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# ASSESSING ENERGY RESOURCE USE EFFICIENCY IN THE DISTRICTS OF THE KASHKADARYA REGION BASED ON THE IEFI AND A DIFFERENTIATED MANAGEMENT MECHANISM

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**Abstract.** This article examines the assessment of energy-resource efficiency across districts of the Kashkadarya region and proposes a differentiated management mechanism tailored to local energy profiles. District-level energy-efficiency indicators for 2019-2025 are analysed through an Integrated Energy Efficiency Index (IEFI), combining current-year efficiency, average efficiency over the observed period, the reduction in energy losses, and the share of solar energy. A common Min-Max normalisation base is used to make annual values comparable. Based on the final 2025 IEFI, 16 districts with comparable historical data are ranked into high, medium, and low groups. Kokdala district, established in 2022, is treated separately as a monitoring area because a standalone historical series for earlier years is unavailable. The findings support a shift from uniform energy-management measures toward targeted interventions based on each district's energy profile.

**Keywords:** energy efficiency, IEFI, energy losses, district energy passport, Min–Max normalisation, differentiated management, Kashkadarya region, renewable energy.

**Introduction.** The efficient use of energy resources is an important prerequisite for regional economic development, the management of production costs, reliable energy supply, and environmental sustainability. Reliance on a single indicator to measure energy efficiency does not fully capture differences among districts in their technical condition, long-term performance, and renewable-energy potential. The International Energy Agency emphasises the need for reliable statistical indicators and a consistent data system to develop energy-efficiency policies and evaluate their outcomes.[1]

The modernisation of distribution infrastructure and the integration of renewable energy sources are practically important for Uzbekistan's energy system. According to World Bank information published in 2025, technical losses in the country's electricity distribution networks were estimated at approximately 13% in 2024, while a substantial proportion of network assets had been in service for a long time.[2] Uzbekistan's policy for transitioning to a green economy also identifies the expansion of renewable-energy capacity and improvements in energy efficiency across economic sectors as priority tasks.[3] Effective implementation of these objectives at the

[1] International Energy Agency (IEA). Energy Efficiency Indicators: Fundamentals on Statistics. Paris: IEA, 2014. https://doi.org/10.1787/9789264215672-en

[2] World Bank. Uzbekistan to Invest in Modernizing Electricity Distribution Networks with World Bank Support. 15 May 2025. https://www.worldbank.org/en/news/press-release/2025/05/15/uzbekistan-to-invest-in-modernizing-electricity-distribution-networks-with-world-bank-support

[3] O'zbekiston Respublikasi Prezidentining 2022-yil 2-dekabrdagi qarori. 2030-yilgacha O'zbekiston Respublikasining "yashil" iqtisodiyotga o'tishiga qaratilgan islohotlar samaradorligini oshirish bo'yicha chora-tadbirlar to'g'risida.

regional level requires methodological tools capable of identifying intra-regional disparities and adapting management measures to local needs. Energy-efficiency indicators for electricity supply differ across districts of the Kashkadarya region. Data for 2019–2025 show that efficiency increased substantially in some districts, whereas in others a high initial level was maintained or declined slightly. Therefore, comparing districts solely by their 2025 efficiency percentage does not fully account for their historical performance, the dynamics of energy losses, or the level of renewable-energy use.

The purpose of this article is to provide a comprehensive assessment of the energy status of districts in the Kashkadarya region, classify them differentially using the IEFI, and scientifically substantiate a mechanism for selecting targeted management instruments for each group. The practical significance of the study lies in interpreting the IEFI not merely as a ranking, but as a decision-support tool for maintaining district energy passports, prioritising infrastructure projects, and monitoring outcomes.

**Materials and method**s. The empirical basis of the study consists of indicators for energy resources, useful consumption, energy losses, energy efficiency, and solar-energy use in the districts of the Kashkadarya region for 2019-2025. Sixteen areas with complete historical series were included in the main comparative analysis. Official documentation stipulates that Kokdala district was established in 2022 from parts of Chirakchi district[4] Consequently, separate district-level data for Kokdala are unavailable for 2019–2021; it is therefore treated as a monitoring area rather than classified as a low-efficiency district. The study uses descriptive-statistical and comparative analysis, time-series analysis, construction of a composite indicator, and comparison of panel econometric models. The econometric assessment compares pooled OLS, fixed-effects (FE), and random-effects (RE) models, and examines model selection using the Hausman and Mundlak tests. The Hausman test yielded $\chi^2(2)=12.94$; $p=0.0016$, while the Mundlak test yielded $\chi^2(2)=20.07$; $p<0.001$. These results support the use of the FE approach over the conventional RE model and indicate the importance of accounting for district-specific characteristics that do not change over time. The econometric estimates are used as supplementary evidence to identify regional relationships; interpreting them as definitive causal effects would require complete operational definitions of the variables and additional robustness checks.

Methodology for calculating the IEFI. The IEFI summarises the energy status of an area using four indicators: S1-energy efficiency in the current year; S2-average energy efficiency from 2019 through year t; S3-the reduction in the level of energy losses relative to 2019; and S4-the share of solar electricity in total energy resources in the relevant year. Within the study methodology, the weights were set at 0.35 for S1, 0.25 for S2, 0.25 for S3, and 0.15 for S4. The weights sum to one.

$$N(S_{kit}) = (S_{kit} - S_k,min) / (S_k,max - S_k,min)$$

$$IEFI_{it} = [0.35N(S1_{it}) + 0.25N(S2_{it}) + 0.25N(S3_{it}) + 0.15N(S4_{it})] \times 100$$

Here, i denotes the area, t denotes the year, and $N(S_{kit})$ denotes the normalised value of indicator k. To ensure consistency in dynamic comparisons, Min–Max values were determined using a single base derived from comparable observations for 2020–2025, rather than recalculating

https://president.uz/oz/lists/view/5805

[4] O‘zbekiston Respublikasi Oliy Majlisi Senatining 2022-yil 17-martdagi SQ-503-IV-son qarori. Qashqadaryo viloyati Chiroqchi tumanining chegaralarini o‘zgartirish va Ko‘kdala tumanini tashkil etish to‘g‘risida. https://lex.uz/uz/acts/-5936224

them separately for each year. This creates a common scale across years and enables meaningful comparisons of IEFI dynamics. The year 2019 was used as the baseline for calculating reductions in losses. The final IEFI for 2025 was used to classify areas. Classification was based not on universally fixed score thresholds but on the final ranking among the 16 comparable areas: high, medium, and low groups. This avoids presenting group labels as absolute technical standards; instead, they express the relative position of districts within this study. Since normalisation and the selection of weights can affect composite-indicator results, the methodology is stated explicitly.[5]

**Results.** Energy-efficiency indicators for 2019–2025 show increases in many districts, although growth rates varied. In Qamashi district, for example, energy efficiency rose from 74.08% in 2019 to 84.05% in 2025, an increase of 9.97 percentage points. The indicator changed from 75.56% to 85.37% in Kasbi, from 78.92% to 88.00% in Bahoriston, from 77.68% to 86.72% in Mirishkor, and from 85.76% to 94.51% in Guzor. In contrast, the indicator in Muborak declined from 97.17% to 95.94%, while Nishon remained virtually unchanged. This indicates the need to assess separately both the scope for further improvement and the challenge of maintaining performance in areas with high initial efficiency.

**Table 1.**

**District energy-efficiency dynamics and final IEFI results for 2025**

| Area | Efficiency in 2019 (%) | Efficiency in 2025 (%) | Change (percentage points) | IEFI 2025 (points) | Group |
|---|---|---|---|---|---|
| Guzor | 85.76 | 94.51 | 8.75 | 68.88 | High |
| Dehkanabad | 89.92 | 93.90 | 3.99 | 59.81 | High |
| Qamashi | 74.08 | 84.05 | 9.97 | 46.76 | Low |
| Qarshi district | 77.87 | 86.86 | 8.99 | 50.72 | Medium |
| Qarshi city | 79.53 | 86.54 | 7.01 | 46.18 | Low |
| Kasbi | 75.56 | 85.37 | 9.81 | 50.13 | Medium |
| Kitab | 79.10 | 87.91 | 8.81 | 54.40 | Medium |
| Koson | 76.87 | 84.31 | 7.45 | 39.31 | Low |
| Mirishkor | 77.68 | 86.72 | 9.03 | 62.73 | High |
| Muborak | 97.17 | 95.94 | −1.22 | 58.12 | High |
| Nishon | 99.00 | 98.99 | 0.00 | 63.53 | High |
| Chirakchi | 76.53 | 83.31 | 6.77 | 37.40 | Low |
| Shahrisabz district | 78.13 | 86.01 | 7.88 | 52.65 | Medium |
| Shahrisabz city | 78.17 | 86.94 | 8.77 | 54.68 | Medium |
| Yakkabog | 74.62 | 83.09 | 8.47 | 37.50 | Low |

According to the calculated results, the highest IEFI value was reported for Guzor, at 64.39 points. In this area, energy-use efficiency in 2025 was 94.51%, average efficiency for 2019–2025

[5] OECD, European Union, European Commission, Joint Research Centre. Handbook on Constructing Composite Indicators: Methodology and User Guide. Paris: OECD Publishing, 2008. https://doi.org/10.1787/9789264043466-en

was 90.80%, and the level of losses declined by 8.75 percentage points over the period. These indicators suggest a relatively stable trajectory in the use of energy resources. In 2025, solar electricity accounted for 0.23% of total energy resources in Guzor. Although this share remains small, it indicates that the use of renewable energy sources has begun. Nishon recorded an IEFI of 62.73 points and was also included among the high-performing areas. Its principal characteristic is a high level of energy efficiency: 98.99% in 2025 and an average of 98.72% over 2019–2025. The loss rate was only 1.01% in 2025. Thus, the area's high composite-index result is primarily explained by highly efficient energy use and low losses.

Muborak and Dehkanabad also ranked among the areas with high IEFI values. Muborak recorded an IEFI of 54.87 points, 2025 efficiency of 95.94%, and average efficiency of 96.72%. In Dehkanabad, efficiency in 2025 was 93.90%, while the average was 92.01%. The level of losses in Dehkanabad fell by 3.98 percentage points during 2019–2025. These two cases indicate that high composite results are mainly associated with strong current and long-term efficiency indicators. Mirishkor was assigned to the high group with an IEFI of 51.96 points. Although its 2025 efficiency was 86.72%, the share of solar electricity reached 2.60%. This suggests that the renewable-energy component has developed more actively here than in many other areas. The Mirishkor case therefore illustrates that the green-energy component, as well as energy efficiency, can play an important role in the composite index.

Qarshi city merits a separate comment. In 2025, it had an efficiency rate of 86.54%, a loss rate of 13.46%, and a solar-energy share of 0.70%. Its IEFI value was 34.77 points, placing it in the low group under the relative-ranking rule applied. However, this does not mean that all energy indicators in Qarshi city are absolutely the lowest. The classification reflects the area's relative position compared with other districts, based on the combination of indicators selected for the IEFI.

Overall, the calculations indicate the need for differentiated management of energy-resource-use efficiency across the Kashkadarya region. In high-group areas, priorities include consolidating existing efficiency, expanding energy-saving technologies, and scaling up renewable-energy projects. In medium-group areas, measures to reduce network losses and improve efficiency are important. In low-group areas, the primary tasks are to modernise energy infrastructure, address the technical and organisational causes of losses, and strengthen metering systems. Integrated assessment can thus transform district energy passports from simple collections of statistical data into instruments of regional management. The disparities identified by the IEFI provide a methodological basis for developing group-specific management measures, identifying funding sources, and monitoring results in the next stage of the study.

The integrated assessment of energy-resource use in the districts of the Kashkadarya region revealed substantial differences in energy efficiency, loss dynamics, and the use of renewable energy sources. These differences mean that energy resources should not be managed through identical measures in every area. Instead, a differentiated approach should reflect each district's existing energy profile, problems, and development potential. Based on the IEFI, 16 comparable areas were provisionally classified into high, medium, and low groups, while Kokdala was treated as a separate monitoring area because its historical data series is incomplete. The core of the differentiated management mechanism is that IEFI classification serves not merely as a ranking but as an initial diagnostic criterion for identifying the management instruments that should

receive priority. The index does not define an area as absolutely "good" or "bad"; it indicates its relative position against other comparable areas based on the selected combination of indicators.

The study classified Guzor, Dehkanabad, Mirishkor, Muborak, and Nishon in the high group; Bahoriston, Qarshi district, Kasbi, Kitab, Shahrisabz district, and Shahrisabz city in the medium group; and Qamashi, Qarshi city, Koson, Chirakchi, and Yakkabog in the low group. Because data for Kokdala are unavailable for 2019–2022, it remains a separate monitoring area.

**Table 2.**

**Differentiated management mechanism aligned with districts' energy status**

| Group | Areas | Main status | Priority management instruments | Main objective |
|---|---|---|---|---|
| High | Guzor, Dehkanabad, Mirishkor, Muborak, Nishon | Maintaining efficiency and activating new reserves | Digital monitoring, smart meters, energy management, energy-efficient technologies, solar energy | Stabilise high efficiency and expand green energy |
| Medium | Bahoriston, Qarshi district, Kasbi, Kitab, Shahrisabz district, Shahrisabz city | Improving efficiency and reducing losses | Network modernisation, energy audits, metering systems, reduction of technical losses, small-scale solar projects | Move the area closer to the high-efficiency group |
| Low | Qamashi, Qarshi city, Koson, Chirakchi, Yakkabog | High losses and remaining potential to improve efficiency | Network reconstruction, replacement of transformers and lines, meters, technical-loss diagnostics, energy-saving programmes | Rapidly reduce losses and improve efficiency |
| Monitoring | Kokdala | Insufficient historical data series | Complete the database, expand the 2023–2025 data base, account for new connections and loads | Prepare a complete energy passport and enable future IEFI assessment |

Under this approach, the measures assigned to each group differ substantially. The principal task in the high group is to preserve existing performance, whereas the low group requires the immediate resolution of infrastructure and organisational problems. The medium group is an intermediate segment with the potential to reach higher efficiency through technical and managerial interventions. In high-group areas, the main focus is on maintaining current energy efficiency and activating additional technological potential. In 2025, efficiency was 94.51% in Guzor, 93.90% in Dehkanabad, 95.94% in Muborak, and 98.99% in Nishon. Accordingly, priorities include strengthening energy-management systems, digital monitoring, smart metering, more comprehensive energy audits in industrial enterprises, and expanding renewable-energy

projects.The importance of the renewable-energy component is particularly evident in Mirishkor, where solar electricity accounted for 2.60% of total resources in 2025. Expanding the existing solar-energy experience and integrating it with local economic activity could therefore become an important element of the mechanism.

In the medium group, the main management objective is to improve the current energy situation and bring performance closer to that of the high group. In these areas, efficiency in 2025 was generally in the range of 85–88%. Energy audits, identification of technical losses, network modernisation, improvements in metering, and expansion of solar energy in line with local conditions should therefore be implemented as an integrated management package.

In the low group, the management mechanism should be primarily remedial and efficiency-enhancing. In 2025, the loss rate was 15.95% in Qamashi, 15.69% in Koson, 16.69% in Chirakchi, and 16.91% in Yakkabog. The first priorities are therefore to improve the technical condition of electricity networks, reduce losses in transformers and lines, upgrade metering equipment, and introduce energy-efficient technologies.

**Discussion.** The findings show that assessing energy efficiency solely on the basis of the current year's indicator is insufficient. For example, although efficiency in Muborak and Nishon was high in 2025, their dynamics over 2019–2025 differed: efficiency declined slightly in Muborak but remained almost unchanged in Nishon. Conversely, Qamashi, Kasbi, and Bahoriston recorded substantial increases over the period despite lower initial levels. Including long-term average efficiency and loss dynamics alongside current performance in the IEFI therefore helps provide a more comprehensive interpretation of regional conditions. The methodological advantage of using a common Min-Max normalisation base is that values are not rescaled against separate annual minima and maxima. If normalisation were performed independently each year, the same IEFI score could represent different relative positions in different years. A common base allows changes in an area's index to be compared over time on the same scale. Nevertheless, composite-index results may be sensitive to the composition of indicators, their weights, and extreme values; future research should therefore include sensitivity analysis of the weights and additional technical indicators.[6]

Management instruments should be differentiated by group according to IEFI results. In the high group, the main tasks are to preserve efficiency, implement digital monitoring and energy management, and expand renewable-energy projects. In the medium group, important measures include the gradual modernisation of networks, stronger energy audits, improved metering, and the development of small-scale solar projects. In low-group areas, technical diagnostics of networks and transformers, reconstruction, installation of meters, and identification of loss sources should be the initial measures. Such classification helps direct investment and organisational resources towards the priority needs of each area. The Hausman and Mundlak tests, which supported selecting the FE model in the econometric analysis, indicate the importance of accounting for persistent district-specific differences. Since the signs of the energy-loss coefficient differed between the pooled OLS and FE models in earlier calculations, inter-district differences and changes over time within each district must be interpreted separately. This cautions against

[6] OECD, European Union, European Commission, Joint Research Centre. Handbook on Constructing Composite Indicators: Methodology and User Guide. Paris: OECD Publishing, 2008. https://doi.org/10.1787/9789264043466-en

treating model estimates as straightforward causal conclusions and supports using them alongside technical diagnostics, energy passports, and regular monitoring.

**Conclusion.** The study found substantial differences in the dynamics of energy efficiency across districts of the Kashkadarya region. Although efficiency increased in many areas during 2019-2025, growth rates and final levels varied. Regional management should therefore not be limited to the current efficiency percentage, but should also account for loss dynamics, long-term indicators, and the share of renewable energy. The article applies an IEFI approach that combines current-year efficiency, average efficiency over the period, reductions in losses, and the share of solar energy. Using a common Min–Max normalisation base for 2020-2025 enables annual indices to be compared on a consistent scale. The final IEFI ranking for 2025 made it possible to classify areas into high, medium, and low groups and identify targeted management instruments for each group. The separate treatment of Kokdala as a monitoring area also demonstrates the methodological importance of accounting for data availability and administrative-territorial changes. The practical proposal of the study is to integrate the energy passport, IEFI, differentiated classification, group-specific management measures, and KPI-based reassessment into a single adaptive management cycle. Applying this mechanism within the Kashkadarya regional branch of JSC “Regional Electric Networks” could provide a methodological basis for systematising regional data, prioritising problem areas, selecting technical and investment projects, and regularly monitoring outcomes. However, to quantify the expected economic benefits, further calculations are required concerning project costs, energy volumes supplied and traded, scenarios for reducing losses, and payback periods.

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