The Relationship Between Renewable Energy Use and Energy Poverty: a study on Turkey using the nighttime lights data

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Abstract:
Energy poverty is a non-monetary aspect of poverty that has started to emerge in the literature in parallel with the recognition of energy as a cornerstone of sustainable economic growth. Scarcity of fossil fuels, its uneven geographical distribution and rising awareness on its negative environmental impacts have led the international society to consider the substitution of fossil fuels with renewable energy sources in their agenda. Turkey, as a rapidly developing country with an increased demand on energy services and an alarming energy security due to import dependency on fossil fuels, faces energy poverty related issues caused by the domination of thermal energy in its energy mix. Despite being abundant with renewable energy sources, only limited amount of its indigenous energy potential has been exploited so far. In this context, this study aims at investigating the effect of renewable energy use on energy poverty in Turkey, and employs a novel methodological approach by using the time series of the Version 4 of the US Defense Meteorological Satellite Program - Operational Linescan System (DMSP-OLS) Stable Nighttime Lights as a proxy for energy poverty. Wavelet coherence analysis has revealed a statistically significant positive association between renewable energy and expansion of lit area in the short, medium and long run, which is promising for the future developments of renewable energy sector in Turkey.

Keywords: Renewable Energy, DMSP-OLS, Energy Poverty

JEL Codes: Q42, P48, I32, Q01
1. Introduction

Energy poverty is a non-monetary aspect of poverty that has started to emerge in the literature in parallel with the recognition of energy as a cornerstone of sustainable economic growth. Scarcity of fossil fuels, its uneven geographical distribution and rising awareness on its negative environmental impacts have led the international society to consider the substitution of fossil fuels with renewable energy sources in their agenda. Energy poverty and access to energy is also included in the Sustainable Development Goals (SDGs) of the United Nations (UN), where the Goal 7 aims at ensuring access to reliable, affordable and modern energy worldwide by 2030.

Turkey, as a rapidly developing country with an increased demand on energy services and an alarming energy security due to import dependency on fossil fuels, faces energy poverty related issues caused by the domination of thermal energy in its energy mix. Despite being abundant with renewable energy sources, only limited amount of its indigenous energy potential has been exploited so far. This particular paper addresses at filling the gap in the existing literature regarding to analyzing dimensions of energy poverty in Turkey and evaluating potential of renewable energy sources for alleviating it. Findings of the empirical analysis contain valuable information for policy makers in energy sector, whereas the research methodology contributes to the implementation of using satellite imagery as a proxy for socioeconomic variables. The outline of the paper is given as follows:

- Energy poverty and fuel poverty
- Overview of energy mix, energy security and profile of renewable energy in Turkey
- Empirical analysis
- Conclusion and policy recommendations
2. ‘Energy Poverty’ And ‘Fuel Poverty’

The UN defines absolute poverty as "a condition characterised by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information. It depends not only on income but also on access to services" (UN, 1995, p. 57).

Determination of ‘need’ has never been simple and straightforward. Maslow (1954) presented his pyramid-shaped ‘hierarchy of needs’. By taking a careful look at the basic physiological, security and psychological needs of a human, it can be concluded that none of them can be delivered without an access to energy. Energy is a fundament and a very strong determinant of the level of health, education, social status of a person and their life standards in general. If we switch from individual to macro analysis, industrial revolution provides an unequivocal statement of acknowledging energy as a cornerstone of the industrial process and essential fuel of economic growth. Globally uneven distribution and inefficient exploitation of energy resources is another issue. Based upon this, the concepts of energy and fuel poverty started to appear both in scientific researches and national policies in the 1970s.

Derivation of the effective energy policy urges for the answers to the fundamental questions about conceptual and quantifying aspects of energy poverty: Is there a universally accepted metric mechanism addressing to energy poverty? Does energy poverty concern only the poorest nations? Does it have the same implications in the developed and developing world? The answer is no. There is no internationally accepted threshold level of ‘energy need’ or quantifying methodology that allocates energy poverty in a definite and strictly boarded frame. Approaches and metric techniques provided by the researchers vary according to the development of the country, structure of the society, climate and other specific characteristics of the area of interest.

It is essential to provide a brief conceptual distinctions between energy poverty and fuel poverty. Both terms started to appear in the literature in the 1970s (Johnson, 1974, Lister, 1978, Isherwood and Hancock, 1979, Bradshaw and Hutton, 1983, Osbaldeston, 1984). In the beginning, energy poverty was addressed to the underdeveloped world where the population had literally no access to energy services for lighting, heating and cooking, whereas fuel poverty was used to outline the insufficient household heating due to the high prices of the fossil fuels. Energy policies
of the developed countries have changed dramatically since then. Concerned with the scarcity and exhaustibility of the fossil fuels, their devastating effect on climate change, political disabilities, fluctuating prices on fossil fuel markets, high-income countries exhibited a very powerful will to switch from the traditional energy sources to the clean, renewable ones and therefore, energy-related issues started to be discussed with the name of energy poverty rather than the fuel poverty.

Bouzarovski and Petrova (2015) provided a systematized primary elements of ‘energy poverty’ in developing world and ‘fuel poverty’ in developed world. Within the framework of traditional understanding, energy poverty in the poor countries is caused by technological constraints which results in the extremely low level of electrification. No connection to electric grid is expressed with the lack of access to household heating and cooling, adequate tools for cooking and night lighting. Indoor fires are used to meet the very basic needs of lighting and heating. Women and children usually spend more than a half of a day in a polluted environment, therefore, they represent the most vulnerable segment towards low-quality energy sources. Due to the energy shortage, the population of the developing world suffers from the health issues and together with the low standards of life, getting primary education is hindered as well. Principal policies are mainly focused on increasing investments in power grid expansion and implementing modern fuel consumption in Africa, developing Asia and South America.

Urge-Vorsatz and Herrero (2012) discuss about the potential trade-offs between energy poverty alleviation and contraction of GHG emissions. Nationally Determined Contributions (NDCs) for mitigating GHG may increase energy prices which can make energy poverty even more severe. Improving the energy efficiency of buildings is offered as the most important synergy in this sense (Urge-Vorsatz and Herrero, 2012). Santamouris (2016) also believes that directing investments to innovative zero the building sector in Europe can be a solution for the abovementioned trade-off and can exhibit benefits regarding to health condition and economically deprived population.

On the other hand, ‘fuel poverty’ underlines the rising prices of fossil fuels which result in the inadequate household heating in the developed countries (Osbaldeston, 1984, Shortt and Rugkasa, 2007, Boardman, 2010, Walker et al., 2014). Fluctuations on the energy market decrease the real income of the population and force them to either increase the share of their expenditures
on the energy services or decrease electricity consumption, which has a short and long term outcomes on physical and mental health. This trade-off encouraged the policy makers to rise the energy efficiency and energy security without causing environmental degradation. It is worth mentioning, that some scholars use energy poverty and fuel poverty interchangeably regardless to the development level of the research area. Therefore, despite some differences in origins, there is not any significant distinction between these concepts anymore. As underlined before, the concept of energy poverty has become more broad and common in the literature.

Nowadays, together with the developing world, European countries and even the European Union itself use ‘energy poverty’ in order to address accessibility, affordability, flexibility and efficiency of energy services. International Energy Agency (IEA, 2017) declares energy access to be the ‘golden thread’ that simultaneously regulates economic growth, environmental degradation and human well-being. Furthermore, international society took a step forward in acknowledging the irreplaceable role of energy services in sustainable development. Although the number of population with no access to electricity decreased by 1.2 billion between 2000 and 2016, 1.1 billion people still suffer from lagging back the modern technology and energy access. The seventh goal of the SDGs (SDG7), which was adopted in 2015, aims at ensuring access to reliable, affordable and modern energy worldwide by 2030. Within this framework, developing Asia and especially India show a spectacular progress, whereas Sub-Saharan Africa still needs to be supported from the developed world (IBRD, 2018). In any case, empowering renewable energy sector and transition from traditional sources to cleaner energy is the cornerstone of alleviating every aspect of energy poverty worldwide.

3. Overview of energy mix, energy security and profile of renewable energy in Turkey

A number of studies have shown that energy is the driving force for economic development and that electricity consumption is strongly correlated with the economic growth (Samawi et al., 2007; Aydin, 2019; Kantar et al., 2016; Osman et al., 2016; Polemis et al., 2013). As GDP grows, electricity demand for consumption, transportation and manufacturing grows as well (Chen et al., 2007). In the case of Turkey, electricity is vital to sustain economic growth (Altinay, Karagöl,
High rate of urbanization, growing population, industrialization, demand on transportation are catalyzing its increased demand on energy too (Kilickaplan et al., 2017).

Figure 1 shows that total electricity consumption of Turkey has been increasing since 1990 (WB) reaching 243.68 TWh in 2016, which is 386% higher than electricity consumption in 1990 (IEA, 2018). Installed capacity in 2017 reached 81.563,32 MW which is 5.16% higher than the previous year (EPDK, 2018). Compared to the European Union, where electricity consumption has increased with a negligible rate of 0.93% between 2015 and 2016 (Eurostat, 2018), Turkey’s demand increased by 6.3%, which means that Turkey is catching up with the average aggregate energy consumption of the developed countries. However, behind the impressive numbers and smooth upward curve there is an evidence that can put Turkey’s sustainable growth and welfare under the threat.

**Figure 1:** Total Electricity Consumption (1990-2016) (TWh)

**Source:** IEA, World Energy Balances 2018

Sustainable development is based on harmonization among three pillars: economic growth, energy resources and environment. Country’s energy mix is one of the tools for evaluating these pillars and their future prospective.

**Figure 2:** Share of Electricity Generation by Fuel (2016) (%)
According to the World Energy Balance 2018 of IEA, Turkey’s energy mix is shown in the Figure 2. Natural gas and coal represent the primary sources for electricity generation with almost equal shares in total generation. Together with the small portion of oil, fossil fuels account for 67% of the electricity production in Turkey. Greenhouse gases extracted during burning fossil fuels is considered to be important factors behind climate change and air pollution, which has already reached alarming level.

**Figure 3:** CO2 Emissions (kt) and Energy Use (kg of oil equivalent per capita) in Turkey

*Source: World Bank¹, World Development Indicators. (2019)*

Starting from the 1970s, parallel to the increase of energy consumption, carbon dioxide emissions have also increased in Turkey. Moreover, emissions in 2014 was 285% higher than they were in 1960. By taking a look at the curvature of CO₂ emissions and energy use graphs in Figure 3, it is obvious that they show almost identical shapes, which once again gives signal that almost none of the environmental issues can be solved without reconsidering energy policies and incorporating ecological aspects in it. Although its effects show up slowly, Climate change is an inconvertible process with devastating long-lasting threat both for global ecosystems and national economies (Hansen et al., 2005). As a Mediterranean country, Turkey is predicted to experience severe impacts of climate change including drought, heat waves, water shortage and agricultural issues (Sahin et al., 2015, Bulut and Muratoglu, 2018). Therefore, policies that create incentives for using coal to produce electricity should be abandoned.

Besides environmental deterioration, current energy mix of Turkey violates economic aspect of sustainability as well. Turkey lacks fossil fuel resources, therefore it has to import crude oil, natural gas and coal in order to produce electricity.

Turkey has been importing considerably increasing amount of fossil fuels throughout years, which implies that raising demand on electricity has been supplied mainly with traditional energy sources. Turkey purchased 55.250 million sm\(^3\) natural gas from Russia (51.93%), Iran (16.74), Azerbaijan (11.85), Algeria (8.36) and Nigeria (3.76) in 2017 (EPDK, 2018). 37475 thousand tons of coal was consumed in 2017, which exceeds the previous year utilization with 3.5%. 37474 thousand tons of coal – 99.9% of total consumption was imported for USD 5387 thousand (MENR, 2018).

Figure 4: Energy Imports, net (% of energy use)

Source: World Bank\(^2\), World Development Indicators. (2018)

Figure 4 is another illustration of extremely high energy import dependency of Turkey. Due to its current energy mix, between 2000 and 2015 Turkey imported 70.8% of its energy at average, with the highest value of 75.2% in 2015. Because of the high expenses (20-25% of total imported goods, TUIK, 2016), energy import dependency of Turkey is one of the essential reasons of its high current account and trade deficit (Bulut and Muratoglu, 2018). Moreover, economies of import dependent countries show high vulnerability to price shocks on energy. Empirical evidence proves that price fluctuation on oil market has significant effect on Turkey’s current account balance (Yalta, 2017).

International Energy Association defines energy security as continuous availability of energy in various forms, in sufficient quantities and at a reasonable price (IEA, 2018). Turkey’s

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\(^2\) https://data.worldbank.org/indicator/EG.IMP.CONS.ZS?locations=TR
self-sufficiency in total primary generation (electricity generation) has decreased from 54.42\% (77\%) in 1980 to 25.05\% (37\%) in 2014 (Ozcan, 2018). Global Energy Institute uses comprehensive quantitative analysis to offer International Index of Energy Security Risk according to which Turkey’s Energy Security Risk has been lower than OECD average starting from 1980 (914) until 1987, minimizing its risk index (816) in 1985. However, after becoming a net importer of natural gas and incorporating it in country’s energy mix in 1987, Turkey’s risk index has exceeded OECD average with a fairly large swing and this gap has been increasing since then, hitting its highest score in 2011 (1229), which means that Turkey’s energy security has deteriorated both in absolute and relative terms, with respect to OECD (U.S. Chamber of Commerce, 2018:60). What is more important, due to the fact that energy security index reflects country’s political, social, economic and environmental structure, it has multidimensional effect on investments, contracts and agreements (Kocaslan, 2014).

Alarmed by the increasing demand on electricity, high rate of urbanization and GDP growth, together with the local and international non-governmental organizations, the government of Turkey as well as its legal entities responsible for energy market regulation (Ministry of Energy and Natural Resources, Energy Market Regulatory Authority, Energy Exchange Istanbul, etc.) put an effort in enhancing the diversification of energy mix and prioritizing renewable energy sources by providing extra incentives and transparent, reliable, competitive market conditions.

Turkey is well-known for being rich with renewable energy resources, whereas these resources are not used sufficiently and the country suffers from import dependency and other economic as well as environmental issues chained with the low energy security. However, rational and effective exploitation of clean energy can offer a variety of long-term benefits and replace fossil fuels in all kinds of energy-related services, such as heating and cooling, electricity generation and transportation (Tukenmez and Demireli, 2012). Estimated total renewable energy potential (excluding hydropower) is 176000 MW, while just 8000 MW is used in electricity generation (Uğurlu, Gokcol, 2017). Spatial analysis of renewable energy potential and use in Turkey shows that spatial distribution of inexhaustible resources allows the countrywide utilization of renewable energy. Western Turkey is abundant with geothermal and wind resources, while Eastern part has considerable amount of hydropower. Biomass energy can be utilized in central as well as in Western parts, while South and South-Eastern Turkey can be provided with solar energy
Moreover, empirical analysis that employs LUT energy system model (Bogdanov and Breyer, 2016) and incorporates relevant power generation and storage technologies for long-term cost optimization has shown that 100% transition to renewable energy sources with competitive costs is possible in Turkey by the end of 2050. According to the scenario provided in the research, new energy mix is perfectly compatible with COP21 of Paris Agreement and suggests solar PV and wind energy as main contributors (Kilickaplan et al., 2017). Although further research is needed for comprehensive understanding of Turkey’s energy prospective, the possibility of full transition emphasizes its high potential in exploring and developing renewable sector once again.

Ministry of Energy and Natural Resources expects electricity consumption to increase by 5.5% to 357.4 TWh in 2023 (MENR, 2018). Within the framework of Strategic Plan 2010-2014, the government aimed at presenting at least one third of Turkey’s energy mix with indigenous, clean energy until 2023, more precisely, Ministry of Energy and Natural Resources targets at increasing the generation of electricity with renewable energy resources to 37.6% and incorporating them in a quarter of total energy consumption, which is still valid as an ultimate long term goal (IEA, 2010). Within this scope, 34000MW of hydropower, 20000MW of wind, 10000MW of solar, 1500MW of geothermal and 1000MW of biomass energy is planned to be harvested (Sagir et al. 2017). In order to reach this target, which certainly is quite a big and inspiring challenge, approximately 21 billion USD (1.5 billion USD/year) has to be invested in renewable energy sector. General Directorate of Renewable Energy (YEGM), General Directorate of Mineral Research and Exploration (MTA), Turkish Electricity Transmission Corporation (TEİAŞ) and Energy Market Regulatory Authority (EPDK) are in charge of energy mix transformation. According to 2015-2019 Strategy Plan, by the end of 2019 10.000MW of wind, 32.000MW of hydroelectric, 700MW of geothermal, 3000MW of solar and 700MW of biomass is going to be utilized (MENR, 2015).

Besides seeking for increasing energy security by making greater use of domestic, indigenous, inexhaustible resources, Turkey focuses on extinguishing the environmental issues related with the Greenhouse Gas emissions. In 2015, Turkey joined an international platform of 133 countries within the framework of Paris Agreement offered by the United Nations Framework Convention on Climate Change (UNFCCC) with submitting its Intended Nationally Determined
Contribution (INDC). Although its GHG emission per capita is significantly lower than the EU and OECD average, Turkey expressed its will to participate in combating climate change and to reduce its emissions with 21% until 2030 in accordance with its national circumstances and capabilities by implementing changes in energy, industry, transport, buildings and urban transformation, agriculture, managing waste and forestry. Alarmed by higher than 70% share of energy sector in total emissions, Turkey seeks to utilize all its hydro, 10 GW of solar and 16 GW of wind power by the end of 2030 (UNFCCC, 2015).

4. Empirical Analysis

4.1 Data and Variables

This study aims at shedding light on the impact of renewable energy use on energy poverty in Turkey between 1992 and 2013. Time period of interest is chosen based on the data availability. In addition to this central question, the relation between thermal (non-renewable) energy and energy poverty is estimated as well in order to provide comparison between the effectiveness of two types of energy sources. Three categories of datasets are used for conducting empirical analysis:

- Version 4 DMSP-OLS Nighttime Lights;
- Installed capacity of renewable and thermal (non-renewable) energy;
- Electricity generation of renewable and thermal (non-renewable) energy.

Time series of Version 4 DMSP-OLS Nighttime Lights is used as a proxy for energy poverty. Yearly composites of satellite imagery from 1992 to 2013 are collected by US Air Force Weather Agency and processed by NOAA’s National Geophysical Data Center, which is accessible at the official webpage of NOAA National Centers for Environmental Information. Before moving to the data extraction, stable lights images need to be corrected in order to construct continuous and precise dataset. Although ephemeral events, such as fires have been discarded from stable lights, the fundamental issues of incomparability, saturation (top coding), gas flares and blurring still need to be solved. ArcGIS 10.2.1 and QGIS 2.18.28 with GRASS 7.4.4 version of GIS software applications have been used for extracting the data from corrected images.
The data for installed capacity of renewable (hydro+solar+wind+geothermal) and non-renewable (thermal) energy in Turkey (1992-2013) is obtained from Turkish Electricity Transmission Corporation (TEIAS). Installed capacity is measured in megawatts (MW) and refers to the maximum output of electricity that can be produced by the given power station under ideal conditions (EIA). The data for electricity generation from renewable (hydro, solar, wind and geothermal) and non-renewable (thermal) energy sources is provided by TEIAS as well. Electricity generation computes the amount of electricity that is actually produced in a given time period and is measured in gigawatt-hours (gWh).

Considering the fact that generated electricity is not constant for the given power station, it is reasonable to incorporate both – installed capacity and electricity generation in the analysis.

In order to attain more precise estimation, yearly data series are interpolated into quarterly frequency by using quadratic-match sum method. Quadratic-match sum fits a local quadratic polynomial for each observation of the given time series and rebuilds the observations of the higher frequency of the given time period by using the fitted polynomial. Source data point of each specific period is the summation of the interpolated points. Moreover, quadratic-match sum method provides adjustments for seasonal variations by reducing point-to-point data variations. Therefore, it is preferable compared to other interpolation methods such as constant-match average, constant-match sum, quadratic-match, linear and cubic match due to its convenience in operational processes (Cheng et al., 2012; Li, 2015; Shahbaz et al., 2018; Sharif et al., 2019a; Sharif et al., 2019b). By applying quadratic-match sum method I obtained a balanced continuous dataset of 88 observations between 1992 and 2013 at quarterly frequency.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Symbol</th>
<th>Unit</th>
<th>Source</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Light Intensity</td>
<td>Int</td>
<td>DN</td>
<td>NGDC/NOAA (author's estimation)</td>
<td>Average light intensity (DN) of illuminated pixels</td>
</tr>
<tr>
<td>Sum of Lights</td>
<td>Sol</td>
<td>pixel</td>
<td>NGDC/NOAA (author's estimation)</td>
<td>Sum of illuminated pixels</td>
</tr>
<tr>
<td>Electricity generation (renewable energy sources)</td>
<td>Rengwh</td>
<td>gWh</td>
<td>TEIAS</td>
<td>amount of electricity that is actually produced in a given time period by (hydro+solar+wind+geothermal) power stations</td>
</tr>
<tr>
<td></td>
<td>Nrenwh</td>
<td>gWh</td>
<td>TEIAS</td>
<td>Amount of electricity that is actually produced in a given time period by (thermal) power stations</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------</td>
<td>-----</td>
<td>-------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Installed capacity (thermal energy sources)</td>
<td>Renmw</td>
<td>MW</td>
<td>TEIAS</td>
<td>Maximum output of electricity that can be produced by the given (hydro+solar+wind+geothermal) power station under ideal conditions</td>
</tr>
<tr>
<td>Installed capacity (renewable energy sources)</td>
<td>Nrenmw</td>
<td>MW</td>
<td>TEIAS</td>
<td>Maximum output of electricity that can be produced by the given (thermal) power station under ideal conditions</td>
</tr>
</tbody>
</table>

**Figure 5: Graphical Illustration of the Raw Data**
4.2 PEARSON’S PRODUCT MOMENT CORRELATION COEFFICIENT

In order to measure a statistical association between the pairs of the nighttime light-related and energy source-related variables I have applied Pearson’s product moment correlation coefficient (Pearson’s r). Pearson’s r was developed by Karl Pearson in 1948 and measures the strength and direction of linear relationship between two continuous variables. The output of the Pearson’s Correlation is given in Table 2 and exhibits a very strong relation between the variables. Paired variables of interest are highlighted.

<table>
<thead>
<tr>
<th></th>
<th>Int</th>
<th>Sol</th>
<th>rengwh</th>
<th>Nrengwh</th>
<th>renmw</th>
<th>nrenmw</th>
</tr>
</thead>
<tbody>
<tr>
<td>int</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sol</td>
<td>0.8892</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rengwh</td>
<td>0.8595</td>
<td>0.7776</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nrengwh</td>
<td>0.8878</td>
<td>0.6694</td>
<td>0.6300</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>renmw</td>
<td>0.9870</td>
<td>0.8789</td>
<td>0.8616</td>
<td>0.8480</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>nrenmw</td>
<td>0.9215</td>
<td>0.6748</td>
<td>0.7462</td>
<td>0.9665</td>
<td>0.9112</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Note: Coefficient values between +/-0.5 and +/-1 are said to be a strong correlation

4.3 Stationarity Checking – Unit Root Tests

Before taking a step forward I have transformed the series of all the variables into natural logarithms. Stationarity of the variables is essential for the reliability of the regression output. In order to check whether the variable is stationary or possesses unit root, I have applied Augmented Dickey-Fuller (ADF) (Dicky and Fuller, 1979) and Phillips-Perron (PP) (Phillips and Perron, 1988) tests for unit root. Augmented Dickey-Fuller and Phillips-Perron test the null hypothesis that a unit root is present. Table 3 summarizes the output of ADF and PP test results. Both of the unit root tests provide conclusive information. All variables fail to reject null hypothesis for unit root at level. However, after taking the first difference, all of them become stationary at 1% significance level and therefore, there is no issue of the unit root in all six variables. Graphical illustration of the stationary variables are presented in the Figure 6.
Table 3
Augmented Dickey-Fuller and Phillips-Perron Unit Root Test Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Augmented Dickey-Fuller</th>
<th>Phillips-Perron</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I(0)</td>
<td>I(1)</td>
</tr>
<tr>
<td></td>
<td>Test Statistic</td>
<td>p-value</td>
</tr>
<tr>
<td>Int</td>
<td>-2.188</td>
<td>0.2108</td>
</tr>
<tr>
<td>Nrengwh</td>
<td>-1.640</td>
<td>0.4623</td>
</tr>
<tr>
<td>Nrenmw</td>
<td>0.754</td>
<td>0.9909</td>
</tr>
<tr>
<td>Rengwh</td>
<td>-1.266</td>
<td>0.6445</td>
</tr>
<tr>
<td>Renmw</td>
<td>4.140</td>
<td>1.0000</td>
</tr>
<tr>
<td>Sol</td>
<td>-1.101</td>
<td>0.7147</td>
</tr>
</tbody>
</table>

Note: *** denotes the rejection of null hypothesis at 1% significance level. Test critical values: 1% level – (-3.5); 5% level – (-2.9); 10% level – (-2.6).

Figure 6: Graphical illustration of the stationary variables

4.4 Granger- Causality Test

After solving the stationarity issue I have moved to the causality analysis. Granger (1969) developed a time-series based technique to track the causality and its direction between continuous, stationary variables. Granger causality tests two null hypothesis:
X does not Granger cause Y
Y does not Granger cause X

Therefore, x is the cause of y in case x is successful in predicting the future values of y by considering the past values of y and vice versa. Simple Granger-causality test consists of two variables and their lags. The test can detect uni-directional, bi-directional or no causation between the respective variables. Tronton and Batten (1984) have shown that the results of Granger-causality are extremely sensitive to the number of lags. In order to choose an optimal leg, I have fitted standard Vector Autoregressive (VAR) models, which is a widely used tool for macroeconomic forecasting. VAR provides a number of criteria for lag order selection: Akaike information criterion (AIC), Hannan-Quinn information criterion (HQ), Schwarz information criterion (SC), Final prediction error (FPE) and sequential modified LR test statistic (LR). Lag order selected by the criterion is indicated with asterisk. I have taken a look at all the criterions and chosen smallest lag length among them.

Table 4
Results of Pairwise Granger-Causality Test

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>F-statistic</th>
<th>Prob.</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LNREN) does not Granger Cause</td>
<td>0.57387</td>
<td>0.7198</td>
<td>No causation. Failed to reject both null hypothesis</td>
</tr>
<tr>
<td>D(LNINT)</td>
<td>0.60958</td>
<td>0.6928</td>
<td></td>
</tr>
<tr>
<td>D(LNREN) does not Granger Cause</td>
<td>0.32597</td>
<td>0.8957</td>
<td>No causation. Failed to reject both null hypothesis</td>
</tr>
<tr>
<td>D(LNINT) does not Granger Cause</td>
<td>0.34579</td>
<td>0.8833</td>
<td></td>
</tr>
<tr>
<td>D(LNREN) does not Granger Cause</td>
<td>0.45893</td>
<td>0.8055</td>
<td>No causation. Failed to reject both null hypothesis</td>
</tr>
<tr>
<td>D(LNINT) does not Granger Cause</td>
<td>0.47142</td>
<td>0.7963</td>
<td></td>
</tr>
<tr>
<td>D(LNREN) does not Granger Cause</td>
<td>0.14889</td>
<td>0.9797</td>
<td>No causation. Failed to reject both null hypothesis</td>
</tr>
<tr>
<td>D(LNINT) does not Granger Cause</td>
<td>0.31054</td>
<td>0.9051</td>
<td></td>
</tr>
<tr>
<td>D(LNREN) does not Granger Cause</td>
<td>0.20108</td>
<td>0.9609</td>
<td>D(LNSOL) Granger cause D(LNREN); uni-directional causation</td>
</tr>
<tr>
<td>D(LNSOL) does not Granger Cause</td>
<td>2.51840</td>
<td>0.0378</td>
<td></td>
</tr>
<tr>
<td>D(LNREN) does not Granger Cause</td>
<td>0.07684</td>
<td>0.9956</td>
<td>D(LNNREN) does not Granger Cause D(LNSOL); uni-directional causation</td>
</tr>
</tbody>
</table>
According to the results of pairwise Granger-causality tests, there is a uni-directional causal relationship between the number of lit pixels and energy related variables. Causal relationship is running from the number of lit pixels to the electricity generation from renewable energy. On the other hand, there is a causal relationship which is running from installed capacity of renewable and thermal energy and thermal electricity generation to the illumination. However, no causal relation is detected between energy variables and average light intensity. In order to obtain more precise information about the association between thermal/renewable energy and nighttime lights I employ Wavelet Transformation analysis.

4.5 Wavelet Transformation

Wavelet transformation is a purely time-series based technique, which has a quite strong background in geophysics applications and has started to appear in the economics literature afterwards. Schleicher (2002) compares wavelets to a wide-angle camera that allows taking broad landscape portraits and at the same time makes it possible to zoom in the micro details that cannot be observed by the human eye.

Although there are principal differences, wavelet technique has its roots in Fourier transformation, which was proposed by Joseph Fourier in 1807. Fourier transformation converts signals from time domain to frequency domain by integrating over the whole time axis and requires the signals to be stationary. Fan and Gencay (2010) suggest that wavelets were introduced in applied econometrics in order to overcome the limitations of the Fourier approach. Fourier technique is suitable for the stationary variables, while the real world indicators usually turn out to be non-stationary. On the other hand, wavelet filters arrange a natural platform for dealing with the time-variant characteristics in time series and therefore, the issue of unit root may be avoided.
Wavelet transformation is considered to be an ideal tool for working with the non-stationary data as it is able to detect a wide range of frequencies and identify the events that are localized in time.

Maximum overlap discrete wavelet transformation (MODWT), Morlet continuous wavelet transformation and wavelet coherence techniques are going to be employed in this particular investigation.

4.5.1 Discrete Wavelet Transform (DWT)

Discrete wavelet technique (DWT) transforms the time series of the given variable by decomposing it to the sections of the time sphere, namely scales or frequency bands. Regardless to the shape of the wavelet, fundamental wavelets are represented with two main varieties: mother wavelet $\psi$ and father wavelet $\phi$, which are defined in the following manner:

$$\int \phi(t) \, dt = 1$$  \hspace{1cm} (7)

$$\int \psi(t) \, dt = 0$$  \hspace{1cm} (8)

Father wavelets represent the short frequency, while mother wavelets stand for the long frequency time components of the signal. At the same time, father wavelets are responsible for trend mechanisms, while mother wavelets control the variation from the trend. These features can be shown with the following functions:

$$\phi_{j,k}(t) = 2^{j/2} \phi(2^j t - k)$$  \hspace{1cm} (9)

$$\psi_{j,k}(t) = 2^{j/2} \psi(2^j t - k),$$  \hspace{1cm} (10)

Where $j=1,\ldots,J$ means measure and $k=1,\ldots,2^j$ stands for the transformation. The factor $k$ rearranges the wavelets in chronological order and $j$ defines the numbers of levels for data decomposition. Referring to the short run, medium run, long run and very long run variation, the optimum number of $j$ is based on the number of observations.

Based on one of the orthogonal mechanisms of the wavelets family, the decomposed and reconstructed version of the original data i.e. wavelet multiresolution analysis (MRA) can be formulated as follows:
\[ f(t) = S_J(t) + D_J(t) + D_{J-1}(t) + \cdots + D_1(t), \quad (11) \]

Where \( S_J(t) \) estimates long run characteristics in the low frequency dynamics, whereas the series of \( D_J(t) \) is responsible for capturing local fluctuations in high frequency dynamics.

### 4.5.2 Continuous Wavelet Transform (CWT)

The fundamental characteristic of continuous wavelet transformation is expressed with its ability to decompose and seamlessly reconstruct the time series of the given variable \( x(t) \in L^2(R) \) in the following way:

\[ x(t) = \frac{1}{C_\psi} \int_0^\infty \left[ \int_{-\infty}^{\infty} W_x(m,n) \psi_{mn}(t) \, du \right] \frac{dn}{N^2}, N > 0 \quad (12) \]

Where \( W_x(m,n) \) represents the projection of the definite wavelet \( \psi(.) \) against the time array, \( m \) is a location index and \( n \) is the measure. Putting differently, \( W_x(m,n) \) can be formulated as

\[ W_x(m,n) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{N}} \psi \left( \frac{t-m}{N} \right) \, dt. \quad (13) \]

What is more, while capturing the variations over time and frequency domain, continues wavelet maintain the power of the given time sequence:

\[ \|x\|^2 = \frac{1}{C_\psi} \int_0^\infty \left[ \int_{-\infty}^{\infty} |W_x(m,n)|^2 \, dm \right] \frac{dn}{N^2} \quad (14) \]

### 4.5.3 Wavelet Coherence

Wavelet coherence analyzes the bivariate association between two time-series. Before moving to wavelet coherence properties cross-wavelet transform needs to be introduced.

Torrence and Compo (1988) express cross-wavelet transform with two-time sequence \( x(t) \) and \( y(t) \) in the following way:

\[ W_{xy}(m,n) = W_x(m,n) W_y^*(m,n) \quad (15) \]
Where $W_x(m, n)$ and $W_y(m, n)$ represent two continuous wavelet transform of $x(t)$ and $y(t)$ discussed in the previous section, $m$ is a location index, $n$ stands for the measure and * indicates a composite conjugation. Regarding to the cross-wavelet power spectra, which will be useful for calculating the coherence coefficient can be easily calculated by transforming cross-wavelet as $W_x(m, n)$. After defining cross-wavelet transform we can move to the wavelet coherence.

Torrence and Webster (1999) state that the squared wavelet coherence coefficient can be expressed mathematically:

$$R^2(m, n) = \frac{|N^{-1}W_{xy}(m, n)|^2}{N(N^{-1}|W_x(m, n)|^2) N(N^{-1}|W_y(m, n)|^2)}$$

(16)

Where S is a smoothing mechanism. Squared wavelet coherence ranges between 0 and 1. Values close to zero indicate a week correlation (comovement, association), whereas values close to 1 exhibit a strong correlation between the variables.

Interpretation of graphical outputs of continuous wavelets and wavelet coherence will be provided in the following section.

4.6.1 Discrete and Continuous Wavelet Transform

Average Light Intensity

Figure 32 depicts discrete (a) and continuous (b) wavelet transformations of average light intensity. It can be easily noticed, that high variation in the mean light intensity had been occurring in the short (d1) and medium (d2) run, while it became more stable in the long (d3) and very long run (d4) period. Continuous wavelet spectrum (b) approves the stated interpretation. There has been a significance variation on the edge of long and medium run throughout whole investigated time period, whereas polygons of strong variation cannot be observed at the long and very long run frequency.
Unlike the average light intensity, Figure 33 depicts that the magnitude of variation of SOL is lower at average. Relatively higher short and medium run variation can be observed during 2000-2005, which has become more stable in long and very long run period (Figure 33, a). Continuous wavelet plot (b) has also captured two polygons with significant short run variation in 1993-1995 and 2000-2003. Moreover, strong variation can be observed in medium and long run period in 1998-2003 as well.

**Figure 7:** Discrete and Continuous Wavelet Transform of INT

**Sum of Lights**

Thermal Electricity Generation (gWh)
Discrete and continuous decomposition of thermal electricity generation repeats almost
the same pattern as the variation of sum of lights. Notably high variation can be detected at d1
(Figure 32, a) in 2003-2006, which becomes more stable at lower frequency. Continuous wavelet
spectrum has bordered a small-sized polygon of high short run variation in 1993-1995.
Furthermore, strong short, medium and long run variation is depicted with the polygons in 2001-
2005.

![Figure 9: Discrete and Continuous Wavelet Transform of Thermal Electricity Generation (gWh)](a)

**Installed Capacity of Thermal Energy (MW)**

Similar to the sum of lights, discrete decomposition of installed capacity of thermal
energy also noted strong short run variation in 2000-2005, which obviously had an effect on
increasing variation at lower frequency i.e. medium and long run periods in the following years.
Regarding to the continuous wavelet spectrum, the variance of installed capacity of thermal energy
usually occurred in 1997-2005. The largest polygon covering the respective time period belongs
to the long and very long run scale. Medium and short run variance have occurred in 1998-2001
with one more small polygon of short run period in 2002-2003.
Electricity generation from renewable energy sources can be compared with the pattern of lit area variance. Additionally, it seems that the variations in renewable energy generation leads to the same variation in sum of lights after a quite short period of time. The curvatures of medium and long run frequency variation (d2 and d3) are almost similar, which become more stable in a very long run period (d4). Short run variation at 5% significance is detected in 2000-2005, whereas strong variation polygon in 1999-2006 is located on the edge of medium and long run effect.

Installed capacity of renewable energy (MW)
Installed capacity of renewable energy exhibits the smallest variation compared to other variables. Variation at 5% significance level can be depicted only at short run frequency in 2010-2011. Patterns of this variance is observed not only on continuous wavelet plot, but also on discrete wavelet decomposition as well - both on short and medium run (d1 and d2) level. What is more, almost precise similarity in the very long run (d4) variation patterns of installed capacity of renewable energy and sum of lights need to be noticed by all means.

Figure 12: Discrete and Continuous Wavelet Transform of Installed Capacity Renewable Electricity

4.6.2 Wavelet Coherence

\textit{INT-nRen (MW)}

Wavelet-based correlation and covariation on Figure 13 (1) show that in the short run there is an extremely week positive relation between the average light intensity and installed capacity of thermal energy, which becomes negative in the medium run and this tendency remains unchanged in the long run as well even with the higher magnitude. On the other hand, wavelet coherence shows that there is a strong association between light intensity and installed capacity of thermal energy in the long and very long run. However, it does not contain any information about the direction of the relation or causality pattern between the variables. The arrows that point left and claim the negative correlation are located out of cone of influence and therefore, they cannot be taken into consideration.
**INT-nRen (gWh)**

The covariance and correlation between average light intensity and thermal electricity generation is positive in the short run and is quite small in magnitude, which decreases and even becomes negative in the medium run (Figure 13 (2)). However, in the long run they are almost independent from each other. Wavelet coherence exhibits the consistent results as well. Statistically significant medium and long run comovement between the aforementioned variables can be observed in approximately 1997-2007. What is more important, the arrows indicate that during this period of time they had been moving in the opposite direction with the light intensity taking the lead.

**INT – Ren (MW)**

Based on the wavelet covariation and correlation analysis we can assume that although almost insignificant relation can be detected between average light intensity and installed capacity of renewable energy, the sign of their comovement changes from negative to positive as the frequency decreases (Figure 13 (3)). Remembering the previously discussed output, the relation between thermal energy installation and average light intensity showed the opposite pattern. Wavelet coherence was unable to identify powerful association between the inspected variables. Statistically significant comovement polygon can be observed on the edge of short and medium run between 1993 and 1995, but it does not provide any valuable information.

**INT-Ren (gWh)**

Similar to the previous analysis, the pattern of the wavelet covariance and correlation between average light intensity and renewable electricity generation is the opposite of the thermal electricity generation case (Figure 13 (4)). Wavelet correlation does not significantly differ from zero. However, by looking at wavelet covariance and coherence, it can be assumed that positive association can be observed between the inspected variables on the edge of middle and long run period. The arrows suggest that they comove in the same direction and average light intensity is leading. There are two other polygons of short and long run correlation, but they do not provide any information about causality.

**SOL – nRen (MW)**
Wavelet based covariance and correlation output state a very weak relation between the lit area and installed capacity of thermal energy, which moves from negative to positive sign parallel to the lowering the time frequency (Figure 13 (5)). Wavelet coherence sketches small polygons of statistically significant association in the short run period. The polygons containing the phase difference arrows prove the statement of wavelet covariance and suggest that the coverage of lit area and the installed capacity of non-renewable energy move to the opposite directions.

\textit{SOL – nRen (gWh)}

The patterns of wavelet covariance and correlation of installed capacity and generated electricity with respect to sum of lights are the same for the non-renewable energy, but generated electricity is characterized with higher magnitudes (Figure 13 (6)). Moreover, wavelet coherence has captured more massive comovement polygons. It is obvious that higher correlation can be depicted in the short and medium run. Opposite comovement in mid-1990s and early 2000s is changed to a positive one in around 2007-2010. What is more, thermal electricity generation is leading in the short run in mid-1990s, whereas it is lagged in the medium run of the same time period.

\textit{SOL – Ren (MW)}

Unlike thermal energy, there is a positive wavelet correlation (covariation) between the sum of light and the installed capacity of renewable energy in the short run, which decreases in the medium run and even becomes negative in the long run (Figure 13 (7)). Unfortunately, the large portion of bordered polygons are detected out of cone of influence and they cannot be included into the analysis. However, there is a strong association between lit area and renewable energy capacity in the short as well as in the medium and long run. Moreover, their comovement has a positive sign in late 1990s whereas they start to move in the opposite directions from the beginning of the 21st century.

\textit{SOL-Ren (gWh)}

Analysis of the relation between the variation of renewable electricity generation and the lit area probably is the key tool for answering the main question of this thesis. Wavelet covariance and coherence suggest relatively tight positive association between these variables in the short and
medium run which decreases in the long run (Figure 13 (8)). Wavelet coherence detects a huge polygon of 5% significant correlation which covers almost the whole area of the investigated time period at every frequency. The arrows indicate comovement in the same direction. What is more, according to the alignment of the arrows, in the short run, generation of renewable energy has been causing the changes in the coverage of the lit area whereas sum of lights turn out to lead the process in the medium and long run.
5. Conclusion and Recommendations

The main purpose of this study is to evaluate the impact of renewable energy use on alleviating energy poverty in Turkey. Although there is no serious concern about electrification issue, energy mix of Turkey, which is completely irrelevant in any terms of sustainability turns out to be the main contributor to energy poverty. In order to analyze the characteristics of renewable and thermal components of energy mix, DMSP-OLS nighttime lights satellite data has been used as a proxy for energy poverty. Nighttime lights imagery, which can be considered as a revolution in data obtaining sources is used in wide range of socioeconomic studies – including energy consumption. Satellite data allows us to observe the dynamics in electricity consumption in Turkey and by decomposing energy mix into renewable and non-renewable sources it is possible to reveal their roles and importance for causing changes in anthropogenic nighttime lights during the given time period.
After carrying out relevant procedures for DMSP-OLS stable lights imagery correction in terms of alleviating blooming, saturation and incomparability issues, quarterly data has been extracted from the rasters of Turkey that spans between 1992 and 2013, including 88 observations. Sum of lit pixels and average light intensity have been chosen as the units for nighttime lights. As for the electricity-related variables, installed capacity (MW) and electricity generation (gWh) from renewable and non-renewable energy sources have been employed in the empirical analysis.

Pearson’s correlation coefficient revealed a very powerful relation among nighttime lights data and independent variables of energy mix. Augmented Dickey-Fuller (ADF) (Dicky and Fuller, 1979) and Phillips-Perron (PP) (Phillips and Perron, 1988) tests for unit root have been used for stationarity check. Both of the tests show the conclusive results claiming that the variables contain unit root at level but all of them become stationary after taking first difference and therefore, there is no further issue of non-stationarity in all six variables.

Although Granger Causality test failed to detect any causal relation between growth of light intensity and independent variables, it shows a unidirectional causal relation running from installed capacity of thermal energy, thermal electricity generation and renewable electricity generation to the growth of lit area. A unidirectional causation from lit area to the installed capacity of renewable energy sources are detected as well.

By decomposing data into time and frequency bands with wavelet transformation, this study serves as a pioneer attempt to look into the association between two types of energy sources and DMSP-OLS nighttime lights in Turkey.

Discrete and continuous wavelet transform suggest that the variables are characterized with statistically significant variations in the short (2-4 quarters) and medium (4-8) run period whereas in the long run (8-16 quarters) observed variations decrease and in the very long run (16-32 quarters) they become stable.

According to the wavelet covariance and correlation, electricity generation from thermal and renewable energy sources with respect to average light intensity follow the opposite patterns. Wavelet coherence shows that there is a statistically significant association between both of energy sources and average light intensity in the medium and long run period. However, there is an
opposite co-movement between thermal electricity generation and light intensity, whereas renewables are leading the positive one. Installed (thermal) capacity is strongly correlated with average light intensity in the very long run period, which is not surprising according to its share in the energy mix of Turkey.

Empirical analysis results become even more interesting for the case of the sum of lit pixels (sum of lights) as a dependent variable. There is a negative association between the growth of installed capacity of thermal stations and the coverage of lit area in the short run, whereas installed capacity of renewable energy sources are correlated with sum of lights at any frequency. However, the arrows show both – in-phase and out-phase co-movement patterns.

The most important finding of this study is revealing the relation between electricity generation and growth in the number of lit pixels. There is a short and medium run association between thermal electricity generation and sum of lights, which has been negative in the 90s and has become positive later on. Thermal electricity generation has been causing the increase in the sum of lights in the short run, whereas the direction of causal relation changes in the medium run. Surprisingly, wavelet coherence has explored a huge polygon of strong positive association between the lit area and renewable electricity generation, which covers short, medium and long run period. Same like the case of thermal electricity, short-run causal relation is running from renewable electricity generation to the sum of lights, while in the medium and long run expansion of the lit area leads to the increase in electricity generation from renewable energy sources.

Based upon this, one can assume that even though energy mix of Turkey is strictly dominated with thermal energy sources, renewable energy turns out to be impressively successful in meeting the demand coming from the increased electricity consumption. What is more, electrification rate of Turkey has been high and stable during investigated time period. Accordingly, significant role of renewable electricity generation in expanding the coverage area of nighttime lights may be perceived as a step forward in terms of guaranteeing affordability. Furthermore, in case of Turkey, together with the efficiency and affordability, the success of renewable energy sources automatically means decreased import dependency, improved trade balance and minimized environmental issues. Therefore, this study strongly supports the transition from fossil fuels to renewable energy sources, which calls for attaining more comprehensive energy policy. I believe,
that conducted theoretical and empirical analysis contains valuable information for policy makers and it would be beneficial to provide some recommendations:

- It is crucial for the government to redesign its energy policy and give priority to the utilization of clean energy sources. Within this framework, all kinds of subsides provided for the thermal energy production should be transferred to the renewable energy sources.
- Promotion of using locally produced technology in electric power plant construction (Law No. 5346) should be empowered i.e. Turkey should be able to handle the whole process of adding installed capacity without depending on the external sources.
- Privatization of energy sector has played the main role in developing renewable electricity generation and therefore, policy mechanisms should guarantee the profitable and safe environment in order to attract both, domestic and foreign investors and to accumulate financial capital.
- The government should put more effort in providing effective package of incentives such as favorable loans, tax credits and deductions, price supports (feed-in-tariffs), mandate purchase quotas etc.
- Updated targets have to be set, accurately followed and monitored in order to empower renewable energy sector. Moreover, the targets need to be flexible for reconsiderations (if needed).
- The government should consider the EU Water Framework Directive (2016) in terms of excluding ecologically vulnerable areas from HES constructions and instead of utilizing total potential of hydro power, other renewable energy sources should be strengthened to allow preserving some water resources without any loss in electricity generation.
- Considering the restrictions on land availability for WPP construction, offshore wind speed spatial map has to be provided in order to give precise estimations for offshore wind energy potential in Turkey and to attract investors.
- As solar energy has the highest potential among the renewable energy sources in Turkey, complicated bureaucracy has to be simplified in order to accumulate investments even with the considerably low feed-in-tariffs.
• Technological constraints for drilling and geothermal electricity generation should be overcome in order to guarantee a more efficient utilization of the resource.

• Gas emissions from geothermal electricity generation need to be controlled as in some cases the amount of emissions are considered to be hazardous for environment and additional safety mechanisms have to be applied.

• Land use and deforestation should be put under a strict control while exploiting biomass. Modern biomass technology has to be implemented and spread as well.

• Various campaigns should be carried out in order to raise the awareness of the society about renewable energy, possible side effects (aesthetic impact, land use, deforestation, etc.) and its importance for the sustainable development of Turkey.

• Sufficient financial support has to be transferred for the research and development of renewable energy sector in order to maximize the efficiency of technology and to provide properly educated, qualified human resources being able to explore and effectively utilize the potential of Turkey.

Besides policy suggestions, I would like to share the recommendations for further investigation in this area as well. Although this study has generated valuable information in order to provide a precise answer for the main research question, it still has some limitations. Time period chosen for the empirical analysis has been limited according to the availability of DMSP-OLS nighttime lights data. Upgraded NPP-VIIRS satellite, which has started providing monthly composites of high resolution nighttime lights imagery in December, 2011. Considering the fact, that NTL imagery for 2012 and 2013 can be obtained both from NPP-VIIRS and DMSP-OLS satellites, it is possible to take them as a reference category for intercalibrating two datasets. Consequently, we may obtain a time series of NTL spanning from 1992 until now. Renewable energy sector has exhibited outstanding progress since 2013, which implies that nowadays renewable energy sources may be far more significant in alleviating energy poverty of Turkey than investigated time period (1992-2013) could show. Therefore, by overcoming data limitations the quality of the empirical analysis may be improved and individual effects of the various types of renewable energy sources may be investigated as well.
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