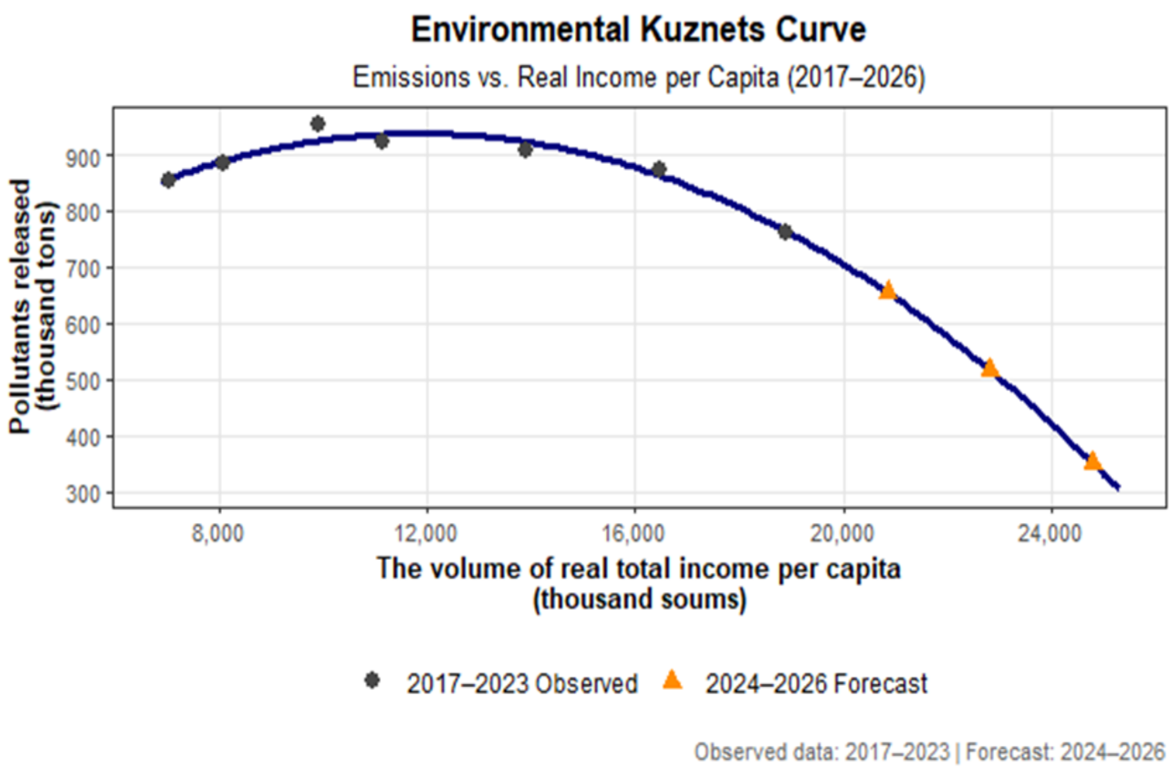


**Figure 1. Graph of the Kuznets Curve in Uzbekistan (2017–2023)**

Econometric model equation:

$$Y= 447{,}80 + 0{,}08282x - 0{,}0000035x^2$$

Here, Y denotes pollutants emitted into the atmosphere, and x denotes per capita real income.

**Table 3. Coefficient Estimates for the Quadratic EKC Model**

| Statistic | Value | p-value |
|---|---|---|
| **Adjusted R²** | 0.9145 | — |
| **F-Statistic (df 2, 4)** | 33.08 | 0.00325 |
| **Durbin–Watson DW** | 2.7106 | 0.4722 |
| **Shapiro–Wilk W (normality)** | 0.8848 | 0.2485 |
| **Breusch–Pagan BP (heteroskedasticity)** | 2.0536 | 0.3582 |
| **VIF (RevPerCap)** | 63.84 | — |

Presents the estimated coefficients, standard errors, t-values, and p-values for the intercept, linear income term (RevPerCap), and quadratic income term ($RevPerCap^2$) in the fitted EKC model. All three parameters are highly significant ($p < 0.01$), confirming an inverted-U relationship between income and emissions.

**Table 4.**
**Model Fit & Diagnostic Statistics**

| Variable | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|
| (Intercept) | 447.80 | 79.28 | 5.649 | 0.00484 |
| RevPerCap | 0.08282 | 0.01329 | 6.230 | 0.00338 |
| $RevPerCap^2$ | –0.000003496 | 0.0000005114 | –6.836 | 0.00240 |

Summarizes the model's goodness-of-fit ($R^2 = 0.943$, Adjusted $R^2 = 0.9145$), overall F-statistic (33.08, $p = 0.00325$), and key diagnostic tests: Durbin–Watson (no autocorrelation), Shapiro–Wilk (residuals ≈ normal), Breusch–Pagan (no heteroskedasticity), and VIF values (high due to quadratic specification but not invalidating significance).

## CONCLUSION

This study has demonstrated that Uzbekistan's rapid economic expansion, driven by intensive resource use and industrial prioritization, has engendered significant environmental costs—manifested in elevated healthcare expenditures, reduced labor productivity, and increased premature mortality. Empirical evidence from the Cobb–Douglas production function indicates that, over 2010–2023, the elasticity of capital steadily rose (from 1.0388 to 1.3253), while the labor elasticity coefficient declined (from 5.6081 to 4.7373), pointing to increasing capital intensity but diminishing labor productivity. Moreover, the observed 92 percent reduction in the technological-progress indicator over the same period underscores a pronounced slowdown in total factor productivity growth, likely exacerbated by pandemic-related disruptions and ecological imbalance. The inverted-U-shaped Kuznets curve fitted for 2017–2023 confirms that pollutant emissions initially rise with per-capita real income (coefficient = 0.08282, $p < 0.01$) but eventually decrease when income growth surpasses a critical threshold (quadratic coefficient = –0.000003496, $p < 0.01$). These findings collectively reveal that, although Uzbekistan is approaching the turning point of environmental degradation, its current growth trajectory still imposes unsustainable ecological burdens. A transition to a green economy is therefore imperative—not only to curb the upward segment of the Kuznets curve but also to restore technological progress and labor efficiency, thereby securing long-term, inclusive economic development. Based on the above analysis, the following recommendations can be made for transitioning to a green economy:

**1. Increase employer spending on worker health maintenance.** Employers should integrate comprehensive preventive care and wellness activities into a Theory Y management framework, positioning these health initiatives as strategic investments that trust employees' capacity for self-direction and enhance intrinsic motivation. Providing preventive screenings and subsidizing on-site wellness programs addresses both physical and psychological dimensions of health, fostering a supportive organizational culture. Regular empirical feedback—via anonymous surveys tracking absenteeism, stress, and productivity—enables iterative refinement of wellness programs to maximize their effectiveness. Aligning health expenditures with Theory Y principles of autonomy and responsibility encourages higher engagement, reduces turnover, and mitigates productivity declines associated with poor health. Embedding worker health maintenance within a data-driven, supportive environment cultivates a more committed and innovative workforce, yielding measurable gains in efficiency and performance. [1]

**2. Refine measurement of technological progress.** Conduct sector-level total factor productivity (TFP) decompositions—using stochastic frontier analysis or Malmquist indices—to disentangle gains from innovation versus efficiency. Augment macro aggregates with firm-level data on R&D expenditures, technology licensing, and patent activity, enabling a more precise assessment of how technology adoption drives output growth and offsets environmental costs. These methods will reveal which industries require targeted R&D subsidies versus those needing process-oriented improvements. By clarifying the sources of productivity change, policymakers can tailor incentives to maximize both economic and ecological returns.

**3. Expand econometric models to capture regional and nonlinear dynamics.** Estimate panel-data EKC specifications across Uzbekistan's regions (fixed- or random-effects) to identify local turning points and understand heterogeneity in pollution-income relationships. Introduce interaction terms (e.g., income × industrial share, income × governance index) to reveal conditional effects and improve the predictive accuracy of both the Kuznets curve and Cobb–Douglas frameworks. Regional analysis will highlight provinces that need earlier interventions or different policy mixes. Incorporating governance indicators also ensures that improvements in environmental quality are aligned with strengthened local institutions.

**4. Accelerate renewable energy deployment through competitive auctions and grid modernization.** Implement transparent, competitive auctions for utility-scale solar and wind projects, coupled with clear feed-in tariffs for distributed renewable generation (e.g., rooftop PV). Simultaneously, modernize transmission infrastructure and invest in grid-scale energy storage (battery or pumped hydro) to ensure reliability, aiming to raise renewables' share to at least 25 percent of electricity generation by 2030. Competitive auctions will lower the cost of capital by attracting experienced international developers. Upgraded grids and storage solutions will reduce curtailment losses, ensuring that new renewable capacity can be fully utilized.

**5. Institute mandatory energy audits and incentivized retrofit programs.** Require all large industrial facilities (≥ 1 MW thermal) to conduct energy audits biennially and adopt ISO 50001 energy-management systems. Offer concessional, long-term loans (e.g., sub-5 percent interest over ten years) for energy-efficiency retrofits—such as combined-cycle gas turbines in power plants and high-efficiency motors in manufacturing—to achieve a 20 percent reduction in industrial energy intensity by 2030. Regular audits will create a baseline for tracking progress and ensuring accountability. Subsidized financing will lower barriers to modernizing equipment, yielding rapid paybacks and reducing overall emissions.

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