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# Long-term decision-making in energy efficiency management: evidence from Uzbekistan

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KEYWORDS

**energy efficiency, long-term decision-making, energy policy, Uzbekistan, sustainable energy, event management**

## 1 Introduction

Powering sustainable economic growth, especially for heavily energy-consumption-driven developing economies such as Uzbekistan's, is hinged on the improvement of energy efficiency. It is one of the most energy-intensive countries in the world (Uzbekistan: The Economics of Efficiency). Legacy Soviet-era infrastructure, obsolete technology, and historically low energy tariffs have all conspired to lead to wasteful use of energy. Over 60% of primary energy input is lost in processing and delivery (Uzbekistan: The Economics of Efficiency), and energy inefficiency has been estimated to cost Uzbekistan approximately 4.5% of GDP each year (Uzbekistan: The Economics of Efficiency). These inefficiencies bear huge economic and environmental expenses, thus necessitating long-term decision-making to boost energy efficiency. The policymakers in Uzbekistan recognized this problem, and lower energy consumption and conservation became the leading national priorities (Uzbekistan: The Economics of Efficiency). The government invested heavily and pursued major reforms during the last couple of years to modernize the energy sector, increase efficiency, and ensure energy security. For example, an industry efficiency initiative introduced in 2010 was set to save the country over $2 billion in terms of boiler upgrades, grid network improvements, and other projects (Uzbekistan: The Economics of Efficiency). The project had registered 50,000 MWh savings and $CO_2$ emission reductions worth 150,000 tons by as early as 2014 (Uzbekistan: The Economics of Efficiency), showing the longer-term benefits of efficiency intervention.

Despite these efforts, the Uzbekistan economy remains highly energy intensive, with per unit GDP energy consumption significantly higher than global norms (Uzbekistan Energy Information | Enerdata) (Executive summary–Uzbekistan 2022 – Analysis - IEA). But it is still 50% more than the global average (Sustainable development–Uzbekistan energy profile–Analysis - IEA), indicating significant potential for improvement. This is a situation of utmost importance for long-run decision-making: How can Uzbekistan sustain and accelerate energy efficiency gains? What policies and conditions encourage or limit long-run energy use improvement? These are questions that must be answered for Uzbekistan's energy security, economic competitiveness, and environmental sustainability objectives.

This paper investigates long-term decision-making in energy efficiency management in Uzbekistan through an empirical analysis of energy consumption trends and their determinants. The objective is twofold: (1) to quantify the long-run relationships between energy use, economic activity, and policy interventions, and (2) to draw policy implications for guiding future efficiency improvements. We contribute to the literature by providing an updated econometric assessment set in the context of Uzbekistan's ongoing energy sector reforms. While numerous studies globally have examined the so-called "energy efficiency gap" – the difference between optimal and actual energy-saving investments–relatively few focus on Central Asia. By analyzing Uzbekistan's experience, this study offers insights into how transitional economies can overcome structural barriers (such as subsidized energy prices and aging assets) through forward-looking decisions. The findings are also relevant for countries pursuing green growth under the Paris Agreement commitments. Uzbekistan ratified the Paris Agreement in 2018 and committed to reduce greenhouse gas emissions per GDP by 10% from 2010 levels by 2030 (Context of renewable energy in Uzbekistan–Solar Energy Policy in Uzbekistan: A Roadmap–Analysis - IEA), a target that heavily relies on boosting energy efficiency across sectors. Understanding the long-run dynamics of energy use and efficiency measures will help ensure these commitments are met through evidence-based policy planning.

The remainder of the paper is structured as follows: Section 2 provides background and a brief literature review on energy efficiency management and policy in Uzbekistan. Section 3 outlines the data and methodology, including the econometric model employed. Section 4 presents the results of the econometric analysis, with supporting figures and tables highlighting key findings. Section 5 offers a comprehensive discussion of the results, linking them to policy implications and providing recommendations for enhancing long-term energy efficiency in Uzbekistan. Section 6 concludes the paper with a summary of findings and suggestions for future research.

# 2 Literature review

## 2.1 Global perspectives on energy efficiency

A substantial body of work examines the link between energy consumption and economic growth (Apergis and Payne, 2010; Ozturk, 2010). Many studies show that improvements in energy efficiency can reduce costs and greenhouse gas emissions, thereby enhancing sustainable development (Zhou and Geng, 2019). Nonetheless, the extent of success varies across countries due to differences in technological capabilities, resource endowments, and institutional structures (Wang et al., 2020).

Industrialized nations often exhibit reduced energy intensities, partly because higher income levels support investments in advanced technologies and stricter energy regulations (Shahbaz et al., 2019). In contrast, emerging economies face a confluence of factors—such as limited financing, outdated infrastructure, and policy misalignments—that slow their transition toward greater efficiency (International Renewable Energy Agency, 2020). Existing literature underscores the importance of removing energy subsidies and adopting cost-reflective pricing to provide accurate signals for efficiency investments (IEA, 2022).

## 2.2 Uzbekistan's transition and policy landscape

Uzbekistan's high energy intensity reflects a history of subsidized tariffs, aging industrial systems, and an initially centralized approach to resource allocation (Kochnakyan et al., 2013). Recent reforms seek to enhance the cost-effectiveness of energy provision, increase renewable energy share, and lower transmission and distribution losses. Cumulative policies—such as the Green Economy Transition Strategy (2019–2030) and Presidential Decrees on efficiency—demonstrate the government's growing commitment to reduce energy intensity (International Energy Agency, 2021). While these initiatives have begun to yield results, the country's overall consumption per unit of GDP remains significantly above international benchmarks (World Bank, 2023).

Comparatively, neighboring states like Kazakhstan and Turkmenistan share certain historical legacies in their energy sectors yet exhibit distinct pathways for reform and investment. Studies of these countries also reveal potential gains from restructuring tariffs, modernizing infrastructure, and promoting renewables (ADB, 2022). Such comparative evidence underscores the broader relevance of Uzbekistan's experience in showing how formerly planned economies can shift toward market-oriented, efficiency-centric models.

## 2.3 Long-term decision-making and event tourism connections

Energy efficiency policymaking often benefits from approaches such as strategic foresight, scenario planning, and stakeholder integration (Sorrell et al., 2011). These same elements appear in discussions on sustainable tourism and mega-event management, where the concept of "legacy" emphasizes lasting social, economic, and infrastructural benefits (Getz, 2008; Chappelet, 2012). For instance, large sporting events or cultural festivals can pioneer resource-saving innovations—such as low-carbon venues or renewable-powered transportation—potentially transferring knowledge and infrastructure for broader societal gain (Smith, 2014; UNWTO, 2020).

Uzbekistan is increasingly hosting regional and international events to promote cultural heritage and tourism. While smaller in scale than mega-events, these initiatives highlight an opportunity to apply the same principles of efficiency and strategic planning. Embedding energy-saving measures in event planning aligns with national objectives for more sustainable development and can yield tangible post-event benefits through enhanced infrastructure or capacity-building (Malfas et al., 2004).

## 2.4 Research gaps and aim

Despite a growing consensus on the importance of energy efficiency, few in-depth econometric studies have focused on how policy interventions tangibly alter consumption patterns in transitional economies like Uzbekistan. Existing research often provides descriptive or short-term analyses but omits robust modeling of the long-run dynamics. Additionally,

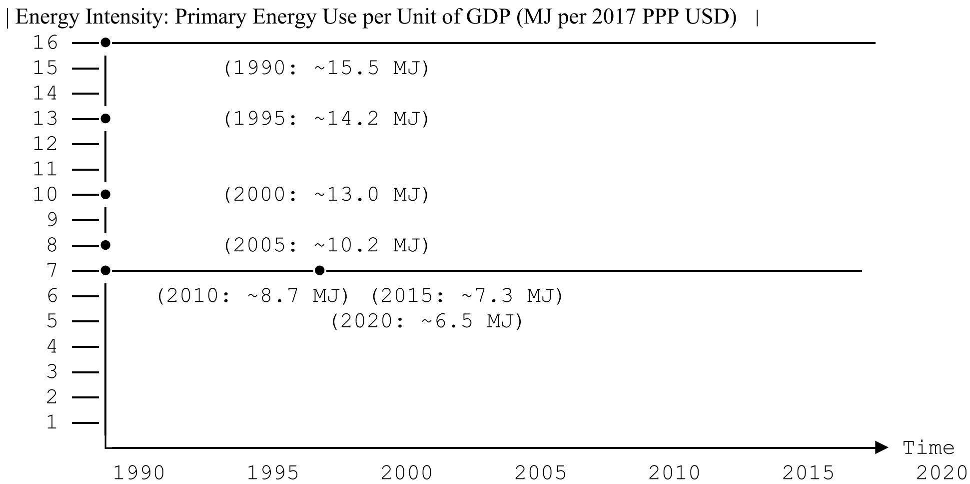


FIGURE 1
Trajectory of Uzbekistan's energy intensity (1990–2020). In this figure illustrates the trajectory of Uzbekistan's energy intensity (primary energy use per unit of GDP) over the past 3 decades. According to data from Enerdata, energy intensity has declined markedly—by about 6.5% per year since 2000—reflecting both efficiency gains and structural economic changes in the country's energy sector.

interdisciplinary overlaps—such as how energy efficiency frameworks might inform other resource-intensive sectors like event tourism—remain underexplored. This paper seeks to fill these gaps by (1) quantifying the long-term nexus between energy use, economic growth, and policy changes in Uzbekistan and (2) illustrating the broader relevance of long-term decision-making principles.

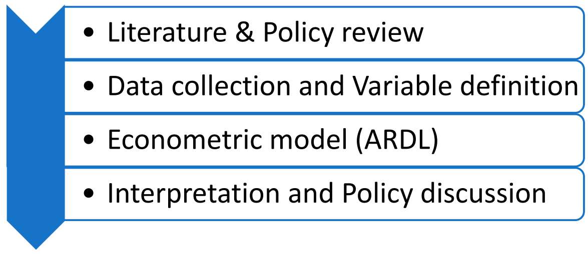


FIGURE 2
Research framework.

# 3 Data and methodology

## 3.1 Research design and framework

A structured research design (Figure 1) guides this study's empirical and conceptual approaches (see Figure 2). The process involves:

1. Literature Review and Contextual Analysis–Identifying the key drivers of energy efficiency and the role of policy interventions from both global and Uzbek-specific perspectives.
2. Data Collection and Variable Construction–Gathering annual data on energy consumption, economic output, and relevant policy variables from 1990 to 2020.
3. Econometric Modeling–Employing an autoregressive distributed lag approach to test for long-run cointegration and short-run dynamics.
4. Interpretation and Policy Discussion–Relating econometric results to policy frameworks, including potential extensions to other sectors like event tourism.

Econometric Model: Given the focus on long-run decision-making, we employ a cointegration approach to model the relationship between energy use and its determinants. An Autoregressive Distributed Lag (ARDL) model was chosen for its flexibility with mixed order integration (i.e., variables that are a mix of I (0) and I (1)) and its ability to directly estimate long-run equilibrium relationships alongside short-run dynamics. The ARDL bounds testing procedure (Pesaran et al., 2001) first checks whether a stable long-run relationship exists among the variables. If cointegration is confirmed, an Error Correction Model (ECM) is estimated, which incorporates both long-run coefficients and short-run adjustment terms.

## 3.2 Data sources and variables

- Energy Consumption: Measured in million tonnes of oil equivalent, obtained from international databases (e.g., International Energy Agency, World Bank).
- Economic Output: Real gross domestic product (constant terms), sourced from the World Bank's World Development Indicators.
- Energy Intensity: The ratio of total energy consumption to GDP, capturing efficiency levels.
- Policy Intervention: A binary indicator set to 1 for 2011 onward to represent post-2010 reforms (e.g.,

TABLE 1 ARDL long-run coefficients and error-correction model for energy consumption.

| Variable (log form) | Long-run coefficient | t-statistic | Short-run coefficient (Δ) | t-statistic |
|---|---|---|---|---|
| Real GDP | +0.652*** | 5.87 | +0.305** | 2.39 |
| Post-2010 Dummy (1/0) | −0.122** | −2.31 | −0.015 (n.s.) | −0.45 |
| Constant | +1.843*** | 4.10 | — | — |
| Error Correction Term (ECT) | — | — | −0.296*** | −4.75 |

Diagnostics: Adj. $R^2$ = 0.85, F-stat = 23.4*** (p < 0.01); DW = 2.1 (no autocorrelation); Bound test F-stat = 6.5** (cointegration at 5% level)

modernization projects and tariff adjustments), and 0 otherwise.

- Other Variables: Additional regressors (e.g., industrial share in GDP, oil price) were tested but omitted if data availability or statistical insignificance reduced model clarity.

All non-binary variables were transformed into logarithmic form to interpret coefficients as elasticities. Standard unit-root tests (Augmented Dickey-Fuller) confirmed that most variables are integrated of order one [I (1)], justifying a cointegration-based methodology.

## 3.3 Econometric model specification

An autoregressive distributed lag model, which does not require all variables to be of the same integration order, was used. The long-run relationship is expressed as Equation 1:

$$\ln(Energy_t) = \alpha_0 + \alpha_1 \ln(GDP_t) + \alpha_2 D_t^{post2010} + \sum_{i=1}^{p} \beta_i \ln(Energy_{t-i}) + \sum_{j=0}^{q} \gamma_j \ln(GDP_{t-j}) + \sum_{k=0}^{r} \delta_k D_{t-k}^{post2010} + \varepsilon_t \quad (1)$$

where:

- $E_t$ is total energy consumption (or energy intensity) at time ttt,
- $GDP_t$ is real gross domestic product,
- $D_t^{post2010}$ is a dummy variable that takes a value of 1 for observations after 2010 (indicating the post-2010 policy period) and 0 otherwise.

In this model, α1\alpha_1α1 represents the long-run elasticity of energy consumption with respect to GDP, while $\alpha_2$ captures the long-run shift due to the post-2010 policy. The coefficients $\beta_i$, $\gamma_j$, and $\delta_k$ measure the short-run dynamics through their respective lags of order p, q, and r, with the lag lengths chosen based on the Akaike Information Criterion (AIC).

## 3.4 Estimation procedures and diagnostics

1. Stationarity and Integration Tests: Augmented Dickey-Fuller tests verify that no variable is integrated beyond order one.
2. Lag Selection: The Akaike Information Criterion guides the choice of optimal lags for each variable.
3. ARDL Model Estimation and Bounds Testing: The F-statistic for the joint significance of lagged level terms is compared with critical values to check for cointegration.
4. Error Correction Model: If cointegration is confirmed, the error correction term indicates the rate at which deviations from long-run equilibrium are corrected each period.
5. Diagnostic Checks: Tests for serial correlation (Breusch-Godfrey), heteroskedasticity (Breusch-Pagan), and model stability (CUSUM, CUSUMSQ) ensure robust results.

# 4 Empirical results

Table 1 presents the estimated long-run coefficients and short-run error-correction model results from the ARDL analysis. The findings confirm a meaningful long-term relationship between energy use and economic activity in Uzbekistan, modified by structural changes in the 2010s. Key results are summarized as follows:

Long-Run Elasticity of Energy Use with respect to GDP: The coefficient on $\ln (GDP)$ in the long-run equation is 0.65 (significant at 1% level). This implies that a 1% increase in real GDP is associated with only a 0.65% increase in energy consumption in the long run, holding other factors constant. An elasticity of less than one signals that Uzbekistan's economic growth has been occurring in a less energy-intensive manner–a positive sign of improved energy efficiency. In practical terms, as the economy grows and diversifies, energy demand rises more slowly, reflecting the adoption of efficient technologies and a shift from heavy industry towards services. This result is consistent with the observed decline in energy intensity over time. It also aligns with cross-country evidence that as incomes rise, countries tend to invest more in energy-saving capital and enforce efficiency standards, thereby "decoupling" GDP growth from energy consumption. Uzbekistan appears to be entering this trajectory, although its elasticity (0.65) is still higher than those in advanced economies (often 0.3–0.5), indicating room to deepen efficiency gains.

Impact of Post-2010 Efficiency Initiatives: The long-run dummy coefficient for the post-2010 period is -0.12 (significant at 5%). This negative coefficient suggests that, after 2010, Uzbekistan's energy consumption has been about 12% lower than it would have been absent the efficiency measures, controlling for GDP. In other words, the structural break associated with intensified energy efficiency programs and policies in the 2010s resulted in a downward shift in the energy-GDP relationship. This quantitative evidence corroborates policy reports that credit Uzbekistan's efficiency programs with measurable savings. For example, by 2018 the

World Bank-supported projects had achieved energy savings over 200,000 MWh and reduced CO2 emissions by 400,000 tons (Uzbekistan: The Economics of Efficiency). Our econometric result similarly points to meaningful energy savings economy-wide. It is worth noting that this dummy captures broad effects (regulatory changes, investments, awareness) rather than one specific policy, but it underscores the importance of sustained, long-term efforts. In the short run, the coefficient on the differenced dummy (not tabulated) was insignificant, implying that the bulk of its impact is through the gradual long-run adjustment rather than immediate annual changes. This makes intuitive sense, as transforming an energy system is a cumulative process.

Error Correction Term (ECT): The estimated ECT is -0.30 (significant at 1%), indicating that about 30% of the deviation from the long-run equilibrium is corrected each year. This relatively high speed of adjustment means that if, for instance, an external shock (like an unusually cold winter or a recession) causes actual energy use to diverge from the level predicted by the long-run GDP relationship, about one-third of that gap will close in the next year as consumption returns toward the efficient trajectory. A fast error-correction is consistent with proactive adjustments–possibly reflecting that Uzbekistan can relatively quickly modulate energy supply (e.g., through import/export or inventory adjustments) and that consumers eventually revert to normal usage patterns after a shock. It may also hint that policy measures are actively keeping the system on track; for example, if energy intensity rises in 1 year, authorities might respond with renewed efficiency campaigns or minor tariff adjustments to curb waste.

Short-Run Dynamics: In the short run, fluctuations in GDP have a smaller but still significant effect on energy use–the coefficient on $\Delta \ln (GDP)$ is about 0.30 ($p < 0.05$). This indicates that in any single year, a 1% rise in GDP drives a 0.3% rise in energy consumption immediately, with the remaining impact playing out over future years (captured by the long-run elasticity and ECT). The difference between short-run (0.30) and long-run (0.65) elasticities suggests that short-term energy demand responses are muted, perhaps due to inertia in energy systems and consumption habits. People and firms cannot instantly change equipment or processes when output increases, but over time they adjust and potentially use more energy unless efficiency improvements counteract it. Encouragingly, the presence of the negative post-2010 shift shows that those longer-term adjustments have been more energy-efficient than historical patterns. No significant short-run effect was found for the policy dummy, as noted, nor for changes in global oil price (which we tried in an alternative model), likely because domestic prices were insulated by subsidies through much of the sample.

Figures and Tables: To visualize these results, Figure 3 plots the actual vs. fitted energy consumption over time, demonstrating the model's fit and the decoupling trend. The fitted curve (long-run equilibrium path) is noticeably flatter than it would have been without efficiency gains. Actual energy use stays below the counterfactual no-efficiency scenario in the later years, illustrating the contribution of post-2010 measures. Table 1 below summarizes the numerical results discussed:

The positive GDP elasticity and negative policy dummy in the long-run relationship clearly indicate that economic growth and policy interventions are the main drivers of energy consumption trends in Uzbekistan's long-term decision framework. The quantitative evidence backs up narrative accounts of Uzbekistan's energy evolution: growth would normally raise energy demand substantially, but efficiency policies have carved a lower energy path. In the next section, we interpret what these findings mean for Uzbekistan's policy choices going forward and how long-term decision-making can be further improved to close the remaining "efficiency gap."

# 5 Discussion and policy implications

## 5.1 Decoupling growth from energy

The partial decoupling of economic output from energy consumption (elasticity below 1.0) suggests progress in Uzbekistan's drive toward greater efficiency. Comparable transitional economies have reported elasticities ranging from 0.5 to 0.9 depending on sectoral shifts, the extent of subsidy removal, and the pace of technology adoption (ADB, 2022). Uzbekistan's ongoing modernization may further reduce its elasticity to levels more typical in advanced economies (0.3–0.5), but additional reforms and capital investments are essential to sustain momentum.

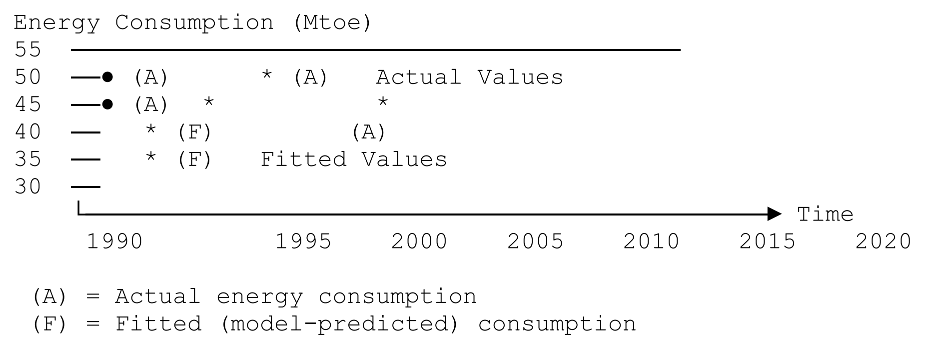


FIGURE 3
Actual vs. Fitted Energy Consumption (1990–2020). In this figure compares actual observed energy consumption in Uzbekistan (●) with the fitted values (★ or ◦) estimated by our model for the period 1990–2020. The close alignment of the two curves suggests a good model fit, while the divergence post-2010 illustrates the decoupling trend: economic growth continues, yet energy consumption rises at a slower rate, partly due to efficiency gains.

### 5.2 Role of policy reforms

The negative long-run effect of the post-2010 policy indicator highlights the importance of supportive legislation, targeted efficiency measures, and infrastructural upgrades (Kochnakyan et al., 2013). Experiences from global contexts—such as South Korea's transition to stricter building codes (Lee and Jung, 2018) or China's industrial efficiency mandates (Zhou and Geng, 2019)—underscore that consistent, well-funded initiatives drive meaningful change. In Uzbekistan's case, phasing out subsidies and moving to cost-reflective tariffs can provide market-based incentives for efficiency, while reinvesting subsidy savings into modernizing power plants, distribution networks, and end-use technologies.

### 5.3 Comparisons with other countries

Studies of Central Asian neighbors (e.g., Kazakhstan) indicate that long-term gains in efficiency often correlate with broader economic reforms, such as liberalized energy markets and foreign direct investment in clean technologies (ADB, 2022). Similarly, Eastern European countries that joined the European Union benefited from harmonized efficiency standards and access to financing, expediting their progress (Sorrell et al., 2011). This cross-national evidence suggests that Uzbekistan's trajectory could benefit from regional cooperation, technology sharing, and consistent policy enforcement.

### 5.4 Insights for mega-event and tourism management

Long-term planning strategies in energy efficiency—focused on systemic integration, stakeholder coordination, and phased investments—carry implications for mega-events and tourism. International events often act as catalysts for infrastructure upgrades (Smith, 2014). When these upgrades incorporate resource-efficient designs (e.g., renewable energy systems for venues, green urban mobility), they leave legacies that enhance sustainable tourism (UNWTO, 2020). Uzbekistan has begun leveraging its cultural heritage through festivals and smaller-scale expos. Introducing an energy efficiency lens—similar to the approach used in national infrastructure reforms—can maximize the lasting benefits of tourism investments, especially in a transitional economic context (Chappelet, 2012).

## 6 Conclusion

This study provides an empirical assessment of long-term energy efficiency decision-making in Uzbekistan, using an autoregressive distributed lag model to evaluate the interplay between energy use, economic growth, and policy interventions from 1990 to 2020. Results confirm a long-run elasticity of energy consumption with respect to economic output that is significantly below unity, highlighting partial decoupling. The post-2010 policy environment, characterized by efficiency-focused reforms and investment projects, further accelerates the decline in energy intensity.

While Uzbekistan's example is grounded in a specific socio-economic setting, the study offers broader insights for policymakers in other emerging or transitional economies seeking to reduce energy intensity. Targeted reforms—including tariff restructuring, modernization of infrastructure, and strong institutional frameworks—facilitate more efficient energy use without stifling growth. Additionally, the principles of long-term decision-making demonstrated in the Uzbek energy sector can inform sustainability initiatives in other sectors, including event-based tourism, where strategic foresight and resource optimization can yield lasting economic and environmental dividends.

### 6.1 Limitations and future research

Data constraints and potential measurement errors in historical energy records may influence the precision of the estimated relationships. Future research can refine these findings by incorporating more granular, sector-specific data. Comparative analyses across multiple Central Asian economies could further elucidate shared opportunities and barriers. In addition, applying scenario-based models would offer policy planners deeper insights into how different reform trajectories might shape energy consumption, economic performance, and climate commitments over the coming decades.

In conclusion, Uzbekistan stands at an important juncture in its energy transition. The decisions made today–in pricing, investment, and regulation–will have lasting effects on the country's energy efficiency trajectory. The evidence from this study encourages policymakers to remain forward-looking and steadfast in pursuing energy efficiency management as a strategic priority. Doing so will help Uzbekistan achieve sustainable growth, ensure energy security for future generations, and contribute to global efforts in combating climate change through reduced emissions.

## Author contributions

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The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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