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Research Article

AN OVERVIEW OF ENERGY CONSUMPTION AND CO2 EMISSIONS IN IRAN'S RESIDENTIAL SECTOR: ENERGY TRANSITION AND SUBSIDY POLICIES

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ABSTRACT

The transition from fossil fuels to renewable energy sources has become a critical global issue, particularly in response to climate change. This study aims to analyse the trends in energy consumption and CO2 emissions within Iran's household sector. The findings reveal a significant increase in energy consumption in Iran between 2001 and 2019. Despite the household sector's heavy reliance on fossil fuels, a shift in fuel consumption patterns can be observed, with a transition from oil to natural gas starting in 2008. Electricity generation in Iran is also predominantly fossil fuel-based, with natural gas playing a major role. This underscores the urgent need to reinforce renewable energy sources to mitigate CO2 emissions from the household sector. Another key factor influencing energy consumption in Iran is the country's extensive energy subsidies. The disparity in fuel prices compared to neighbouring countries has also led to fuel smuggling. However, the results show that the two-phase subsidy reform plan implemented in 2010 and 2013 did not lead to a reduction in energy consumption. Therefore, further reforms are needed to improve energy equity and reduce CO2 emissions in the household sector.

Keywords: Energy consumption, Subsidy, Household sector, Energy transition, Iran.

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

INTRODUCTION

Fossil fuels, which are finite and unevenly distributed across regions, currently dominate the global energy system and are a major contributor to greenhouse gas (GHG) emissions. However, the growing global energy demand, concerns about energy security, the climate crisis, and the increasingly favorable economics of renewable energy (RE) have shifted attention towards RE as a sustainable alternative. Renewable energy sources offer a viable solution to reducing carbon emissions and ensuring a more balanced and secure energy future (Ghorbani et al., 2020). The rising CO_2 emissions, coupled with population growth and increasing GDP, are expected to elevate the concentration of pollutants in the household sector across Iran's provinces (Ata et al., 2022). The latter poses a serious threat to the essentials of life by reducing access to water, food, healthcare, and land, while also triggering environmental disruptions and abrupt climate changes. Therefore, it is crucial to lower CO_2 emissions by cutting down on fossil fuel use (Mirzaei and Bekri, 2017).

The main objectives of energy subsidies are to promote industrial growth and facilitate rural development (Gangopadhyay et al., 2005; Petkova and Stanek, 2013). The critical role that primary fuels and electricity play in driving both economic and social development gives many governments strong justification for subsidizing energy prices and closely regulating the domestic energy sector. Keeping energy prices low, especially for electricity and petroleum products, enables lower-income groups to access modern energy sources more affordably (Fattouh and El-Katiri, 2013).

According to (IEA, 2021), Iran ranks among the largest providers of energy subsidies worldwide. Over the past decade, these subsidies have fluctuated between $30 billion and $137 billion. The IEA's estimate uses a price-gap method, meaning this significant variation is primarily due to changes in international fossil fuel prices. In 2020, subsidies for electricity, natural gas, and oil products amounted to $12.5 billion, $12.2 billion, and $5.0 billion, respectively, with the power sector emerging as the largest recipient of these subsidies. Despite this, Iran possesses substantial renewable energy potential, particularly in solar and wind energy (Ghorbani et al., 2020).

For precise energy system modeling, energy modelers, planners, and decision-makers must take into account a range of factors, including technical, social, and economic considerations. The challenge of making sustainable and green energy management decisions is often heightened by the uncertainties in energy system components, which vary across different countries due to their diverse energy structures (Giannakidis et al., 2015; Mohammadi et al., 2018). Taking into account the features of energy systems in oil-rich nations such as Iran, it is crucial to develop an energy model that promotes sustainability. This model would illustrate a pathway for transitioning from an unsustainable energy system to one that is more sustainable (Alamdari et al., 2012).

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

Although Iran has significant potential in both fossil and renewable energy sources, it is encountering several issues in its energy sector, particularly in power generation. A major challenge on this point is its heavy reliance on fossil fuels, with renewable resources contributing only about 5% to electricity generation (TAVANIR, 2015).

Iran it ranks among the countries with the highest CO_2 emissions globally, largely due to fossil fuel consumption, low energy prices, and the prevalence of inefficient vehicles and appliances. The residential sector is one of the largest consumers of energy in Iran. Additionally, the diverse climate and social conditions across different regions lead to significant variations in energy consumption throughout the country. This research aims to examine the trends in energy consumption and CO_2 emissions in Iran, as well as to understand the impact of subsidy reform and energy transition efforts on reducing CO_2 emissions in the residential sector.

Many researches have studied the effect of subsidy and energy transition in the world and Iran (Noorollahi et al., 2021). In oil-rich countries like Iran, enhancing energy efficiency, particularly in electricity generation, plays a crucial role in achieving CO_2 reduction targets. These efforts not only improve the national energy system's economic performance but also benefit the global community by creating a more efficient energy system. Furthermore, by reducing the total primary energy supply in such countries, the international energy market can experience an increase in supply, which in turn helps alleviate pressure on global oil and gas prices.

The study simulated predicts that total energy consumption will reach 2,150 units by 2025, up from 1,910 in 2010, reflecting a 4.3% annual growth rate. CO_2 emissions are expected to rise to 985 million tons by 2025, showing a yearly increase of about 5%. Policy scenarios focused on reducing energy intensity indicate that CO_2 emissions could drop by 12.14% with a 5% energy intensity reduction and by 17.8% with a 10% reduction by 2025, compared to 2010 levels. These findings provide valuable insights into Iran's future energy consumption and CO_2 emission trends (Mirzaei and Bekri, 2017).

Another study empirical findings from the static method indicate that household CO_2 emissions increase in relation to Heating Degree Days (HDD), Cooling Degree Days (CDD), precipitation levels, oil and gas consumption, household income, household size, and building stock. On the other hand, factors such as educational attainment, a dummy variable representing the removal of energy subsidies, and oil prices have the most significant negative impact on household CO_2 emissions (Ata et al., 2023).

The study compares cost-optimal transition pathways under subsidy removal scenarios with actual energy system developments over the study period. It finds that subsidy reform could have reduced total cumulative electricity consumption

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

by 22% and increased the renewable energy share in power generation from 5% to 15%. Additionally, the reform combined with a cost-optimal generation strategy would have saved $69 billion and prevented 944 million tons of CO_2 emissions. The analysis highlights that a five-year delay in subsidy removal results in an additional 100 million tons of CO_2 emissions. The paper concludes with key lessons for future energy modeling (Aryanpur et al., 2022).

In another study findings show that energy subsidy reforms can lower overall electricity demand by 16% and reduce cumulative CO_2 emissions by 31%. Scenario analysis indicates that early and gradual subsidy removal makes renewable energy technologies and energy efficiency plans more cost-competitive. In contrast, a delayed and rapid removal poses a risk of locking in less efficient energy systems. The results suggest that prioritizing early reform is more important than the speed of removal. The paper also explores the broader policy implications of these findings beyond Iran (Aryanpur et al., 2022).

The empirical analysis shows that, in the long run, economic growth and inflation hinder Iran's energy transition, while higher CO_2 emissions and currency appreciation accelerate it. In the short run, exchange rate improvements positively affect energy transition, but other factors have negative effects. The study recommends reducing budget dependence on oil revenues and implementing short-term decarbonization policies (Esfahani and Rasoulinezhad, 2020).

This article conducts various trend analyses on electricity production and consumption, focusing on key global players in climate change and policy. China has become a leading trend-setter in climate action, showing upward trends in its energy economy, while the U.S. and EU remain crucial actors. The analyses reveal shifts in electricity generation, with renewables playing an increasing role and oil-based production declining. Furthermore, nuclear energy's prominence appears to have passed its peak, as turning points are evident in its trends (Kaivo-Oja et al., 2016).

All research highlights the importance of subsidy reform in Iran's energy sector and the shift to renewable energy to enhance efficiency and reduce CO_2 emissions. Building on the existing literature, this study aims to examine the trends in energy consumption and CO_2 emissions, while assessing the impact of subsidies and energy transition on reducing emissions. Additionally, the research evaluates policies related to subsidies and energy consumption in Iran's household sector.

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

METHODOLOGY

Trend Analysis Models

To identify trends in the time series, the Mann-Kendall (MK) test is used in conjunction with Sen's Slope estimator developed by (Mann, 1945), were employed. The MK test is nonparametric, making it resilient to outliers and effective in detecting trends in data series. In this test, the null hypothesis (H_0) posits that no trend exists in the series, whereas the alternative hypothesis (H_a) indicates that a trend is present. The test statistic S can be calculated as follows:

$$S = \sum_{j=1}^{n-1} \sum_{k=j+1}^{n} Sign\ (\mathrm{y}\,k - \mathrm{y}\,i) \quad (1)$$

Where, n = total observations, yK and yJ represent the data point where k > j.

Data

Data for all Iranian provinces were sourced Based on data from the Statistical Yearbook published by the Statistical Centre of Iran and the Energy Balance Sheets provided by the Ministry of Energy of Iran, covering the interval from 2001 to 2019. Energy consumption data is reported as follows: oil is measured in thousand liters, natural gas in cubic meters (m^3), electricity consumption in kilowatt-hours (kWh), and CO2 emissions in tons.

RESULTS

Trend of Energy and CO_2 Emissions

The trend analysis results in Figure 1 and Appendices 1 to 4 show that different fuels consumption and CO_2 emissions Sen's slope and P-value among provinces of Iran. Figure 1 A and Appendix 1 represent oil usage which indicates negative Sen's slope values for all provinces. Hormozgan is the only province that is not significant concerning its Sen's slope. Notably, Sistan and Baluchestan and Hormozgan are the only provinces with a positive trend, showing a Sen's slope value of 12,312, 1557.9091, respectively. Most of provinces showed reduction in oil use. However, some provinces represent dramatical reduction during study period according Appendix 1, Tehran soley with Sen's slope -129504, recorded a tremendous decrease. With Kendall's tau at -0.9883 ($p<0.0001$). Provinces such as Khorasan, Mazandaran, and both Eastern and Western Azerbaijan are in the second group of reduction based on map A in Figure 31 and Appendix 3 with Sen's slope -53470.54, -60913.52, -49553.87 and -64596.8, respectively.

In terms of gas usage, according to Figure 1 (B) and Appendix 2, all provinces show a positive trend, with Tehran having the highest Sen's slope value at around 417. While some provinces exhibit a positive trend, the amounts are extremely low, including Sistan and Baluchestan, Hormozgan, Chaharmahal and

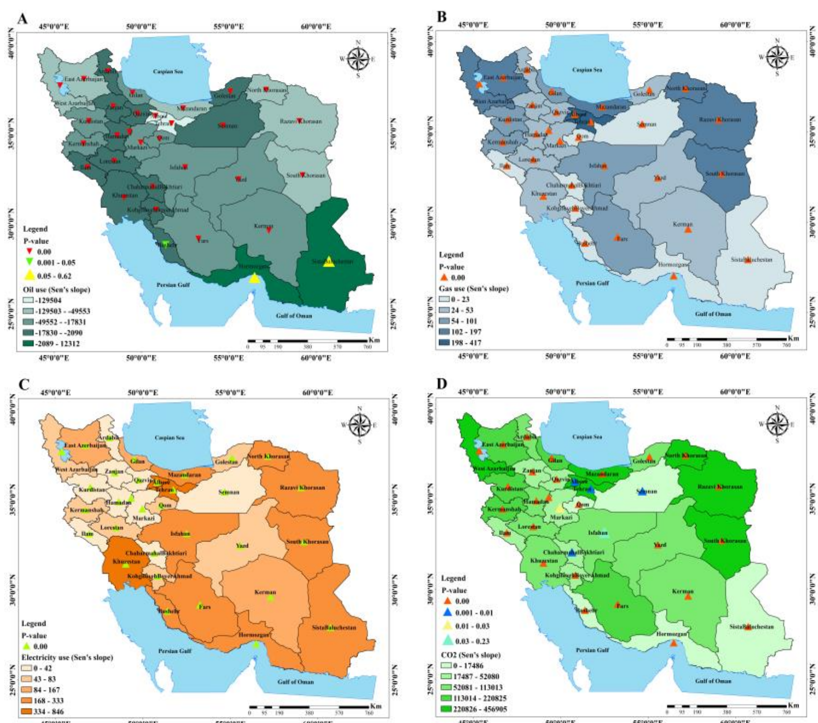
Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

Bakhtiari, Bushehr, and Ilam with Sen's slope 0.7214, 0.40, 23.6, 6.95, 19.12, respectively.

As illustrated in Figure 1 (B), all provinces show a positive and significant trend regarding electricity consumption. Khuzestan and Tehran have the highest Sen's slope values, 846 and 808, respectively (see Appendix 3). Meanwhile, Ardebil, Chaharmahal and Bakhtiari, Semnan, and Zanjan have the lowest Sen's slope values, recorded at 28, 18, 27, and 27, respectively.

CO_2 emissions have increased significantly in all provinces, except for Isfahan, which does not exhibit a significant trend. Among the provinces, Tehran, Khorasan, Mazandaran, and Western Azerbaijan have the highest Sen's slope values, with growth amounts of 456,905, 315,775, 306,495, and 297,754, respectively (see Appendix 4 and Figure 1 (D)). In contrast, Hormozgan and SistaRen and Baluchestan have the lowest increases in Sen's slope, with values of 1,894 and 1,082, respectively.

Figure 1. *Man-Kendall trend and Sen's slope distribution of oil use (A), gas use (B), electricity use (C) and CO_2 emissions (D), among provinces of Iran*



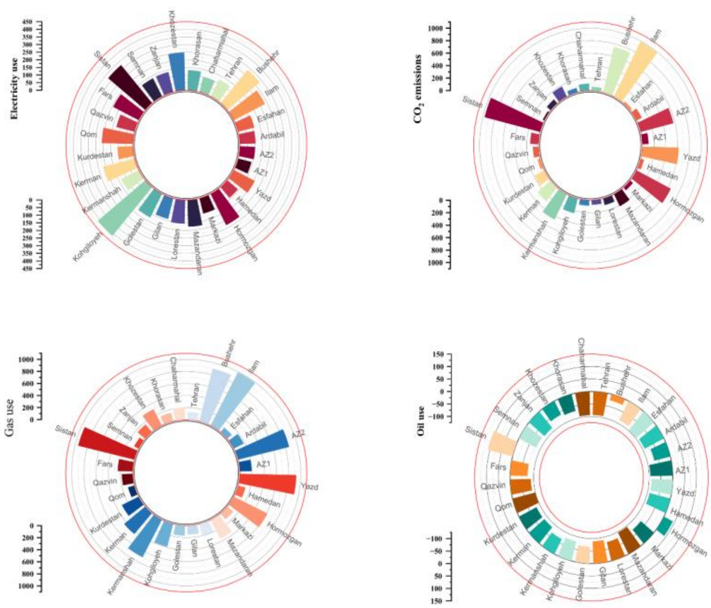
Source: Prepared by Author based on analysis of data from the Ministry of Energy of Iran

Eurasian
Research
Journal
Autumn 2024
Vol. 6, No. 4.

Changes in Energy Consumption and CO_2 Emissions from 2001 to 2019

Figure 2 presents changes in CO_2 emissions and energy expenditure (oil, gas, and electricity) across the provinces of Iran from 2000 to 2019. The first graph illustrates changes in electricity usage, with the most significant fluctuations occurring in Kohgiluyeh, Khuzestan, Hormozgan, Bushehr, and Sistan and Baluchestan. In contrast, the provinces with the least change are Hamedan, Chaharmahal and Bakhtiari, and Ardebil. The second graph in Figure 2 shows changes in CO_2 emissions, revealing extreme variations in Ilam, Sistan and Baluchestan, Bushehr and Hormozgan. Conversely, the minimal changes are observed in the provinces of Tehran, Semnan, Qom, Golestan, Gilan, Hamedan, and Isfahan.

Figure 2. *Changes % between 2001 and 2019 of Iran provinces for some energy variables: Percentage Change= (Value in 2022−Value in 2000/ Value in 2000)×100*



Source: Prepared by Author based on data from the Ministry of Energy of Iran

Gas usage demonstrates the most significant changes in Sistan and Baluchestan, Yazd, Western Azerbaijan, Hormozgan, Ilam, Bushehr, and Kermanshah. On the other hand, Semnan, Qom, Gilan, Golestan, and Tehran exhibit the lowest changes in gas consumption during the study period. The last graph depicts changes in oil consumption from 2001 to 2019 among the provinces of Iran. All provinces show negative changes, except for Sistan and Baluchestan and Hormozgan, which still represent a significant amount of oil usage. These two

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

provinces also exhibit substantial changes in CO_2 emissions during the study period.

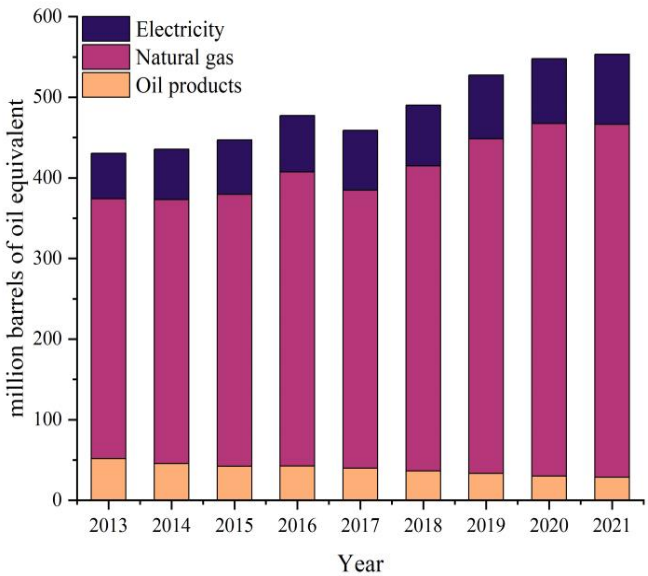
Energy Transition from 2001 to 2019 in Iran

Over the past two decades, Iran has seen a significant rise in fossil fuel consumption in the household sector. In the early 2000s, oil was a major fuel source, especially in rural areas and small cities, and remained the primary fuel until 2008. With the expansion of natural gas pipelines and infrastructure, oil consumption sharply declined as households transitioned to natural gas. Figure 3 illustrates the fuel mix from 2013 to 2021, showing a dominant reliance on natural gas and a steady reduction in oil use, while electricity consumption has continued to rise. Since electricity generation in Iran is largely dependent on natural gas and oil, it is crucial to accelerate the adoption of renewable energy for power production, given Iran's vast renewable energy potential. In the early 2000s, the household and transportation sectors together contributed around 50% of CO2 emissions in Iran due to the extensive use of oil. To mitigate these emissions, the government initially focused on increasing natural gas consumption in the household sector, followed by the transportation sector. However, significant subsidies on fossil fuels and the low cost of energy in Iran led both the public and the government to overlook the transition to renewable energy sources. The government also refrained from redirecting subsidies from fossil fuels to renewables in order to maintain low energy prices for low-income households across the country.

In 2010 and 2013, the government implemented two phases of a subsidy reform plan aimed at reducing inequality in energy consumption among different social classes. As part of the reform, the government provided cash payments to households, with nearly 100% of the population receiving these payments during the first phase. The primary goal was to enhance economic equality for low-income families while addressing energy consumption patterns.

Eurasian
Research
Journal
Autumn 2024
Vol. 6, No. 4.

Figure 3. *Share of different fuels in household sector from 2013 to 2021*



Source: Ministry of Energy of Iran, 2021

An Overview of Renewable Energy in Iran

Iran holds the fourth-largest oil reserves and the second-largest natural gas reserves globally. Despite its abundant hydrocarbon resources, the country has recently shown significant interest in expanding its renewable energy sector. Under the Paris Agreement, Iran committed to reducing CO_2 emissions by 4% through domestic investments of $17.5 million, or by 12% with international investments totaling $35 billion. As part of this commitment, Iran aimed to generate 7% of its electricity from renewable energy sources by 2020 (Khatinoglu, 2016). As shown in Figure 4, the share of renewable electricity generation in Iran from 2000 to 2021 is dominated by hydropower, followed by wind and solar PV. Solar power began contributing to electricity generation only after 2015, reflecting its relatively recent introduction and steady growth as awareness of climate change increases and peak load electricity shortages prompt a shift towards solar energy to reduce reliance on fossil fuel power plants, which still generate over 90% of Iran's electricity. Wind energy, which saw a significant rise after 2006, continues to grow at a steady pace.

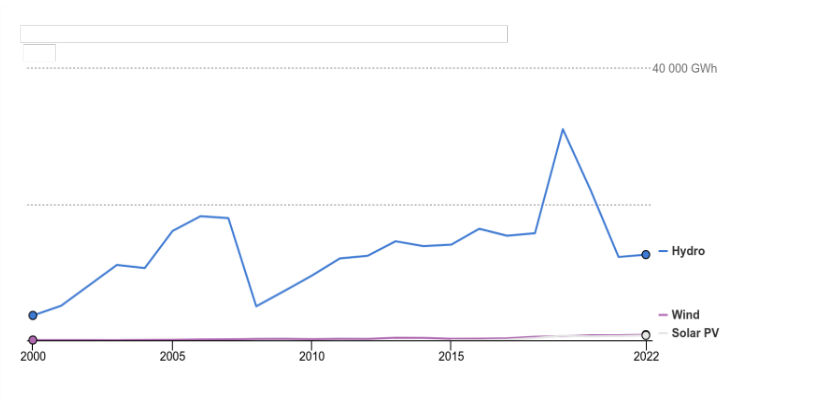
Iran is among the world's wealthiest nations in terms of energy resources, boasting vast reserves of fossil fuels like oil and natural gas, along with significant potential for renewable energy, particularly wind power (Bahrami and

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

Abbaszadeh, 2013). In Iran, solar energy holds the highest potential among renewable sources. According to Bahrami et al. (2013), the total installed photovoltaic power in the country increased significantly, being approximately five times greater in 2010 compared to 2004, reaching a capacity of 67 MW (Bahrami and Abbaszadeh, 2013).

Developing renewable energy requires aligning long-term policies with evaluation programs and technical feasibility. The government should establish a comprehensive policy informed by environmental knowledge and clear goals, supported by strategic planning and incentive systems to drive legislation and project implementation. Additionally, technical experts should promote renewable energy by offering recommendations and innovations based on relevant technologies and applications across different sectors to support policy and economic development (Noorollahi et al., 2021).

Figure 4. *Evolution of renewable electricity generation by source in Iran since 2000, (World Energy Outlook 2021 – Analysis - IEA, 2021)*

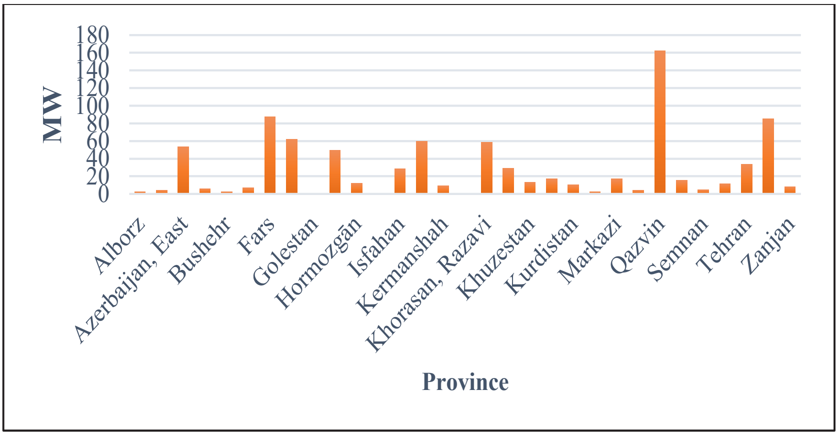


Source: World Energy Outlook 2021, IEA, 2021

Figure 5 illustrates the distribution of renewable and clean power plants across Iran's provinces in 2019. Qazvin, Yazd, and Fars have the highest concentrations of renewable energy sources, particularly wind and solar farms. Conversely, provinces such as Bushehr, Alborz, Lorestan, Ilam, and North Khorasan have a smaller share of renewable energy. The most notable wind farm in Iran is the Manjil Wind Farm, located in Gilan Province, recognized as the country's first large-scale wind project. Additionally, Khorasan Razavi is home to another significant wind farm, making it the second largest in Iran. In terms of solar energy, the most prominent solar farms are found in Fars and Yazd provinces.

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

Figure 5. *Capacity of installed renewable and clean plant powers in each province of Iran*



Source: Ministry of Energy of Iran, 2021

DISCUSSION

Our results show that during the study period, Iran's energy transition from oil to gas consumption has intensified, particularly after 2010. Although the share of renewables in final energy consumption remains low, it has been increasing over the past decade. The government is currently implementing new projects to achieve a 7% share of renewables in electricity generation by 2025. Despite Iran's vast potential for renewable energy, the country's abundant fossil fuel resources pose challenges to shifting towards cleaner energy. The availability of cheap fossil fuels, coupled with high energy subsidies, has led to increased consumption and higher CO_2 emissions.

Recently, climate change concerns and global geopolitical crises have highlighted energy as a key factor influencing international relations. However, sanctions have hindered the growth of renewable energy in Iran, forcing the country to sell crude oil at low prices. Many countries are also reluctant to purchase Iranian oil or gas, further exacerbating the situation. As a result, these challenges contribute to rising CO_2 emissions in Iran, particularly within the household sector.

Iran began implementing an energy reform plan in 2010, which has led to a reduction in energy consumption in residential sector, as indicated by trend analysis, and contributed to mitigating CO_2 emissions in the household sector. Previous research supports these findings, highlighting the impact of the reforms on energy efficiency and emission reductions (Aryanpur et al., 2022; Noorollahi et al., 2021).

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

In Iran, rising demand and consumption intensity necessitate capacity building for electricity generation, making renewable energy a fast and clean solution due to its wide availability. However, challenges persist in developing renewable energy, as many projects lack economic viability. Effective plans and policies are needed to attract and encourage investment. Enhancing energy efficiency and system productivity, optimizing processes, and establishing research and development centres are essential steps to boost the economy and improve the appeal of renewable energy sources (Noorollahi et al., 2021). Bitcoin mining in Iran has seen significant growth, accounting for nearly 4% of global Bitcoin mining activities in April 2020 (University of Cambridge, 2020), with estimates suggesting this share could rise to as much as 17% by May 2021. Iranian Bitcoin miners consume around 20 terawatt-hours (TWh) of energy annually (Tassev, 2021), compared to a global consumption of 117 TWh as of May 2021 (Digiconomist, 2021). It is estimated that over 86% of the electricity used for Bitcoin mining in Iran is acquired illegally (Tassev, 2021). Our study shows that massive energy subsidies are a key factor driving increased consumption. One consequence of this is the use of cheap household energy for activities like Bitcoin mining, which has a significant negative impact on the environment. This activity places immense pressure on the power grid, leading to electricity shortages in the household sector due to the strain on the network.

CONCLUSION

The study, which examines energy consumption and CO_2 emissions trends in Iran from 2001 to 2019, focuses on two key issues during this period: the subsidy reform and the energy transition in the household sector. The findings indicate a significant decrease in oil consumption across most provinces, with the exception of Sistan and Baluchestan and Hormozgan, where access to infrastructure is limited, and these regions are classified as low-income. In contrast, gas consumption showed a marked increase in all provinces, particularly after 2008. Electricity consumption also followed an upward trend across all provinces, with full access to electricity being extended to all villages and cities throughout Iran. CO_2 emissions were found to have increased primarily in major cities and provinces, including Tehran, Khorasan Razavi, and Azerbaijan. The two-phase energy subsidy reform was not successful in practice. However, the transition from oil to natural gas helped prevent a further increase in CO2 emissions from Iran's household sector. Moving forward, effective subsidy reform combined with a stronger focus on transitioning to renewable energy are two key strategies for achieving sustainability and reducing CO_2 emissions in Iran. Despite this progress, Iran still faces considerable challenges in its electricity transition, especially in generating electricity from renewable sources. Given Iran's vast potential for renewable energy, it is crucial to prioritize the integration of renewables in the electricity sector and accelerate the

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

transition, especially as household appliance usage and electricity consumption continue to rise.

The research relied on data that is not yet officially published, with much of the information sourced from academic papers and websites. These sources highlight several recent issues in the household sector, such as the growing use of household electricity for bitcoin mining and the impact of international sanctions, which hinder efforts to reduce CO_2 emissions. In response, the Iranian government has recently implemented some measures to promote renewable energy in the household sector. One such initiative is the provision of solar panels to vulnerable families, aimed at mitigating the effects of inflation and encouraging the adoption of solar power and other renewable energy sources.

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

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Eurasian Research Journal *Autumn 2024 Vol. 6, No. 4.*

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Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

APPENDICES

Appendix 1. *Mann-Kendall's test for Oil consumption in provinces of Iran*

Series\Test	Kendall's tau	p-value	Sen's slope
AZ1	-0.9649	**< 0.0001**	-49553.8782
AZ2	-0.9649	**< 0.0001**	-64596.8000
Ardabil	-0.9298	**< 0.0001**	-13152.3463
Esfahan	-0.7661	**< 0.0001**	-33821.4000
Ilam	-0.6140	**0.0003**	-7919.1917
Bushehr	-0.3216	0.0589	-2186.2630
Tehran	-0.9883	**< 0.0001**	-129504.2000
Chaharmahal	-0.8830	**< 0.0001**	-8517.5714
Khorasan	-0.7427	**< 0.0001**	-53470.5466
Khozestan	-0.5556	**0.0010**	-6710.6978
Zanjan	-0.5673	**0.0008**	-10253.2231
Semnan	-0.9766	**< 0.0001**	-5178.6404
Sistan	0.5789	**0.0006**	12312.6364
Fars	-0.7778	**< 0.0001**	-21121.9333
Qazvin	-0.9181	**< 0.0001**	-12930.6429
Qom	-0.8246	**< 0.0001**	-19027.8095
Kurdestan	-0.8129	**< 0.0001**	-26146.5000
Kerman	-0.7895	**< 0.0001**	-25109.0000
Kermanshah	-0.8129	**< 0.0001**	-23100.6667
Kohgiloyeh	-0.5088	**0.0026**	-3153.0000
Golestan	-0.8830	**< 0.0001**	-10760.6643
Gilan	-0.9532	**< 0.0001**	-29132.5833
Lorestan	-0.9532	**< 0.0001**	-16197.7568
Mazandaran	-1.0000	**< 0.0001**	-60913.5264
Markazi	-0.6608	**< 0.0001**	-17831.6667
Hormozgan	0.0877	0.6243	1557.9091
Hamedan	-0.9415	**< 0.0001**	-16611.1668
Yazd	-0.9298	**< 0.0001**	-21571.7143

Appendix 2. *Mann-Kendall's test for Gas consumption in provinces of Iran*

Series\Test	Kendall's tau	p-value	Sen's slope
AZ1	0.7895	**< 0.0001**	139.4551
AZ2	0.9181	**< 0.0001**	137.1800
Ardabil	0.9181	**< 0.0001**	37.6372

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

Esfahan	0.6725	**< 0.0001**	101.7333
Ilam	1.0000	**< 0.0001**	19.1200
Bushehr	0.9766	**< 0.0001**	6.9571
Tehran	0.8363	**< 0.0001**	417.6000
Chaharmahal	0.7076	**< 0.0001**	23.6000
Khorasan	0.9298	**< 0.0001**	197.7559
Khozestan	0.9181	**< 0.0001**	44.8160
Zanjan	0.9298	**< 0.0001**	31.5000
Semnan	0.8480	**< 0.0001**	13.9571
Sistan	0.7836	**< 0.0001**	0.7214
Fars	0.9649	**< 0.0001**	88.4500
Qazvin	0.9064	**< 0.0001**	36.5667
Qom	0.8480	**< 0.0001**	21.0667
Kurdestan	0.9298	**< 0.0001**	70.9483
Kerman	0.9766	**< 0.0001**	53.4901
Kermanshah	0.9384	**< 0.0001**	67.5000
Kohgiloyeh	0.9736	**< 0.0001**	17.0000
Golestan	0.9415	**< 0.0001**	44.1857
Gilan	0.8713	**< 0.0001**	78.5990
Lorestan	0.8713	**< 0.0001**	39.3659
Mazandaran	0.9181	**< 0.0001**	156.5545
Markazi	0.7310	**< 0.0001**	36.8083
Hormozgan	0.8790	**< 0.0001**	0.4000
Hamedan	0.8129	**< 0.0001**	48.8000
Yazd	0.9064	**< 0.0001**	42.7357

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

Appendix 3. *Mann-Kendall's test for electricity consumption in provinces of Iran*

Series\Test	Kendall's tau	p-value	Sen's slope
AZ1	0.8129	< **0.0001**	106.4000
AZ2	0.8480	< **0.0001**	80.2000
Ardabil	0.8480	< **0.0001**	28.6357
Esfahan	0.9181	< **0.0001**	199.2267
Ilam	0.9181	< **0.0001**	38.9333
Bushehr	0.9298	< **0.0001**	247.3333
Tehran	0.9532	< **0.0001**	808.4143
Chaharmahal	0.7661	< **0.0001**	18.6813
Khorasan	0.9298	< **0.0001**	269.6214
Khozestan	0.9532	< **0.0001**	846.6000
Zanjan	0.8012	< **0.0001**	27.9286
Semnan	0.9064	< **0.0001**	27.7400
Sistan	0.9532	< **0.0001**	206.4355
Fars	0.9415	< **0.0001**	268.5357
Qazvin	0.8363	< **0.0001**	42.0846
Qom	0.9766	< **0.0001**	71.9000
Kurdestan	0.9181	< **0.0001**	38.9286
Kerman	0.8363	< **0.0001**	167.5857
Kermanshah	0.8596	< **0.0001**	68.1685
Kohgiloyeh	0.9298	< **0.0001**	50.3500
Golestan	0.9181	< **0.0001**	83.3000
Gilan	0.9415	< **0.0001**	118.4172
Lorestan	0.9181	< **0.0001**	59.0700
Mazandaran	0.9415	< **0.0001**	197.1615
Markazi	0.8480	< **0.0001**	42.4813
Hormozgan	0.9883	< **0.0001**	333.9800
Hamedan	0.9064	< **0.0001**	42.6500
Yazd	0.9532	< **0.0001**	54.2231

Appendix 4. *Mann-Kendall's test for CO_2 emissions in provinces of Iran*

Series\Test	Kendall's tau	p-value	Sen's slope
AZ1	0.5556	**0.0010**	220825.1472
AZ2	0.8129	< **0.0001**	297754.8859
Ardabil	0.7544	< **0.0001**	65195.1877

Eurasian Research Journal
Autumn 2024
Vol. 6, No. 4.

Esfahan	0.2047	0.2342	78752.6167
Ilam	1.0000	< **0.0001**	46302.3196
Bushehr	0.9766	< **0.0001**	17486.6134
Tehran	0.4269	**0.0118**	456905.7097
Chaharmahal	0.4035	**0.0174**	32434.3143
Khorasan	0.7778	< **0.0001**	315775.4362
Khozestan	0.8713	< **0.0001**	91042.1844
Zanjan	0.8363	< **0.0001**	50672.2083
Semnan	0.4152	**0.0143**	11383.6185
Sistan	0.7895	< **0.0001**	1894.8985
Fars	0.8713	< **0.0001**	151674.9600
Qazvin	0.6959	< **0.0001**	52080.1784
Qom	0.4620	**0.0064**	16985.7429
Kurdestan	0.9181	< **0.0001**	144157.6788
Kerman	0.9064	< **0.0001**	113013.6034
Kermanshah	0.8363	< **0.0001**	137918.8803
Kohgiloyeh	0.9298	< **0.0001**	34582.8086
Golestan	0.7895	< **0.0001**	72101.8502
Gilan	0.7778	< **0.0001**	125214.9549
Lorestan	0.6491	**0.0001**	73113.7527
Mazandaran	0.8596	< **0.0001**	306495.7643
Markazi	0.3567	**0.0358**	42085.8403
Hormozgan	0.9532	< **0.0001**	1082.9977
Hamedan	0.5789	**0.0006**	65288.9440
Yazd	0.8129	< **0.0001**	92546.5639