SUSTAINABLE DEVELOPMENT AND RENEWABLE ENERGY NEXUS: EMPIRICAL EVIDENCE FROM TURKIYE

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THESIS APPROVAL PAGE

I certify that in my opinion the thesis submitted by Saeeda LUBABA titled "SUSTAINABLE DEVELOPMENT AND RENEWABLE ENERGY NEXUS: EMPIRICAL EVIDENCE FROM TURKIYE" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

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This thesis is accepted by the examining committee with a unanimous vote in the Department of Economics as a Master of Science thesis. June 12, 2023

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DECLARATION

I hereby declare that this thesis is the result of my own work and all information included has been obtained and expounded in accordance with the academic rules and ethical policy specified by the institute. Besides, I declare that all the statements, results, materials, not original to this thesis have been cited and referenced literally.

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FOREWORD

My humble gratitude, to The Almighty Allah (SWT), the ultimate source of all wisdom and knowledge and without Whose divine help it was impossible for me to drag an end to this enormous dissertation.

To my ever supportive parents, for having faith in me in every steps of my journey to higher studies abroad.

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ABSTRACT

This research article studies the sustainable development and renewable energy consumption nexus in Turkiye from 1980-2019 using the ARDL bounds testing approach. It has a unique identity since it uses the three elements of sustainable development: society, environment, and economic efficiency to assess the relationship.

The result of the empirical analysis showed a one-way relationship from economic growth to the renewable energy consumption of Turkiye in the long run. Moreover, using renewable sources will decrease carbon emissions keeping a positive impact on the environmental aspect of sustainability in Turkiye. On the other hand, it is observed that as society improves in terms of MHDI, the need to utilize alternative energy sources reduces.

The findings of this research would be crucial for the government, policymakers, researchers, etc., because this study is a fresh evidence in assessing the relationship of renewable energy consumption in Turkiye with sustainable development encompassing all the pillars (i.e., social, economic, and environmental) of it. The paper would also help address climate change, environmental pollution, quality of life, Turkiye's development sustainably, etc. This paper will also be an essential addition to the literature on Turkiye's sustainable development perspective.

Keywords: Sustainable Development; Renewable Energy Consumption; Turkiye; Relationship; CO2 Emission; ARDL

ÖZ

Bu makale, 1980-2019 dönemi için Türkiye'de yenilenebilir enerji tüketiminin sürdürülebilir kalkınma ile ilişkisini ARDL sınır testi yaklaşımıyla incelemeyi amaçlamaktadır. Makale, sürdürülebilir kalkınmanın üç unsurunu (yani ekonomik, sosyal ve çevresel yön) kullandığı bağlamda benzersiz bir kimliğe sahiptir.

Ampirik analizin sonucu, uzun dönemde Türkiye'nin ekonomik büyümesinden yenilenebilir enerji tüketimine doğru tek yönlü bir ilişki olduğunu göstermiştir. Ayrıca, yenilenebilir kaynakların kullanılması, Türkiye'de sürdürülebilirliğin çevresel boyutu üzerinde olumlu bir etki yaratarak karbon emisyonlarını azaltacaktır. Öte yandan, toplum MHDI açısından geliştikçe alternatif enerji kaynaklarından yararlanma ihtiyacının azaldığı görülmektedir..

Bu araştırma, Türkiye'deki yenilenebilir enerji tüketiminin sürdürülebilir kalkınma ile ilişkisini değerlendirmede yeni bir kanıttır; yani, sosyal, ekonomik ve çevresel tüm sütunları kapsar. Bu analizden elde ettiği sonuçlar devlet, politika yapıcılar, araştırmacılar vb. için çok önemli olacaktır. Belge aynı zamanda iklim değişikliği, çevre kirliliği, yaşam kalitesi ve Türkiye'nin sürdürülebilir kalkınması vb. konuların ele alınmasında da yardımcı olacaktır. Aynı zamanda bu makale Türkiye'nin sürdürülebilir kalkınma perspektifi hakkındaki literatüre önemli bir katkı sağlayacaktır.

Anahtar Kelimeler: Sürdürülebilir Kalkınma, Yenilenebilir Enerji Tüketimi, Türkiye, Bağlantı, CO2 Emisyonu, ARDL

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ABBREVIATIONS

ARDL	**:** Auto Regressive Distributed Lag
BEPA	**:** Biomass Energy Potential Atlas
BG	**:** Breusch-Godfrey
CE	**:** Carbon-dioxide Emission
EJ	**:** Exajoule
EIA	**:** US Energy Information Administration
IRENA	**:** International Renewable Energy Agency
GDP	**:** Gross Domestic Product
GHP	**:** Geothermal Heat Pump
IQ	**:** Institutional Quality
IUCN	**:** International Union for the Conservation of Nature and Natural Resources
MENR	**:** Ministry of Energy and Natural Resources
MEUCC	**:** Ministry of Environment Urbanization and Climate Change
MHDI	**:** Modified Human Development Index
NARDL	**:** A Nonlinear Autoregressive Distributed Lag
OP	**:** Oil Price
RE	**:** Renewable Energy
REC	**:** Renewable Energy Consumption
REPA	**:** Turkish Wind Energy Potential Atlas
SD	**:** Sustainable Development
SDG	**:** Sustainable Development Goal

TROPEN **:** Trade Openness

UNCED **:** United Nations Conference on Environment and Development

UNESCO **:** United Nations Educational, Scientific and Cultural Organization

VECM **:** Vector Error Correction Model

WCED **:** World Commission on Environment and Development

WCS **:** World Conservation Strategy

WDI **:** World Development Indicators

SUBJECT OF THE RESEARCH

This research report studies the connection of renewable energy consumption with sustainable development in Turkiye from 1980 to 2019 by the ARDL test of cointegration. Unlike other studies on Turkiye, this study incorporated variables representing the pillars of sustainable development (namely, economic, social, and environmental) to elaborate on the link of renewable energy with sustainable development. As dimensions of sustainable development, this study includes variables like the Gross Domestic Product (GDP), Fixed Capital (FK), Labor Force (L), Modified Human Development Index (MHDI), Renewable Energy (RE), Carbon Emissions (CE), and good governance as an indicator of Institutional Quality (IQ) etc. Moreover, following the study of Tiba and Belaid (2021), this paper takes renewable energy (RE) as a determining factor of sustainable development as it has been recognized by many studies (Tiba et al., 2016; Dincer, 2000; Tiba & Frikha, 2020) that RE significantly contributes to sustainable development.

PURPOSE AND IMPORTANCE OF THE RESEARCH

The purposes of this research are:

- Studying the relationship of RE and sustainable development (SD) in Turkiye
- Studying the nexus of RE with GDP, MHDI, CE, and vice versa
- Enriching the current literature on the RE-SD nexus in the context of Turkiye

Switching from traditional energy sources to alternative energy sources is crucial for Turkiye as 70% of its energy consumption is contributed through imported energy supplies (Capik, Kolayli, & Yilmaz, 2013). That means, for the energy sector Turkiye is an import-driven country. Moreover, there is an increasing demand for energy supply in this country which doubled by the period (2000-2010) and is expected to increase fourfold within the years 2000-2025 (Demirbaş Ayhan, 2003; Kiliç, 2006; Balat, Balat, & Acici, 2016).

Hence, it can be said that unless Turkiye enriches its domestic energy resources with renewable energy production, its foreign dependency will be higher day by day. Higher foreign dependency is a threat to the long-run well-being of a country.

Accordingly, it is crucial to examine the prospect of alternative energy as a determinant of Turkiye's sustainable development.

METHOD OF THE RESEARCH

Following the research method of Tiba and Belaid (2021), this study incorporated variables representing the three pillars of sustainable development (namely, economic, social, and environmental) to have a detailed study of the nexus between sustainable development and renewable energy. The elements of sustainable development have been represented through the following variables: GDP, MHDI, RE, CE, FK, L, HE and IQ.

This study used secondary data sourced from various data sites like WDI of World Bank, EIA, BP statistical review, UNESCO Institute for Statistics, OECD.stat, etc. Using a data range from 1980 to the year 2019, this research investigates the connection between renewable energy use of Turkiye and its economic growth through the ARDL approach.

RESEARCH PROBLEM

This research aims to give answer to the question,

'Is renewable energy consumption (REC) of Turkiye related to its sustainable development?'

From this basic question following sub questions has been extracted:

Does REC have any effect on GDP of Turkiye?

Are carbon emission and REC of Turkiye related to each other?

Can REC help increase social wellbeing?

SCOPE AND LIMITATIONS

Due to insufficient data for measuring Turkiye's institutional quality, the indicator IQ has been removed from the production function. Because "*Worldwide*

Governance Indicators (WGI)"- an important institutional factor of IQ couldn't be added to the data set as the data for WGI began to be calculated from the year 1996 only. Moreover, this research could not employ a more big data range except for 40 years as the variables like government's spending on public health, rate of adult's literacy, REC etc. has limited data range available for Turkiye. In addition to this, the study incorporates only a time series analysis performed separately on four different regression equations. It is expected that this type of empirical investigation may give a more comprehensive result when tested with a panel approach. Hence, the same variables can be tested through a panel analysis taking into account the data from different regions of Turkiye to get a more robust result.

INTRODUCTION

Energy, environment, and growth are highly intertwined with each other. Sufficient energy generation, conservation of the environment and sustained growth are all equally important for the development of any country. In the energy economics literature, the nexus of energy consumption and growth of economy is a widely discussed topic (Payne, 2010; Ozturk, 2010; Tugcu, Ozturk, & Aslan, 2012). While, in most cases, energy production and growth are positively related, environmental protection is just the opposite of them.

Uncontrolled growth and energy production often threaten environmental well-being and hence the sustainable development of a country. That's why countries are now very concerned about arbitrating among these three. In addition, Economic growth obtained with nonrenewable energy consumption pressurizes the environmental quality (Tiba, Omri, & Frikha, 2016; IRENA, 2020); because energy supply and use entail environmental risks such as global warming, atmospheric damage, the release of radioactive substances, exploitation of the ozone layer and the destruction of forests, etc. (Dinç & Akdoğan, 2019). Therefore, we must use eco-friendly energy sources for sustainable development (Dinç *et al.*, 2019).

Regarding eco-friendly energy, renewable and nuclear energy can be the best choices. Energy sector investments turn costly when switched from the established fossil fuel dependent energy system to a renewable one. Still, renewable energy, particularly solar energy, and the spread of foreign technologies can pave the way to a low-carbon economy and meet emission lessening targets (Leimbach, Roming, Schultes, & Schwerhoff, 2018).

1. CHAPTER ONE

GLOBAL SUSTAINABLE DEVELOPMENT SCENARIO IN TERMS OF RE CONSUMPTION

This chapter talks over sustainable development, its compositions and importance, elaborates SDGs and its significance and finally enlightens the readers about the global sustainable development scenario in terms of RE use.

1.1. Sustainable Development (SD)

SD first came into light through the IUCN's proposal of the "*World Conservation Strategy (WCS)*" in 1980 (IUCN, 1980; Lélé, 1991). However, the way WCS defined SD was less comprehensive, as it only restricted the concept of safeguarding living resources and primarily concentrated on the need to maintain genetic diversity, ecological processes, and habits (Khosla, 1987). In contrast to the definition of WCS, the UNEP conceptualized SD within five elaborated notions, which were somewhat more ambiguous. Similar definitions were also prevalent at the conference on "*Conservation and Development*" funded by IUCN-UNEP-World Wildlife Fund (Lélé, 1991). Among all the definitions of SD, the most accepted one is the one mentioned in the Brutland report by the WCED in 1987- which states sustainable development as:

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

However, sustainable development has become the overreaching goal of the international community after the UNCED conference in 1992 (Voumik & Shah, 2011).

1.2. Compositions of SD

SD is often shown as the composition of the following aspects:“*economic, environmental, and social*” (Hardi & Zdan, 1997; West Midlands Round Table, 2000). These three parts are generally presented as three interconnected rings (ICLEI and IDRC, 1996; Brandon et al., 2000; Barton, 2013) (as shown in figure 1), which are of the same size and with symmetrical interconnection (Giddings, Hopwood, & O'Brien, 2002). The three circles have separate identities, and a part of each lies inside the other. This figure is a fundamental expression to explain the nature of integrity among social, environmental, and economic parts of sustainable development. However, the diagram has many drawbacks as the society, environment, and economy are not autonomous identities that can be traded off for each other, and neither can they be separated from each other, as the model says. Because environment can continue without society, but society cannot (Lovelock, 1988).

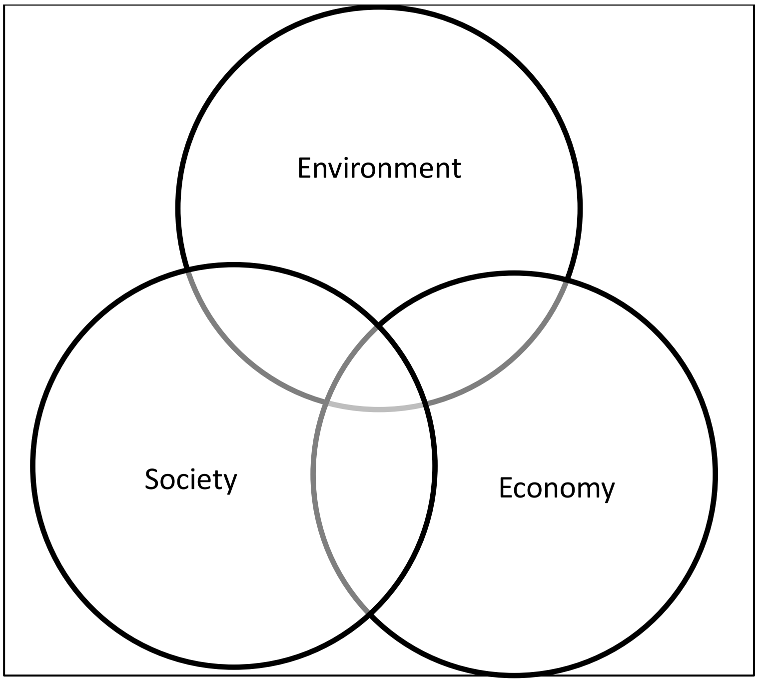

Figure 1: Basic model of sustainable development

Source: (Giddings et al., 2002)

Hence researchers like Giddings et al., (2002) proposed a nested sustainable development model (figure 2) where the environment is seen as autonomous, and society and the economy depend on it. The model has an economy at its center, but it doesn't mean everything evolve around the economy; rather, it represents that economy is a subset that depends on society and society is also a subset of the environment that depends on it (Giddings et al., 2002).

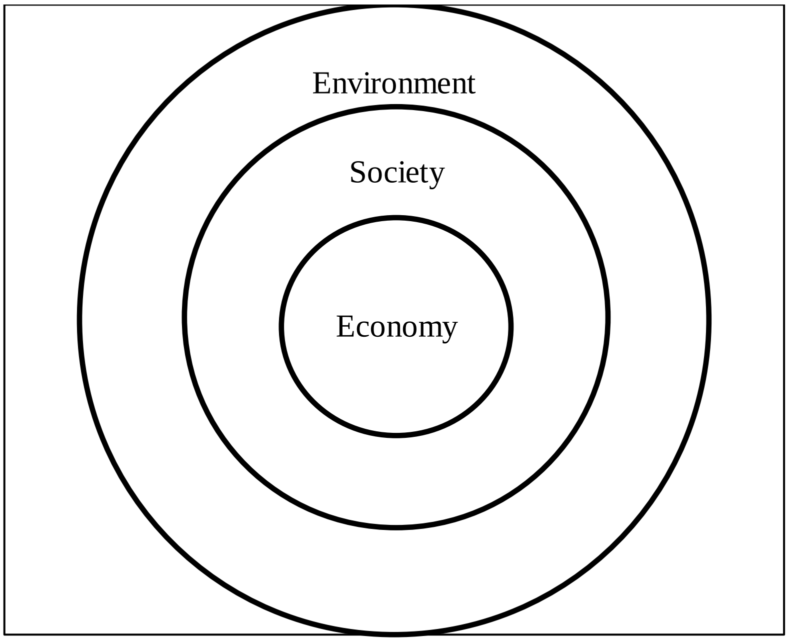

Figure 2: Nested view of sustainable development

Source: (Giddings et al., 2002)

Besides the three pillars, some researchers (Abou-Ali & Abdelfattah, 2013; Joshi, Hughes, & Sisk, 2015; Tiba, 2019b, 2019c, 2019a; Tiba & Belaid, 2021) also consider an additional pillar named "institution" with the economic, social and environmental dimensions of the sustainability concept.

1.3. Sustainable Development Goals (SDGs)

SDGs, also known in another term as the "*Global Goals*" have been familiarized by UN in the year 2015. It aims to call the global leaders to take action for ending poverty, protecting the earth and ensuring that all humankind has peace and success by 2030. It can be seen that eliminating global scarcity altogether especially extreme poverty- which is the single greatest challenge is needed for ensuring sustainable development. It is necessary that every country and every stakeholder collaborate with each other to implement the SDG goals. It will help accomplish the UN mission to free humanity from poverty, scarcity and make this planet a secure and safe place.

SDGs are also a continuation of the "*Millennium Development Programs (MDPs)*" targeted to achieve those goals not fulfilled by MDPs. These goals are interconnected, inseparable and equally works on all the aspects of sustainable development like social, economic and environmental. To ensure sustainable development UN have introduced 17 goals accompanied with 169 targets (United Nations, 2018).

The 17 SDGs are stated below:

1. End Poverty in all its Form
2. Zero Hunger
3. Good Health and Well-Being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and clean Energy
8. Decent work and Economic Growth
9. Industry, innovation and infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace, Justice and Strong Organizations
17. Partnerships for the Goals

There are five pillars, well-known as the "*5 Ps of the sustainable development*" that UN considers before implementing any of its development agendas. These are:

1. People
2. Peace
3. Partnership
4. Planet
5. Prosperity

These pillars are important in the sense that any policies taken by governments have direct or indirect impacts on them. It is required to be sure that, while taking the sustainable development plans, countries should think of the possible consequences on these five pillars. The 5 Ps also help in taking efficient decisions and actions by the governing bodies. The United Nations in its 2018 report on *"The 2030 Agenda for Sustainable Development (United Nations, 2018)"* narrates the rationality of considering these 5 pillars in their plans. This can be briefed as below:

People: Considering people in the development plans is important because SDGs aims to guarantee that everyone have a life of dignity where they can explore their potentials, get fare pay, don't suffer from hunger and malnutrition and also enjoy a safe and clean environment. That's why the very first goal of UN sustainable development strategies is "*to end all forms of global scarcity*"

Planet: To meet the needs of generations after generations it is important that our planet is protected from over-exploitation. That's why one of the SDGs concentrates on the target to consume and produce responsively. By giving importance to the planet we live in, it is possible to fight the climate change and keep the earth's natural resources in harmony.

Prosperity: Though SDGs aim to eliminate global poverty, provide a dignified life for every global citizen and ensure a healthy pollution free environment for all, it doesn't overlook economic prosperity. Moreover, the sustainable development objectives are designed such that it gives human being a flourishing and fulfilling life including progress in economy, social life and technologies. It is also determined to ensure that all these prosperities come in line with environmental protection.

Peace: SDGs aim for a peace inclusive society with no fear and no violence. Peace will be ensured in all its dimensions and forms. Societies will see justice and law when the objectives of sustainable development are followed. According to the UN's 2030 agenda, 'peace is inevitable for reaching sustainable development. Similarly, only a sustainable development can ensure global peace' (United Nations, 2018).

Partnership: Without partnership there can be no peace, no sustainable development. Standing on the base of strong global solidarity SDGs are aimed to be implemented all over the world with special attention to the most vulnerable, poor and needy countries. Partnership is important in realizing SDGs because, no country can fulfill all of their needs without the help of others; moreover participation of all the countries will reflect the common interests on developing a livable planet for future generations. In this way no country will live behind nor will any prosper at the cost of the other.

1.3.1. Significance of SDGs

The importance of SDGs can be understood from its 2030 agenda report. It says SDGs are a "*global blueprint*" to ensure that every human being of this world live with honour, have peace and success in their lives both in the present and future time (United Nations, 2020). It can also be understood from the process through which SDGs shaped nations' and governments' shared vision to implement SDG related development actions and strategies.

SDGs being interconnected to each other need integrated actions from the governing bodies to put them in action. That means one goal cannot be enforced without ignoring the other. Moreover, the goals for attaining sustainable development are such that, it aims to eradicate global hunger, ensure economic prosperity keeping the environmental effects in mind (Practical Action, 2022).

One of the notions of SD is to develop countries, cities, lands, communities, businesses etc. in such a way that these developments meet the necessities of both present and future generations. Therefore the goals of sustainable development help solving the problems of the current generation without creating any problem or any issues for the future generation.

The United Nations (2020) in its essay "*why the SDGs matters*" narrates beautifully about the significance of each and every SDG goals. For example, SDG goal 7 states that, it aims

"to ensure access to affordable, reliable, sustainable and modern energy for all (Brandão, 2021)."

Having a secured energy structure is important in the sense that it will support all the sectors of the society: from economy, health and education to agronomy, industry, transportations and technological advancement.

Energy in all its different forms is an indispensible part and parcel of our life. From individuals to nations, we cannot but pass a day without utilizing different type of energies. Families need thermal energy for cooking; electric energy for lighting, maintaining in-house temperature and operating all the small to big machines needed for various purposes etc. Farms and industries can also not go a day without consuming different direct and transformed form of energies. Survival of big industries depends on the flawless flow of energies. In the same way, nations having secured energy supply, nuclear power plants, sustainable energy sources are deemed to be super powers than others who lack those. Hence the significance of having access to stable, cheap, consistent and up-to-date energy goes beyond explanation. A sustainable energy program can help lower income countries in gaining energy efficiency within their budgets. Similarly if according to SDG goal 7, safe and clean energies are used for cooking then there will be less environment pollution and climate change problems.

Another important goal from SDGs is the SDG 8. It talks about ensuring decent employment for all and enabling an *"inclusive and sustainable economic growth"* in this process. Realization of goal 8 of SDG in the national development plans is crucial because having means to fulfill the basic needs of life is an absolute right of a human being. Having a steady source of income not only benefits the associated families, but also revolves the economy's wheel. On the other hand an established economic system guarantees decent employment and fair pay for all, gives recognitions to individual's skills and improves life styles for all. Therefore, employment and economic progress are interconnected to each other. One cannot go far without the other.

1.3.2. SDG Goal 7 Explanation

Although there are 17 Sustainable Development Goals as mentioned above, this dissertation solely focuses on Sustainable Development Goal 7: Ensure access to cheap, continuous, sustainable, and up-to-date energy for all.

Energy is essential for accomplishing nearly each and every SDG, from eradicating poverty to improving health, imparting quality education, supplying enough water, and industrialization, as well as addressing climate change. Advancements in sustainable energy are supporting sign for confirming entree to reasonable dependable and up-to-date energy for all. Renewable energies are the most sustainable forms of energies as they can be reproduced naturally without harming the nature. Moreover they have almost a non-perishing lifespan in most of the cases.

Renewable energies are *"clean energies"* as their productions do not pollute the atmosphere. These energies have easily accessible sources like the sun, wind flows, water bodies, animal wastages etc. The most needed form of energy- electricity, if produced from renewable sources will help countries to progress economically with a cheaper cost of production. Additionally it will allow less harm or no harm at all to the environment. Hence utilizing SDG goal 7 in different countries of the world is an essential step towards building a better world for the new generation.

SDG goal 7 comprises of the following objectives and targets (Güney, 2019; United Nations, 2018):

- Make sure every human being has reasonable, safe and up-to-date energy within 2030.
- By 2030, increasing the amount of renewable energy in the world's energy mix by a significant amount.
- Ensure that within 2030, global energy efficiency rate multiplies twice the present situation.
- By 2030, strengthen international collaboration to allow access to clean energy development and technology. In addition to this, encourage investments in energy infrastructure and green energy technologies, renewable energy sources, energy efficiency measures, and more refined and environment friendly fossil fuel technology.
- Within 2030, ensure that every developing country have supply of up-to date and sustainable energy facilities by improving old technologies and infrastructures. Special care should be take should be given to countries that are least developed, developing states surrounded by sea and developing nations with no access to sea.

The developments in countries of the world in electricity and other energy composition sectors can be understood from the "*SDG Progress Reports*" published by UN every year. The research article now focuses on giving a short preview on the present situation of the world's RE consumption, electricity consumption and financial help towards increasing the proportion of RE in global energy mix.

1.3.3. Global RE Consumption Scenario

Table 1 below portrays the share of RE in the world's overall energy consumption. The data retrieved from UN's SDG report shows the consumption scenario from the year 2000 to 2012. As it can be seen from the information on renewables, the proportion of RE in compared to world's overall energy consumption has not increased significantly from the year 2000 to 2012. It is evident from figure 3; which depicts only a slight change (from approx. 17% in 2000 to approx. 18%) in the consumption of renewables in compared to total energy consumption from the year 2000 to 2012.

Table 1: Share of renewable energy in total energy consumption

Year	Other renewables	Modern renewables
2000	10.2	7.2
2005	9.7	7.3
2010	9.4	8.4
2012	9.3	8.8

Source: SDG Progress Report 2016

However, table 1 also shows a positive trend in the share of modern renewables which doesn't include use of solid biofuels. While share of modern renewables was only 7.2% in the year 2000, it became 8.8% by the year 2012. In contrary to that, share of other renewables (sourced from the sun, wind, water, animal wastes, geothermal etc.) kept decreasing in the mentioned years.

It is also seen that modern renewables are significantly contributing in the production of the world's electricity. For example, in 2014, modern renewable energy sources made up to 60% of all newly constructed power plants (SDG report, 2016).

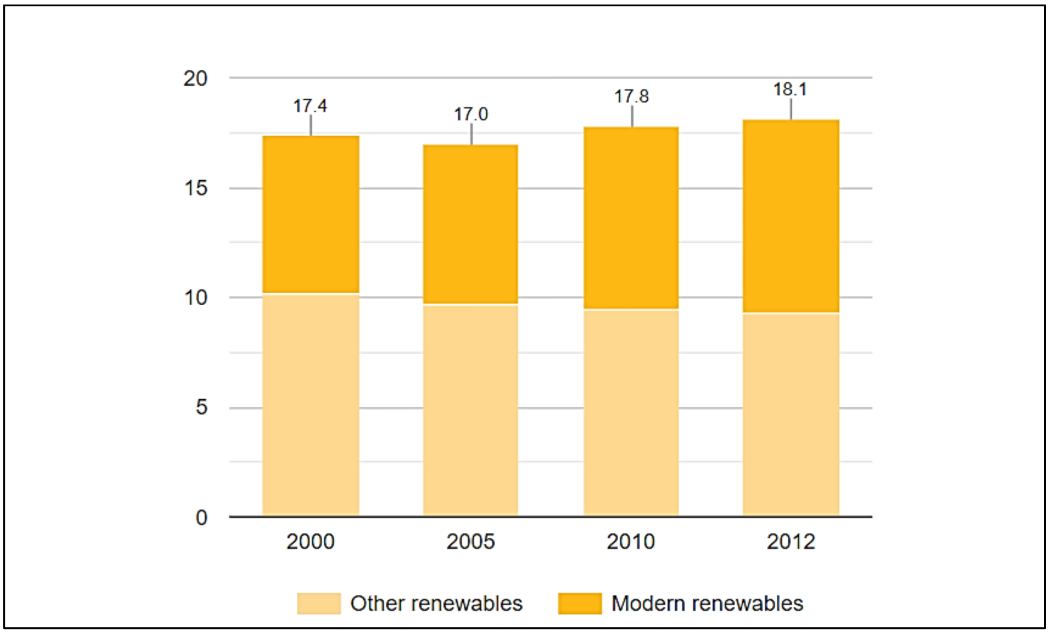

Figure 3: Percentage share of RE in the overall energy consumption (2000, 2005, 2010 & 2012)

Source: SDG Progress Report 2016

1.3.4. Region Based Share of Renewables (Year 2015)

From the 2018 SDG report, it is evident that different regions of the world still lack behind in utilizing RE in their gross energy consumption. Globally RE consumption has increased slightly by 18 percent within the years 2000 to 2015. Moreover, only 55% of the total RE consumption has used modern renewable sources; remaining energy usage came from the use of traditional biomass like burning wood, coal etc. Therefore, it is crucial to increase the use of modern renewables worldwide.

Table 2: Ratio of individual renewables in the overall energy consumption

Regions	Traditional biomass	Modern bioenergy	Hydro-Power	Wind	Solar	Other renewables
Sub-Saharan Africa	273.8	27.96	6.77	0.22	0.27	0.31
Oceania	0	7.24	2.93	1.01	0.8	0.75
Northern Africa and Western Asia	6.4	7.52	7.4	1.13	1.63	2.14

Latin America and the Caribbean	25.04	81.1	48.66	2.79	1.15	0.71
Europe and Northern America	0	211.41	97.93	37.77	15.05	4.11
Eastern and South-Eastern Asia	164.09	49.84	98.34	14.29	28.17	7.05
Central and Southern Asia	188.59	46.37	15.73	2.84	1.04	0

Source: (SDG Report, 2018)

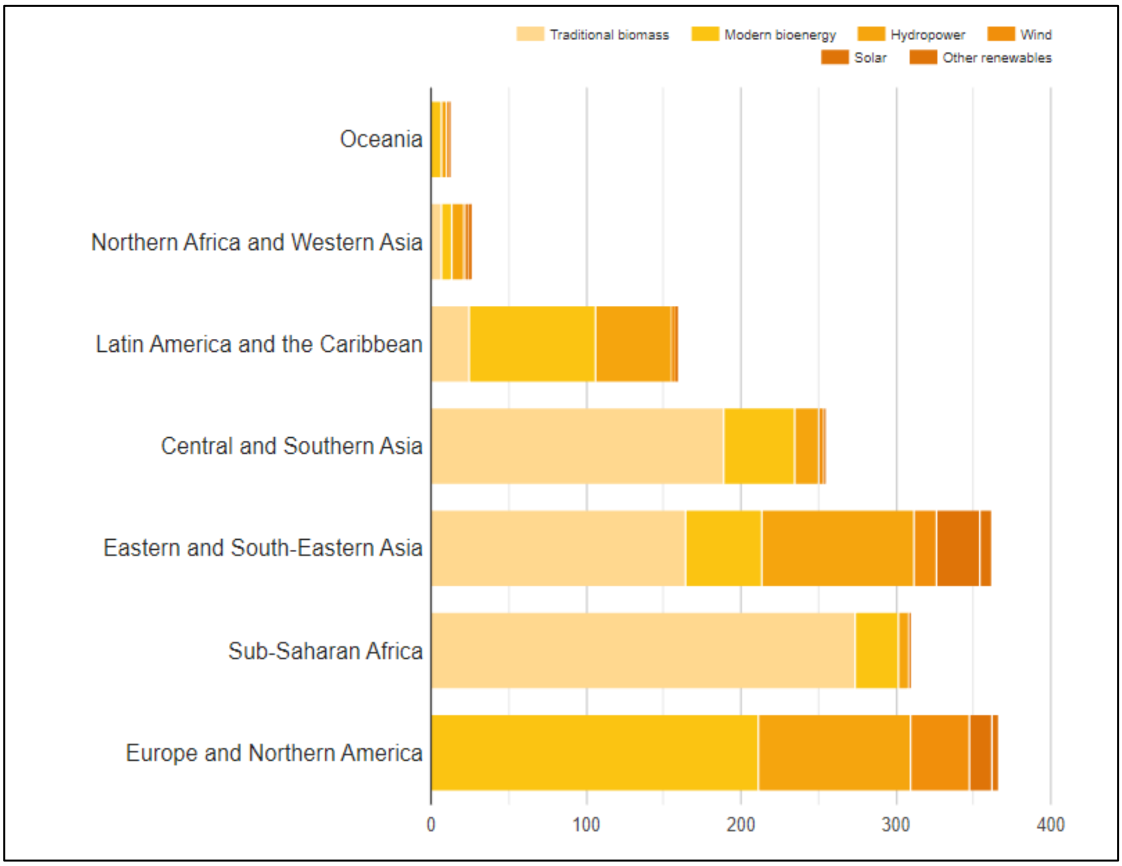

Figure 4: Ratio of individual renewables in the overall energy consumption

Source: (SDG Report, 2018)

SDG 2018 report on the progress of SDG goal-7 also shows that regions like Europe and Northern America, Eastern and South-Eastern Asia have the major proportion in energy consumption; and regions like Oceania, Northern Africa and Western Asia have the lowest use of energy in 2015 (fig. 4). However, Oceania region shows the lowest harm to environment in 2015 (table 2) as none of its energy usage came from the use of traditional biomass. Similar is the case for the regions of Europe and Northern America. This region also shows the highest (211.41) use of modern renewable sources among all the regions in the world.

1.3.5. Sector-wise RE share

RE generally contributes to three sectors worldwide: electricity, heat and transport. Among these, mostly electric sector is seen to be benefitted from renewables. Year by year RE contributed to the growth of electricity usage worldwide.

Table 3: Sector-wise RE consumption

Year	Heat	Electricity	Transport
2010	25.7	19.6	2.3
2012	26	20.9	2.6
2014	26.3	22.3	2.8

Source: (SDG Report, 2017)

For instance, within the period 2010-2014, the proportion of RE sources in electricity generation increased by 3% approximately (19.6% in 2010 to 22.3% in 2014). On the other hand, use of RE in the other two sectors (i.e. heat and transport) increased only marginally. For example, in 2010, renewable's contribution in heat generation was 25.7% of the total energy production; it became 26% in 2012 and 26.3% in 2014 showing a very slow progress. Similar trend was seen in the case of transport which increased only by 0.5 percent within the period 2010-2014 (table 3; figure 5; SDG Report, 2017).

In the year 2015, RE consumption went up by 18% in compared to the year 2000. Half of this increment came from the growth in electricity sector and the remaining half came from the use of RE in heating and transportation sector (SDG Report, 2018). Contribution of RE in the global power consumption kept on increasing. In 2016, 24% of the total RE consumption came from electricity (SDG Report, 2019); in 2017 it became 24.7%; in 2018, 25.4% and 26.2% in 2019 respectively (fig. 6). Though electricity consumption kept rising continuously, its share in the total energy use is seen to be less than the other two sectors. For example, within the period 2014-2019, electricity accounted for approximately 20% of the world's aggregated energy consumption and the remaining 80% came from the use of energy in heat and transportation sectors.

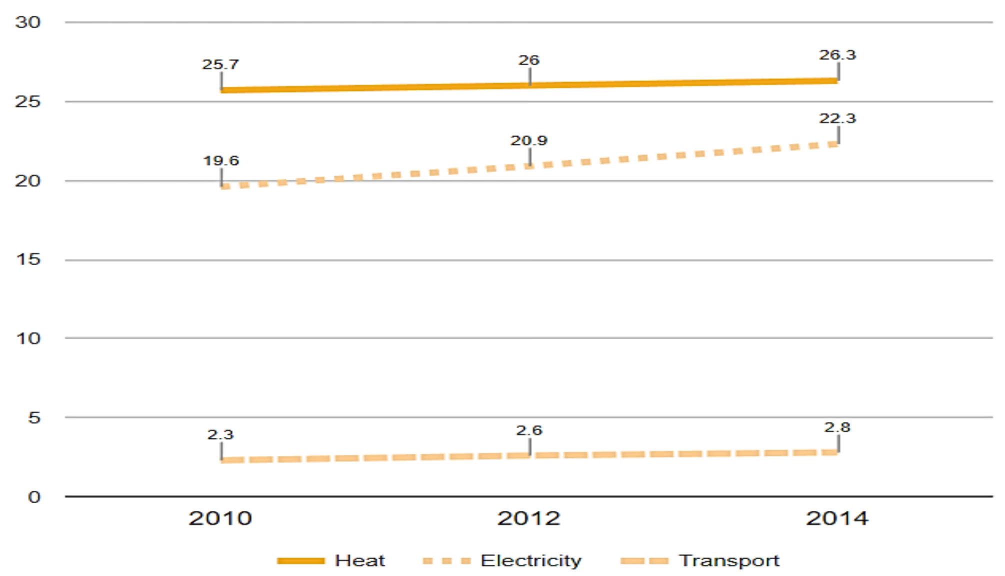

Figure 5: Graphical representation of the sector-wise RE consumption

Source: (SDG Report, 2017)

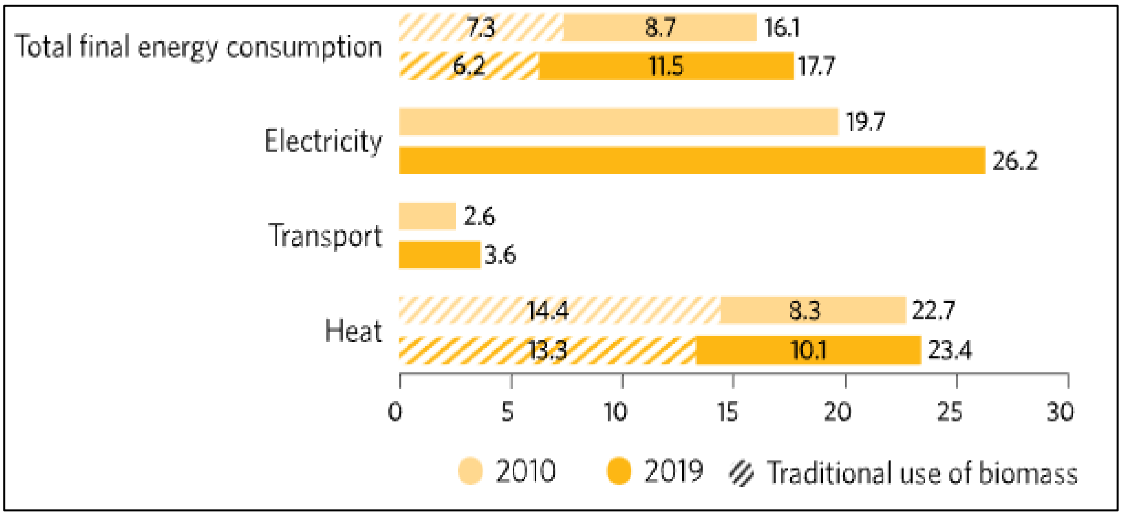

Figure 6: Share of RE by sector in total energy consumption (2010 & 2019)

Source: (SDG Report, 2022)

Share of RE in heat and transportation sector didn't show essential growth within the period 2010 to 2019. In 2014, heat sector showed an increase of 26.3 percent from 25.7 percent in 2010 and transport sector showed a rise of 2.8% from 2.3% in 2010 (SDG Report, 2017). In the year 2015, renewable's share in the overall energy use became 17.5% from 17.3% in 2014. Heat and transportation together contributed to half of this increase, which was very negligible in terms of power sector's contribution. Power sector's growth was behind the rise in RE use in the overall energy consumption of the year 2015.

In the years 2016 and 2017, use of RE in heating sector was 24.1 and 24.3 points respectively- which shows a very slow progress. However, in the year 2018 heating sector showed a decrease of 1.1% from the previous year and in 2019 it increased slightly and became 23.4% of the total increase in renewable's consumption (SDG Report, 2019, 2020, 2021, 2022). Similarly in the transportation sector no significant progress has been seen in the last ten years (from 2010 to 2019). In 2010, transport sectors accounted for 2.6% of the total RE consumption which became only 3.6% by the year 2019 (fig 6). Moreover, even by the year 2019 the use of traditional biomass has not decreased much and accounts for more than one third of the overall RE consumption (SDG Report, 2022). Hence, to reach the objectives of SDG goal 7 within 2030, it is crucial to increase the use of renewable sources in heating and transportation sectors.

1.3.6. Global Electricity Efficiency Scenario

One of the targets of SDG 7 is to ensure "access to affordable, reliable, and modern energy services" for all. To reach this target it is necessary that nations around the world get proper electricity service within 2030. Countries are working hard in this regard. Still much attention is needed to continue progress in worldwide energy access. Due to COVID pandemic in 2019 and Ukraine-Russia war in 2022, expected progress in global energy security couldn't be obtained. War drove up energy prices worldwide leading to some country's decision on a return to using traditional fuels such as coal.

Moreover, the target of reaching an annual growth of 0.9 in global electricity access couldn't be fulfilled by the period 2018-2020. This much growth was essential to meet the target of universal access to electricity by 2030. The scenario of global electricity efficiency for the period (2000-2019) has been briefly discussed below with related graphs and tables.

Table 4: Electricity access by region 2000 & 2012

Region	2000	2012
Oceania	23	29
Sub-Saharan Africa	26	35
Southern Asia	63	79
South-Eastern Asia	79	90
Western Asia	89	93
Latin America and the Caribbean	93	96
Eastern Asia	97	99
Nothern Africa	92	100
Caucasis and Central Asia	99	100
Developed regions	100	100
Developing regions	74	81
World	79	85

Source: SDG report, 2016

According to the SDG Report (2016), in the year 2012, 1.1 billion people around the world didn’t have access to electricity services. However, a worldwide steady growth of electricity access has been seen within the period 2000-2012. In 2000, 79 percent of world population could access electricity and in 2012 this service reached 85 percent of the global population (table 4, fig 7).

Most of the progress gained in 2012 came from the Asian regions and 80 percent of the people that had access to electricity since 2010- were urban dwellers. Regions like Oceania and Sub-Saharan Africa still lacked respectively 71% and 65% of access to electricity (fig 7). Where developed regions of the world had 100% access to electricity in the period (2000-2012), developing regions of the world saw only a 7% increase in their electricity production within this period (fig 7).

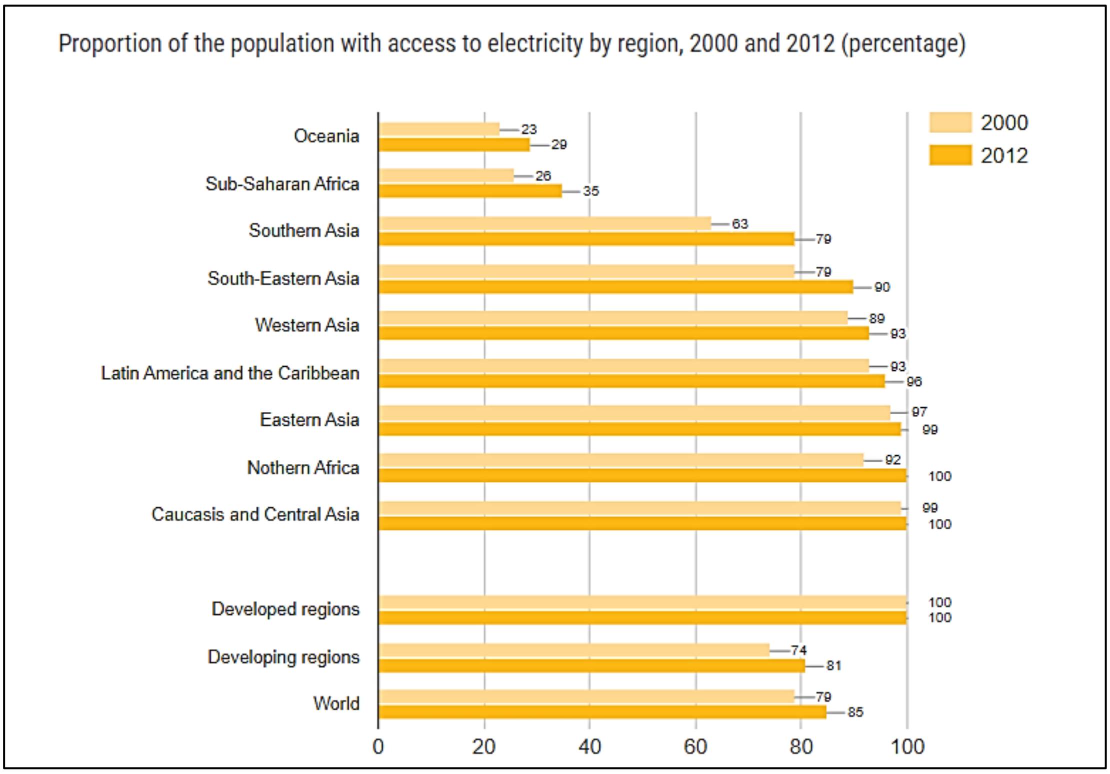

Figure 7: Percentage share of global electricity access by region: 2000 & 2012

Source: SDG report, 2016.

From the year 2012 to 2014 only 0.3% of increase in electricity consumption has been observed worldwide (fig 8). That is, a population of 1.06 billion people (particularly rural residents) didn't have access to electricity by 2014 and half of them were from Sub-Saharan Africa. Fig 8 also shows a sharp increase of about 10% (from 63.1 to 73%) electric power access for rural dwellers in the period from 2000 to 2014. However, this amount is still not enough as 96.3% of the global electricity access still remained among the city dwellers in 2014. The regions of Sub-Saharan Africa still lagged behind to provide electricity services among half of its population in the year 2014. This region also had the lowest rate of electrification amounting to a total of 37 percent only. One of challenges of electrification faced in this period was rapid population growth- which increased electricity demand rapidly. However still 86 million of people got electricity access for the first time in that period (SDG Report, 2017).

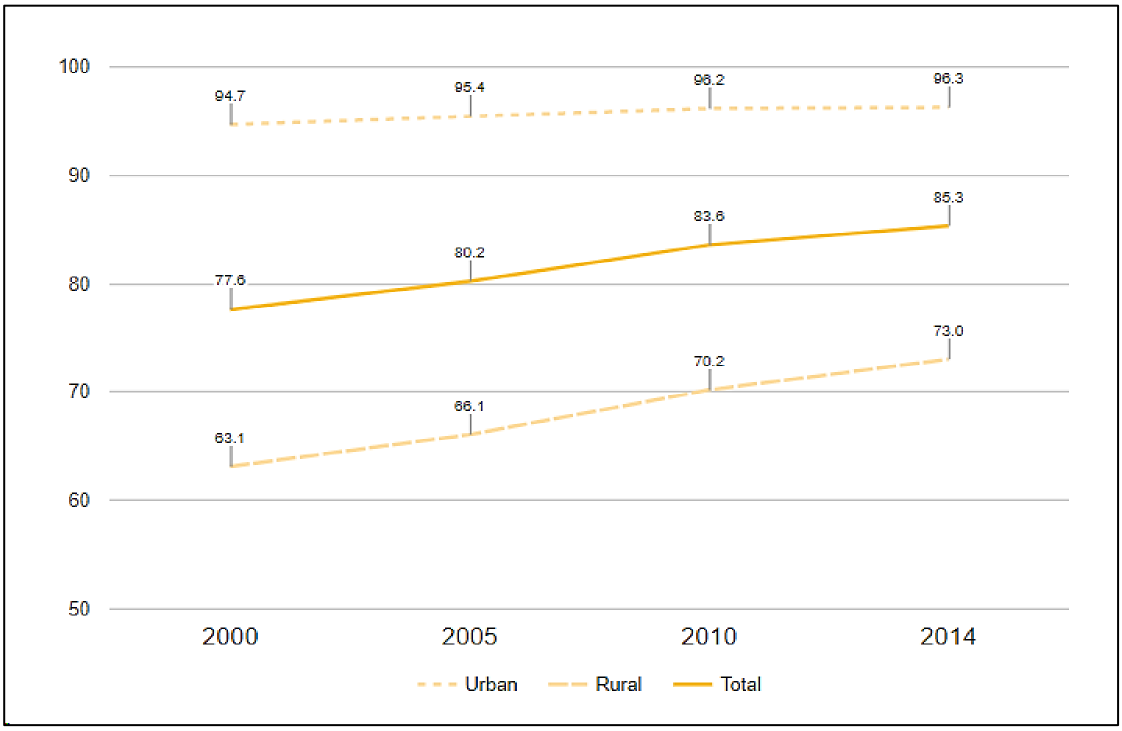

Figure 8: Percentage share of global electricity access: 2000-2014

Source: (SDG Report, 2017)

According to the SDG Report 2018, the year 2016 has seen a satisfactory progress in the field of electricity efficiency. An achievement has been gained by decreasing the number of persons without electricity to less than a billion. An increase of 87 percent of global access to electricity was obtained in the year 2016. This success mainly came from the use of off-grid solar energy in the electrification of the rural areas. A tremendous progress has also been noticed in the areas of Southern Asia and Sub-Saharan Africa where electrification rates increased by 26% and 17% within the period 2000-2016.

Table 5 and figure 9 below shows worldwide electrification rate for the periods 2000 and 2017. In 2017, the world position to electricity access rose to 89 percent keeping still a large population (840 million) without electricity services. While regions of Central and Southern Asia reached a milestone growth of 91% electricity access in 2017, regions of Sub-Saharan Africa still showed a deficit of 66% of electricity services to its population.

By 2018, the world started to make a good progress on electrification reaching 90% of the global citizens with electricity services. Regions of Latin America and the

Carribbean and Eastern and South-Eastern Asia continued to have a high progress (more than 98% electrification rate). However, regions of Sub-Saharan Africa stilled lagged behind keeping its 548 million people without electricity (SDG Report, 2020).

Table 5: Electricity access by region

Region	2000	2017
Sub-Saharan Africa	25	44
Oceania*	29	63
Central and Southern Asia	60	91
Nothern Africa and Western Asia	87	95
Eastern and South-Eastern Asia	91	98
Latin America and the Caribbean	92	98
Europe and Northern America	100	100
Australia and New Zealand	100	100
World	78	89

Source: (SDG Report, 2019)

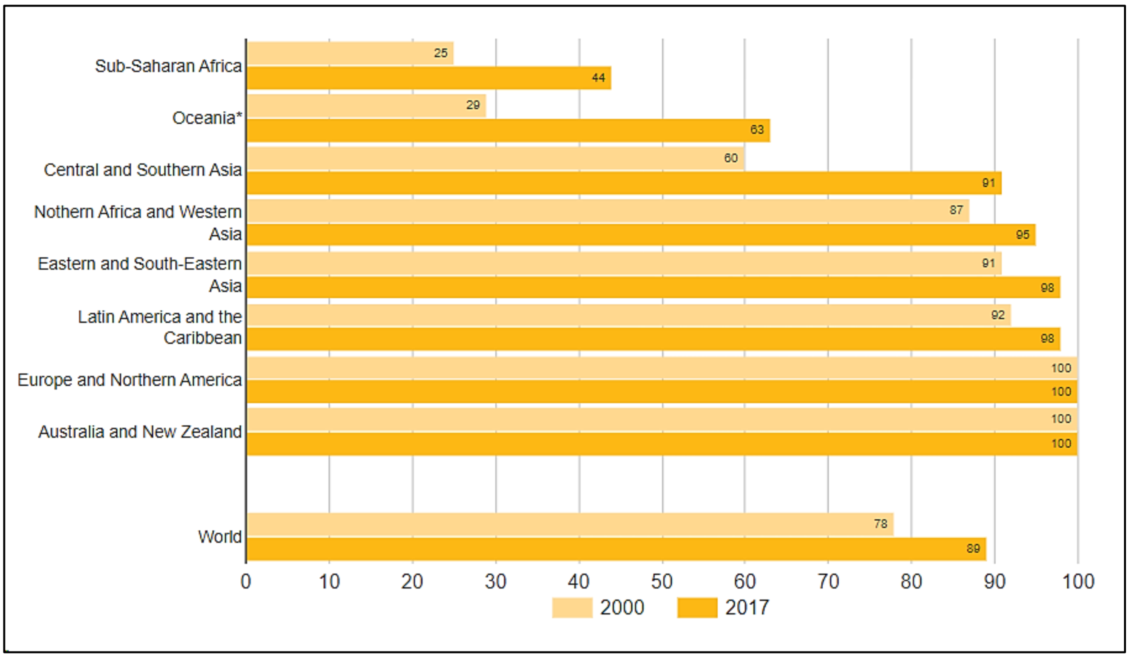

Figure 9: Percentage share of global electricity access by region

Source: (SDG Report, 2019)

With the emergence of COVID-19 pandemic in 2019, the deficit of enough electrification in the health sector became obvious. According to a survey in some developing countries' health centers, one fourth of the surveyed health centers lacked electricity access and another quarter of those health facilities faced unexpected outages, hampering proper health services on those centers. By 2019, global electricity access remained at 90% (table 6, figure 10) with giving electricity access to 1.1 billion people for the first time. However, much progress has not been seen in the areas of Sub-Saharan Africa keeping its 64% population without electricity. Increase in poverty rate due to pandemic also affected much parts of the world. In the developing regions of Africa and Asia over 25 million people lost their basic electricity services. In addition to this, almost 85 million people from Asia's developing region could not afford more than basic electricity services.

Table 6: Post-COVID global electricity access

Region	2010	2019
Sub-Saharan Africa	33	46
Oceania (excluding Australia and New Zealand)	36	70
Nothern Africa and Western Asia	91	94
Central and Southern Asia	75	95
Latin America and the Caribbean	96	98
Eastern and South-Eastern Asia	96	98
Australia and New Zealand	100	100
Europe and Northern America	100	100
World	83	90

Source: (SDG Report, 2021)

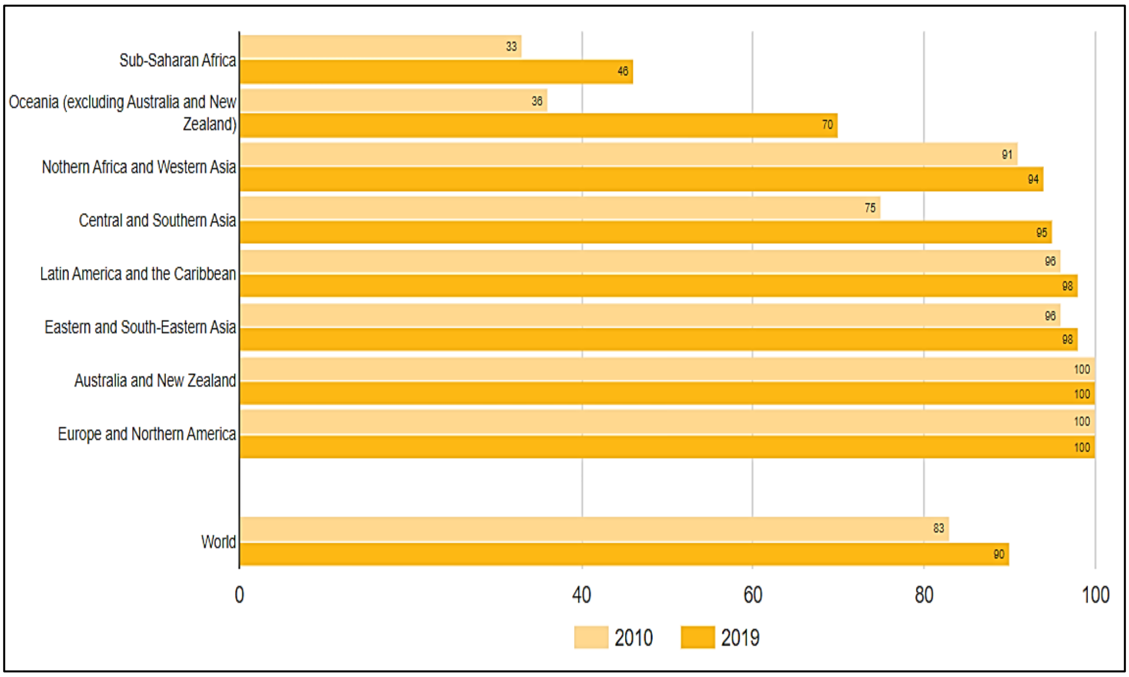

Figure 10: Post-COVID global electricity access (2019)

Source: (SDG Report, 2021)

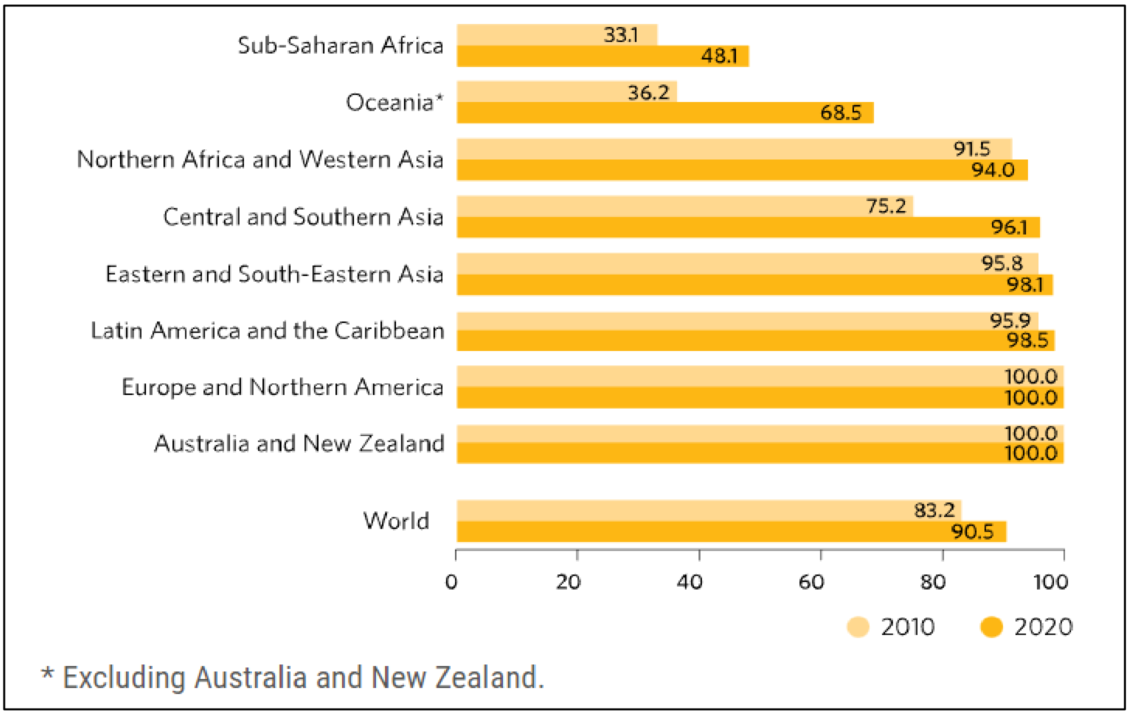

Figure 11: Post-COVID global electricity access

Source: (SDG report, 2022)

COVID outrage has affected electricity affordability in many countries worldwide. About 90 million of African and Asian population from developing countries lost the affordability of an extra electricity service in their lives. Moreover, despite an expected annual progress of 0.9 within 2018-2020 periods, the world has seen only a progress of 0.5 percentages as a result of the pandemic situation. However, despite the pandemic global access to electrification reached a 90.5 percent rate in the year 2020 reaching a 1.3 billion of population with electricity access (figure 11).

1.3.7. SD Policies in Turkiye

According to the "*Energy efficiency Strategy Document (2012-2023)"*, published by MENR in 2012, The SD policies in relation to renewable energy utilization can be listed as below:

- To construct sustainable environment-friendly buildings which will use RE resources to meet their energy need.
- To decrease carbon emissions and energy demands of the existing buildings.
- Prevent unnecessary fuel consumption in urban transportation by increasing the share of public transport on land, sea and railways.
- Encouraging low-emission, environmentally friendly hybrid vehicles with a small engine volume, fuel cell or electric vehicles, and gradually withdrawing vehicles that have reached the end of their economic life.
- Encouraging increased blending ratios of biofuels and synthetic fuels in fossil fuels.
- To reduce the yearly energy consumption in the buildings and premises of public institutions by ten percent within 2015 and by twenty percent within 2023.
- To establish a strong administrative and institutional structure which will conduct studies on energy efficiency, RE resources and energy information and technologies
- To make the capacity of integrated resource planning in the field of energy efficiency and renewable sources of energy.
- To create energy performance indicators through which the development in Turkiye can be compared with its previous years and also with other countries.
- By 2023, increase the number of products produced considering the efficiency of energy use and RE resources to at least fifty (50)

- To prepare a technology master plan, coordination between supporting institutions and a national technology inventory to benefit investors in the fields of RE and energy efficiency.
- Improve the laws and legislation regarding the efficient use of energy and renewables for encouraging more R&D in this sector.
- To increase share of installed power capacity from RE and domestic resources from 59 to 69 percentage points by 2023 (MENR strategic plan 2019-2023).

2. CHAPTER TWO

RE AND ITS CONSUMPTION IN TURKIYE

This chapter introduces RE and presents an overall scenario of the various RE resources that are present in Turkiye along with the policies regarding RE. The chapter ends by emphasizing the importance of RE for sustainable development.

2.1. Renewable Energy (RE) Concept

Renewable sources of energy are one of the alternatives that improve environmental quality while contributing significantly to economic growth (Demirbas, 2000; Demirbaş & Bakiş, 2005). This energy comes from flow-limited energy sources that can be naturally restocked. Furthermore, the lifespan of these kind of energy sources is almost endless, but the amount of energy they can provide per unit of time is constrained (Bethel et al., 2021) (EIA, 2022).

Renewable energies come from the nature and can be renewed and returned back to the environment without harming it. It is also a safe form of energy as renewable sources like sun, wind, water, and animal wastages have almost a never ending life span. Since the production and consumption of renewables do not harm the environment unlike non-renewables hence they are often termed as *"clean energy"* and *"green energy"*.

2.2. RE Scenario in Turkiye

Turkiye has about 60% of the world's natural gas and oil reserves, which made this country one of the giant powers in the field of these energy markets. In the last two decades Turkiye's energy demand has been seen to grow rapidly in compare to other OECD countries. This demand is such that it positioned Turkiye in the second place after China in terms of oil and gas demand (MFA, 2021). Unfortunately, this huge demand is being met by energy imports counting 93% for oil and 99% for gas respectively (IEA, 2021).

To lessen the import burdens Turkiye has taken some energy efficiency strategies like, diversification of energy sources, increase of domestic exploration, use of more renewable sources in electricity production etc. With the help of these energy policies, high energy demand and abundant quality resources, Turkiye has been able to show a notable progress in the field of renewable energy. For instance, the country has already passed the 38.8% target of energy production from renewables (IEA, 2021). Even its energy production from renewables has increased thrice in the last few decades. With significant rise in solar power use, Turkiye's share of renewables in the total energy production has become 44% in terms of power generation (IEA, 2021) and 14.1% in terms of power consumption by 2019 (WorldData.info). However, from the percentages of Turkiye's power generation and usage we can say that, though Turkiye produces a notable amount of renewable energy it still lacks significantly in utilizing these energies.

2.3. Various RE Used in Turkiye

The advancement of renewable energy sources is highly valued in Turkiye. According to the National Energy Policy in 2017, one of the top priorities of Turkiye is to increase the usage of domestic and renewable energy resources. Furthermore, Turkiye ranks fifth in Europe as well as twelfth globally for renewable energy installed capacity. Renewables will account for 54% of power capacity in Turkiye by the end of 2022 (MFA, 2022).

The scenario of renewable energies in Turkiye can be understood from the energy sources the country uses. Turkiye has the following renewable power generating sectors:

- Hydraulics
- Solar
- Wind
- Geothermal
- Biomass

The production, capacity and consumption of these RE sources have been elaborated below.

2.3.1. Hydraulics energy

Hydraulics energy is produced using the potential and kinetic energies obtained from water current. Usually hydraulics is used to generate electricity by placing a dam or barrier on various water resources. Hydroelectricity plants that works with hydraulics energy are clean, environment friendly, easy to install and do not require extra fuel to operate. Moreover, this domestic source of energy has a long life in spite of a very small operating cost.

According to MENR (2020), theoretically Turkiye has 1% of the world's total hydroelectricity generation capacity and from the perspective of economic potential it is as much 16% of the Europe's total potential. Hydraulic resources have a very significant position in Turkiye's energy mix. Electricity production potential in Turkiye using hydroelectricity plants is 433 billion kWh. However, from this only 216 billion kWh can be used for real. It is seen that in 2021, 55.5 billion kWh of electricity was produced from hydraulics plants in Turkiye and by the end of May 2022, the amount of electricity made from water sources reached about 35.2 billion kWh (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2020).

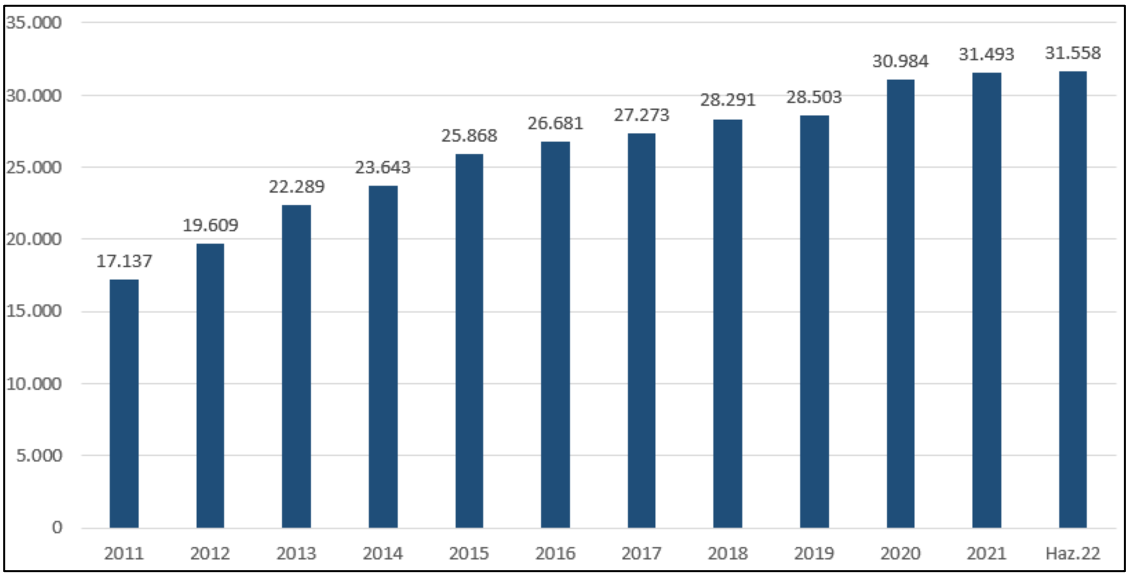

Figure 12: Installed power based on hydraulics energy (MW)

Source: (*"T.C. Enerji ve Tabii Kaynaklar Bakanlığı,"* 2020) https://enerji.gov.tr/bilgi-merkezi-enerji-hidrolik

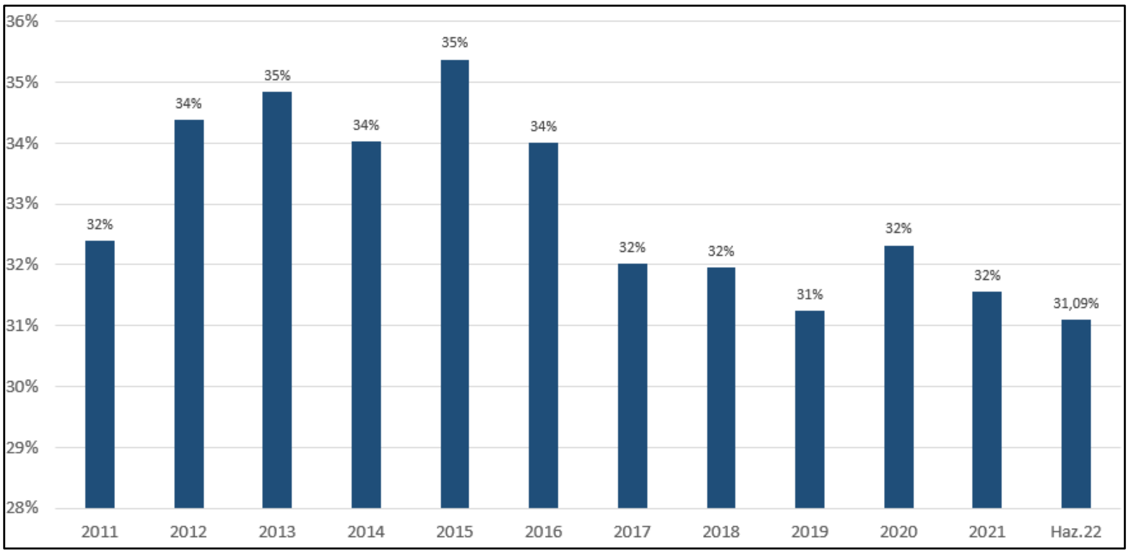

Figure 13: Ratio in total installed power

Source: (*"T.C. Enerji ve Tabii Kaynaklar Bakanlığı,"* 2020) https://enerji.gov.tr/bilgi-merkezi-enerji-hidrolik

The graphs above show how the installed power has changed over time and how it compares to the total installed power. As it can be seen from figure 11, hydroelectric power generating capacity of Turkiye is increasing day by day. While, installed hydroelectricity power plants were producing just 17,137 MW of electricity in 2011, it became as much as 31,558 MW by the end of June. 2022. This is 31% of the total installed power.

However, when looked at the percentage of hydroelectricity in the total installed power (figure 12), the numerical figures give rather a disappointed result. While the ratio of hydraulics in the total installed power showed an upward trend from 2011- 2015, it is seen to have a decreasing trend afterwards (2016- 2022) with figures showing around 32%.

2.3.2. Wind Energy

Wind energy is a type of recyclable energy produced from wind's kinetic energy with the help of windmills or wind turbines. Wind turbines are generally used to produce electricity. First the kinetic energy obtained from the air's motion is transformed into a mechanical energy; later the mechanical energy produces electricity by rotating the motors of the generators in wind turbines. Wind energy is clean, renewable and easy to reproduce. Wind power has a non-perishable lifespan since it gains its energy from the sun. Almost 2% of the energies reaching the earth surface from the sun turn into wind energy (MENR, 2020).

According to the REPA-V1 data prepared in 2006, Turkiye has a wind energy potential of 47,849.44 MW, which is equivalent to 1.30 percent of its total surface area. The change in installed wind power over the years and its ratio in the total installed power are shown in the graphs below.

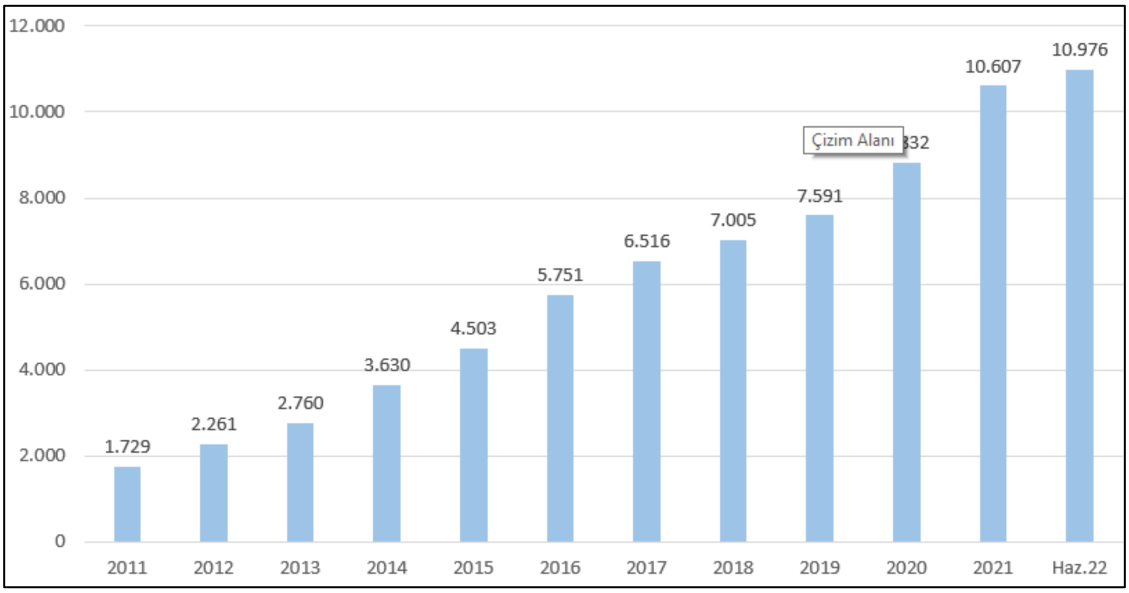

Figure 14: Installed power based on wind energy (mw)

Source: ("Rüzgar - T.C. Enerji ve Tabii Kaynaklar Bakanlığı," n.d.) https://enerji.gov.tr/bilgi-merkezi-enerji-ruzgar

Figure 14 shows that, by mid-2022, Turkiye's power capacity sourced from the wind energy have become 10,976 MW which is 10.81% of its overall installed power (figure 15). The graph also illustrates that, installed wind power of Turkiye has risen continuously starting from the year 2011. When at 2011 the installed wind energy capacity was only 1729 MW, it became 10607 in 2021 and 10976 by the half of 2022. Hence it can be said that power generation capacity of wind energy have increased almost by ten times within ten years.

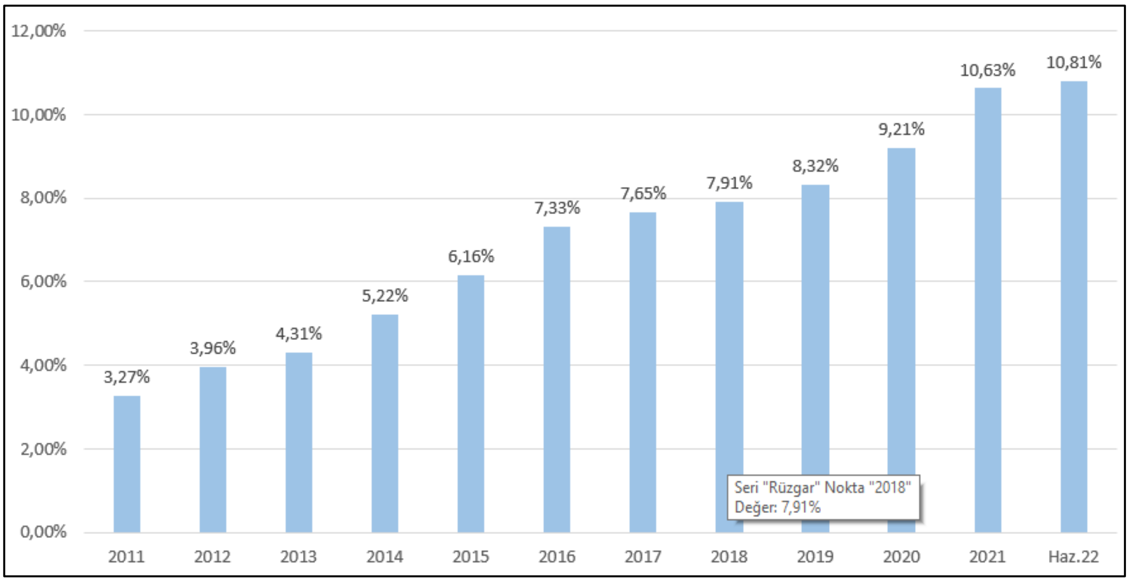

Figure 15: Ratio of wind energy in total installed power

Source: ("Rüzgar - T.C. Enerji ve Tabii Kaynaklar Bakanlığı," n.d.) https://enerji.gov.tr/bilgi-merkezi-enerji-ruzgar

Graph (15) also shows that, ratio of wind energy in overall installed power of Turkiye has been rising year-by-year. When the share of wind power in total installed power was only 3.27% in 2011, it has risen to about 10.81% by the middle of 2022.

2.3.3. Solar Energy

Solar energy is obtained through the process of utilizing the power of sun. It is the most available renewable energy in the world. Solar panels are cost effective, easy to produce, easy to carry and yet have great potentials. Since the power of sun is non-exhaustible and abundant, solar energy has the longest span of life in compared to other forms of energies.

Turkiye has a great solar potential with a daily average sunshine time of 7.2 hours (table 7). The months of June, July and August receives highest amounts of sunshine per hour with an average of 344 hours (approx.) of sunshine time per month. Turkiye experiences the heat of summer within these three months. These months have the highest potentials in utilizing the energies obtained from the sun. For instance, table 7 shows the month of July have the highest potential of producing 175.38 kWh/m^2 of energy. June has the second highest potential of producing of energy

(168.75 kWh/m^2-month) followed by August, which can produce energy of 158.40 kWh/m^2 in a month.

Table 7: Turkiye's solar potential (monthly average)

Months	Monthly total sun energy		Sunshine time
	(kcal/cm2-month)	(kWh/m2-month)	(hours/months)
January	4.45	51.75	103.0
February	5.44	63.27	115.0
March	8.31	96.65	165.0
April	10.51	122.23	197.0
May	13.23	153.86	273.0
June	14.51	168.75	325.0
July	15.08	175.38	365.0
August	13.62	158.40	343.0
September	10.60	123.28	280.0
October	7.73	89.90	214.0
November	5.23	60.82	157.0
December	4.03	46.87	103.0
Total	112.74	1311	2640
Average	308.0 cal/cm2-daily	3.6 kWh/m2-daily	7.2 hours /daily

Source: MENR, 2020

Table 8: Turkiye's annual solar energy potential (by region)

Regions	Total Energy (kWh/m^2/year)	Sunshine Time (hours / year)
Southeastern Anatolia	1460	2993
Mediterranean	1390	2956
Eastern Anatolia	1365	2664
Central Anatolia	1314	2628
Aegean	1304	2738

Marmara	1168	2409
Black Sea	1120	1971

Source: MENR, 2020

Table 8 gives an idea of Turkiye's annual solar energy potential in terms of its different regions. It is observed from the table that Southeastern Anatolian region of Turkiye has the highest potential to be benefitted from the solar power. The climate of Anatolia is cold and strong with most radiations receiving in the winter. It has high altitude, less humidity, and a clearer atmosphere leading to minimal radiation shelter. Hence, solar power plant transplantation in this area will give the greatest amount of solar energy for Turkiye.

Turkiye's Mediterranean region has the second largest potential of utilizing solar energy. It has a sunshine time of 2956 hours/year producing a total energy of 1390 kWh/m^2. The region that has the least potential of solar energy benefits is the Black Sea region. The central and eastern side of this region receives the lowest radiation in a year (1971 hours/year). With a high latitude and humid climate this region's atmosphere shields a great amount of radiations. This specification of the Black Sea causes this region to receive the least benefits from solar energy.

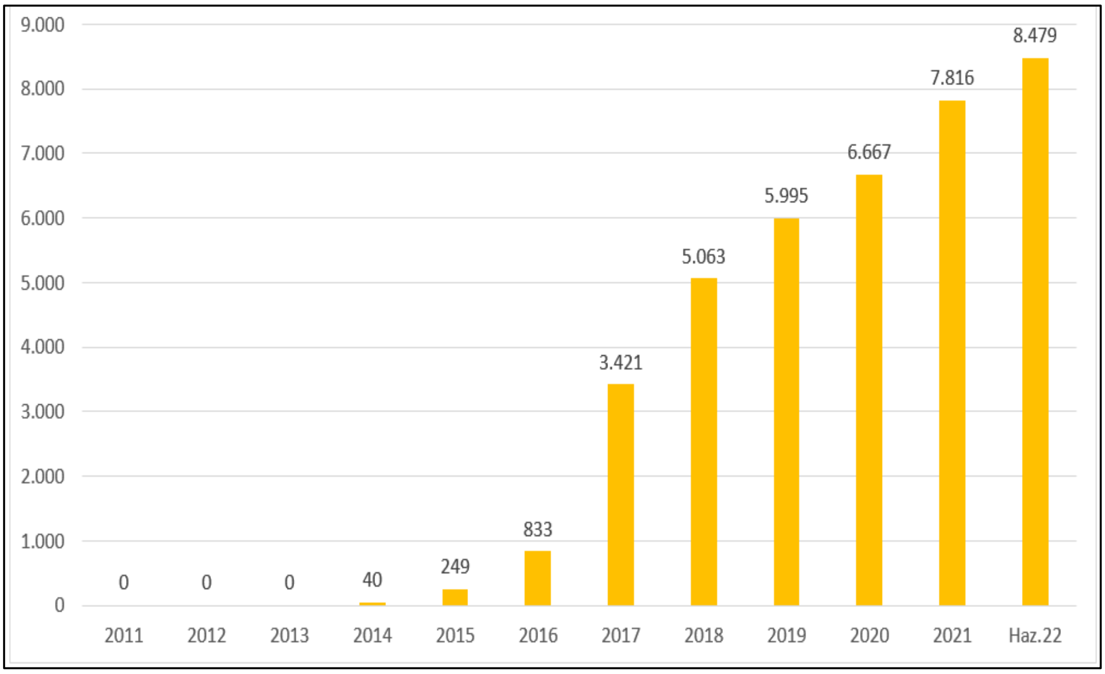

Figure 16: Annual power capacity from solar energy (MW)

Source: MENR, 2022

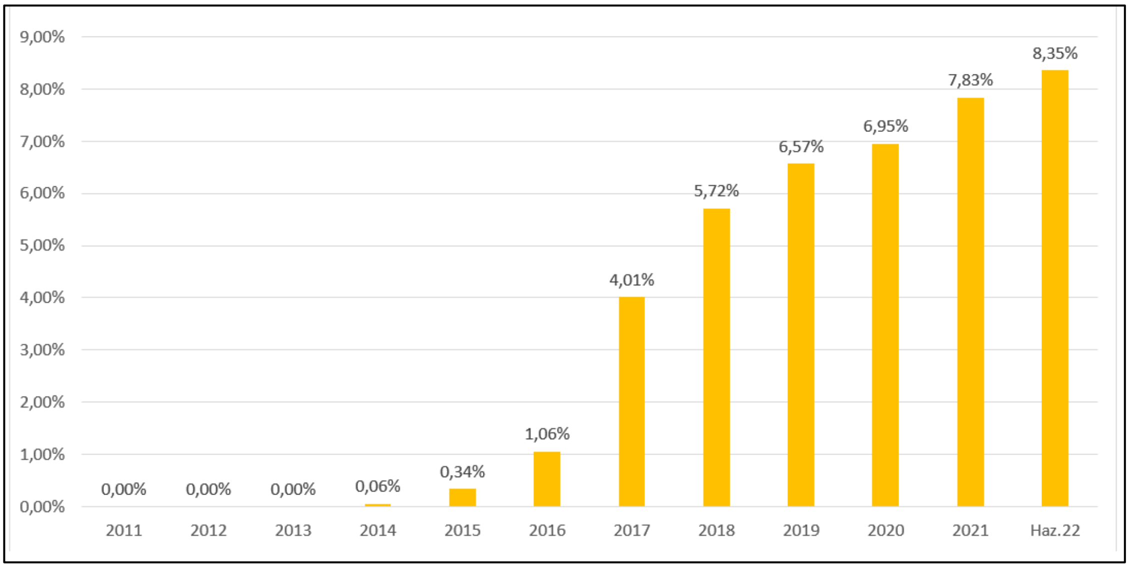

Figure 17: Share of solar energy in total power capacity

Source: MENR, 2022

As of the end of June 2022, Turkiye's installed power based on solar energy is 8,479 MW, its ratio in the total installed power is 8.35%, and the change in installed power over the years and its ratio in the total installed power can be seen from the graphs given above.

2.3.4. Geothermal Energy

The thermal energy trapped at different levels of the earth's surface due to pressure and heat is the geothermal energy (MENR, 2022). In a simple word, it is the heat energy found beneath the earth's crust. This energy is utilized in different forms; such as district heating, GHPs, hydrothermal reservoirs for electric power generation etc. (IRENA, n.d.). Geothermal energy is a renewable energy and has an approximate life span of twenty to thirty years. It is sourced mostly in the areas of active volcanism. The potential of the earth's superficial geothermal power amounts to $4.5X10^6$ EJ, which is approximately thrice the annual global energy consumption from all energies (Lund, 2022).

Turkiye stands first in Europe for its geothermal potential and fourth in the world on the basis of installed thermal plants. USA, Indonesia, Philippines, Turkiye and New Zealand are the top five countries that produce electricity using geothermal technology (ETKB, 2022a). The following graphs provide a picture of Turkiye's energy consumption from geothermal installations.

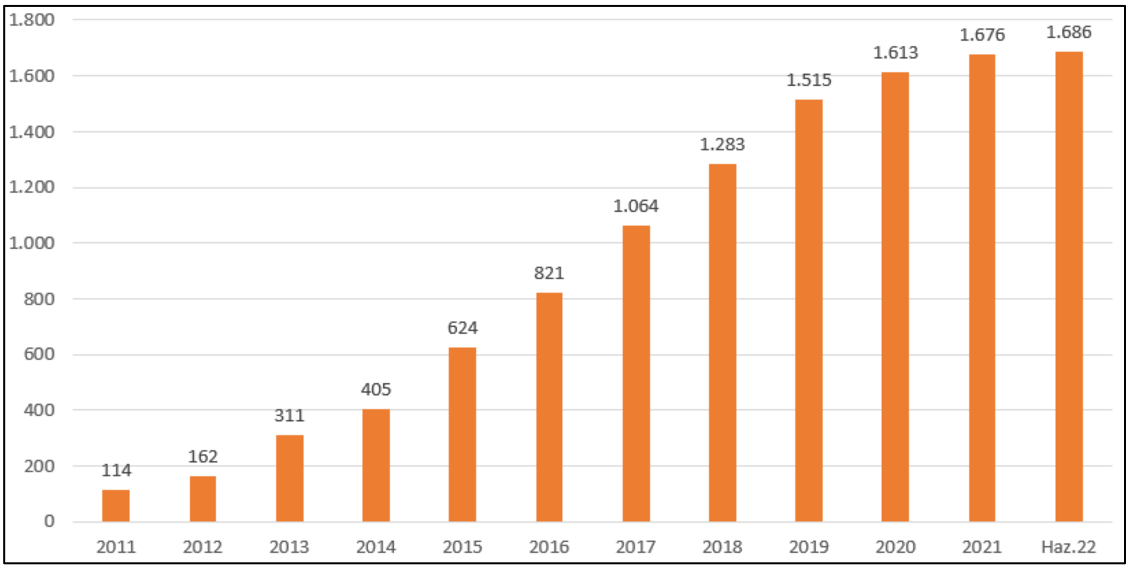

Figure 18: Installed power based on geothermal energy (MW)

Source: (ETKB, 2022a)

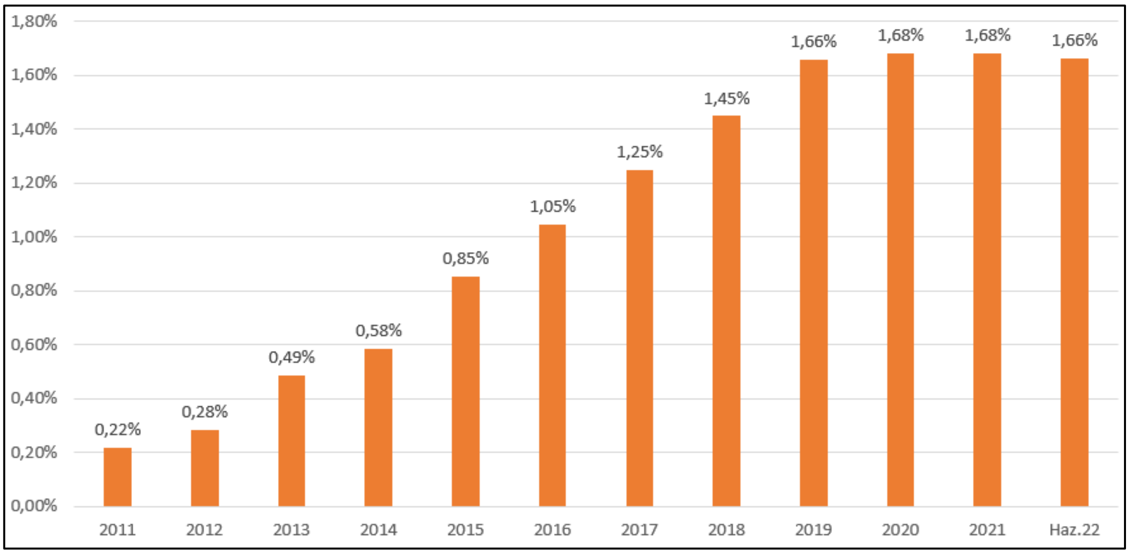

Figure 19: Ratio in total installed power

Source: (ETKB, 2022a)

Figure 18 reports that, in June 2022, the geothermal energy installed power, which is widely used in electricity generation as well as district heating, was 1686 MW. The energy chart also shows a dramatic expansion in the installed geothermal power capacity of Turkiye from 2011-2021. When in 2011 the capacity was just 114 MW, it reached 1676 MW by the year 2011.

With the expansion of installed power, geothermal's share in the total energy installation has increased too. By the middle of 2022, geothermal shared 1.66% of the total power capacity in Turkiye. Graph (19) demonstrates a rapid change in the capacity of geothermal energy production from 2011-2019. However, after this year its growth has seen to be somewhat slowed down. In the years 2020 and 2021, installation of geothermal plants is seen to stay rigid (1.68%) in compare to the overall power installation.

2.3.5. Biomass Energy

Biomass is the total mass of living species residing in a specific area (ETKB, 2022a). Hence biomass energy refers to the fuel obtained from the residuals of plants, animals or other species. Biomass energies can be categorized into two: *"traditional"* and *"modern"*. Traditional biofuels come from the combustion of wood and charcoal, animal residues etc. (IRENA, n.d.). However, modern bioenergy do not include traditional exploration of the biomass in its production. Renewable bioenergy is actually the modern biomass energy which includes generation of electricity, heat and fuels for vehicles using solid or liquid waste, agricultural and forest residuals etc. (Goldemberg & Teixeira Coelho, 2004).

The share of biomass energy in the total RE consumption of the world is about three-quarters and half of the bioenergy in use comes from traditional biofuels (IRENA, n.d.). Therefore, biomass energies have a great contribution in the world's overall energy consumption.

Turkiye has a great potential for bioenergy. According to the BEPA data of Turkish ministry, Turkiye has an annual potential of 3.9 MTEP (approx.) biomass energy that can be collected from its total waste (ETKB, 2022b). Different types of bioenergy that Turkiye utilizes can be listed as follows:

- Herbal bioenergy,
- Forest and forestry sourced biofuels,
- Animal sourced bioenergy, and
- Biomass sourced by industry and urban wastages

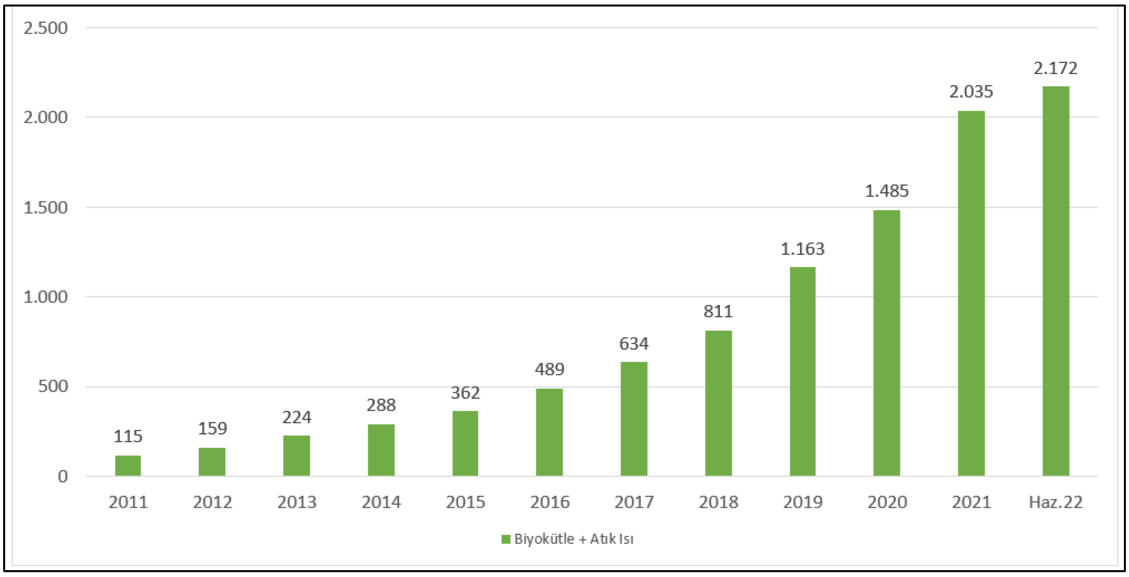

Figure 20: Installed biomass energy by year (MW)

Source: https://enerji.gov.tr/bilgi-merkezi-enerji-biyokutle

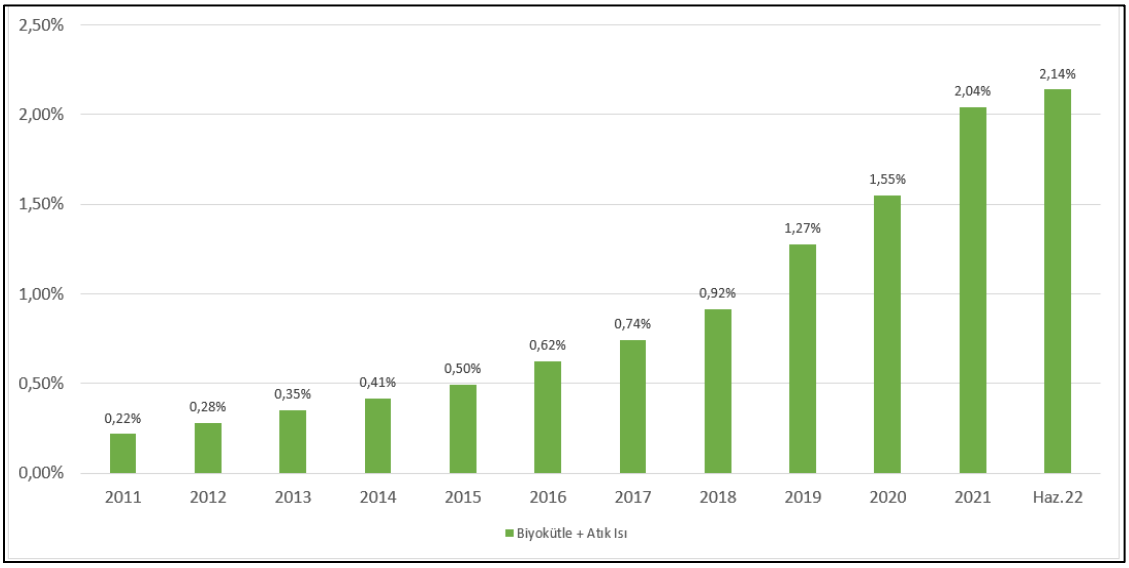

Figure 21: Ratio in total installed power

Source: https://enerji.gov.tr/bilgi-merkezi-enerji-biyokutle

Graph 20 and 21 gives a pictorial view of Turkiye's installed bioenergy for the period 2011- mid 2022. As seen from the figures, in June 2022, the total power capacity sourced from Turkiye's biomass and waste heat energy amounted to 2.172 MW. This is 2.14% of the overall power capacity installed by mid-2022. Figure 21 also shows that the biomass energy sector has developed significantly within the last twelve years. In 2011 share of bioenergy in total installed power was only 0.22% which became almost ten times more by the middle of 2022.

2.4. Consumption of RE in Turkiye

2.4.1. Energy Consumption as of 2021 (by Source)

The graph (22) below shows the annual change in energy consumption of Turkiye (by source) in 2021. In the year 2021, the highest consumed energy was natural gas (111TWh) and the lowest was hydropower energies (-59TWh) coming from renewable sources.

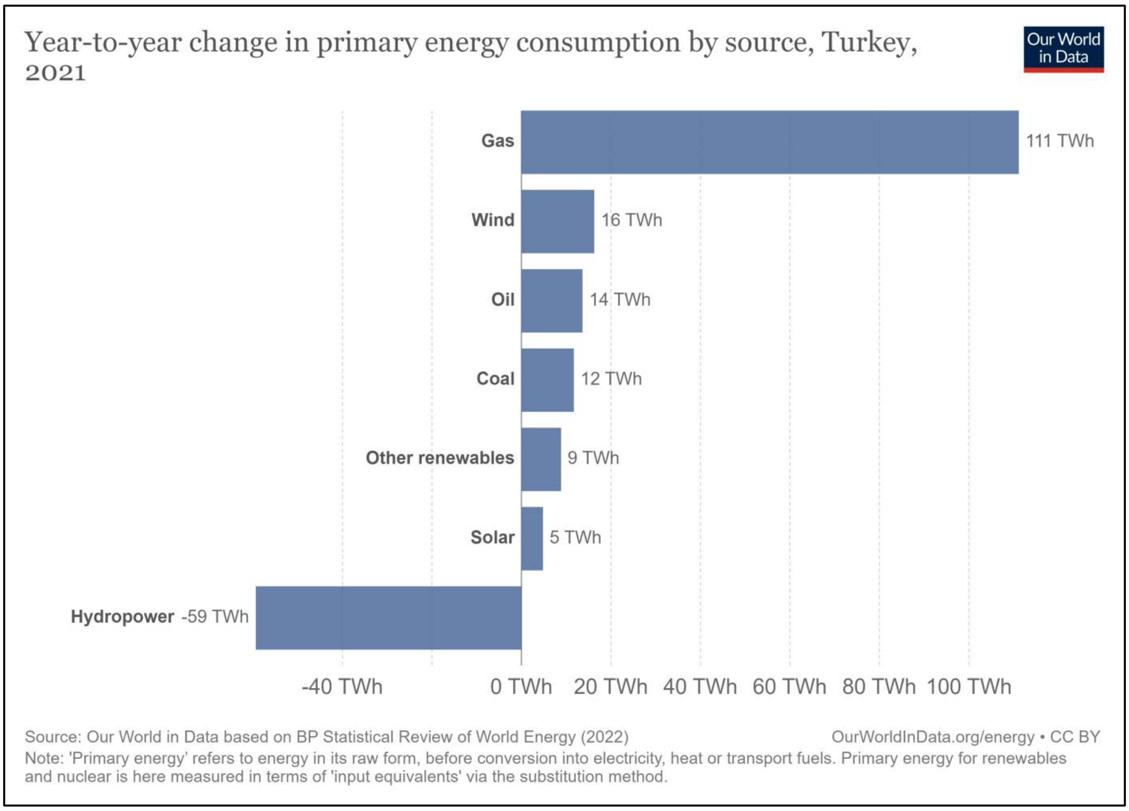

Figure 22: Annual change in energy consumption of Turkiye by source (year 2021)

Source: (OurWorldinData, 2022)

Among the REs, wind power is seen to have the highest amount of utilization with a figure of 16TWh consumption. Next most consumed renewable energy in 2021 was solar energy, whose total consumption was equivalent to only 5TWh. Hence it can be said that, Turkiye is still highly dependent on non-renewable sources to fulfill its ever growing energy demand.

2.4.2. Share of RE in Primary Energy Use

Overall consumption of primary energy based on different fuel types indicates how energy mix of a country develops over time (MEUCC, 2021). By looking at this indicator for Turkiye from 1990-2019 we can see the percentage growth of RE in overall energy consumption of Turkiye.

According to the data of MEUCC, in 1990 total primary energy consumed by Turkiye was 52.465 Mtoe which increased to 144.205 Mtoe in 2019. In 1990, most share of consumed energy came from oil consumption (46.1%); while in 2019 its consumption decreased to 28.6%. In 2019, most consumed energy in the share of total energy was solid fuels with a percentage of 29.1 units, a 1.1% lower than its share in the year 1990. Natural gas consumption has seen the most rapid increase in the last three decades. While its share was just 5.4% in 1990, it reached to a percentage of 25.7 points in 2019.

Graph 24 is a representation of different RE's share in the overall energy consumption. It can be seen that a lot of change has occurred within the last three decades. From 1990 to 2019, share of bioenergy has seen a gradual decrease and other REs specially geothermal and hydraulic energy has seen a significant increase in the total RE consumption. Starting from 2008, Turkiye's energy mix is seen to get more diversified with the inclusion of solar and wind energies in its total REC. Moreover, a decrease in the use of traditional biomass indicates more sustainable use of resources in the recent years than in the 1990s.

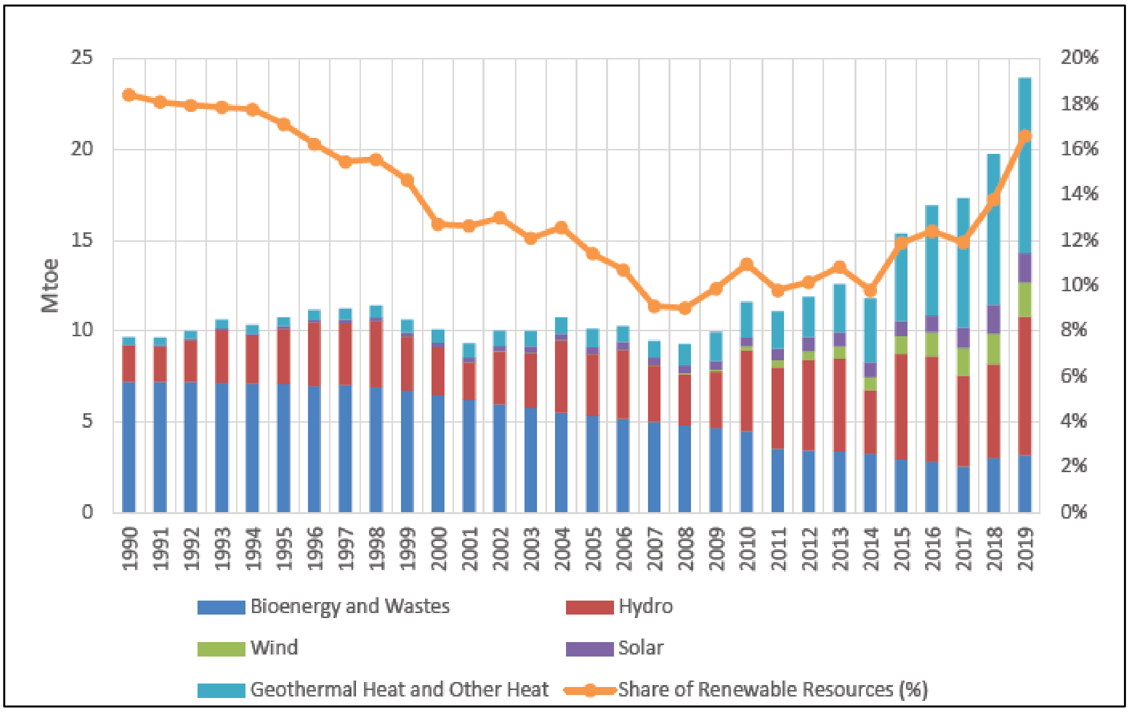

Figure 23: Ratio of different REs in Turkiye's total energy consumption

Source:(MEUCC, 2021.)

2.4.3. Share of RE in Total Electricity Production of Turkiye

Table 9 and graph 25 below gives an idea about electricity generation in Turkiye using renewables. While table 9 shows the percentage share of each RE resources in producing electricity (for 2019), graph 24 demonstrates the total production of electricity from RE sources in the last three decades (1990-2019).

Table 9: Electricity generation from RE in 2019 (% share by source)

Source	Generation (GWh)	Share (%)
Hydro	88,822.8	66.6
Wind	21,730.7	16.3
Geothermal	8,951.7	6.7
Bioenergy and Wastes	4,624.2	6.9
Solar	9,249.8	3.5
Total	133,379.2	100

Source: (MEUCC, n.d.) https://cevreselgostergeler.csb.gov.tr/en/share-of-renewable-electricity-in-gross-electricity-production-i-86048

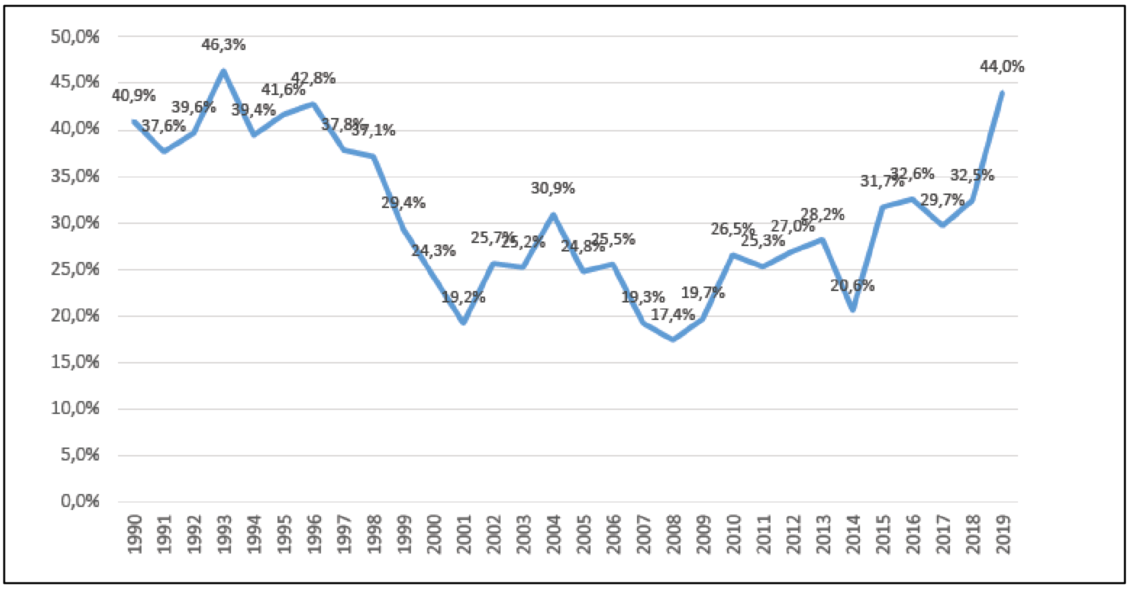

Figure 24: Share of RE in total electricity production of Turkiye

Source:(MEUCC, n.d.) https://cevreselgostergeler.csb.gov.tr/en/share-of-renewable-electricity-in-gross-electricity-production-i-86048

As of 2019, the total electricity consumption in Turkiye was 3030, 302.4 GWh and the share of RE in the total consumption was 44% (figure 25). The amount of electricity produced using RE resources was 133,379.2 GWh (MEUCC, n.d.). Hydro powers had the highest (66.6%) and solar power had the lowest (3.5) share in the total electricity production of 2019.

Within the last three decades, electricity production from RE was highest in 1993 with a percentage point of 46.3%. The year 2019 marks the second highest production of electricity from renewable sources with a share of 44%.

2.5. Turkiye's RE Policies

Turkiye is very concern about its energy policies. One of the Turkiye's main energy strategies is to find different routes and energy sources to ensure a secure supply of energy. It also has the ambition of becoming the *"regional trade center in energy"* in its own region by contributing to the energy security of its regions and the world as well. Hence the core elements of Turkiye's RE policies can be briefed as below (MFA, 2022):

- Ensure sustainable growth of energy without any harm to the environment or the society in every steps of the energy line
- Be sure that the composition of electricity production has more of domestic and clean energy.
- To add nuclear energy into its energy compositions
- To achieve 30% of electricity production sourced by RE within 2023
- To increase share of installed power capacity from RE and domestic resources from 59 to 69 percentage points by 2023 (MENR strategic plan 2019-2023).

2.6. RE on Ensuring Sustainable Development

Renewable sources of energy can generate energy without compromising the environment. Many researchers have documented that renewable sources of energy are essential in ensuring environmental sustainability. Because renewable energy sources are so important, research has begun to look into the link between them and the quality of the environment.

For example, Apergis & Payne (2009) used data from six Central American countries from 1974 to 2004 to examine the econometrical relation between sources of renewable energy and environmental quality and demonstrated that the use and generation of renewable energy reduces GHG emission levels.

In their study of the impact of renewable and nonrenewable energy sources on reducing carbon emissions in the context of South Africa, Sarkodie and Adams (2018) demonstrated a statistically significant correlation between the chosen variables. According to the study, a 1% increase in nonrenewable energy sources led to an increase in carbon emissions by 10,436 kt. The same is only 2855 kt for every 1% increase in renewable energy sources. Hence, renewable energy resources cause less harm to the environment.

"Renewable sources of energy" are considered the *"cleaner sources of energy"* which have a positive impact on enhancing atmospheric effectiveness (Panwar, Kaushik, and Kothari, 2011). Wind energy, an important form of RE resources, is found to have positive empirical contributions in ensuring environmental quality (Wang & Wang, 2015). Similarly, another renewable source of energy, solar power, directly impacts optimizing environmental quality (Tsoutsos, Frantzeskaki, & Gekas, 2005).

In countries like Turkiye, Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan, a rise in renewable energy use remarkably reduces carbon emissions by about 0.26 percent, according to statistical results from the *"Dynamic Ordinary Least Squares (DOLS)" and "Fully Modified Ordinary Least Squares (FMOLS)"* techniques (Onifade, Erdoğan, Alagöz, & Bekun, 2021).

3. CHAPTER THREE

EMPIRICAL EVIDENCE OF SD-RE NEXUS IN TURKIYE

This chapter details the methodology followed to reach the desired result of the study. First, it gives a brief snapshot on the literature that studies the energy-growth nexus conducted worldwide and on Turkiye. Then, it specifies the models of the study with detailed information on the variables. Next, it adds a chronological discussion on the overall econometric test procedures after mentioning the data collection method, and test statistics respectively.

3.1. Scholarly Studies on Energy-Growth Nexus

The energy-growth relationship is often studied with four core hypotheses; to name *"growth", "conservation", "feedback",* and *"neutrality hypothesis"*. When the causal relationship runs from the direction of energy consumption to growth, it is called the *"growth hypothesis"*. That is in the growth hypothesis; energy consumption can directly or indirectly affect economic growth. As a result, an energy conservation policy can negatively influence economic growth. Contrary to the growth theory, the causality in the *"conservation hypothesis"* runs from economic growth to energy use. So a rise in economic growth helps increase energy consumption. If in any energy-growth nexus, the nature of the relationship is bidirectional, that is, energy and economic growth affect each other, this relationship is said to support the *"feedback hypothesis"*. On the contrary, the *"neutrality hypothesis"* states that growth and energy are neutral in relation to each other.

Due to the present energy economics literature's increased emphasis on sustainability objectives, researchers are becoming more and more interested in how RE works to prevent environmental deterioration and promote economic growth (Tiba & Belaid, 2021). As a result, a great number of researchers focused on unraveling the energy-environment and energy-growth links. The following sections are intended to give a summarized idea on those literature studies conducted worldwide and on Turkiye.

3.1.1. RE-Growth Nexus: World

The study of the RE-growth link and its use in measuring sustainability is widespread. While some researchers (Tiba & Belaid, 2021) included renewable energy as the sustainable development indicator in their studies, many (e.g., Payne (2009); Apergis & Payne, (2010), (2010b), (2011); Alper & Oguz, (2016)) examined its relationship with economic growth. However, there is no common agreement on the findings of these researches because of using different data, periods, and methods. Hence, different researches revealed unidirectional, bidirectional, and even no causality between these two variables (Ocal & Aslan, 2013).

RE-economic development nexus attained the attention of researchers in 1997, along with the first commitment to the Kyoto Protocol, the rise in crude oil prices, and the growing volatile prices of traditional energy (Tiba & Belaid, 2021). Some studies (Abanda, Ng'Mbe, Keivani, & Tah, 2012; Esso & Keho, 2016; Fotourehchi, 2017; Razmi, Ramezanian Bajgiran, Behname, Salari, & Razmi, 2020) found a positive impact of clean energy on the economic output of different developing countries. And some other studies showed that RE has a detrimental economic impact due to the high energy production costs and the abolition of conventional energy production technologies (Can & Korkmaz, 2019).

Due to the present energy economics literature's increased emphasis on sustainability objectives, researchers are becoming more and more interested in how RE works to prevent environmental deterioration and promote economic growth (Tiba & Belaid, 2021). As a result, some studies focused on unraveling the RE-environment link.

The work of Sadorsky (2009) is of the first kind that researched the nexus of renewable energy and income for countries with emerging economies. Sadorsky (2009), conducting a panel cointegration test on 18 developing nations, concluded that rising real income per capita shows a favorable and statistically meaningful impact on per capita RE consumption. Hence, suggesting a conservation hypothesis between energy consumption and the economy.

Apergis & Payne (2010b) examined the RE-growth causality for 13 European and Asian nations from 1992-2007. Their study concluded showing RE-growth causal relationship for both long and short period of time. Menegaki (2011) used a multivariate panel test to evaluate RE-economic growth correlation across 27 European nations throughout 1997–2007 and obtained empirical results that supported the neutrality hypothesis for both variables.

Salim and Rafiq (2012) showed that income and CO2 emissions influence the RE consumption of the countries like Turkiye, Brazil, China, India, Indonesia, and the Philippines. Exploring the factors affecting RE use in 64 countries, Omri and Nguyen (2014) emphasized that per capita CO2 emissions positively affect RE consumption.

Apergis and Danuletiu (2014) investigated on 80 countries employing Canning and Pedroni's (2008) long-run test of causality and suggested a feedback hypothesis between RE use and real GDP. Their empirical study provided clear evidence of renewable energy's significant long-term positive influence on economic growth.

Employing data from the 1982–2011 period, Hung-Pin (2014) examined both short- and long-term causal relationships between RE use and economic growth in nine OECD nations. They found that cointegration and causation relationships existed in five countries (‘America, Japan, Germany, Italy, and England’). However, it was determined that France, Denmark, Portugal, and Spain's renewable energy-saving programs had little impact on economic expansion. Destek and Sinha (2020) also investigated the same but for 24 OECD economies and found “an inverted U-shaped relationship” between economic progress and consumption of RE.

Based on the EKC hypothesis, Ben Jebli, Ben Youssef, and Ozturk (2015) researched 24 Sub-Saharan African nations between 1980-2010 to determine the correlation between RE usage, CO2 emissions, international trade, and GDP. Their findings indicated to a short-run indirect feedback hypothesis for economic growth and RE consumption.

Çildir & Bayraç (2017) studied European Union (EU) countries from 2006-2015 and found that RE sources are essential in ensuring a livable environment. They also demonstrated that renewable energy output in EU countries has a substantial positive correlation with GDP per capita.

3.1.2. RE-Growth Nexus: Turkiye

Studies on the RE-growth nexus from the context of Turkiye are a recent phenomenon. For example, Alper (2018) explored the connection between the RE use in Turkiye and economic growth from 1990-2017 using the Bayer-Hanck cointegration and Toda Yamamoto causality test. Their result supported the conservation hypothesis for Turkiye, i.e., a one way causality from economic growth to RE.

However, when Durğun and Durğun (2018) investigated the same relationship, including hydropower in RE consumption, they found an opposite result showing a unilateral causality from RE use to economic growth, confirming the growth hypothesis. It means an increase in RE usage will flourish the economy and vice versa. Durğun and Durğun (2018) found this result by conducting ARDL and Toda-Yamamoto test of causality for Turkiye from the year 1980 to 2015.

Erdoğan, Dücan, Şentürk, & Şentür, (2018) also found the growth hypothesis being true for Turkiye when they tested the nexus of RE production and economic growth with the Johansen cointegration test and VECM causation. The study was based on the period 1998-2015, where they found that economic growth has a long-term connection with the production of RE, and a change in the production of RE affects economic growth in a long period of time.

Usupbeyli and Uçak (2018) also found similar evidence of the growth hypothesis for Turkiye for the period 1970–2017 in their analysis on the nexus of renewable electricity production as a share of overall electricity production and real GDP ratio. Their ARDL research revealed that GDP in Turkiye would increase by 1.7% if the proportion of renewable electricity in overall electricity production goes up by 10%. Additionally, when the proportion of renewable energy sources in overall electricity production rises, the economy will benefit from higher GDP, which will boost economic expansion.

Apaydin, Güngör, and Taşdoğan (2019) examined the asymmetrical connection between the RE use and growth of Turkiye for the period 1965-2017. Applying the NARDL model, these researchers showed that the two variables are directly correlated with other. However, the positive and negative change in RE consumption doesn’t affect economy’s growth symmetrically. The adverse shock in RE usage affects the economy's growth more than positive shocks.

In 2020, researchers like Demirgil and Birol (2020) studied the impact of RE usage on per capita GDP for 39 years (1980-2018) using ARDL and the Toda-Yamamoto test of causality. Similar to the study of other researchers (Durğun & Durğun, 2018; Erdoğan et al., 2018), their results also proved the existence of a growth hypothesis between the two variables RE consumption and GDP per capita. That is, a unidirectional causality runs from RE consumption to the economic growth of Turkiye.

ÖZBEK and APAYDIN (2020) employed the ARDL approach to analyze the data on Turkiye's GDP, capital stock, renewable energy production, and employment from 1990-2017. The results demonstrated that growth in capital stock, renewable energy output and employment positively impact economic growth.

Örk Özel & Ekiz (2021) attempted to determine the relationship between the environmental sustainability of Turkiye with its economic growth for the years 1998 to 2015. They used the variable "RE consumption" to represent renewable energy policies, CO2 emissions as a proxy for the environment, and real GDP to symbolize economic growth. Their empirical analysis using Johansson cointegration and granger causality revealed a unidirectional causality from RE use and CO2 emissions to real GDP.

The last two pearls in the thread of literature for the RE-Sustainability nexus are from Çetinbakiş and Şahin Kutlu (2022), and Çetin (2022). Çetin (2022), leveraging annual data of only 20 years (1998-2018), and Çetinbakiş and Şahin Kutlu (2022), using a more broad range of data set (1988-2019), found that RE use and economic growth of Turkiye are related both in the short and long run. While Çetin (2022) included only two variables of study in their empirical research Çetinbakiş and Şahin Kutlu (2022) included more study variables like final consumption expenditure, FDI, and CO2 emission besides GDP and RE use. Hence, their research gave a more comprehensive picture of the bond between RE and SD of Turkiye. Their study showed that besides using RE, final consumption expenditures and FDI also positively impact GDP for a short and long period. However, the exact impact has not been seen for CO2 emissions, as CO2 emissions have only a short-term positive consequence on the growth of the Turkish economy.

3.2. Model Specification

Following the research method of Tiba and Belaid (2021), this study incorporated variables representing the three pillars of sustainable development (namely, economic, social, and environmental) to have a detailed study of the nexus between sustainable development and renewable energy. The elements of sustainable development have been represented through the following variables: Gross Domestic Product (GDP), Modified Human Development Index (MHDI)[1], Renewable Energy (RE), Carbon-dioxide Emission representing environmental quality (CE), Fixed Capital representing Capital (FK), The Labor Force (L), and good governance as an indicator of Institutional Quality (IQ).

Firstly, an augmented Cobb-Douglas production function is taken into consideration;

$$Y_t = AMHDI_t^{\alpha_1} RE_t^{\alpha_2} CE_t^{\alpha_3} FK_t^{\alpha_4} L_t^{\alpha_5} IQ_t^{\alpha_6}$$

Due to insufficient data for measuring Turkiye's institutional quality, the indicator IQ has been removed from the production function. Moreover, the augmented Cobb-Douglas function has been transformed into a log-linear form for estimation purposes:

$$lnY_t = \alpha_0 + \alpha_1 \ln(MHDI)_t + \alpha_2 \ln(RE)_t + \alpha_3 \ln(CE)_t + \alpha_4 \ln(FK)_t + \alpha_5 \ln(L)_t + \varepsilon_t$$

……………………….(1)

As all of our variables are taken in per-capita form, dividing both sides of equation (1) by Labour (L), we get:

$$lnY_t = \alpha_0 + \alpha_1 \ln(MHDI)_t + \alpha_2 \ln(RE)_t + \alpha_3 \ln(CE)_t + \alpha_4 \ln(FK)_t + \varepsilon_t$$

……………………….(2)

Here in equation 2,

"[1]The HDI is obtained as a simple arithmetic average of GDP, education, and life expectancy (e.g., Sagar & Najam, 1998; UNDP, 2008): HDI = 1/3((GDP) + (Education) + (Life expectancy)). The conventional HDI has been criticized by several authors; therefore, we chose the MHDI, which excludes the income component to avoid problems of multicolinearity. The MHDI is written as follows: MHDI = 1/2(Gross enrolment+ Life expectancy)" as mentioned in the research by (Tiba & Belaid, 2021).

α_0=ln A_0; where A_0 represents constant technology level;

α_1, α_2, α_3, α_4…. … … α_n = coefficients of explanatory variables

t = 1,……, T is the period of analysis (1980–2019).

lnY_t is per capita GDP at constant 2015 US$,

$lnMHDI_t$ is the modified human development index,

$lnRE_t$ is the aggregate consumption of renewable energy,

$lnCE_t$ is CO2 emission measured in a million metric tonnes, and

$lnFK_t$ is the gross fixed capital formation.

ε_t is the error term, which is supposed to be distributed independently and identically. Note that a simple linear specification does not yield consistent findings; consequently, log-linear specification is used in this investigation.

The four models, as represented in log-linear form, can be stated below:

Growth Model

$$\mathrm{lnGDP_t} = \alpha_0 + \alpha_1 \ln \mathrm{MHDI_t} + \alpha_2 \ln \mathrm{RE_t} + \alpha_3 \ln \mathrm{CE_t} + \alpha_4 \ln \mathrm{FK_t} + \varepsilon_t \quad \ldots\ldots\ldots\ldots(3)$$

Environmental Model

$$\mathrm{lnCE_t} = \beta_0 + \beta_1 \mathrm{lnGDP_t} + \beta_2 \ln \mathrm{MHDI_t} + \beta_3 \ln \mathrm{RE_t} + \beta_4 \ln \mathrm{FD_t} + \beta_5 \ln \mathrm{TROPEN_t} + \varepsilon_t \quad \ldots\ldots\ldots\ldots(4)$$

Social Well-being Model

$$\mathrm{lnMHDI_t} = \gamma_0 + \gamma_1 \ln \mathrm{GDP_t} + \gamma_2 \ln \mathrm{RE_t} + \gamma_3 \ln \mathrm{CE_t} + \gamma_4 \ln \mathrm{HE_t} + \varepsilon_t \quad \ldots\ldots\ldots\ldots(5)$$

Renewable Energy Model

$$\mathrm{lnRE_t} = \delta_0 + \delta_1 \mathrm{lnGDP_t} + \delta_2 \mathrm{lnMHDI_t} + \delta_3 \mathrm{lnCE_t} + \delta_4 \mathrm{lnOP_t} + \varepsilon_t \quad \ldots\ldots\ldots\ldots(6)$$

3.3. Collection of Data

This paper works on the secondary data from 40 years (from 1980 to 2019). All the data are collected from various sources like the World Bank, WDI, BP statistical review, EIA, UNESCO Institute for Statistics, OECD.stat, etc. The data collected from different sources and their explanations are shown in Table 10.

3.4. Test Statistic

Different test statistics have been used to conduct the empirical calculations of this research. ARDL cointegration test has been preferred as the primary statistic to forecast all the four models. ARDL is a popular model of testing the cointegration among time series variables initially proposed by Pesaran & Shin (1999) and further extended by M. Hashem Pesaran, Shin, & Smith in 2001. Eviews 9 software has been used to ascertain the causal relationships amongst the explanatory variables with an annual data range of (1980-2019).

Table 10: A Tabulated Description of the Variables Used in the Research

Variables	Description	Sources
GDP	Gross Domestic Product (constant 2015 US $)	WDI 2022
CE	Carbon dioxide Emission (in annual million metric tonnes)	EIA - Independent Statistics and Analysis
RE	Total Renewable Energy consumption (EJ.)	BP statistical review, (2022)
FK	Gross fixed capital formation (% of GDP)	WDI 2022
TROPEN	Total Trade as a proxy to Trade openness	WDI 2022
FD	Private credit by deposit money banks to GDP (%) as a proxy for Financial Development	IFS, IMF, Global Financial Development Database (World Bank 2021)
HE	Government Health Expenditure (% GDP)	OECD.stat
MHDI	Adult Literacy Rate (above 15) % (estimated value) Life expectancy at birth, total (years)	UNESCO Institute for Statistic (UIS, 2010) WDI, 2022
OP	Oil Rents (% of GDP) as a proxy of oil price	WDI, 2021

Sources: Author's collection

3.5. Test Procedure

The following test procedures were followed to examine the causal effects of the variables: gross domestic product- GDP, carbon dioxide emission- CE, fixed capital- FK, moderated human development index- MHDI, renewable energy- RE, trade openness- TROPEN, financial development- FD, and government health expenditure- HE :

- The (ADF & PP) unit root test is used to check the stationary level and the order of integration of all dependent & independent variables.
- The ARDL and ARDL bounds test of cointegration has been utilized to establish the short-run and long-run cointegration among the dependent & explanatory variables.
- The Error Correction Model (ECM) has been estimated to determine how efficient the models are in the eve of any short run shocks.

To estimate the four models of the study, equations 3-6 can be rewritten in ARDL format as below:

The Growth Model

$$\Delta \ln GDP_t = \alpha_0 + \alpha_1 \ln GDP_{t-1} + \alpha_2 \ln MHDI_{t-1} + \alpha_3 \ln RE_{t-1} + \alpha_4 \ln CE_{t-1} + \alpha_5 \ln FK_{t-1} + \sum_{i=1}^{m} a_{0i} \Delta \ln GDP_{t-i} + \sum_{i=0}^{m_1} a_{1i} \Delta \ln MHDI_{t-i} + \sum_{i=0}^{m_2} a_{2i} \Delta \ln RE_{t-i} + \sum_{i=0}^{m_3} a_{3i} \Delta \ln CE_{t-i} + \sum_{i=0}^{m_4} a_{4i} \Delta \ln FK_{t-i} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

The Environmental Model

$$\Delta \ln CE_t = \beta_0 + \beta_1 \ln CE_{t-1} + \beta_2 \ln GDP_{t-1} + \beta_3 \ln MHDI_{t-1} + \beta_4 \ln RE_{t-1} + \beta_5 \ln FD_{t-1} + \beta_6 \ln TROPEN_{t-1} + \sum_{j=1}^{n} b_{0j} \Delta \ln CE_{t-j} + \sum_{j=0}^{n_1} b_{1j} \Delta \ln GDP_{t-j} + \sum_{j=0}^{n_2} b_{2j} \Delta \ln MHDI_{t-j} + \sum_{j=0}^{n_3} b_{3j} \Delta \ln RE_{t-j} + \sum_{j=0}^{n_4} b_{4j} \Delta \ln FD_{t-j} + \sum_{j=0}^{n_5} b_{5j} \Delta \ln TROPEN_{t-j} + \varepsilon_t$$

……………………..(8)

The Social Well-being Model

$$\Delta \ln MHDI_t = \gamma_0 + \gamma_1 \ln MHDI_{t-1} + \gamma_2 \ln GDP_{t-1} + \gamma_3 \ln RE_{t-1} + \gamma_4 \ln CE_{t-1} + \gamma_5 \ln HE_{t-1} + \sum_{k=1}^{p} c_{0k} \Delta \ln MHDI_{t-k} + \sum_{k=0}^{p_1} c_{1k} \Delta \ln GDP_{t-k} + \sum_{k=0}^{p_2} c_{2k} \Delta \ln RE_{t-k} + \sum_{k=0}^{p_3} c_{3k} \Delta \ln CE_{t-k} + \sum_{k=0}^{p_4} c_{4k} \Delta \ln HE_{t-k} + \varepsilon_t$$

……………………..(9)

The Renewable Energy Model

$$\Delta \ln RE_t = \delta_0 + \delta_1 \ln RE_{t-1} + \delta_2 \ln GDP_{t-1} + \delta_3 \ln MHDI_{t-1} + \delta_4 \ln CE_{t-1} + \delta_5 \ln OP_{t-1} + \sum_{l=1}^{q} d_{0l} \Delta \ln RE_{t-l} + \sum_{l=0}^{q_1} d_{1l} \Delta \ln GDP_{t-l} + \sum_{l=0}^{q_2} d_{2l} \Delta \ln MHDI_{t-l} + \sum_{l=0}^{q_3} d_{3l} \Delta \ln CE_{t-l} + \sum_{l=0}^{q_4} d_{4l} \Delta \ln OP_{t-l} + \varepsilon_t$$

…………………….(10)

Each of these equations consists of two parts. For example, the growth model from equation 7 can be fractioned as:

The long-run cointegration form

$$\alpha_0 + \alpha_1 \ln GDP_{t-1} + \alpha_2 \ln MHDI_{t-1} + \alpha_3 \ln RE_{t-1} + \alpha_4 \ln CE_{t-1} + \alpha_5 \ln FK_{t-1}$$

And the short-run dynamic form

$$\sum_{i=1}^{m} a_{0i} \Delta \ln GDP_{t-i} + \sum_{i=0}^{m_1} a_{1i} \Delta \ln MHDI_{t-i} + \sum_{i=0}^{m_2} a_{2i} \Delta \ln RE_{t-i} + \sum_{i=0}^{m_3} a_{3i} \Delta \ln CE_{t-i} + \sum_{i=0}^{m_4} a_{4i} \Delta \ln FK_{t-i} + \varepsilon_t$$

[Where, α_0 = intercept term, α_n (n= 1, 2 … 5) = long run coefficients influencing the model, a_{ni} (n= 1, 2 … 5) (i= 0, 1, 2, 3….m_0, m_1, m_2, m_3, …..m_n) = short-run dynamic coefficients of the explanatory variables, m= maximum lag order, ε_t = white noise]. Similarly, the rest of the three models also possess two parts which can be explained in the same way as the long-run and short-run form of the growth model.

Models 7-10 can be rewritten in ECM format as below:

$$\Delta \ln GDP_t = \alpha_0 + \alpha\, ECT_{t-1} + \sum_{i=1}^{m} a_{0i}\, \Delta \ln GDP_{t-i} + \sum_{i=0}^{m_1} a_{1i}\, \Delta \ln MHDI_{t-i} + \sum_{i=0}^{m_2} a_{2i}\, \Delta \ln RE_{t-i} + \sum_{i=0}^{m_3} a_{3i}\, \Delta \ln CE_{t-i} + \sum_{i=0}^{m_4} a_{4i}\, \Delta \ln FK_{t-i} + \varepsilon_t$$

$$\Delta \ln CE_t = \beta_0 + \beta ECT_{t-1} + \sum_{j=1}^{n} b_{0j}\, \Delta \ln CE_{t-j} + \sum_{j=0}^{n_1} b_{1j}\, \Delta \ln GDP_{t-j} + \sum_{j=0}^{n_2} b_{2j}\, \Delta \ln MHDI_{t-j} + \sum_{j=0}^{n_3} b_{3j}\, \Delta \ln RE_{t-j} + \sum_{j=0}^{n_4} b_{4j}\, \Delta \ln FD_{t-j} + \sum_{j=0}^{n_5} b_{5j}\, \Delta \ln TROPEN_{t-j} + \varepsilon_t$$

$$\Delta \ln MHDI_t = \gamma_0 + \gamma ECT_{t-1} + \sum_{k=1}^{p} c_{0k}\, \Delta \ln MHDI_{t-k} + \sum_{k=0}^{p_1} c_{1k}\, \Delta \ln GDP_{t-k} + \sum_{k=0}^{p_2} c_{2k}\, \Delta \ln RE_{t-k} + \sum_{k=0}^{p_3} c_{3k}\, \Delta \ln CE_{t-k} + \sum_{k=0}^{p_4} c_{4k}\, \Delta \ln HE_{t-k} + \varepsilon_t$$

$$\Delta \ln RE_t = \delta_0 + \delta ECT_{t-1} + \sum_{l=1}^{q} d_{0l}\, \Delta \ln RE_{t-l} + \sum_{l=0}^{q_1} d_{1l}\, \Delta \ln GDP_{t-l} + \sum_{l=0}^{q_2} d_{2l}\, \Delta \ln MHDI_{t-l} + \sum_{l=0}^{q_3} d_{3l}\, \Delta \ln CE_{t-l} + \sum_{l=0}^{q_4} d_{4l}\, \Delta \ln OP_{t-l} + \varepsilon_t$$

Here $\alpha, \beta, \gamma,$ and δ denotes the speed of adjustment of the short-run variables (in all the four models respectively) while cointegrating over time. The term ECTt-1 is the “Error Correction Term” representing the cointegrated information of long-run variables.

3.6. Empirical Results and Interpretations

3.6.1. Unit Root Test

Unit root test measures the stationarity level of the variables included in any model. Hence, it is also known as the "stationarity test". This model defines whether a variable has a unit root or not.

Thus the hypotheses of this test are:

"Ho: variable has a unit root"

"H1: variable has no unit root"

Stationarity test also provides an insight into the level of integration of the variables (e.g. zero, first order, second order differences etc.). It determines if the variables are integrated with an intercept and/or intercept plus trend. There are various test statistics for performing unit root tests. Among them, the ADF test (Dickey & Fuller, 1979) equation and the PP test (Phillips & Perron, 1988) equation are the most popular ones. Hence, both tests were performed to see at what level the variables become stationary. The lag length for the variables was selected through Schwarz Info Criterion. The spectral estimation method was chosen by default as (the Bartlett Kernel method).

Stationarity of a variable can be determined in two ways. One is to see if calculated value shows higher value than the critical value. If it happens so, then the decision rule is: 'rejecting the null hypothesis of having a unit root in favor of the alternative of not having a unit root'. Another way to check the stationarty in variables is to look at the p-values. If the p-value is less than 5% then the alternative hypothesis is to be accepted and hence the test variable will be counted as stationary.

Table 11: ADF Test Results

Variables:	Level		First Difference			Order of integration
	Intercept	Intercept & trend	Intercept	Intercept & trend	None	
LNGDP	0.526606 (0.9853)	-2.501182 (0.3259)	-4.298225 (0.0017)	-4.319989 (0.0083)	-0.081658 (0.6470)	I(1)
LNMHDI	-1.646985 (0.4494)	-2.038892 (0.5587)	-2.544334 (0.1134)	-2.690796 (0.2459)	-2.281632 (0.0235)	I(1)
LNRE	-0.741509 (0.8242)	-2.435786 (0.3552)	-7.733276 (0.0000)	-7.643856 (0.0000)	-1.354550 (0.1594)	I(1)
LNCE	-3.849367 (0.0053)	-3.816000 (0.0262)	-9.531784 (0.0000)	-9.446928 (0.0000)	-9.669672 (0.0000)	I(0)
LNFK	-1.957093 (0.3038)	-2.265696 (0.4418)	-5.481150 (0.0001)	-5.485815 (0.0003)	-5.468692 (0.0000)	I(1)
LNFD	-0.198767 (0.9302)	-1.704920 (0.7295)	-4.841961 (0.0003)	-4.906552 (0.0017)	-0.784339 (0.3676)	I(1)
LNTROPEN	-1.226557 (0.6501)	-1.298147 (0.8697)	-4.036747 (0.0039)	-3.352782 (0.0779)	-5.176258 (0.0000)	I(1)
LNHE	-3.393250 (0.0173)	-4.224836 (0.0097)	-12.54515 (0.0000)	-12.54300 (0.0000)	-12.61856 (0.0000)	I(0)
LNOP	-3.243043 (0.0249)	-3.858842 (0.0237)	-6.219300 (0.0000)	-6.215832 (0.0000)	-6.257628 (0.0000)	I(0)

Note: Numbers inside parentheses indicates p-values.

According to the ADF test (table 11), LNCE, LNOP, and LNHE are integrated at level, i.e., it is stationary at I(0), whereas all other variables like LNGDP, LNMHDI, LNRE, LNFK, LNFD, LNTROPEN are integrated of order one, i.e., I (1). Whereas according to the PP test (table 12), LNMHDI, LNCE, LNHE, LNOP, and LNTROPEN are stationary at level, i.e., I(0) and LNGDP, LNRE, LNFK, and LNFD are stationary after first difference, i.e., at I(1).

Table 12: Phillips-Perron Unit Root Test Result

Variables	**Level**		**First difference**		**Order of integration**
	Intercept	**Intercept & trend**	**Intercept**	**Intercept & trend**	
LNGDP	0.140797 (0.9649)	-2.542839 (0.3072)	-6.731203 (0.0000)	-6.664626 (0.0000)	I(1)
LNMHDI	-4.338058 (0.0014)	-4.291797 (0.0082)	-2.526659 (0.1173)	-2.671592 (0.2533)	I(0)
LNRE	-0.193909 (0.9309)	-2.920895 (0.1673)	-8.752678 (0.0000)	-8.593391 (0.0000)	I(1)
LNCE	-4.091610 (0.0028)	-4.058398 (0.0146)	-11.13025 (0.0000)	-14.50134 (0.0000)	I(0)
LNFK	-1.977644 (0.2951)	-2.447937 (0.3507)	-5.428774 (0.0001)	-5.541152 (0.0003)	I(1)
LNFD	-0.198767 (0.9302)	-1.202210 (0.8961)	-4.772094 (0.0004)	-4.845194 (0.0020)	I(1)
LNTROPEN	-3.086493 (0.0359)	-4.636699 (0.0033)	-6.121849 (0.0000)	-6.482767 (0.0000)	I(0)
LNHE	-3.256641 (0.0241)	-4.366904 (0.0067)	-17.38010 (0.0001)	-24.65930 (0.0000)	I(0)
LNOP	-3.111548 (0.0339)	-3.659230 (0.0375)	-11.91398 (0.0000)	-20.07250 (0.0000)	I(0)

Note: Numbers inside parentheses indicate p-values.

Both ADF and PP test for stationarity shows that all the variables are either stationary at level or after the first difference. None of them needed to go through a second difference to be stationary. Therefore, to find the cointegrated relationships between the variables ARDL bounds testing approach would be a good one.

3.6.2. Test for Cointegration

After confirming the stationarity levels of the parameters of the study, a cointegration test is conducted to look at the relationships between the variables of the models. According to Nkoro & Uko, (2016),

> Cointegration is an econometric concept that mimics the existence of a long-run equilibrium among underlying economic time series that converges over time. Thus, cointegration establishes a stronger statistical and economic basis for the empirical error correction model, which brings together short and long-run information in modeling variables.

Therefore a test for cointegration will show how in a model the dependent and independent variables are connected together. It will also guide us for performing an ECM, if variables do not show cointegation over time.

3.6.2.1. ARDL Test

There are various cointegration tests, but when the variables are integrated of both I(0) and I(1), the ARDL bounds testing approach is an excellent choice to find out the short-run and long-run relationship amongst the variables. Unlike other multivariate cointegration techniques, ARDL permits to predict the nature of cointegration by OLS method when a model has a known lag order. Additionally, it permits cointegration tests without the need to perform unit root tests beforehand (Abdul Rahim & Noraida, 2015)

The decision rule for the ARDL bounds test is:

- When the calculated F value lies above the upper and lower bound of critical values (i.e. I(1) and I(0)), the null hypothesis of having no cointegration cannot be accepted.
- When the calculated F-statistic value is under the lower critical bound- the null hypothesis of no cointegration should be accepted.
- Again the decision will be inconclusive, if the F-statistics value lies in between the upper and lower bound.

3.6.2.2. The rationale for Using ARDL Bound Test Approach

The rationales for including the ARDL bound test in this research are:

- ARDL cointegration technique provides practical and significant estimates even when the variables are integrated of I(0), I(1) level or a combination of both.
- Once the lag order has been identified, ARDL allows cointegration estimation using the OLS method.
- Unlike the Johansen, (1995) cointegration test, it allows a cointegration test with variables having different lag orders.
- ARDL can be used even for a small sample consisting of 30-80 observations with the critical values proposed by Narayan (2005).
- ARDL is not sensitive to endogenous & exogenous variables.
- Moreover, the ARDL bounds test approach is helpful for simultaneously measuring one variable's short-run and long-run effects over other variables (Bentzen & Engsted, 2001).

Considering the above rationale ARDL model has been applied to conduct the empirical research.

3.6.2.3. Result of Bounds Test of Cointegration

ARDL Bounds test determines the presence of long-run relationships in between a model’s study variables. For this, the model equation is estimated by ordinary least squares (OLS), and an F-statistics is obtained, which helps decide the long-run integration among the variables. For example, for the growth model,

$$\begin{aligned}\Delta \mathrm{lnGDP_t} &= \alpha_0 + \alpha_1 \ln \mathrm{GDP_{t-1}} + \alpha_2 \ln \mathrm{MHDI_{t-1}} + \alpha_3 \ln \mathrm{RE_{t-1}} + \alpha_4 \ln \mathrm{CE_{t-1}} \\ &\quad + \alpha_5 \ln \mathrm{FK_{t-1}} + \sum_{i=1}^{m} a_{0i}\, \Delta \ln \mathrm{GDP_{t-i}} + \sum_{i=0}^{m_1} a_{1i}\, \Delta \ln \mathrm{MHDI_{t-i}} \\ &\quad + \sum_{i=0}^{m_2} a_{2i}\, \Delta \ln \mathrm{RE_{t-i}} + \sum_{i=0}^{m_3} a_{3i}\, \Delta \ln \mathrm{CE_{t-i}} + \sum_{i=0}^{m_4} a_{4i}\, \Delta \ln \mathrm{FK_{t-i}} + \varepsilon_t\end{aligned}$$

The hypothesis for an ARDL bounds test for the growth model will be,

$H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5$ (no long-run relationships)

$H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5$ (have long-run relationships)

Table 13: ARDL Bounds Test

Null Hypothesis: No long-run relationship is present								
Variables: LNGDP, LNMHDI, LNRE, LNCE, LNFK, LNFD, LNTROPEN								
	Growth model		**Environmental model**		**Social Well-being model**		**Renewable energy model**	
Dependent variables	**LNGDP**		**LNCE**		**LNMHDI**		**LNRE**	
Lags	(1, 1, 3, 2, 4)		(4, 4, 3, 4, 3, 4)		(4, 4, 4, 4, 3)		(4, 4, 4, 4, 1)	
K	4		5		4		4	
Fixed Regressors	Const.		Const.		Const.		Const.	
F-statistics	2.551178		7.055168***		4.630375**		6.256455***	
Critical Values^	I(0) Bound	I(1) Bound	I(0) Bound	I(1) Bound	I(0) Bound	I(1) Bound	I(0) Bound	I(1) Bound
10%	2.43	3.40	2.31	3.35	2.43	3.40	2.43	3.40
5%	2.90	4.00	2.73	3.92	2.90	4.00	2.90	4.00
1%	3.97	5.46	3.66	5.26	3.97	5.46	3.97	5.46
Decision	Result is indecisive, because F-statistics (2.55) is between I(0) and I(1) bound at 10% level of significance.		Reject null hypothesis, because F-statistics (7.06) > I(1) bound at 1% & 5% level of significance.		Reject null hypothesis, because F-statistics (4.63) > I(1) bound at 5% level of significance.		Reject null hypothesis, because F-statistics (6.26) > I(1) bound at 1% & 5% level of significance.	

Note the author's calculation (Eviews 9). ***indicates the t-value is significant at 1% significance level, **at 5% significance, and * at 10% significance. ^ indicates critical values as calculated by (Narayan, 2005) for observations n= 30 to 80. Akaike Info criterion (AIC) has been used to select optimal lags.

Table 13 represents the results of the ARDL bound tests for all four models. The table shows that at a 5% significance level, the F-statistics value is greater and above the values of I(1) bound for all the models except the growth model. Therefore, all the variables except the variables of the growth model are cointegrated in the long run. Hence, we cannot accept the null hypothesis of "no long-run relationships" among the variables for all the models except the growth model.

3.6.2.4. Results of Long Run Cointegration and ECM

3.6.2.4.a. Long-run Coefficients

Table 14 below represents the long-run relationships between the variables of the growth (GDP) model and the environment (CE) model, respectively. The growth model shows that the dependent variable lnGDP has a significant positive relationship with all of its explanatory variables. However, it doesn't show any relationship with RE. It is seen from the coefficients of the variables of growth model that, with one percent increase in the economic growth of Turkiye (GDP), MHDI, CE and FK increases by 2.76, 0.14 and 0.53 percentage points respectively.

Table 14: Growth Model & Environment Model

Variables	LNGDP	Variables	LNCE
LNMHDI	2.758484 (0.0000)***	**LNGDP**	2.841614 (0.3259)
LNRE	0.044934 (0.7285)	**LNMHDI**	-12.988431 (0.1212)
LNCE	0.149671 (0.0013)***	**LNRE**	-6.029374 (0.0096)***
LNFK	0.528616 (0.0377)**	**LNFD**	1.935961 (0.0564)*
C	-8.660974 (0.0039)***	**LNTROPEN**	8.790795 (0.0065)***
		C	12.900434 (0.4394)

Note Author's calculation (Eviews 9). Numbers inside parentheses show p values. ***indicates the t-value is significant at 1% significance level, **at 5% significance, and * at 10% significance.

From the coefficients of the variables of the environmental model it can be seen that, while the variables GDP and MHDI have no effect, variables FD and TROPEN have significant positive and RE has significant negative relationship with CO2 emissions. With one percentage point increase in renewable energy consumption, CO2 emission reduces by 6.02 percentage points. That is, increased RE consumption can help in lowering environmental degradation of Turkiye. However, trade openness significantly raises carbon emission by 8.79% with a unit increase in it. Financial development also causes carbon emission to be higher by 1.94% with a rise in one unit of it.

Table 15: The Social Well-being Model & Renewable Energy Model

Variables	MHDI Model		Variables	RE Model	
LNGDP	0.408681	(0.0000)***	**LNGDP**	3.630962	(0.0027)***
LNRE	-0.119913	(0.0000)***	**LNMHDI**	-1.908818	(0.0770)*
LNCE	-0.016369	(0.0007)***	**LNCE**	-1.624485	(0.1266)
LNHE	0.031705	(0.0000)***	**LNOP**	-2.797778	(0.0142)***
C	1.044734	(0.0000)***	**C**	0.167372	(0.8695)

Note Author's calculation (Eviews 9). Numbers inside parentheses show p values. ***indicates the t-value is significant at 1% significance level, **at 5% significance, and * at 10% significance.

Table 15 above represents the long-run cointegration among the variables of the Social Well-being (MHDI) model and the Renewable Energy (RE) model, respectively. It is clear from the table that RE and CE have a significant long-term negative impact on MHDI at 1% significance levels respectively. That is, with a 1% increase in renewable energy and carbon emission, social well-being will be degraded to 0.12% and 0.02% respectively. On the other hand, economic growth and government’s expenditure on health sector (HE) accelerates social wellbeing by 0.41% and 0.03% respectively.

The RE model in the table 15 also depicts that economic growth of Turkiye has a significant positive effect in increasing renewable energy consumption by 3.63 percentage units with a percentage unit rise in economic growth. However, the coefficient of MHDI decreases renewable energy consumption significantly by 1.90 percentage points. That is, if Turkiye's overall social well-being improves, the need for renewable energy consumption may be lowered. It is also evident from table 15 that increased consumption of renewable energy will decrease the oil price by 2.80 percentage points.

3.6.2.4.b. Short-run Coefficients/ECM

An Error Correction Model (ECM) has been estimated to find the short-run relationships among the variables. The rate at which variables return to equilibrium is shown by a negative and significant ECM. It describes how quickly equilibrium is restored after disrupting the long-run equilibrium relationship (Sari, Ewing, & Soytas, 2008). Table 16-19 shows the results of ECM for the four models under consideration.

Table 16: Short-run Coefficients of the Growth Model

Dependent Variable: D(LNGDP)		
Lag orders: (1, 1, 3, 2, 4)		
Variables	**Coefficient**	**Probabilities**
D(LNMHDI)	3.434153	0.0766*
D(LNRE)	0.032428	0.2324
D(LNRE(-1))	-0.062698	0.0557*
D(LNRE(-2))	0.050004	0.0861*
D(LNCE)	0.018145	0.1245
D(LNCE(-1))	-0.015082	0.2769
D(LNFK)	0.262136	0.0003***
D(LNFK(-1))	-0.073755	0.3244

D(LNFK(-2))	-0.116166	0.1318
D(LNFK(-3))	0.071269	0.1475
ECM(-1)	-0.368397	0.0168***

Note Author's calculation (Eviews 9). The numbers in the parentheses are p-values. ***indicates the t-value is significant at 1% significance level, **at 5% significance, and * at 10% significance.

Table 16 represents the short-term relationship between the variables of the growth model. It is seen from the probability result that variables like MHDI, RE and FK has impact on GDP in the short period of time. While the relation of MHDI and RE with GDP is only significant at 10 percent level of significance, fixed capital shows significant positive relationship of 0.26% with it at 5% significance level. Another extract from table 16 is the value of Error Correction Model (ECM) which is (-0.37) and significant at 1% significance level.

Table 17 below shows how response and explanatory variables of the environment model are related to each other in the short run. The results from this table depict that GDP has significant negative effect on carbon emissions at all the points of the short run timeline. MHDI has both negative (in the first lag) and significant positive impact (in the second lag) on carbon emission for short period of time. RE also shows a positive relationship with CO2 in the current period which turns out as negative when the lags increase. FD shows highly significant positive impact on carbon emission in the second lag period while TROPEN shows a negative (with 0 lag period) and then a positive (with 1^{st} and 3^{rd} lag periods) relationship with CO2 emission. That means trade openness first helps in carbon reduction, but with time it deteriorates the environment with increased carbon emissions. The ECT value for the environment model is found to be positive but it is not significant at 5% level of significance.

Table 18 shows how the explanatory variables of the social-wellbeing model affect the outcome variable MHDI in a short period of time. Looking at the p-values of this model, it is seen that at GDP has a negative relationship with MHDI in the 1^{st} and 3^{rd} lag of the short-term period. In the current period, RE shows a negative relationship with MHDI which becomes positive in the 1^{st} and 3^{rd} lag period of time. Similarly, carbon emission is also seen to have short term positive effect on MHDI in the first and third lags. HE on the other hand seems to increase MHDI significantly in its current short run period. However, it hampers social wellbeing when its 1st and 2nd lags are taken into consideration. Table 18 also depicts the ECM value of this model, which is significant at a 1% level of significance with a value of (-0.20).

Table 17: Short-run Coefficients of Environment Model

Dependent Variable: D(LNCE)		
Lag orders: (4, 4, 3, 4, 3, 4)		
Independent Variables	**Coefficient**	**Probabilities**
D(LNCE(-1))	-2.062094	0.0018***
D(LNCE(-2))	-1.201735	0.0043***
D(LNCE(-3))	-0.706733	0.0103**
D(LNGDP)	-11.955599	0.0465**
D(LNGDP(-1))	5.013652	0.2366
D(LNGDP(-2))	-9.689234	0.0242**
D(LNGDP(-3))	-4.435668	0.1150
D(LNMHDI)	18.159908	0.7072
D(LNMHDI(-1))	-327.881609	0.0028***
D(LNMHDI(-2))	280.050623	0.0003***
D(LNRE)	2.499544	0.0044***
D(LNRE(-1))	-2.302532	0.0279**
D(LNRE(-2))	0.597219	0.3380
D(LNRE(-3))	-1.416348	0.0660*
D(LNFD)	1.821064	0.0869*
D(LNFD(-1))	0.951374	0.4140
D(LNFD(-2))	3.422665	0.0099***
D(LNTROPEN)	-7.099128	0.0040***

D(LNTROPEN(-1))	3.004127	0.0305**
D(LNTROPEN(-2))	-1.174398	0.3097
D(LNTROPEN(-3))	2.586440	0.0234**
ECM(-1)	1.199356	0.0511

Note: Author's calculation (Eviews 9). The numbers in the parentheses are p values. ***indicates the t-value is significant at 1% significance level, **at 5% significance, and * at 10% significance respectively.

Table 18: Short-run Coefficient of Social Well-being Model

Dependent Variable: D(LNMHDI)		
Lag orders: (3, 0, 2, 2, 1)		
Independent Variables	**Coefficient**	**Probabilities**
D(LNMHDI(-1))	0.316479	0.0297**
D(LNMHDI(-2))	-0.417905	0.1603
D(LNMHDI(-3))	0.658961	0.0312**
D(LNGDP)	0.004176	0.6290
D(LNGDP(-1))	-0.047746	0.0029***
D(LNGDP(-2))	-0.009946	0.4929
D(LNGDP(-3))	-0.045945	0.0491**
D(LNRE)	-0.010342	0.0076***
D(LNRE(-1))	0.010371	0.0193**
D(LNRE(-2))	-0.003785	0.4243

D(LNRE(-3))	0.010311	0.0202**
D(LNCE)	-0.000030	0.9564
D(LNCE(-1))	0.001267	0.0282**
D(LNCE(-2))	-0.000074	0.9359
D(LNCE(-3))	0.002869	0.0094***
D(LNHE)	0.001251	0.0090***
D(LNHE(-1))	-0.001480	0.0044***
D(LNHE(-2))	-0.001072	0.0939*
ECM(-1)	-0.202254	0.0012***

Note Author's calculation (Eviews 9). The numbers in the parentheses are p values. ***indicates the t-value is significant at 1% significance level, **at 5% significance, and * at 10% significance respectively.

Table 19: Short-run Coefficient of Renewable Energy Model

Dependent Variable: D(LNRE)		
Lag orders: (4, 4, 4, 4, 1)		
Independent Variables	**Coefficient**	**Probabilities**
D(LNRE(-1))	0.435461	0.0456**
D(LNRE(-2))	0.195194	0.3586
D(LNRE(-3))	0.564830	0.0091***
D(LNGDP)	2.661472	0.0104**
D(LNGDP(-1))	-0.615059	0.5571
D(LNGDP(-2))	1.799858	0.0779*
D(LNGDP(-3))	-3.499221	0.0010***

D(LNMHDI)	-12.478969	0.3745
D(LNMHDI(-1))	69.200021	0.0343**
D(LNMHDI(-2))	-120.528310	0.0028***
D(LNMHDI(-3))	54.509325	0.0097***
D(LNCE)	0.124164	0.1470
D(LNCE(-1))	0.131972	0.0431**
D(LNCE(-2))	-0.045783	0.4695
D(LNCE(-3))	0.154465	0.0094***
D(LNOP)	-0.160522	0.0306**
ECM(-1)	-1.072666	0.0005***

Note Author's calculation (Eviews 9). The numbers in the parentheses are p values. ***indicates the t-value is significant at 1% significance level, **at 5% significance, and * at 10% significance respectively.

Table 19 represents the short-run relationships amongst the variables of the RE model. It is seen from the results of table 19 that, GDP helps increase renewable energy use in the current period and 2nd lag period of time. However, at the third lag period it decrease the consumption of RE. Other variables like CE has only positive and OP has only negative link with RE in the short term period of time. The ECM value of the RE model is also significant at 1% level of significance with a value of (-1.07).

One of the crucial extracts from the tables 16 to 19 is the error correction model (ECM). Error Correction Model (ECM) ascertains how quickly dependent variables adjust to the short-run shocks by explanatory variables before reaching equilibrium. Among all the four models, the estimated coefficient of ECM as presented in table 16-19, is meaningful for the GDP, MHDI and RE models only. Table 16 and table18 shows that the coefficients of ECM for the GDP and the MHDI model are negative and has a value of (-0.37) and (-0.20) respectively. Both the values are significant at a 1% level of significance. These values indicate that, the variables are convergence over time i.e. they will be cointegrated over time while reaching from short period to long period of time. The values (-0.37) and (-0.20) indicates that 37% of the short-run variables of GDP model and 20% of the short-run variables of the MHDI model converges to equilibrium in the long run. On the other hand, the ECM value for the renewable energy model is (-1.07), which is significant at a 1% significance level. Therefore, the short-run explanatory variables of the RE model converge to equilibrium by 107%. The value (-1.07) also indicates an oscillatory convergence to equilibrium for the variables of RE model over time.

3.6.3. Diagnostic tests

Several diagnostic procedures, including the Breusch-Godfrey LM Test for testing correlation, the ARCH Heteroskedasticity Test, and the Ramsey RESET Test of Specification, have been used to confirm the conclusions of this work. All five diagnostic tests have been performed separately for each model included under analysis.

Table 20: Results of Diagnostic Tests

Tests	**GDP model**	**CE model**	**MHDI model**	**RE model**
LM test	0.166820 (0.8476)	0.122326 (0.7368)	2.558728 (0.1267)	0.188013 (0.8310)
ARCH Heteroskedasticity test	0.001412 (0.9703)	2.381348 (0.0899)	0.259452 (0.8540)	0.262975 (0.6116)
Ramsey RESET test	1.869663 (0.0770)	4.643674 (0.0657)	0.957720 (0.3588)	0.565886 (0.5811)
CUSUM test	Stable	Stable	Stable	Stable
CUSUM sq test	Stable	Stable	Stable	Stable

Note Author's calculation (Eviews 9). Numbers inside parentheses shows p-values.

Test results in table 20 shows that the p-value is more than 0.05 in all the models. Hence, the models have no autocorrelation and heteroscedasticity. Moreover, the Ramsey RESET test confirmed that the models are perfectly specified with the correct functional form. Finally, the robustness of the estimation is confirmed by CUSUM and CUSUM square tests which confirmed all the models lying with 5% critical bound lines (see appendix).

CONCLUSION

Energy, environment, and growth are all intricately linked with each other. For the development of any nation, producing enough energy, protecting the environment, and maintaining growth are all equally crucial. On the other hand, unchecked expansion and energy production frequently endanger environmental health and, as a result, national sustainability. Turkiye must shift to alternative energy sources to achieve sustainable development since it imports nonrenewable energy. It can be achieved by analyzing the statistical effects of renewable energy use on several facets of the sustainable growth.

This analysis explores RE-SD nexus taking into account the different dimensions (i.e. society, environment, and economic efficiency) of the sustainable development in Turkiye. For this purpose, four models have been developed. These are the growth model with GDP, the environment model with CE, the social well-being model with MHDI, and the renewable energy model taking RE consumption as the output variables respectively. Therefore, this paper studies the renewable energy and sustainable development nexus for Turkiye in 1980-2019 using the ARDL bounds testing approach.

Variables GDP, CE, FK, MHDI, RE, TROPEN, FD, and HE has been included in the four models of the study. ARDL cointegration model has been used to see the relationships among these variables. From the empirical analysis, it is observed according to the growth model that, MHDI and FK have significant positive relationship with GDP both in the short and long-run. Among other variables RE doesn’t show any connection with GDP in the long run but affects in the short run both negatively (in the 1st lag) and positively (in the 2nd lag); CE significantly increases GDP in the long run only. Among all the variables, MHDI has the greatest long-run impact on GDP growth of Turkiye i.e. with a percentage increase in social wellbeing indicator, economic growth of Turkiye increases by 2.76% over time.

In the environment model, only the explanatory variables RE, FD and TROPEN are seen to affect CE over the long period of time. While RE has a significant negative impact of as much as 6.02 percentage points, the other two variables affects CO2 emission positively.

For the social well-being model, it is seen that among all the four variables, RE and CE have a significant long-term negative impact on MHDI at 1% significance levels respectively. That is, with a 1% increase in renewable energy and carbon emission, social well-being will be degraded to 0.12% and 0.02% respectively. On the other hand, economic growth and government's expenditure on health sector (HE) accelerates social wellbeing by 0.41% and 0.03% respectively. All the variables of the MHDI model have also short term effect on MHDI either positively or negatively. Another extract of this model is its ECM value. The significant ECM value of (-0.20) indicates that this model is a well fitted model.

The last model in the study- the RE model, indicates that GDP has a positive (3.63%) and MHDI has a negative (-1.91%) impression on RE over time. However, for short-period effects, it is seen that GDP has both a negative and positive relationship with RE alternatively. The same trend is seen for the variable MHDI also. It can be clear from the ECM value of the RE model. The ECM value of the renewable energy model is greater than 1 (-1.07). This value indicates an oscillatory movement towards equilibrium from short to long run for the variables of this model. Statistical results from the renewable energy model also depict that within short time period CE positively impacts renewable energy. However, oil price decreases renewable energy use for both short and long periods.

From the overall analysis on the RE-growth nexus of Turkiye, it can be concluded that consumption of RE does not affect economic growth of Turkiye but economic growth accelerates RE consumption by 3.63 percentage units. Hence there is a one-way relationship from economic growth towards RE which is similar to the study of Alper (2018) . Moreover, use of RE will improve the environmental sustainability as RE is seen to decrease environmental pollution by decreasing carbon emissions to 6.03 percentage units with one percentage unit increase in its consumption. In terms of RE's impact on the social sustainability, it is seen that in the long run period, both RE and MHDI negatively impact each other. Hence, RE doesn't help in improving social sustainability of Turkiye.

The findings of this research indicates that, increased consumption of RE will improve the environmental quality of Turkiye and will not affect its economic growth adversely. Since RE has not been seen to affect GDP in the long run, it suggests that

Turkiye is way behind in utilizing REs in compared to the traditional energies. Hence, there is still a lot of scope for Turkiye to establish more infrastructures that can produce more REs and bring them to use in full swing.

The study also recommends that, this type of empirical investigation may give a more comprehensive result when tested with a panel approach. Hence, future researchers can use the same variables to test through a panel analysis taking into account the data from different regions of Turkiye.

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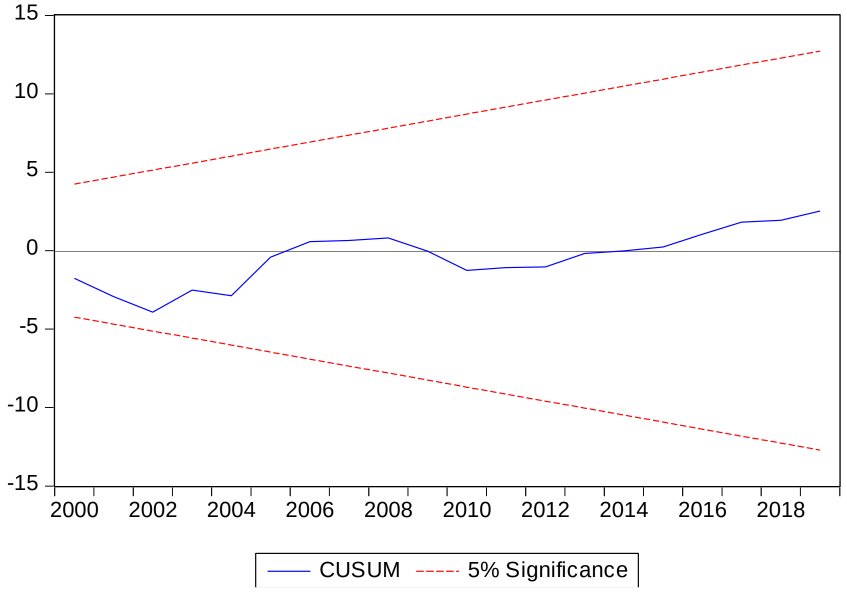
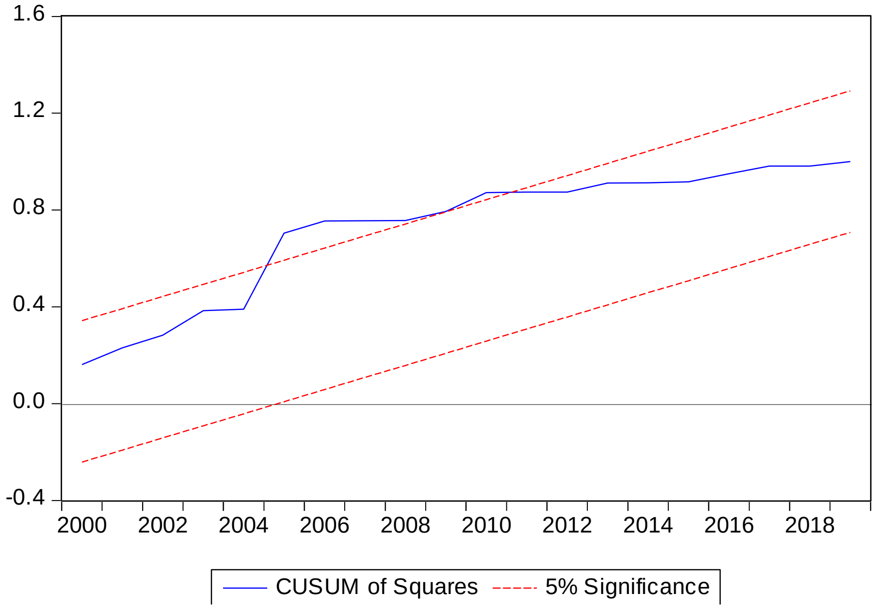
APPENDICES

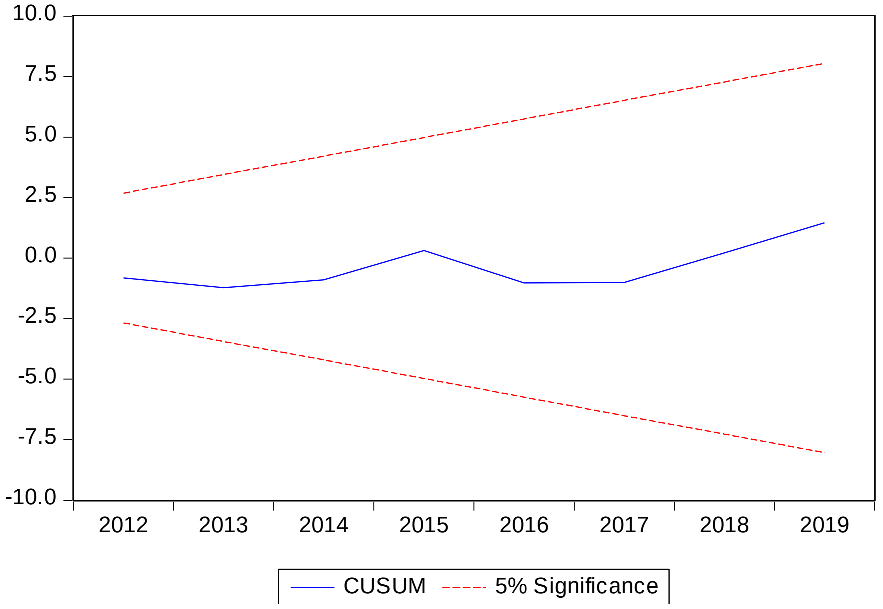
Result from CUSUM and CUSUM squares tests:

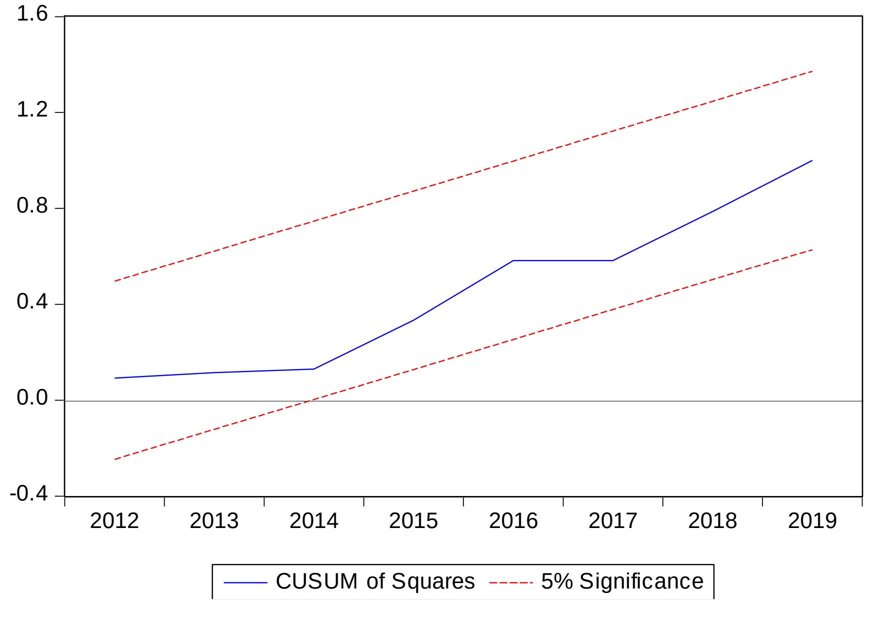
The Growth Model



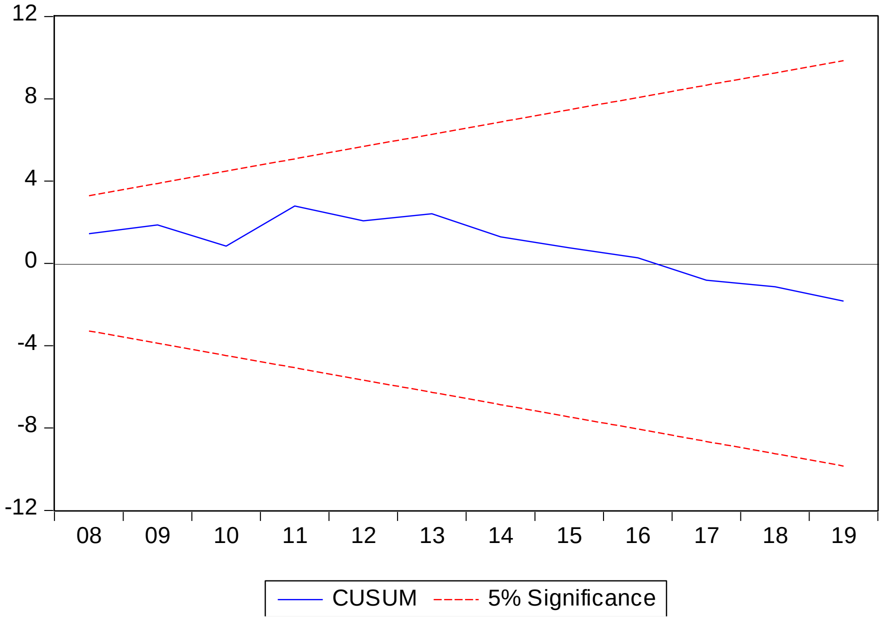


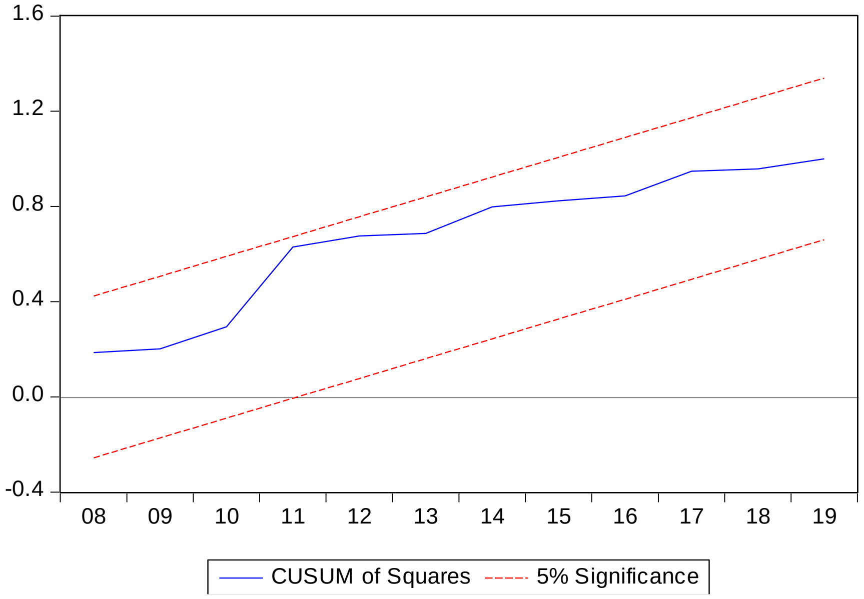
The Environmental Model



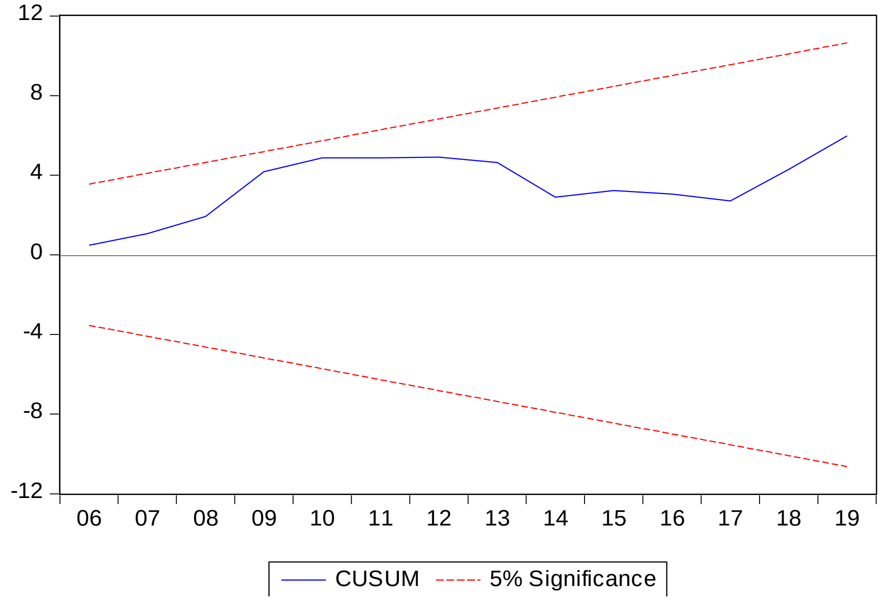


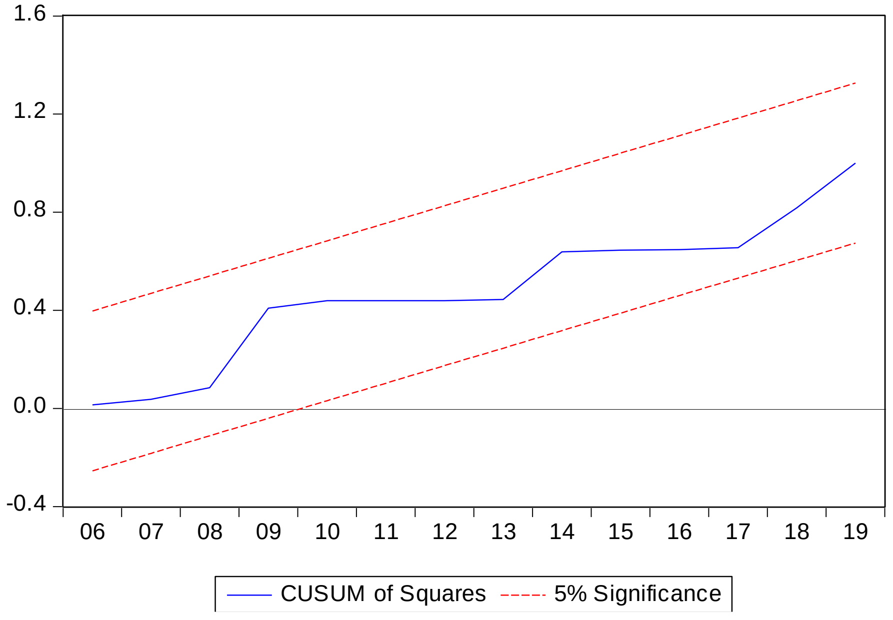
The Social Well-being Model





The Renewable Energy Model





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Saeeda LUBABA completed her Bachelor of Social Science (BSS) degree in Economics and Banking from the department of Economics and Banking at International Islamic University Chittagong, Bangladesh. She is a chancellor gold medalist who secured the first position in her department with a CGPA 4 out of 4.

Saeeda LUBABA also authored and coauthored several research articles. Two of her publications have been published in peer-reviewed international journals, of which one is ESCI and SCOPUS indexed.

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