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Futures Studies of Energy Imbalance and Its Implications for Regional Energy Security: A Scenario-Based Approach in Yazd Province

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Abstract

Objective: Energy security, as one of the pillars of sustainable development, faces serious challenges in Iran due to its heavy dependence on fossil resources, international sanctions, and imbalances in energy supply and demand. This study aims to explore the future of energy imbalance and its implications for energy security to forecast future scenarios and propose strategies that guide Yazd Province toward sustainable energy security and reduced regional disparities.

Method: The research adopts a mixed descriptive-analytical and foresight approach, utilizing data from official reports of the Statistical Center of Iran and provincial documents. Analytical tools such as MATLAB software and linear regression are employed for trend analysis and scenario writing.

Results: Analyzing eight-year trends indicates that Yazd Province faces energy imbalance and an uneven distribution of energy production and consumption. Investment in renewable energy sources and strengthening regional cooperation can enhance energy security and reduce disparities.

Conclusion: Energy imbalance poses a threat to regional security that will intensify without sustainable measures. The development of technology and balanced energy distribution will improve resilience and energy security.

Key Words: Energy Imbalance, Energy Security, Regional Planning, Sustainability, Futures Studies.
Research Article

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Introduction

Energy security is a critical challenge for regional sustainability, particularly in developing countries where imbalances in production and consumption threaten economic and environmental stability [1], [2], [3]. Yazd Province, as a semi-arid region in Iran, faces significant energy disparities due to uneven distribution networks, dependency on fossil fuels, and inadequate renewable energy utilization. Addressing these issues requires a forward-looking approach that integrates spatial planning with energy policy to enhance regional resilience and sustainability.

Purpose

This study aims to investigate the future of energy imbalance in Yazd Province and its implications for regional energy security over a 10-year horizon (until 1411). It seeks to forecast plausible future scenarios using a scenario-based approach and propose strategies to guide the province toward sustainable energy security and reduced regional disparities. The research addresses the critical question of how energy imbalance will impact energy security and sustainable regional development in Yazd by 1411, considering factors such as production-consumption disparities, reliance on fossil fuels, and renewable energy potential.

Methodology

The research employs a mixed descriptive-analytical and futures studies approach. Data were collected from official sources, including the Statistical Center of Iran's reports, provincial development plans, and the Ministry of Energy's records for 2015–2022 (1394–1401). Missing data for 2015–2016 were estimated using trend extrapolation. Analytical tools, including MATLAB software for linear regression-based trend analysis and forecasting, alongside a 2×2 matrix method for scenario development, were utilized. The study focuses on county-level energy imbalances, leveraging historical trends and key uncertainties (e.g., international sanctions and technological development pace) to construct four future scenarios.

Findings

Analysis of eight-year trends (1394–1401) reveals significant regional energy imbalances in Yazd Province. Total energy production grew from 12.1 million units in 1394 to 14.6 million units in 1401 (annual growth of 2.62%), while consumption rose from 6.9 million to 11.4 million units (annual growth of 6.47%), reducing the overall imbalance from 5.1 million to 3.2 million units. However, county-level disparities persist: Yazd County shows a surplus (8.4 million units in 1401), while counties like Ashkezar (-1.65 million), Meybod (-1.03 million), and Bafq (-548,122 units) face deficits. Linear regression forecasts suggest that by 1411, production could reach 18.91 million units and consumption 21.32 million units, shifting to a negative imbalance of -2.41 million units. Four scenarios—Green Sustainability (positive imbalance of 4 million units), Limited Innovation (-2.5 million), Balanced Growth (-0.5 million), and Energy Crisis (-5 million)—highlight varying outcomes based on sanctions and technology development. Investment in renewables (e.g., solar, given Yazd's climatic potential) and regional cooperation could mitigate

imbalances, while persistent fossil fuel reliance and infrastructure weaknesses exacerbate vulnerabilities.

Conclusion

Energy imbalance threatens Yazd Province's energy security and regional sustainability, with a projected shift to a negative imbalance by 1411 unless sustainable measures are adopted. The current positive imbalance masks deep regional disparities, with production concentrated in urban centers and deficits in less-developed counties undermining equitable access. Without interventions, scenarios like Energy Crisis predict severe shortages, power outages, and environmental strain from fossil fuel dependency. Conversely, the Green Sustainability scenario demonstrates that reduced sanctions, rapid technological advancement, and renewable energy investments can enhance energy security (stable access, affordability) and regional sustainability (reduced disparities, resource efficiency). Strategic recommendations include prioritizing solar energy development, optimizing consumption, and improving distribution infrastructure through spatial planning to ensure resilience and balanced growth by 1411.

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