ENERGY SUSTAINABILITY: BRIDGING THE NEXUS BETWEEN SUSTAINABILITY AND DEVELOPMENT IN TÜRKİYE

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ABSTRACT

ENERGY SUSTAINABILITY: BRIDGING THE NEXUS BETWEEN SUSTAINABILITY AND DEVELOPMENT IN TÜRKİYE

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Energy is central to sustainable development, balancing economic growth, social progress, and environmental sustainability. This thesis examines Türkiye's energy and development policies within the context of sustainable development, evaluating progress towards energy sustainability. Employing a mixed-methods approach, the study combines policy analysis and comparative benchmarking. A key contribution is the development of a novel Energy Sustainability Index, assessing Türkiye's energy sustainability progress while considering interlinkages among Sustainable Development Goals (SDGs). Comparative analysis with Spain, Poland, South Korea, Mexico, and South Africa provides global context for Türkiye's sustainable energy transition.

Contrary to some views arguing that there is a weak coherence between Türkiye's energy policies and sustainability principles, the findings of the study reveals that Türkiye has made significant progress in aligning national energy and development policies with international sustainability frameworks, particularly the SDGs. Despite strengths in renewable energy capacity and energy access, challenges persist in dependency on imported fossil fuels, emission reductions, energy efficiency, and biodiversity conservation. Comparative analysis highlights gaps in integrating energy policies with socioeconomic and environmental goals.

To address these challenges, this study recommends accelerating renewable energy investments, enhancing energy efficiency, reducing fossil fuel dependency, and improving policy coherence on sustainability. This research contributes to global efforts by emphasizing the need for integrated policies to reach a sustainable energy future and offers strategic guidance to Türkiye and other developing countries navigating the sustainable energy transition.

Keywords: Energy, Environment, Sustainable Development, Sustainable Energy, Sustainability

ÖZ

ENERJİ SÜRDÜRÜLEBİLİRLİĞİ: TÜRKİYE'DE SÜRDÜRÜLEBİLİRLİK VE KALKINMA ARASINDA KÖPRÜNÜN KURULMASI

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Enerji, ekonomik büyüme, sosyal ilerleme ve çevresel sürdürülebilirliği dengeleyen sürdürülebilir kalkınmanın merkezinde yer almaktadır. Bu tez, sürdürülebilir kalkınma bağlamında Türkiye'nin enerji ve kalkınma politikalarını incelemekte, enerji sürdürülebilirliğine yönelik ilerlemeleri değerlendirmektedir. Karma yöntem yaklaşımıyla çalışma, politika analizi ve karşılaştırmalı analizi bir araya getirmektedir. Çalışmanın temel katkısı, Türkiye'nin enerji sürdürülebilirliği alanındaki ilerlemesini değerlendirirken Sürdürülebilir Kalkınma Amaçları (SKA'lar) arasındaki bağlantıları gözeten yeni bir Enerji Sürdürülebilirliği Endeksinin geliştirilmesidir. İspanya, Polonya, Güney Kore, Meksika ve Güney Afrika ile yapılan karşılaştırmalı analiz, Türkiye'nin enerji dönüşümüne küresel bir bağlam sağlamaktadır.

Türkiye'de enerji politikaları ile sürdürülebilirlik ilkeleri arasında zayıf bir uyum olduğunu savunan bazı görüşlerin aksine, çalışmanın bulguları enerji ve kalkınma politikalarının SKA'lar gibi uluslararası sürdürülebilirlik çerçeveleriyle uyumlaştırılmasında önemli ilerleme kaydedildiğini ortaya koymaktadır. Ülkenin yenilenebilir enerji kapasitesi ve enerjiye erişim konularındaki güçlü yönlerine rağmen ithal ve fosil yakıtlara bağımlılık, emisyon azaltımı, enerji verimliliği ve biyoçeşitliliğin korunması konularında bazı zorlukları bulunmaktadır. Karşılaştırmalı analiz, enerji politikalarının sosyoekonomik ve çevresel hedeflerle entegrasyonunda eksikliklere işaret etmektedir.

Bu zorlukların üstesinden gelmek için yenilenebilir enerji yatırımlarının hızlandırılması, enerji verimliliğinin artırılması, fosil yakıtlara bağımlılığın azaltılması ve sürdürülebilirlik politika uyumunun geliştirilmesi önerilmektedir. Çalışma, enerjide sürdürülebilir bir geleceğe ulaşmak için entegre politikalara olan ihtiyacı vurgulayarak küresel çabalara katkıda bulunmakta, Türkiye ile sürdürülebilir enerji geçiş sürecindeki diğer gelişmekte olan ülkelere stratejik rehberlik sunmaktadır.

Anahtar Kelimeler: Enerji, Çevre, Sürdürülebilir Enerji, Sürdürülebilir Kalkınma, Sürdürülebilirlik

To my beloved daughters,

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TABLE OF CONTENTS

ABSTRACT v

ÖZ vii

ACKNOWLEDGMENTS x

TABLE OF CONTENTS xi

LIST OF TABLES xiv

LIST OF FIGURES xv

LIST OF ABBREVIATIONS xvii

CHAPTERS

1 INTRODUCTION 1

1.1 Scope and Objectives 3

1.2 Research Problem 5

1.3 Literature Review 6

1.4 Argument 11

1.5 Methodology 13

1.6 Organization of the Thesis 16

2 THEORETICAL FRAMEWORK 19

2.1 Conceptualization of Sustainable Development 19

2.2 Economic Growth and Sustainability: Expanding the Debate 23

2.3 Historical Development of the Sustainability Concept in International Arena 28

2.4 Alternative Approaches to Sustainable Development 35

2.5 Energy and Sustainable Development 38

2.6 Chapter Review 41

3 EVOLUTION OF SUSTAINABILITY IN THE DEVELOPMENT STRATEGIES OF TÜRKİYE 45
3.1 Development Plans from 1963 to 1990 46
3.2 Development Plans from 1990 to 2024 48
3.3 Chapter Review 55
4 SUSTAINABILITY OF ENERGY SECTOR IN TÜRKİYE 57
4.1 Energy Sector in Türkiye 60
4.1.1 Primary Energy Supply 60
4.1.2 Domestic Energy Production Trends and Dependency on Imports 63
4.1.3 Energy Consumption Trends 67
4.2 Energy Related International Relations of Türkiye 71
4.3 Energy Policies in National Policy Documents 75
4.4 Chapter Review 95
5 ENERGY SUSTAINABILITY CHALLENGES OF TÜRKİYE 99
5.1 Global Energy Sustainability Challenges 99
5.2 Energy Sustainability Challenges of Türkiye 104
5.3 Chapter Review 111
6 COMPARISON OF TÜRKİYE WITH OTHER COUNTRIES 115
6.1 Sustainability Indices 118
6.2 Comparison of Selected Countries Using Indices 122
6.2.1 Comparison of Selected Countries by Human Development Index 122
6.2.2 Comparison of Selected Countries by Ecological Footprint 128
6.2.3 Comparison of Selected Countries by Environmental Performance Index 137

6.2.4 Comparison of Selected Countries by SDG Index 141
6.2.5 Comparison of Selected Countries by World Energy Council's Trilemma Index 146
6.3 Chapter Review 154
7 DEVELOPMENT OF SDG ENERGY SUSTAINABILITY INDEX 159
7.1 Interlinkages Between SDG 7 and the Other SDGs 160
7.2 Indicator Framework for the SDG Energy Sustainability Index 181
7.3 Index Methodology 185
7.4 Results of SDG Energy Sustainability Index 189
7.5 Chapter Review 204
8 CONCLUSION 209
REFERENCES 221
CURRICULUM VITAE 245

LIST OF TABLES

TABLES

Table 6.1. Human Development Index Categories 125
Table 6.2. Comparison of the Countries Based on 2023 SDG Index.................... 143
Table 6.3. Comparison of Countries Based on ETI... 152
Table 7.1. SDG Energy Sustainability Index Indicator Framework 182
Table 7.2. Performance Thresholds of the Indicators.. 186
Table 7.3. Scores of Energy Sustainability Indices 192
Table 7.4. Comparison with Income Groups... 197
Table 7.5. Comparison with Geographical Groups 199

LIST OF FIGURES

FIGURES

Figure 2.1. Sustainable Development Goals 33
Figure 2.2. Milestones of the UN Agenda of Sustainable Development 34
Figure 4.1. GDP per Capita of Türkiye, PPP (constant 2017 international $) 57
Figure 4.2. Annual GDP Growth Rate of Türkiye, (%) 58
Figure 4.3. Sectoral Employment, Türkiye, (% of Total Employment, modeled ILO estimate) 59
Figure 4.4. Total Primary Energy Supply of Türkiye, by Source, (TJ) 61
Figure 4.5. Total Primary Energy Supply of Türkiye, by Source, (%) 62
Figure 4.6. Total Final Energy Consumption (TFC) of Türkiye, by Sector, (TJ) .. 63
Figure 4.7. Domestic Energy Production of Türkiye, (PJ) 64
Figure 4.8. Domestic Energy Production of Türkiye, (%) 64
Figure 4.9. Energy Trade of Türkiye (1990-2022) 65
Figure 4.10. Net Energy Imports/TES of Türkiye, (%) 66
Figure 4.11. Net Energy Imports/Energy Supply of Türkiye, by Fuel Type, (%) .. 66
Figure 4.12. Total Energy Supply vs. Total Final Consumption, (PJ) 67
Figure 4.13. Sectoral Total Final Consumptions of Türkiye, (PJ) 68
Figure 4.14. TFC by Source, Industry Sector of Türkiye (%) 69
Figure 4.15. TFC by Source, Transport Sector of Türkiye (%) 69
Figure 4.16. TFC by Source, Residential Sector of Türkiye (%) 70
Figure 4.17. TFC by Source, Commercial and Public Services Sector of Türkiye (%) 70
Figure 4.18. Energy Policy Framework in the NDPs. 88
Figure 5.1. GHG Emissions of Türkiye (MtCO_2eq) 106
Figure 6.1. Human Development Index Calculation Framework 123
Figure 6.2. HDI Comparison of Selected Countries 125
Figure 6.3. PHDI Representation and Comparison with HDI 126
Figure 6.4. PHDI Comparison of the Selected Countries 128

Figure 6.5. National Footprint and Biocapacity Accounts (NFA) Accounting Framework 131
Figure 6.6. Ecological Footprints of the Selected Countries (1961-2018) 132
Figure 6.7. Detailed EF Comparisons of the Selected Countries (1990-2018) 136
Figure 6.8. EPI 2022 Framework 138
Figure 6.9. EPI 2022 Comparison of the Selected Countries 139
Figure 6.10. EPI Scores of Countries in Comparison 140
Figure 6.11. Comparison of Selected Countries Based on SDG Index 144
Figure 6.12. Türkiye's Average Performance by SDG 145
Figure 6.13. Map of WEC's Energy Trilemma Index Scores 149
Figure 6.14. Energy Trilemma Index Component Scores of Türkiye 150
Figure 6.15. Trends in Energy Trilemma Index Components of Türkiye 150
Figure 6.16. Scores of Türkiye Under Each Metrics of ETI 151
Figure 7.1. Interlinkages Between SDG 7 Targets with Other SDG Targets 178
Figure 7.2. Major Interlinkages of SDG 7 with Other SDGs 179
Figure 7.3. Visualization Map of Interlinkages between SDG 7 and Other SDGs180
Figure 7.4. Historical Trends in the Indices 201

LIST OF ABBREVIATIONS

ABBREVIATIONS

BSEC	Black Sea Economic Cooperation
CBD	Convention on Biological Diversity
CLRTAP	Convention on Long-range Transboundary Air Pollution
COP	Conference of Parties
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
CSD	Commission on Sustainable Development
DAC	Development Assistance Committee
DCC	Directorate of Climate Change
DPT	Devlet Planlama Teşkilatı
ECT	Energy Charter Treaty
EF	Ecological Footprint
EF_E	Ecological Footprint of exports
EF_I	Ecological Footprint of imports
EFp	Ecological Footprint of production
EKC	Environmental Kuznets Curve
ENTSOE	European Network of Transmission System Operators for Electricity
EPI	Environmental Performance Index
EQF	Equivalence factor
ESI	Environmental Sustainability Index
ETI	World Energy Council's Trilemma Index
EU	European Union
EÜAŞ	Turkish Electricity Generation Corporation
EWI	Ecosystem Wellbeing Index
G20	Group of Twenty
GDP	Gross domestic product
GHG	Greenhouse Gase
GNI	Gross national income
GPI	Genuine Progress Indicator
HDI	Human Development Index
HWI	Human Wellbeing Index
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
ISEW	Sustainable Economic Welfare Index
JPOI	Johannesburg Plan of Implementation

JRC	Joint Research Centre
kep	kilogram of oil equivalent
kWh	Kilowatt-hour
LNG	Liquefied natural gas
LSE	London School of Economics and Political Science
MDG	Millennium Development Goal
MENR	Republic of Türkiye Ministry of Energy and Natural Resources
MFA	Republic of Türkiye Ministry of Foreign Affairs
MoD	Republic of Türkiye Ministry of Development
Mt	Million ton
MTEP	Million ton equivalent of petroleum
Mtoe	Million tons of oil equivalent
MW	Megawatt
NATO	North Atlantic Treaty Organization
NDC	Nationally determined contribution
NDP	National development plan
NEEAP	National energy efficiency action plan
NFA	National footprint account
NGO	Non-governmental organization
NIMBY	Not in my backyard
NPP	Nuclear power plant
OECD	Organisation for Economic Co-operation and Development
PHDI	Planetary pressures–adjusted Human Development Index
PJ	Petajoule
PM2.5	Particulate matter of less than 2.5 microns in diameter
PPP	Purchasing power parity
PSB	Presidency of the Republic of Türkiye Presidency of Strategy and Budget
R&D	Research and development
Rio+20	United Nations Conference on Sustainable Development
SDG	Sustainable Development Goal
SDSN	Sustainable Development Solutions Network
SE4All	Sustainable Energy for All
SPO	State Planning Organization
TANAP	Trans-Anatolian Natural Gas Pipeline
TES	Total energy supply
TFC	Total final consumption
TJ	Terajoule
toe	Ton of oil equivalent
TPES	Total primary energy supply
TURKSTAT	Turkish Statistical Institute

TWh	Terawatt-hour
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Program
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
US	The United States
USA	The United States of America
WCED	World Commission on Environment and Development
WEC	World Energy Council
WHO	World Health Organization
YEKA	Renewable Energy Resource Areas
YEKDEM	Renewable Energy Sources Support Mechanism

CHAPTER 1

INTRODUCTION

Beginning in the 19th century, rapid industrialization and economic growth were accompanied by significant population increases, propelling many nations to advanced stages of development. However, in those times world nations were ignorant of the negative impacts of economic development on environment. As countries continued to grow, environmental problems such as air pollution, soil degradation, and water stress became increasingly evident, affecting human life. Initially perceived as localized challenges, these environmental problems expanded to regional and global scales by the 20th century. Then nations began considering how to reduce the adverse impacts of their development on the environment.

Sustainable development has emerged as a defining framework for addressing those global challenges, particularly aforementioned intertwined issues of economic growth, environmental degradation, and social inequality. The 1987 Brundtland Report famously defined sustainable development as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). This definition underscored the interrelation of economic growth, environmental stewardship, and social equity, setting the step for a global commitment to sustainable practices.

Then it becomes one of the leading principles of development strategies of world nations and international organizations. It is reflected also in the agendas of local governments and private organizations. Over the years, international frameworks such as the Millennium Development Goals (MDGs) and the United Nations Sustainable Development Goals (SDGs) have institutionalized sustainable development, making it a cornerstone of global policy discussions. Among the various dimensions of sustainable development, energy systems lie at the heart, as they underpin economic activity, social well-being, and environmental health. A sustainable energy system provides reliable, affordable, and clean energy while minimizing environmental impacts and ensuring long-term resource availability (United Nations Development Programme, [UNDP] 2014).

Globally, the transition toward energy sustainability has been shaped by efforts to reduce greenhouse gas emissions, increase energy efficiency, and integrate renewable energy sources. These shifts are critical for addressing climate change, improving energy security, and fostering inclusive economic development (Intergovernmental Panel on Climate Change, 2018). However, despite these advancements, developing countries face unique challenges in aligning their energy policies with sustainability goals.

For developing countries like Türkiye, achieving energy sustainability presents significant opportunities and obstacles. Türkiye's rapid industrialization and urbanization have driven a steep rise in energy demand, intensifying reliance on imported fossil fuels (International Energy Agency [IEA], 2023a). Simultaneously, Türkiye faces mounting pressure to align with international climate commitments, such as the Paris Agreement, and reduce its carbon footprint (World Bank, 2022). These dual imperatives (energy security and environmental sustainability) require a careful balance, particularly in the context of socioeconomic constraints and evolving global energy markets.

Türkiye has begun aligning its energy and development strategies with the SDGs as part of a broader effort to transform its energy sector. Türkiye's alignment with the SDGs, particularly SDG 7, offers a roadmap for overcoming these challenges. However, despite considerable advancements, persistent gaps in energy security, environmental performance, and socioeconomic equity highlight the need for targeted and sustainable energy policy solutions.

This thesis examines Türkiye's progress in energy sustainability, with an emphasis on policy development and comparative analysis. By examining Türkiye's policies, challenges, and comparative performance, the study provides insights into the broader paradox of balancing development and sustainability. This research provides insightful implications both for Türkiye’s sustainable development and for global energy sustainability. Lessons from Türkiye’s experience can also inform broader efforts to address similar challenges in other developing nations.

1.1 Scope and Objectives

Türkiye is situated at the intersection of Europe and Asia, with the majority of its land area in southwestern Asia and a small portion in southeastern Europe. Türkiye has a population of more than 85 million (as of 2023) and an area of 783 562 square kilometers, it is the 18th most populated and 36th largest country by total area in the world (Turkish Statistical Institute [TURKSTAT], 2024; World Bank, 2024a).

Due to its strategic central location and rich cultural heritage, Türkiye holds significant influence in its region. As a candidate for the European Union, Türkiye has been engaged in accession negotiations since 2005 (European Commission, 2024a). When looked the memberships to the international organizations, Türkiye has been part of the many international organizations such as Organisation for Economic Co-operation and Development (OECD), International Energy Agency (IEA), North Atlantic Treaty Organization (NATO) and Group of Twenty (G20) (IEA, 2021a).

The primary focus of the study is Türkiye, examining its energy and development policies, sustainability challenges, and sectoral developments. However, to contextualize Türkiye’s progress, the thesis conducts a comparative analysis with selected high-energy-consuming countries, namely Spain, Poland, Mexico, South Korea, and South Africa. All these countries except South Africa are members of OECD, however South Africa is the only key partner of OECD in Africa (Organisation for Economic Co-operation and Development [OECD], 2024). These countries were selected for their diverse economic and geographical contexts as well as their relevance in the global sustainability discourse, more specifically:

- Spain, Poland, and South Korea are high-income nations from Europe and East Asia, being examples for advanced energy and socioeconomic policies.
- Mexico and South Africa are upper-middle-income countries from Latin America and Sub-Saharan Africa, respectively. They share similar developmental challenges with Türkiye but operate within distinct geographical and policy contexts, illustrating the complexities of pursuing energy sustainability in developing regions facing resource constraints.

As this thesis investigates how Türkiye's energy and development policies and their results align with sustainable development principles, it focused on the developments after the 1990s when sustainability became a global priority. Specifically, the study covers a period from 1990 to 2024, capturing significant policy shifts, energy market transformations, and sustainability-related developments in Türkiye. Special attention is paid to the period post-2015, following the adoption of the 2030 Agenda for Sustainable Development and SDGs (United Nations [UN], 2015).

In this scope, this thesis aims to provide a comprehensive assessment of Türkiye's energy and development policies and their alignment with sustainable development principles. The study seeks to analyze the historical trajectory of Türkiye's sustainable development and energy policies by examining 12 national development plans and policy documents. Particular emphasis is placed on how these policies have evolved in response to global sustainability frameworks such as SDGs. Understanding these historical shifts is essential for contextualizing Türkiye's current energy strategies within broader international sustainability efforts.

To provide theoretical baseline for the analyses and discussions in the thesis, this study seeks to explore the evolution of global sustainable development principles and approaches, emphasizing energy sector, and their application in policy frameworks.

A key objective of this research is to evaluate Türkiye's energy sector performance in terms of sustainability. This is achieved by analyzing statistical data and key sustainability indicators, including energy production and consumption trends, dependency on fossil fuel imports, and greenhouse gas emissions. By assessing Türkiye’s energy trajectory, the study aims to identify the effectiveness of past and present policies in promoting sustainable energy transitions.

To further contextualize Türkiye’s energy sustainability performance, the thesis conducts a comparative analysis with selected countries using sustainability indices to benchmark Türkiye’s progress relative to other nations. This comparative approach allows for a better understanding of Türkiye’s achievements and areas where further improvements are needed.

Another major objective of this thesis is the development of a new Energy Sustainability Index specifically in the context of SDGs. This index integrates key energy, environmental, and socio-economic indicators to provide a holistic assessment of Türkiye’s performance in achieving energy sustainability in comparison with other countries. The results of this index will offer insights into Türkiye’s strengths and weaknesses in sustainable energy development.

In addition to evaluating progress, the thesis also aims to identify key challenges in global energy sustainability and Türkiye as well. By highlighting the obstacles on energy sustainability, the study provides a clearer picture of the structural and policy barriers that may hinder Türkiye’s sustainable energy transition.

Finally, the thesis aims to provide actionable policy recommendations to enhance Türkiye’s energy sustainability. By offering policy and data driven insights, the study will contribute to ongoing discussions on how Türkiye can achieve a more sustainable and resilient energy future.

1.2 Research Problem

As the concept of sustainability gained global recognition in the 1990s, Türkiye began to formulate its energy and development policies in line with sustainable development approach. While Türkiye has made notable progress in certain areas of SDG 7, notably in the population’s access to electricity, but there are some areas for further progress i.e., dealing with environmental problems such as air pollution and climate change. In addition to these environmental problems, energy dependency on fossil and imported fuels continue to hinder Türkiye's path toward comprehensive energy sustainability (World Bank, 2022). Ranking 16th globally in total energy consumption in 2023, it is critical to assess Türkiye's progress in energy sustainability in comparison with other high-energy-consuming countries to evaluate how its policies and implementations align with the sustainability agenda (U.S. Energy Information Administration, 2024).

Türkiye's energy sector illustrates the tensions inherent in sustainable development: the country must balance growing energy needs with environmental sustainability and energy security. Its high dependency on imported energy (nearly 70% of its primary energy supply) and its vulnerability to external price shocks present significant risks (IEA, 2021a). At the same time, Türkiye has made strides in renewable energy integration, ranking among the top countries in installed capacity for hydro, wind, and solar power (International Renewable Energy Agency, 2023). This paradox of significant advancements in certain areas alongside persistent systemic challenges defines the core research problem.

Considering the research problem, the main research question guiding this study is determined as:

> "Has Türkiye aligned its energy and development policies in a sustainable manner, particularly in the post-cold war era since 1991 in addition how could Türkiye's performance be evaluated in comparison to the performances of other comparable cases since 1991?"

1.3 Literature Review

This research adopts a multidisciplinary approach, integrating insights from the disciplines of sustainable development, energy policy, and political economy. The study is grounded in the theoretical framework of sustainable development, emphasizing the interactions between environmental, economic, and social dimensions. In this respect the literature review is done to provide a baseline for the argument.

The global sustainability discourse has evolved significantly since the late 20th century, driven by landmark initiatives like the Brundtland Report (1987), Agenda 21, and the United Nations Sustainable Development Goals (SDGs) (Brundtland, 1987; United Nations Conference on Environment and Development [UNCED], 1992; UN, 2015). These global frameworks underscore the multidimensional nature of sustainability, integrating economic, environmental, and social priorities. Among these frameworks, SDGs provide the guideline for energy sustainability policies worldwide until 2030. SDG 7 specifically focuses on ensuring access to affordable, reliable, sustainable, and modern energy for all, emphasizing the transition to renewable energy, energy efficiency, and universal energy access (UN, 2015).

Scholars highlight the importance of sustainable energy systems in achieving these global goals. For instance, Dincer and Acar (2017) emphasize the need for energy systems that ensure reliability, affordability, and minimal environmental impact. Kabeyi and Olanrewaju (2022) stress that successful energy transitions require comprehensive policy frameworks that address economic, environmental, social, technical, and institutional dimensions. Markard et al. (2012) conceptualizes energy systems as socio-technical systems consisting of interdependent networks of actors, institutions, material products, and knowledge. Changes in these systems require transformations across multiple dimensions, including governance, technology, and societal norms. However, these transitions require tailored strategies that align global aspirations with local realities.

The sustainability of Türkiye's energy and development policies has been widely debated in the literature. Serencam and Serencam (2013) discusses Türkiye's need for a sustainable energy strategy that balances environmental concerns, economic development, and social well-being. The study highlights Türkiye's overreliance on fossil fuels, slow adoption of renewable energy, and increasing greenhouse gas

(GHG) emissions. Indicating the lack of visionary thinking such as policies prioritizing economic growth over long-term sustainability, this paper concludes with Türkiye’s energy future remains unsustainable without significant policy changes, increased investments in renewable energy, and stronger regulatory frameworks (Serencam & Serencam, 2013).

Kovancı (2023) examines the historical development of Türkiye’s climate policies and its engagement in international environmental initiatives such as Paris Agreement, indicating contradictions between economic growth strategies and sustainability goals. Although Türkiye has recently taken steps such as ratifying the Paris Agreement and updating its nationally determined contribution (NDC), its ongoing dependence on fossil fuels suggests a disconnect from sustainability objectives. While progress has been made, the persistence of fossil fuel-centered policies indicates that a full transition to renewable energy sources remains a distant goal (Kovancı, 2023).

Canan (2023) critically evaluates Türkiye’s energy and development policies by applying an ecological economics approach focusing on institutional frameworks, developmental policies, resource management, and market structures. This study highlights the limited integration of sustainability principles as a result weak consideration of environmental sustainability in energy policies concluding that “the energy sector in Türkiye does not have a sustainable structure” (Canan, 2023).

Urasoglu & Ilbas (2020) analyzes current and future energy policies, evaluating whether Türkiye can transition successfully or bear the costs of inaction. Despite efforts, Türkiye remains heavily dependent on fossil fuels, particularly domestic coal, which hinders progress toward a low-carbon energy system. The study highlights Türkiye’s need for a sustainable energy transition to align with global environmental goals (Urasoglu & Ilbas, 2020).

Yeldan (2023) examines Türkiye’s challenges and structural constraints in achieving decarbonization and sustainable development. Türkiye’s speculation-led economic growth model and fossil fuel-based production cycle present significant obstacles to its green transformation. Although Türkiye has ratified the Paris Agreement, its energy policies continue to support coal production and fossil fuel-based industrialization. The study highlighted the need for a comprehensive industrial policy focused on sustainability to secure Türkiye’s economic and environmental stability in the long run (Yeldan, 2023).

Richert (2015) discusses Türkiye’s potential to emerge as a sustainable energy leader among emerging economies. However, the study emphasize that current policies are insufficient with weak sustainability targets. The study identifies the over-reliance on coal and fossil fuels weakens Türkiye’s international standing in climate diplomacy and threatens its leadership potential (Richert, 2015).

Tools such as sustainability indices and composite indicators have been widely employed to assess and benchmark energy sustainability. For instance, Ligus and Peternek (2021) developed an aggregated Sustainable Energy Development Index to evaluate and rank European Union (EU) member states’ progress toward energy sustainability by integrating social, economic, and environmental dimensions. They emphasize the need for tailored energy policies and monitoring frameworks to address gaps in performance and ensure progress toward sustainability goals (Ligus & Peternek, 2021). Similarly, Singh et al. (2009) highlighted the role of composite indices in conveying complex data and trends, enabling effective policy communication.

Despite the global push for sustainability, energy transitions in developing economies face significant hurdles. These include high dependency on fossil fuels, technological restrictions, infrastructure deficits, and fiscal constraints (Falcone, 2023). Relva and her friends (2021) highlight that weak governance structures and inadequate long-term energy planning exacerbate these challenges.

Cantarero (2020) indicates economic, socio-cultural, and institutional barriers together with energy poverty, reliance on traditional biomass, and inadequate infrastructure impede progress on sustainable energy transitions in developing countries. Effective policies and frameworks balancing technological, social, and policy dimensions are critical for accelerating just and sustainable energy transitions, including financial incentives and regulatory mechanisms (Cantarero, 2020).

Falcone (2023) explores energy sustainability in developing countries using the case studies of Albania, Kenya, Brazil, and India and identifies these countries have substantial progress in energy sector development especially with implementation of renewable energy but in these emerging countries, there remains challenges such as grid integration, environmental sustainability, and social considerations.

Comparative studies reveal how countries with varying socioeconomic and geopolitical contexts navigate sustainable energy transitions. Pakulska (2021) highlights that Central and Eastern Europe countries are undergoing significant transformations to transition toward renewable and green energy to align with EU climate goals however challenges arise due to historical dependence on fossil fuels and slower adoption of renewable technologies compared to Western Europe.

Brodny and Tutak (2021) developed multidimensional indices for Central and Eastern European countries to compare sustainable energy development levels across nations. Their approach highlights the importance of tailored methodologies in energy assessments for varying regional contexts (Brodny & Tutak, 2021).

Despite the growing research on energy sustainability, some of which are presented in this section, there are several gaps in the literature, particularly concerning Türkiye’s energy and development policies and their alignment with global sustainability frameworks. One of the primary gaps in the literature is the lack of a comprehensive, country-specific evaluation of Türkiye’s energy sustainability policies within the broader context of sustainable development. While there are numerous studies on global energy transitions and sustainability, few studies offer a holistic, longitudinal assessment of sustainability of energy policies and most analyses focus on broader regional trends or individual aspects of energy policy, such as renewable energy adoption or energy security. Another critical gap is the limited number of comparative studies exist that evaluates Türkiye’s energy sustainability performance relative to other nations integrating socioeconomic factors with global benchmarks.

This thesis aims to address these gaps by providing a comprehensive, data-driven, and comparative assessment of Türkiye's energy sustainability efforts. By analyzing Türkiye's national development and energy strategies, this thesis provides a more detailed understanding of the country's long-term policy trajectory.

1.4 Argument

As indicated in the literature review, there are some views claiming that there is a weak coherence between energy policies and sustainability principles in Türkiye. On the contrary to these views, this thesis argues that Türkiye, in fact, has made significant progress in aligning its energy and development policies with sustainable development principles, particularly the global frameworks such as the SDGs. While sustainability was initially a secondary concern, it has progressively become successfully integrated into Türkiye's National Development Plans.

In parallel to the development policies, the evolution of Türkiye's energy policies and strategies reflects a dual focus on economic development and environmental sustainability. Early policies prioritized industrialization and economic growth, while recent strategies, especially after 2015, have emphasized balancing energy security with environmental goals. Over the past three decades, Türkiye has increasingly integrated renewable energy sources such as wind, solar, and hydropower into its energy mix. This progress highlights the country's commitment to achieving SDG 7, which emphasizes affordable, reliable, and sustainable energy access for all. Despite challenges like dependency on fossil fuels and energy imports, Türkiye's energy policies demonstrate an evolving focus on sustainability and energy security. Türkiye's shift from conventional energy dependency to a diversified energy mix, including substantial investments in renewables, showcases its ability to adapt its policies to global sustainability standards (IEA, 2021a).

A comparative analysis of Türkiye’s performance relative to other high-energy-consuming nations reveals notable achievements. In benchmarking against countries such as Poland, South Africa, Mexico, South Korea and Spain, Türkiye’s energy policies exhibit higher effectiveness in renewable energy integration and energy efficiency improvements. These advances position Türkiye as a regional leader in sustainable energy transitions. However, continued efforts are required to mitigate challenges associated with external energy dependencies and to enhance socioeconomic policy frameworks to align fully with sustainable development objectives.

I think renewable energy development has been central to Türkiye’s energy sustainability efforts and will remain critical for its future progress. Large-scale renewable projects, supported by targeted incentives, have significantly increased Türkiye’s installed renewable energy capacities. These advancements have not only reduced greenhouse gas emissions but also strengthened energy security, ensuring a cleaner and more resilient energy future for Türkiye.

Building on this progress, sustainable energy transition requires a combined effort on expanding renewable energy capacity and improving energy efficiency. By integrating technological innovation, regional cooperation, and adaptive policies, Türkiye can address existing challenges such as fossil fuel dependency and energy affordability. Aligning these efforts with broader sustainability goals, such as the SDGs, will be vital in ensuring Türkiye’s leadership in sustainable energy transitions and long-term resilience. By integrating global perspectives, comparative insights, and Türkiye’s unique context, this thesis contributes to the broader discourse on sustainable energy and development while offering actionable strategies tailored to Türkiye’s needs.

1.5 Methodology

In this thesis, a mixed-methods approach is employed to comprehensively analyze Türkiye's energy and development policies and their alignment with sustainable development principles. The mixed-methods approach enables a comprehensive understanding of Türkiye's energy sustainability. The qualitative analysis provides depth and contextual insights, while the quantitative analysis ensures objectivity and comparability. By combining qualitative and quantitative methodologies, this research aims to provide a holistic evaluation of progress, challenges, and comparative insights about energy sustainability within the framework of sustainable development.

The qualitative analysis forms the foundation of this research by examining key policy documents, development plans, and international agreements. National development plans from 1963 to 2024 were reviewed to trace the historical trajectory of Türkiye's sustainability agenda, particularly focusing on the integration of energy and environmental policies after 1990s. In addition, international commitments such as SDGs and United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement were analyzed to assess how Türkiye's strategies align with global frameworks. Sectoral policies addressing renewable energy targets and energy efficiency were critically examined to identify gaps, successes, and policy trajectories. This qualitative approach enables a nuanced understanding of the institutional priorities and policy frameworks driving Türkiye's sustainable energy transition.

Quantitative methods were employed to evaluate Türkiye's performance using key indicators and statistical data. This analysis incorporates energy and environmental statistics sourced from international organizations, such as the IEA, as well as national databases. Temporal trends were analyzed to measure progress in energy sustainability, with particular attention to the post-1990 period and milestones achieved after the adoption of the 2030 Agenda for Sustainable Development. Quantitative analysis complements the qualitative findings by providing measurable benchmarks and identifying trends in energy production, consumption, and greenhouse gas emissions.

As a part of quantitative analysis, indices-based comparisons were also conducted to contextualize Türkiye’s energy performance within a global framework. Existing sustainability indices, including the Human Development Index (HDI), Ecological Footprint (EF), Environmental Performance Index (EPI), SDG Index, the World Energy Council’s Trilemma Index (ETI), were used to benchmark Türkiye’s progress relative to countries such as Spain, Poland, Mexico, South Korea, and South Africa. These countries were selected as benchmarks based on their energy profiles, socioeconomic contexts, and relevance to Türkiye’s sustainability challenges. These comparisons, using sustainability indices, provide insights into Türkiye’s relative achievements and the lessons that can be drawn.

In addition to the existing indices, a new SDG Energy Sustainability Index developed in this thesis as a core component of this research. This index was designed to evaluate Türkiye’s performance in achieving energy sustainability by integrating relevant indicators from SDG 7 with other SDGs. The methodology for developing this index included selecting indicators based on their relevance to energy sustainability considering the interlinkage analysis of SDG 7 with other goals, aggregation of the normalized indicators applying different weightings to reflect the relative importance of indicators. The index results were analyzed to highlight Türkiye’s strengths and areas for improvement in energy sustainability, as well as its progress in aligning with global sustainability goals.

The integration of qualitative and quantitative analyses including indices-based comparisons, and the development of the SDG Energy Sustainability Index ensures a comprehensive approach to evaluating Türkiye’s energy policies with regards to energy sustainability and sustainable development. This mixed-methods framework offers both depth and breadth in assessing the alignment of Türkiye’s energy strategies with sustainable development goals, while also providing actionable insights for future policy directions.

The research relies on diverse data sources and a broad spectrum of literature to ensure a comprehensive evaluation. Statistical data were sourced from international organizations, such as the IEA, the UN, and the World Bank, as well as national data sources such as Ministry of Energy and Natural Resources and TURKSTAT. The literature reviewed includes peer-reviewed journal articles, reports by international organizations, and scholarly books on energy sustainability, indices and sustainable development frameworks.

While this research offers a comprehensive analysis, certain limitations must be acknowledged. As this thesis focuses primarily on Türkiye's energy sustainability trajectory and comparative analysis with Spain, Poland, Mexico, South Korea, and South Africa, which provides international benchmarks, the findings may not be fully generalizable to other developing or developed economies. Türkiye has a unique geopolitical position, economic structure, and policy environment that may not be directly applicable to other nations undergoing energy transitions.

Despite its robustness, the methodology of SDG Energy Sustainability Index also has some limitations. While the two weighting schemes used in the index development offer flexibility and complementary insights, their static nature may not fully capture context-specific sustainability priorities. Future studies could explore more dynamic or advanced weighting approaches to enhance the representation of regional and sectoral nuances in energy sustainability. Although the index incorporates 25 indicators based on the SDG Index Database, some key metrics of energy sustainability such as energy efficiency, grid reliability, and private sector contributions could not be added as they are not available in the database. Expanding the indicator set from other databases in future research would improve the index's ability to capture those aspects of energy sustainability. While the SDG Index database accounts for missing data, disparities in data availability across countries, particularly in developing regions like Sub-Saharan Africa, may introduce biases in cross-country comparisons. Strengthening data collection and statistical systems in those economies would improve comparability and accuracy, ensuring a more comprehensive and globally applicable energy sustainability index.

The thesis' methodology offers a robust framework for evaluating energy sustainability through policy analysis and cross-country comparisons. This approach not only facilitates benchmarking but also provides valuable insights for policymakers to align national strategies with global sustainability agendas.

1.6 Organization of the Thesis

This thesis is organized into 8 chapters, each addressing a distinct aspect of Türkiye's energy and development policies and their alignment with sustainable development principles. The structure is designed to provide a comprehensive analysis, starting from the conceptual and historical foundations to comparative evaluations and the development of an energy sustainability index.

The introductory chapter, Chapter 1, establishes the scope, objectives, and central research question of the thesis. It highlights the importance of sustainable energy development within the global and national context, particularly emphasizing its relevance for Türkiye. The chapter also provides an overview of the methodology employed and outlines the organization of the thesis.

Chapter 2 focuses on the theoretical framework, providing a conceptual foundation by exploring the historical evolution of sustainability and its relevance to energy policies. It examines key theoretical perspectives on sustainable development and energy sustainability, establishing a robust framework for analyzing Türkiye's policies. This chapter sets the stage for understanding the connections between energy, environmental protection, and socioeconomic equity.

Chapter 3 examines the evolution of sustainability in Türkiye's development strategies by reviewing national development plans from 1963 to 2024. It traces the integration of sustainability principles into these plans, highlighting key milestones and shifts toward sustainable development policies.

Chapter 4 presents a detailed sectoral analysis of Türkiye's energy sector. It examines trends in energy production, consumption, and import dependency while assessing the integration of domestic renewable energy resources. This chapter also evaluates Türkiye’s energy-related international relations and national energy policies, analyzing their contributions to sustainable development.

In Chapter 5, the thesis addresses the challenges Türkiye faces in achieving energy sustainability. These include global energy challenges and Türkiye-specific issues such as reliance on fossil fuels, energy security concerns, and environmental degradation. The chapter contextualizes these challenges within the broader sustainability goals outlined in international agreements, providing a clearer picture of the structural and policy barriers that may hinder Türkiye’s sustainable energy transition.

Chapter 6 provides a comparative evaluation of Türkiye’s sustainable development and energy sustainability performance relative to other selected countries, including Spain, Poland, Mexico, South Korea, and South Africa. Using indices such as the SDG Index, Ecological Footprint, and the World Energy Council’s Trilemma Index, the chapter benchmarks Türkiye’s achievements, identifies areas for improvement.

Chapter 7 focuses on the development of a new Energy Sustainability Index tailored to SDG context. It details the methodology, indicator selection, and weighting system employed to construct the index. The results are analyzed to assess Türkiye’s progress in energy sustainability, highlighting its strengths and areas for improvement. This chapter also evaluates interlinkages between SDG 7 and other sustainable development goals.

Finally, the Conclusion summarizes the key findings of the thesis, emphasizing Türkiye’s progress, challenges, and opportunities in achieving energy sustainability. It provides actionable policy recommendations and insights for future research, aiming to guide Türkiye’s energy transition toward sustainable development. This chapter consolidates the contributions of the thesis and outlines pathways for ensuring long-term energy sustainability in Türkiye.

CHAPTER 2

THEORETICAL FRAMEWORK

Since the Industrial Revolution, global population growth, economic expansion, and industrialization have transformed human societies. Technological advancements and industrial processes have significantly boosted these trends, but they have also stressed natural ecosystems, leading to challenges such as climate change, biodiversity loss, and environmental pollution (Becker, 2023; Rockström et al., 2009).

To address these growing concerns, sustainable development has emerged as a critical approach that seeks to balance economic growth with environmental protection and social equity. The interdependence between energy, environment, and development plays a fundamental role in shaping modern sustainability strategies. Energy, as a primary driver of industrialization and economic progress, is at the core of environmental challenges, making it a crucial factor in achieving sustainable development (IEA, 2021b).

This chapter explores the theoretical foundations of sustainable development, the historical evolution of sustainability policies, and the complex relationship between energy consumption and environmental preservation. A critical assessment of these interdependencies will underscore the urgency of sustainable energy transitions and policy interventions to ensure a more sustainable future.

2.1 Conceptualization of Sustainable Development

The concept of sustainable development has evolved as a response to the growing conflicts between economic progress and environmental protection. Recognizing the urgent need for a development model that does not deplete resources irreversibly, the World Commission on Environment and Development (WCED) introduced a widely accepted definition of Sustainable Development in the 1987 Brundtland Report:

> "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).

This definition highlights "intergenerational equity", emphasizing that economic growth should not be achieved at the expense of future generations' ability to succeed. However, sustainable development is a broad and multidimensional concept that integrates three interconnected aspects (pillars): economic, environmental, and social:

1. Economic aspect refers to the ability of an economy to maintain steady growth while ensuring efficient resource allocation and financial stability. It involves producing goods and services consistently while managing government and external debt levels and avoiding imbalances in sectors that could harm agriculture or industry. It emphasizes the importance of maintaining or enhancing four types of capital: manufactured, natural, human, and social. While some substitution among these capitals is possible, they are generally complementary, and maintaining all four is vital for long-term economic sustainability (Harris, 2003).

2. The environmental aspect focuses on sustaining a stable natural resource base by preventing the excessive exploitation of renewable resources and ensuring that non-renewable resources are depleted only as much as adequate substitutes are developed. In other means, it ensures that natural ecosystems remain intact, and resource consumption does not exceed nature's regenerative capacity. This involves conserving biodiversity, preventing atmospheric pollution, and preserving other ecosystem functions that are not usually considered as economic resources. Protecting ecosystems and natural resources is necessary for sustainable economic growth and ensuring equity across generations. Ecologically, it is vital to limit the human population together with total resource demand to maintain ecosystem integrity and species diversity. Market mechanisms often fail to conserve natural capital, leading to its depletion and degradation (Fiorino, 2010).

3. The social aspect emphasizes focuses on ensuring fair access to resources, equal opportunities, and a just society. It highlights achieving equity in distribution and opportunities, providing basic social services such as education and health to society, fostering accountability and public participation and ensuring gender equality and human rights. These elements are intricately linked with environmental sustainability, highlighting their interdependence in sustainable development (Harris, 2003).

These three aspects will be elaborated detailly in continuing paragraphs. But it is important to understand the sustainable development's multidimensional nature. It creates conflicting issues or trade-offs, such as balancing objectives and determining success or failure. For instance, providing adequate food and water may require land use changes that would harm biodiversity. Similarly, electricity production from clean energy sources might be costly, increasing the burden on life of poor people. These conflicts raise questions about which goals should take precedence, highlighting the challenges in prioritizing and balancing these three aspects of sustainable development. Addressing such dilemmas requires holistic policymaking and a systemic approach to sustainability (Harris, 2003).

The concept of sustainable development also encompass various definitions and interpretations. Initially, it is important to delve into the semantic nuances of sustainable development. While the term "development" has been in use for over two centuries, its significance escalated after World War II. Historically, "development" has been employed in three distinct contexts: (1) as an aspiration for an ideal societal state; (2) as a dynamic process unfolding over time; and (3) as intentional endeavors by diverse stakeholders striving for enhancement. Essentially, sustainable development denotes not only a desired future outcome (goal), but also the evolutionary process leading to it (change), alongside the collective actions undertaken to achieve it (endeavors) (Becker, 2023).

While the term “sustainable” is defined as something that is “able to continue over a period of time” or “causing, or made in a way that causes, little or no damage to the environment and therefore able to continue for a long time” in environmental perspective (Cambridge Dictionary, 2023). Consequently, the initial aspect of this definition emphasizes sustainable development as a form of progress that can be sustained over time, while the latter underscores its role in protecting the environment from adverse impacts. These factors are intricately linked because not only can events and processes affect development, but the methods employed for development may also engender new challenges that might hinder its sustainability. For example, the widespread reliance on fossil fuels for energy boosted significant societal advancements since the industrial era, yet concurrently contributed to climate change and ocean acidification, posing threats to humanity’s future. On the other hand, climate change disproportionately affects populations, exacerbating poverty and social inequality (Becker, 2023).

From a holistic viewpoint, sustainable development entails progress that enhances benefits without depleting vital capital stocks, whether they are environmental, productive, or human capital (Talu, 2007). Hence, sustainable development aims not to risk the capacity to meet the needs of future generations while meeting current demands, by considering the economic, social, and environmental aspects together with the limited natural resources. Contamination of resources and degradation of nature steal opportunities from future generations would not be able to replace. In this context, it is important to prevent adverse effects caused by human activities to protect natural resources and prevent pollution. It is important to maintain the vitality of environmental factors (air, water, soil, biodiversity, etc.) by not limiting the development factor only to economic growth and to the improvement of the welfare level of society (Fiorino, 2010).

The conventional definition of sustainable development by the Brundtland Commission (1987) has been widely accepted but also criticized. Critics argue that the definition is too vague and open to multiple interpretations, making it difficult to operationalize in policymaking Terms like “needs” and “future generations” are subjective and can be interpreted in various ways, leading to inconsistent applications in sustainability planning (Redclift, 2005). Moreover, the lack of clear metrics for measuring sustainability within this definition has led to diverse and sometimes conflicting interpretations (Mazı, 2015).

2.2 Economic Growth and Sustainability: Expanding the Debate

The relationship between economic growth and environmental sustainability has been extensively debated. Economic growth can contribute to environmental and social sustainability by fostering democratic governance, increasing demand for environmental protection, improving quality of life, enhancing institutional planning capacities, and encouraging technological innovation (Fiorino, 2010). Conversely, economic growth up to and beyond a certain threshold level can also exacerbate environmental damage. In the early stages of development, this occurs through pollution, while in more advanced development levels, it results from higher consumption of resources, as suggested by the Environmental Kuznets Curve (EKC) hypothesis (Mishra, 2020). While the EKC provides a hopeful narrative, its empirical validity has been questioned. Critics argue that it oversimplifies complex interactions between economic and environmental systems and fails to account for globalized resource flows between rich and poor countries and externalized environmental costs (Stern, 2004).

Consumption is considered as a central cause of unsustainability in both environmental and human terms (Ricketts, 2010). When natural resources are solely perceived within the context of production and consumption, it highlights a predominant economic focus in addressing environmental concerns. However, the creation of irreversible ecological processes due to misguided economic practices poses a direct threat to sustainable development (Talu, 2007). Therefore, governments must consciously intervene in the development policies and that economic growth notion may have to be modified to make it greener to sustain the three systems in a balanced way (Fiorino, 2010).

From the neo-classical economic perspective, the term sustainability is defined as the maximization of welfare over time, often equated with maximizing utility from consumption. While this approach may be criticized for oversimplifying, it encompasses many essential aspects of human welfare, such as food, housing, health, education and transportation. It also provides the analytical advantage by simplifying the complicated issue of sustainability into a measurable and single-dimensional indicator such as Gross Domestic Product (GDP) (Harris, 2003). However, there has been debates on traditional economic indicators like GDP failing to capture environmental degradation and social well-being, prompting the development of alternative metrics such as the SDG Index (Sachs et al., 2023) and Ecological Footprint (Wackernagel et al., 1997). However, debates continue over which indicators best reflect sustainability progress.

The traditional economic growth paradigm also criticized by the degrowth framework arguing that continuous economic expansion is incompatible with ecological sustainability. Proponents of degrowth advocate for reduced production and consumption, emphasizing well-being over GDP growth (Jackson, 2009). It proposes alternative economic structures that prioritize social equity, ecological resilience, and local economies over global market expansion. Degrowth advocates emphasize reducing energy demand through efficiency and sufficiency, particularly in high-consumption societies (Kallis, 2011). However, there are potential social impacts, such as reduced employment opportunities and income levels, which may disproportionately affect vulnerable populations in both developed and developing nations (Jackson, 2009).

In practical terms, sustainability involves maintaining current production levels without compromising future production capabilities. The objective is not merely conserving resources but rather ensuring their ongoing productive utilization. Resources are managed for ongoing use rather than conserved for the future. For resources that can be used only once, such as fossil fuels, it is important to find ways to reuse or avoid their consumption. A sustainability approach might prioritize using non-renewable resources for essential applications like plastics and building materials while replacing them with renewable alternatives. Sustainable practices involve consuming resources that can be replenished or renewed (Cohen et al., 2015).

This perspective also involves leveraging design, engineering, and public policy to enhance the efficiency and efficacy of economic production and consumption. While pollution stemming from these activities may yield short-term advantages, historical evidence from global environmental remediation and restoration efforts suggests that these immediate gains expire quickly, causing long-term costs. Although selling goods that pollute environment may generate profits initially, the subsequent treatment of pollution could cost more than the gains. The responsibility for treatment of pollution would eventually fall upon someone generally to the public, necessitating the allocation of resources to the environmental impact (Cohen, et al., 2015).

A formal economic analysis questions whether sustainability is a valid economic concept. Standard economic theory suggests that efficient allocation of resources maximizes utility from consumption. When time discounting is used to compare the economic values of consumption across different times, sustainability occurs at the point of efficient resource allocation which is already a well-known economic concept (Harris, 2003).

The reductionist approach to sustainability is critiqued for its reliance on discount rates and the notion of natural capital. Natural capital includes components like soils and the atmosphere, encompassing all the world’s natural resources and ecosystem services. From a neo-classical perspective, there is no intrinsic reasoning for conserving natural capital. Higher discount rates, such as 10%, significantly devalues future benefits, which can justify resource depletion and environmental damage for present economic gains. This forms a bias on sustainability, as it prioritizes the welfare of current generations over future ones. To address this, a lower discount rate or sustainability rules may be necessary to achieve intergenerational equity (Harris, 2003; Howarth, 1996).

Conversations on sustainability primarily revolve around the interchangeability of different types of capital and the extent of substitution. The concept of substitutability of the different capital forms has led to the terms weak and strong sustainability. Weak sustainability posits that an economy remains sustainable as long as the subjective well-being of an average individual does not decline across generations. This perspective allows for resource depletion and environmental degradation, provided that compensatory investments are made in reproducible capital and other assets. In other words, it permits the substitution of natural capital with produced capital, assuming their combined value remains constant. On the contrary, the term “strong sustainability” argues that natural and produced capital are complementary and not easily interchangeable, highlighting the unique significance of natural resources. Based on the premise that scientific uncertainty, constraints on the substitutability between natural and human-made capital, and the risk of irreversible environmental damage, strong sustainability necessitate the protection of natural resources and environmental quality for the next generations (Howarth, 1996). Critics of weak sustainability highlight irreversible ecological losses, emphasizing that certain resources and ecosystem services cannot be replicated through technological advancements (Pelenc, 2015). These contrasting perspectives reflect fundamental tensions in sustainability discourses.

In neoclassical economics, there is no inherent reason to conserve natural capital, as it assumes that different forms of capital are substitutable. The Hartwick rule suggests that as non-renewable resources decline, their rents should be reinvested in reproducible capital to maintain consumption levels. However, this does not require maintaining a specific stock of natural capital (Hartwick, 1977). Daly's perspective opposes capital substitutability with emphasizing the complementary nature of natural and man-made capital (Daly, 1994).

Advocated by scholars such as Herman Daly and Robert Costanza, Ecological Economics critiques conventional economic models for neglecting the biophysical constraints of the planet. This perspective asserts that ecological sustainability requires acknowledging that natural and social capital cannot be endlessly substituted by built and human capital. Instead, biophysical limits and planetary boundaries restrict the expansion of the market economy. Ecological Economics emphasizes that human-made capital and natural resources function as complements rather than substitutes, highlighting that ecosystems provide essential life-supporting services that cannot be replicated by human-made capital (Costanza et al., 2015; Daly, 1994).

As indicated by Costanza and Daly (1992), a fundamental principle of sustainability is maintaining the total stock of natural capital at or above its current level, as further depletion poses significant uncertainties and risks. While a reduced natural capital stock might still support sustainability under certain conditions, a precautionary approach advocates against unnecessary depletion unless compelling evidence confirms it is safe to do so. They emphasize this principle by proposing a policy framework for natural capital conservation. They recommend setting sustainable yield limits for renewable resources to ensure that their usage does not exceed natural regeneration rates. For non-renewable resources, they advocate reinvesting extraction revenues into renewable alternatives, such as renewable energy, ecosystem restoration, and other sustainable capital assets. This approach ensures the long-term obtainability of critical resources while aligning economic activities with environmental sustainability.

Toman (1992) suggests the "safe minimum standard" as a way to reconcile competing economic and ecological perspectives on sustainability. This concept proposes a socially determined threshold between moral imperatives (preserving and enhancing natural resources) and economic trade-offs (allowing development where it does not pose significant environmental risks). The safe minimum standard approach aligns with precautionary principle, emphasizing conservation where irreversible damage is possible but permitting trade-offs in other cases. He advocates integrating ecological principles with economic criteria to address long-term sustainability challenges effectively (Toman, 1992).

The economic debates on sustainability indicates that achieving sustainability requires reconciling economic growth with environmental conservation. While economic expansion can support sustainability through improved governance and innovation, it also poses risks of resource depletion and ecological degradation. Therefore, integrating ecological considerations with economic decision-making is crucial to achieving long-term sustainability.

2.3 Historical Development of the Sustainability Concept in International Arena

The discussions in previous sections complements the earlier theoretical framework by reinforcing the multidimensional and often contradictory nature of sustainability policies. However, to understand how sustainable development is understood globally, looking at the historical evolution of sustainable development, especially within the UN system, would be beneficial.

The notion of sustainability has roots back to the 19th century when foresters sought to establish wood production targets. However, the formal assessment of natural resource sustainability, particularly addressing concerns of depletion, emerged during the 1960s and 70s. In this period, it became evident that traditional economic frameworks fell short in adequately valuing finite resources and accounting for environmental externalities such as pollution costs (Talu, 2007).

Acknowledging the limited character of natural resources urged the emergence of an environmentalist perspective initially, which gradually evolved into the more formalized concept of sustainable development worldwide. Over time, the understanding of resource sustainability evolved, encompassing elements such as population growth, economic practices, and resource utilization levels within nations (Talu, 2007).

In 1972, the book "Limits to Growth" marked a significant milestone. This revolutionary book presented the results of the first computerized simulation depicting the consequences of prevailing production and consumption systems on the environment. It accepted as the first scientific prediction of a potential worldwide ecological collapse (Meadows et al., 2004; Vezzoli et al., 2018). Again in 1972, the UN Conference on the Human Environment (Stockholm Conference), considered as the first UN conference on international environmental issues, marked an important milestone in international environmental politics. This conference has brought up the issues of "human-centered" and "protection of the resources of future generations". These two fundamental elements of sustainable development considered in the "eco-development" policy emphasizes the balance between ecology and development (Alagöz, 2004). However, at this stage, the concept of sustainable development was not yet fully articulated.

In 1980, the International Union for the Conservation of Nature's "World Conservation Strategy" was the first officially laid down the foundations of sustainable development as "for development to be sustainable it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long term as well as the short-term advantages and disadvantages of alternative actions" (International Union for the Conservation of Nature, 1980).

Later in 1987, the common and most famous definition of "sustainable development" was put forward as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" by the

World Commission on Environment and Development (WCED) in the "Our Common Future" Report (Brundtland, 1987). With this definition, sustainable development has been expanded to include the interconnection between economic growth, environmental protection, and social equity as indicated in previous section.

The concept of sustainable development was a key focus at the 1992 United Nations Conference on Environment and Development (UNCED), also called as the Earth Summit, which took place in Rio de Janeiro, Brazil. Earth Summit marked a significant milestone in establishing the foundational principles of sustainable development. It resulted in the creation of two pivotal documents: the Rio Declaration, Agenda 21 and two international agreements on environment: The Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC) (UNCED, 1992).

Among these outcomes, the Rio Declaration comprises the main principles that impose responsibilities on governments regarding environmental and developmental rights and obligations. It emphasizes the central role of humans and introduces 27 key principles, including poverty reduction, intergenerational equity, environmental protection, sustainable consumption and production, and the sustainability science and technology. On the other hand, being an action plan, Agenda 21 outlines the sustainable development objectives and strategies. Following the Earth Summit in 1993, the Commission on Sustainable Development (CSD) established to monitoring and evaluation of the achievements in the Rio outcomes (Yıkmaz, 2011).

Then in 2000, the beginning of the new millennium, governments gathered at the Millennium Summit in New York, USA to adopt the UN Millennium Declaration. This declaration outlined a global strategy to eliminate extreme poverty via eight Millennium Development Goals (MDGs) to be achieved by 2015. The MDGs were related to mainly social issues such on extreme poverty and hunger, universal primary education, child mortality, maternal health, infectious diseases such as tuberculosis and malaria, equality between men and women, and empowerment of women. There is an MDG for environmental sustainability, and one for partnerships for development (Keong, 2020).

Although sustainability was included in the overall focus of MDGs, they was on economic and social development rather than a fully integrated sustainability agenda. With MDGs, a shift occurred in sustainable development agenda, aligning with social development and emphasizing human rights in public policies for a fairer society. Sustainable development’s connection with human rights highlighted the importance of ensuring livelihood security to improve sustainability and reduce social and political risks. This approach underscores the need for detailed assessments of macroeconomic policies, including market-based freedoms, and emphasizes complementary strategies such as access to information, transparency, equity, justice, accountability, social inclusion, poverty reduction, and environmental protection (Talu, 2007).

Two years later from Millennium Summit, the World Summit on Sustainable Development took place in Johannesburg, South Africa in 2002 to evaluate progress made since the Earth Summit in 1992. This summit produced three significant outputs a political declaration, the Johannesburg Plan of Implementation (JPOI), and a variety of partnerships involving governments, the private sector, and non-governmental organizations (NGOs). The commitments in the JPOI focused on energy, sustainable consumption and production, water and sanitation, health, and biodiversity (UN, 2002).

With the MDGs and JPOI in place, countries aimed to make advances in sustainable development, but by 2012, it was clear that achievements at all levels were not adequate and there was a need to strengthen the sustainable development agenda. Consequently, in 2012, governments gathered in Rio de Janeiro, Brazil to hold the United Nations Conference on Sustainable Development (Rio+20). Rio+20 aimed to assess accomplishments and shortcomings from the 1992 Earth Summit and propose solutions to future threats to human welfare (UN, 2012).

UN negotiations for the new post-2015 Agenda were consolidated into the "Transforming Our World: The 2030 Agenda for Sustainable Development" document, which was accepted at the Sustainable Development Summit in 2015. This agenda encompasses a declaration, Sustainable Development Goals (SDGs), implementation tools, and a follow-up and review process (UN, 2015).

The SDGs are the 2030 Agenda's most crucial element, consisting of 17 ambitious goals (as seen on Figure 2.1) covering all aspects of sustainable development from economic growth to nature protection, from health to education, from fighting with inequalities to peace and justice.

These goals includes 169 targets and 231 unique indicators that define sustainable development priorities through 2030. The SDGs aim to eradicate poverty across all over the world, to address inequalities and to mobilize climate action ensuring inclusive progress for all countries under the motto "no one left behind". With 169 targets encompassing the three aspects of sustainable development, the SDGs have a broader scope than the MDGs and overtake them by addressing the main drivers of poverty and the common need for equitable development for all people (UN, 2015). Unlike the MDGs, which were targeted mainly at developing nations, the SDGs are universal, requiring all countries, including developed ones, to implement sustainability measures (Biermann et al., 2017).

Figure 2.1. Sustainable Development Goals

Source: United Nations Department of Global Communications, 2015.
https://www.un.org/sustainabledevelopment

The SDGs mark a significant shift in global governance with non-binding goal-setting strategies by focusing on voluntary commitments rather than legally binding regulations. While they offer greater inclusivity and broad participation, their non-binding nature and institutional weaknesses raise concerns about implementation and accountability. The future success of the SDGs will depend on strengthening governance mechanisms, improving measurement tools, securing financial resources, and ensuring national-level commitment (Biermann et al., 2017).

A major critique is that developing countries bear a disproportionate burden in achieving sustainability goals, while developed nations continue unsustainable consumption patterns (Sachs, 2019).

The UN's sustainable development agenda has played a critical role in shaping global policies on sustainability. Figure 2.2 summarizes the progress of the UN sustainable development agenda described in this section.

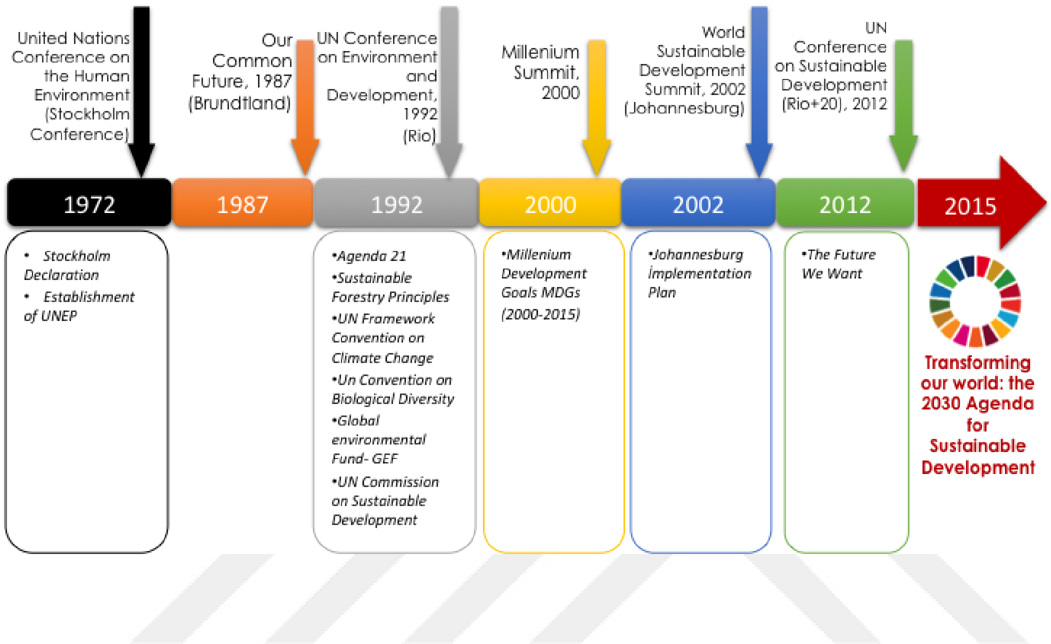


Figure 2.2. Milestones of the UN Agenda of Sustainable Development

Source: Prepared by author.

When the conceptual and historical development of sustainable development evaluated it can be said that there is not a universal definition of it. This concept has evolved mainly through UN processes and become an ambitious and comprehensive development concept through development of global sustainability agenda. However, it has also faced significant criticisms regarding conceptual vagueness, economic contradictions, weak implementation mechanisms, and inequalities between developed and developing nations. Addressing these challenges requires a more inclusive, context-sensitive, and enforceable sustainability framework that integrates economic growth with ecological limits and social justice.

2.4 Alternative Approaches to Sustainable Development

As seen from the previous sections, sustainable development concept has become more sophisticated and comprehensive, however it lacks a universally accepted definition, leading to varying interpretations and policy applications. The evolving nature of sustainable development has led to new concepts and strategies aimed at enhancing sustainability across various sectors. These new foundations are making this concept more practical to improve implementation but at the same time further complicating the debate, as they propose different approaches to integrating economic development with environmental sustainability. Some of these recent approaches include:

- *Green Growth:* This framework, promoted by the OECD, emphasizes economic growth that does not lead to environmental degradation. It focuses on enhancing resource efficiency, advancing clean energy solutions, reducing carbon footprints, and promoting technological innovations to achieve a balance between economic prosperity and environmental health. It is based on the assumption that economic growth (GDP increase) can be decoupled from resource use and carbon emissions (OECD, 2011; Hickel & Kallis, 2020). However, critics argue green growth lacks empirical support as a viable long-term solution to climate change and ecological degradation. Absolute decoupling of GDP from resource use has not occurred, and the rate of decoupling from carbon emissions is insufficient to meet climate targets (Hickel & Kallis, 2020).
- *Green Economy:* The United Nations Environment Programme (UNEP) defines a green economy as “an economy that results in improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities” (United Nations Environment Programme [UNEP], 2011). The green economy concept has been promoted as a catalyst for achieving sustainable development, gaining considerable international recognition over the past decade, particularly in response to the 2008

financial crisis (Ari & Yikmaz, 2019). It prioritizes sustainable production and consumption patterns, renewable energy investments, sustainable agricultural practices and green technologies to drive economic growth while protecting ecosystems. While green economy has different meaning than “green growth”, they can both be considered variations of a similar concept. This similarity arises from their shared central focus on environmentally sustainable growth, as well as their discussion and promotion within largely overlapping networks and institutional contexts. Critics involve that it primarily supports market-driven solutions that may not fundamentally alter exploitative economic structures (Jacobs, 2012).

- Low-Carbon Economy: This economic model focuses on reducing greenhouse gas emissions while maintaining economic stability. Strategies within this framework include renewable energy adoption, carbon pricing, carbon capture technologies, energy efficiency measures across industries and technological innovation to transition towards a sustainable energy system (Stern, 2007). Critics argue that the global economy remains structurally dependent on fossil fuels, making absolute decoupling from carbon emissions unlikely (Hickel & Kallis, 2020)
- Low-Carbon Development: In contrast to low carbon economy, low carbon development approach is a broader development approach that integrates climate action into development policies. Low-carbon development, also known as a low-emission development strategy, first emerged under the United Nations Framework Convention on Climate Change (UNFCCC) as a climate-focused approach distinct from broader sustainability frameworks like sustainable development and green economy. While it lacks a universally accepted definition, low-carbon development generally refers to coordinating socioeconomic progress with emission reductions, aiming to mitigate climate change and lower carbon intensity in economic activities. Its interpretation differs based on economic status: developed countries view it as an economic transition toward low-carbon industries, while developing nations focus on

achieving economic growth with minimal greenhouse gas (GHG) emissions (Du et al., 2020). Some argue that reducing carbon emissions may hinder economic growth, particularly in developing nations that rely on fossil fuels for industrialization (Sheng & Lu, 2016).

- *Doughnut Economics:* Developed by Kate Raworth (2017), this model visualizes a balance between essential human needs (the social foundation) and planetary boundaries (the environmental ceiling) with a doughnut shaped model. It suggests that economic activity should operate within a "safe and just space for humanity," ensuring social foundations (such as food, water, and healthcare) while respecting ecological limits (e.g., climate stability and biodiversity conservation). This approach shifts focus from traditional economic indicators to broader well-being metrics. Although Doughnut Economy framework offers a valuable global perspective for sustainable development, translating its principles into actionable policies for nations, cities, or organizations is challenging due to varying priorities and stakeholder goals. The interconnected nature of its social foundation and ecological ceiling mirrors the interdependence of SDGs, but these interactions differ across contexts and may have positive or negative effects. Additionally, institutions managing different policy areas often work in silos, lacking coordination even when their actions impact each other's outcomes, which complicates achieving cohesive sustainable development strategies (Warnecke, 2023).
- *Regenerative Development:* Moving beyond sustainability, regenerative development focuses on restoring and enhancing ecosystems rather than merely minimizing harm. It is a transformative process aimed at aligning human and social systems with natural systems, creating harmony between them (Mang et al., 2016; Dias, 2018).

These contemporary models refine traditional sustainability frameworks by integrating innovative and technologically driven solutions to make the sustainability concept more practical and accelerate the implementation. However, as seen above significant debates persist regarding their feasibility, scalability, and alignment with existing economic and political structures.

In addition, a literature review by Howes et al. (2017) revealed that the world is falling short in achieving environmental sustainability, with conditions worsening despite the progress in sustainability policies. The primary reason for this is indicated as the failure in policy implementation. Key factors behind policy failures include ongoing economic incentives that encourage resource exploitation without considering environmental harm, inadequate government capacity or political will to enforce effective policies, and ineffective communication about the urgency of sustainability issues (Howes et al., 2017). Market-driven incentives often favor short-term profits over long-term sustainability (Fiorino, 2010).

Additionally, progress varies between developed and developing countries, with developing nations facing greater challenges in transitioning to sustainable models such as public sector capacity, requiring tailored implementation strategies for success (Howes et al., 2017). Economic dependency on natural resource exploitation, external funding and technology is another challenge for developing nations in sustainability (Sovacool et al., 2020).

2.5 Energy and Sustainable Development

Energy is a central subject in discussions on sustainable development because it is intricately linked to sustainability issues and human activities. The strong relationships between energy, environment and development highlight its importance. Energy is vital for accelerating social progress and improving productivity, as other economic and social development goals are unattainable without access to clean, reliable, and affordable energy (UNDP, 2014).

The Industrial Revolution and the advent of new production technologies led to the widespread use of various energy resources in production. These energy sources transformed human civilization, playing a key role in economic growth, political power, and energy security (Dincer & Abu-Rayash, 2020). Concurrently, improved wealth and living conditions of humans together with rapidly increasing population has multiplied the need for energy. Increasing energy consumption has been leading to problems in energy supply security and the increase in budget deficits due to energy imports in most energy importing countries. But scarcity of energy sources, mostly the fossil fuels, has led extensive research and development (R&D) in the field of energy and alternative energy sources to diversify energy sources (Dağlioğlu, 2017).

The link between energy and the environment is complicated and interdependent. Energy is sourced mainly from the environment, and once utilized, it returns again to the environment either as harmless by-products or harmful waste. Prior to the discovery and use of fossil fuels in industrial and commercial activities, human impact on the Earth was minimal (Dincer & Abu-Rayash, 2020). The increasing energy demand, as a result of population increase and development, has led to a significant rise in waste generated from energy production. Greenhouse gases and other pollutants, for instance nitrogen oxides, sulfur dioxides, and particulate matters from energy production and consumption (especially fossil fuels) have caused significant health issues and both local and global environmental problems (Bilginoğlu, 1989). These problems include global climate change, air pollution, atmospheric acidification, and nuclear waste (Çoban & Şahbaz Kılınç, 2016). The energy sector is the main contributor to global climate change, accounting for 75.7% of GHG emissions as of 2021 (Ge et al., 2024).

The environmental impacts of energy production and consumption put emphasis on the urgent need for sustainable energy practices to address these concerns. While technological advancements can help mitigate some of these problems, others require a fundamental rethinking of energy practices with a focus on sustainability. Sustainable energy is defined as "meeting present energy needs without compromising the ability of future generations to meet their own needs" (Ediger, 2009). The idea of sustainable energy involves ensuring environmental protection while providing energy in sustainable, reliable and affordable ways. To achieve sustainability of global energy systems, there are efforts to shift from heavy reliance on fossil fuels to increasing the share of clean and renewable energy sources, i.e., hydro, solar and wind (Köne & Büke, 2007). This transition is unlikely to happen without a significant investment in renewable energy development, particularly in countries that are rapidly expanding their energy systems (Harris, 2003).

At the UN level, these issues were addressed with the designation of the year 2012 as the International Year of Sustainable Energy for All and the declaration of 2014–2024 as the Decade of Sustainable Energy for All (SE4All). The SE4All Initiative set three interconnected goals on access to modern energy services, improvement of energy efficiency, and increasing the share of renewables to be achieved by 2030 (Vezzoli et al., 2018).

SDG 7 under 2030 Agenda is a continuing effort to SE4All, Similar to SE4All, SDG 7 aims to ensure access to modern, reliable, sustainable, affordable energy for all. Under SDG 7, five targets are set, covering four main themes. The first of the four main themes is based on ensuring the equitable distribution of energy, access to clean energy and energy security. The second theme aims to increase the share of renewables in energy production and gradually reduce the share of fossil fuel use in the energy portfolio. The third theme, energy efficiency, underlines the aim of increasing efficiency in all areas of energy use. The final theme is to enhance access to technology and investment in clean energy, with a focus on increasing international financial support for developing countries to advance clean and renewable energy (United Nations Department of Economic and Social Affairs [UNDESA], 2024).

While SDG 7 highlights the importance of energy transitions, its implementation remains loaded with challenges. Critics argue that the emphasis on universal energy access and increasing renewables often overlooks the environmental trade-offs associated with energy production and consumption such as hazardous e-waste from batteries, digital devices, and solar panels (Sovacool et al., 2020).

Renewable energy is frequently proposed as the cornerstone of sustainable energy systems. However, it is not without limitations. Challenges such as intermittency in power generation from solar and wind sources, dependency on critical minerals like lithium and cobalt for battery storage, and the environmental impact of large-scale installations present significant obstacles (Kozechko & Kozechko, 2024). Critics argue that these issues can undermine the long-term sustainability of renewable energy systems, particularly in regions where infrastructure and resource constraints limit adaptive capacities. However, its adoption is not without environmental and social costs. For instance, large-scale solar and wind projects can lead to land-use conflicts, biodiversity loss, and resource extraction challenges (Smil, 2017). Additionally, the reliance on critical minerals for renewable technologies raises concerns about resource dependency and geopolitical tensions. Therefore, establishing robust and resilient supply chains of clean energy is crucial, particularly concerning critical minerals (IEA, 2021c).

2.6 Chapter Review

The theoretical framework provided in this chapter underscores the multidimensional and evolving nature of sustainable development. Drawing from the widely accepted Brundtland definition, sustainable development integrates three critical dimensions: economic, environmental, and social. These dimensions are inherently interdependent but often create trade-offs that complicate policy and implementation. For instance, balancing renewable energy adoption with its associated socioeconomic costs highlights the challenges of reconciling long-term ecological sustainability with immediate economic and social demands (Becker, 2023; Harris, 2003).

The chapter critically examines the theoretical debates surrounding sustainability, including weak and strong sustainability. Weak sustainability's emphasis on substitutability between natural and human-made capital contrasts sharply with strong sustainability, which underscores the irreplaceable value of natural capital

(Howarth, 1996; Daly, 1994). These debates illuminate the limitations of conventional economic frameworks, such as the Environmental Kuznets Curve (EKC), which has been critiqued for oversimplifying the complex interactions between economic growth and ecological degradation (Stern, 2004). Other sustainability paradigms, including degrowth and ecological economics, challenge the traditional growth-centric model. Degrowth advocates emphasize reducing consumption and production in high-income societies to enhance ecological resilience and social equity (Jackson, 2009; Kallis, 2011). This contrasts with neoclassical economics' utility-maximization approach, which prioritizes efficiency but often undervalues environmental and social externalities (Harris, 2003).

Alternative theoretical models provide diverse approaches to addressing sustainability concerns, from green growth to low carbon development, each presenting unique advantages and limitations. Key approaches include Green Growth, which promotes economic expansion without environmental degradation but faces criticism over the feasibility of absolute decoupling (OECD, 2011; Hickel & Kallis, 2020); Green Economy, which emphasizes human well-being and social equity but is critiqued for relying on market-driven solutions (UNEP, 2011; Jacobs, 2012); Low-Carbon Economy, which focuses on reducing emissions while maintaining stability but struggles with structural fossil fuel dependency (Stern, 2007; Hickel & Kallis, 2020); and Low-Carbon Development, which integrates climate action into economic policies but raises concerns about potential growth limitations in developing nations (Du et al., 2020; Sheng & Lu, 2016). Doughnut Economics provides a balance between human needs and planetary boundaries but faces implementation challenges due to varying national priorities (Raworth, 2017; Warnecke, 2023). Regenerative Development aims to restore ecosystems rather than merely reducing harm (Mang et al., 2016; Dias, 2018). Despite these frameworks, sustainability efforts often fall short due to policy implementation failures driven by economic incentives that favor resource exploitation, limited government capacity, and political inaction (Howes et al., 2017; Fiorino, 2010). Developing nations, in particular, face barriers such as dependency on natural resources, external funding, and technology constraints, requiring tailored strategies for effective sustainability transitions (Sovacool et al., 2020).

Likewise, energy sustainability remains a pivotal issue nearly in all sustainability perspectives demanding transitions towards renewable resources, energy efficiency, and equitable energy distribution.

Energy is central to sustainable development as it underpins economic and social progress, yet it is also a major driver of environmental degradation. Historically, industrialization and technological advancements have increased energy demand, leading to energy security concerns and reliance on fossil fuels (Dincer & Abu-Rayash, 2020). This has resulted in greenhouse gas emissions, pollution, and climate change, making the transition to sustainable energy essential (Bilginoğlu, 1989; Çoban & Şahbaz Kılınç, 2016). Sustainable energy aims to balance environmental protection with reliable and affordable energy access, requiring a shift toward renewables like solar, wind, and hydro (Köne & Büke, 2007). Global initiatives, such as the Sustainable Energy for All (SE4All) Initiative and SDG 7, promote energy accessibility, efficiency, and the expansion of renewables, though challenges remain (UN, 2015; Vezzoli et al., 2018). Critics highlight the environmental trade-offs of renewable energy, including resource dependency, intermittency issues, and the geopolitical implications of critical minerals (Sovacool et al., 2020; Kozechko & Kozechko, 2024). Despite these challenges, investing in resilient clean energy infrastructure and supply chains is essential for achieving global sustainability goals (IEA, 2021c; Harris, 2003).

As global economies continue to evolve, the adoption of comprehensive, adaptive, and inclusive sustainability frameworks will be essential to mitigating climate change, fostering economic resilience, and ensuring social equity. Future research and policy efforts should focus on refining sustainability approaches and metrics, improving policy integration, responding the needs of developing world and advancing technological innovations especially in clean energy and sustainable consumption patterns to safeguard a balanced and sustainable future for all.

In conclusion, this chapter establishes the theoretical foundation for analyzing sustainability policies and practices. It highlights the importance of adopting holistic and adaptive approaches to navigate the inherent trade-offs among economic, environmental, and social objectives. This foundation sets the stage for analyzing how these theoretical constructs are applied in practice in the next chapters, particularly in the analysis of sustainability strategies within national contexts in the Chapter 3, evaluating energy policies in Chapter 4 and development of an energy sustainability index in Chapter 7.

CHAPTER 3

EVOLUTION OF SUSTAINABILITY IN THE DEVELOPMENT STRATEGIES OF TÜRKİYE

Considering the theoretical framework presented in Chapter 2, this chapter explores the progression of sustainability within Türkiye's development strategies by analyzing National Development Plans (NDPs) covering the period from 1963 to 2024. It examines the incorporation of sustainable development principles into these policies, emphasizing significant milestones.

In Türkiye, National Development Plans are the main development policy documents including sustainable development strategies and priorities. NDPs form the main framework for the Turkish economy, reveal the measures for industrialization and realization of economic and social development, and determine state policies. NDPs are typically prepared for a five-year period using a comprehensive and inclusive planning approach considering long-term goals and maintains inter-sectoral balance. During the preparation works of NDPs, ad-hoc committees, namely Special Expertise Committees, are formed to collect inputs from experts from public institutions, NGOs, academia, international organizations. These committees are the main ways to incorporate economic and social policy perspectives, recommendations, and targets of diverse stakeholders into the NDPs.

Since 1963, when the first NDP entered into force, 12 development plans have been implemented. In 1962, 1978, 1984, 1995 and 2006, one-year Transition Year programs are also applied. The last and the current one is the Twelfth Development Plan (2024-2028) adopted by the Grand National Assembly of Türkiye on 31 October 2023 (Official Gazette, 2023).

As the concept of sustainability was recognized globally in 1990s, progress of sustainability in Türkiye's development policy environment can be examined in two phases 1963-1990 and 1990-today within the framework of economy-environment-society interactions in the NDPs.

3.1 Development Plans from 1963 to 1990

In this period, the basic components in almost all development plans were to increase the activities of industrialization and modernization of agriculture, to advance the services sector, and to provide a sustainable economy in the long term, so that the country can reach the development targets without the assistance of foreign resources.

The "environment" issue was not addressed as a fundamental objective in the First NDP (1963-1967). However, some components of the environment were evaluated under sectors as the development of water and soil resources, drinking water and sewage. In the First NDP, protection of soil resources from erosion (water and wind) was determined as a priority, it was stated that measures should be taken to prevent pollution of air caused by the lignite used in homes, and it was foreseen to take measures in this area by emphasizing the importance of cleaning services of municipalities in improving environmental health (Devlet Planlama Teşkilatı [DPT], 1963).

In the Second NDP (1968-1972), environmental issues were elaborated under the health sector, which is a component of the "Safety Development and Welfare of the Society" in the form of improving environmental health conditions, efficient use of water and soil resources and prevention of erosion, supply of drinking water. Issues such as the expansion of sewerage were mentioned in the development of water and soil resources, public and municipal services sectors (DPT, 1967).

In the First and Second NDPs, it was stated that making efforts in line with the principles of social justice and equity of opportunities to ensure balanced interregional development rather than increasing the physical welfare of the society as measured by the amount of consumption will ensure the fast growth of the Turkish economy and increase the welfare of future generations (Talu, 2007).

In the Third NDP (1973-1977), ecological problems were elaborated in a separate and broad section for the first time, and measures were taken regarding these problems. In the Plan, social and economic development was seen as the way to reach a social structure that could sustain human-environment relations in a rational balance, and it was accepted as a basis to solve environmental problems without isolating from industrialization and development and adversely affecting the funds allocated for development (DPT, 1972).

In the Fourth NDP (1979-1983), principles were included to take the environment into account in urbanization, industrialization and modernization of agriculture. In addition, the issue of authorizing local administrations on environmental issues was brought to the agenda in the Fourth NDP. In this Plan, the policies for the prevention of environmental problems before they occur are emphasized for the first time (DPT, 1978). The publication of Environmental Law No. 2872, which entered into force in 1983, coincided with this Plan period (Official Gazette, 1983).

The Fifth NDP (1985-1989) was a plan in which “pollution prevention” more broadly considered together with some preliminary aspects of sustainability in the development policies. In this respect, evaluations were made not only to eliminate the existing pollution and prevent pollution, but also to create new policies to safeguard that forthcoming generations can benefit from the resources. Apart from these, protection of the environment was also aimed specifically in energy, tourism, and investment policies of the Plan (DPT, 1984).

3.2 Development Plans from 1990 to 2024

Since the 1990s, principles of sustainable development have begun to be included in the development plans of the relevant periods at various levels and in the sectoral policy and strategy documents. Upon the recognition of sustainable development in the international arena in 1987, its reflection was seen in the NDPs starting with the sixth one.

In the Sixth NDP (1990-1994), the following main principles of the Plan was defined: “Preventing the wastage of human and natural resources and taking the protection of the environment as a basis in the implementation of economic and social activities” and “Industrialization, urbanization and agricultural modernization policies will be implemented in a way that protects the social, cultural and ecological structure, prevents environmental pollution and ensures intersectoral economic balance”. One of the key features of the Plan is that it is foreseen in the Plan to give incentives to those who will invest in environmental pollution prevention as a significant connection between environment and economy. Moreover, sustainability issues like environmental pollution prevention and energy saving are emphasized in the framework of the incentive policy. In the Sixth NDP, many measures supporting environmental sustainability are included in the Plan’s goals and policies of the main economic and social sectors such as energy, manufacturing industry, mining, automotive, tourism, land use planning and health (DPT, 1990).

The Seventh NDP (1996-2000) on the other hand, had strong emphasis on sustainability and clearly mentioned sustainable development approach. In the Plan, in line with the sustainable development approach, the significance of the amalgamation of environmental considerations into economic and social policies was emphasized and the main structural transformation areas were identified as Increasing Efficiency in the Economy, Industry and the World, Integration with Agriculture, Development of Human Resources, Protecting and Improving the Environment and Ensuring Regional Balances (State Planning Organization [SPO], 1995).

In the “Protection and Improvement of Environment” section of the Seventh NDP, the fundamental strategy is outlined as managing natural resources in a manner that supports ongoing economic development while safeguarding human health and maintaining natural balance, with the goal of preserving a suitable physical, social and natural environment for future generations. Instead of passive approaches that consider pollution as an inevitable result of the development process and try to treat this pollution, priority has been given to strategies to pollution prevention with the measures to be taken. In addition, the measurement of sustainable development came to the fore and a measure was defined to start the efforts to internalize the development and environmental protection aspects in the national income accounts. In addition to the comprehensive policies on protection and improvement of environment, sustainability policies have been developed in many sectors such as tourism, industry, transportation, urban infrastructure, agriculture, forestry, regional development and land use planning, health, population and family planning (SPO, 1995).

In the Eighth NDP (2001-2005), the main purpose of the plan was defined as accelerating the integration with the world and rising the quality of life of the people in the perspective of European Union membership as Türkiye gets a larger share from the world income. The primary objective is to achieve continuous growth throughout the Plan period. The long term strategy of the Plan prioritizes sustainable development by fostering a competitive economic structure (SPO, 2000). In the Plan, it is seen that the measures to be taken regarding the environment are associated with increasing the competitiveness of the economy for the first time. This situation became clearer in the Ninth NDP.

In fact, when the macroeconomic targets, forecasts and policies of the Eighth NDP are examined in detail, the place of adopted environmental policies in sustainable growth policies is clearly seen. In the “Environment” section of the Eighth NDP, “preserving human health, ecological balance, historical and aesthetic values while realizing economic and social development” has been determined as the basic principle. It has been established as a guiding principle that the policies and strategies developed to address environmental issues in the medium and long term should align with EU norms and international standards, while taking into account the country's national circumstances. Measures have been set for the production of sustainable development indicators, the use of economic tools in the incorporation of environmental concerns into economic and social policies, and the sustainably utilize natural resources and biological diversity. In the Eighth NDP, principles and policies of sustainable development were introduced in many sectors such as the development of human resources, rural development, energy, agricultural development, and urbanization (SPO, 2000).

The Ninth NDP (2007-2013) has been prepared in such a way that it prioritizes the challenges by observing the macro balances and sets strategies, targets within this framework and shapes the institutional and structural arrangements in a way that will allow the markets to function more effectively. Unlike other development plans, the Ninth NDP was prepared for a seven-year period. While determining the Plan's structure, execution approach and time period, Türkiye's future development strategy has been considered that the approximation with European Union's legal, institutional and, more importantly, financial structures. The Plan includes the principle of "protecting natural and cultural assets and the environment with an understanding that takes into account future generations" for the development of sectoral policies. The Ninth NDP includes sustainable development related policies especially in environment, agriculture, tourism, industry, fisheries and social inclusion sectors (SPO, 2006).

In reaching the development goals of the Ninth NDP; establishing multifaceted and cross-relationships between macro policies, regional development policies, sectoral programs and investments, and defining the main strategic objectives with "development axes" shows that it has an integrated perspective as well. With the disappearance of the clear distinction made as "economic sectors" and "social sectors" in the previous Development Plans, it is seen that the environmental problem has been prevented from being included in the "social sectors" in the

Development Plans for years, and a step forward has been achieved in terms of integration of sustainable development principles (Talu, 2007).

Türkiye's Tenth NDP (2014-2018**)** targets sustainable development by emphasizing inclusive, stable and high economic growth. It also prioritizes human development, the rule of law, the information society, protection of environment, sustainable use of resources and international competitiveness. The Tenth NDP emphasizes that the purpose of development is to achieve lasting improvements in people's well-being, enhance living standards, and create a fair, safe, and peaceful living environment by upholding fundamental rights and freedoms. The Plan explicitly states that "the Tenth Development Plan has been prepared with a sustainable development focus" (Republic of Türkiye Ministry of Development [MoD], 2014).

Considering the global environmental challenges such as pollution, climate change, desertification, and water scarcity and the results of United Nations Conference on Sustainable Development (Rio+20), the Tenth NDP adopts a "green growth" approach as a strategy to integrate environmental protection with economic competitiveness, focusing on clean and eco-efficient production. Key sectors such as agriculture, tourism, energy, transportation, and urbanization are prioritized for their potential to adopt environmentally sensitive practices and create sustainable growth opportunities. This approach promotes innovation and transformation in industries, particularly through research and development (R&D) of clean technologies and green products with high value addition. Public procurement is highlighted as a tool to encourage green manufacturing and support domestic firms in adopting sustainable practices. The plan also stresses the need for policy designs that internalize environmental costs, fostering a shift toward sustainable production and consumption patterns (MoD, 2014).

Tailored to the national context, social inclusion is also a central element of green growth, ensuring that the benefits are shared across all societal segments. Equal opportunities, poverty reduction, and improved access to public services are emphasized to create a fair and equitable transition. Protecting biodiversity and sustainably using natural resources are also integral to the strategy, reflecting Türkiye's commitment to global environmental responsibilities under the principles of "common but differentiated responsibilities" and "respective capacities." (MoD, 2014).

Sustainable development is included as one of the dominant themes in the Eleventh NDP (2019-2023). The Plan continued to follow the green growth approach in its national development strategy. Acknowledging its vulnerability to climate change due to geographical positioning, Türkiye emphasizes developed policies aimed at promoting green growth, limiting emissions, and improving resilience to climate impacts. The Eleventh NDP incorporates green initiatives such as the establishment of a National Green Building Certificate System, which encourages eco-friendly building practices, and Green Port applications to enhance energy efficiency and minimize environmental impacts in port operations. The Plan also underscores the importance of sustainable and integrated natural resource management while promoting environmental awareness and sensitivity across all segments of society (Presidency of the Republic of Türkiye Presidency of Strategy and Budget [PSB], 2019).

Adopted after the SDGs, in the Eleventh NDP, development policies and strategies are formulated in line with the SDGs. There has been a specific part designated for SDGs. In this part, the main objective of the Eleventh NDP regarding SDGs is to reflect SDGs in line with national priorities and to set up an operational follow-up and review mechanism (PSB, 2019). In this respect, the polices and related measures are defined as follows:

- "SDGs will be reflected in sectoral and thematic policy documents in line with national priorities and conditions.
    - Alignment with the SDGs will be considered in the preparation of institutional strategic plans and sectoral and thematic policy documents.

- A well-functioning and participatory institutional coordination mechanism will be established for the follow-up and review of SDGs.
    - In order to ensure the follow-up and review and the coordination of SDG implementation at national level, the National Sustainable Development Coordination Board will be established under the Presidency of Strategy and Budget in a flexible structure for the participation of representatives of local administrations, academia, private sector and NGOs in addition to related public institutions.
- In line with the development of global SDG indicator set, the scope of the national indicator set will be expanded in line with the priorities.
    - National sustainable development goals monitoring and evaluation system will be established." (PSB, 2019).

During the Eleventh NDP period, the National Sustainable Development Coordination Board was established, and an SDG portal was made online by Turkish Statistical Institute that can be seen as the concrete actions on sustainable development (Official Gazette, 2022; TURKSTAT, 2022).

The Twelfth NDP (2024-2028) is the latest and current development plan being implemented by Turkish Government. The Twelfth NDP places significant emphasis on sustainable development by integrating green and digital transformation into its national strategy. The plan prioritizes competitive production through green technologies, renewable energy adoption, and energy efficiency, particularly in sectors such as manufacturing, energy, agriculture, and transportation sectors (PSB, 2023).

In this Plan, "green growth" is specifically mentioned as an approach for addressing climate change mitigation and adaptation. Aligning with international climate goals, including the Paris Agreement and the European Green Deal, the Plan aims to promote emission reductions, circular economy practices, and sustainable production methods. Environmental protection is another critical priority, with an emphasis on SDGs. The objective of Environmental Protection section of the Plan is set as “In accordance with the Sustainable Development Goals (SDGs), the main objective is to ensure a climate resilient transition towards a low-carbon economy, to protect and manage the environment and natural resources with an understanding of social justice, and to increase public awareness towards the environment”. The Twelfth NDP also highlights the importance of green financing mechanisms and R&D investments to accelerate innovation in clean technologies and environmentally friendly practices, reducing dependency on imported technologies. The plan also underscores inclusive and equitable growth by addressing social justice and reducing disparities (PSB, 2023).

In the Twelfth NDP, SDGs have been accepted as a key framework guiding Türkiye’s human-centered development efforts, aligning the country with the global agenda for inclusive and holistic progress. Similar to the Eleventh NDP, a separate section is designated to SDGs in addition to the sectoral policy integration. The main objective on SDGs is to improve the effectiveness of coordination, review, and follow-up processes by ensuring practices that implement them through a participatory approach (PSB, 2023). Related policies and measures are defined as follows:

- “Review and follow-up process of the SDGs will be continued effectively and regularly, and progress regarding implementation will be tracked.
    - The Third National Voluntary Review Report will be prepared to comprehensively assess Türkiye’s progress towards the SDGs within the context of the policies and programs implemented.
    - The National Sustainable Development Council will regularly conduct assessments of the implementation process of the SDGs and make recommendations.
    - An interactive SDG mapping will be developed to evaluate the progress levels of the SDGs, and it will be ensured that this is taken into consideration in decision-making processes.

    - The generation of indicators not yet available within the national SDG indicator framework will be provided, with an emphasis on enhancing the level of data disaggregation and improving the quality of such data.
- Collaboration with local authorities will be established to support the implementation, monitoring and evaluation of the SDGs at the local level.
    - The number of voluntary local review reports prepared by local governments will be increased." (PSB, 2023).

As it covers mostly the last period of SDGs, the Twelfth NDP would be an important leverage for Türkiye in progress to the SDGs by addressing the dimensions of sustainable development in a balanced, integrated and holistic manner.

3.3 Chapter Review

This chapter evaluates the historical progress of sustainable development integration within Türkiye's national development plans (NDPs), reflecting global advancements in sustainability discourse. Türkiye's NDPs have served as foundational documents guiding the country's economic, social, and environmental policies. Early plans primarily focused on industrialization and economic growth, while later iterations, especially after 1990s, increasingly integrated sustainability principles. This progress has been going parallel to the international trends initiated by the Brundtland Report and the subsequent adoption of SDGs (Brundtland, 1987; UN, 2015).

The NDPs from 1963 to 1990 reflected the developmental priorities of a rapidly industrializing nation, with limited focus on environmental sustainability. Early plans recognized environmental issues only as secondary concerns, often addressing them through sector-specific approaches. Notable progress began with the Sixth NDP (1990-1994), which introduced environmental protection as a key policy goal. This marked a significant shift towards integrating ecological considerations within development frameworks. Later in the Seventh NDP, adoption of sustainable development principles was a milestone in progress on sustainability (SPO, 1995).

Subsequent plans, such as the Tenth NDP (2014-2018), adopted more comprehensive approaches to sustainability, emphasizing green growth and integrated strategies for sustainable resource management (MoD, 2014). These plans also prioritized policy mechanisms for climate change mitigation, renewable energy adoption, and biodiversity conservation, reflecting a strong alignment with international climate goals.

The Eleventh NDP (2019-2023) marked a significant alignment with the SDGs, dedicating a specific section to their implementation. Policies under this plan emphasized participatory mechanisms, institutional coordination, and the development of a national indicator framework for monitoring SDG progress. The establishment of the National Sustainable Development Coordination Board and the launch of an SDG portal by TURKSTAT represented concrete steps toward achieving these goals (PSB, 2019).

Finally, the Twelfth NDP (2024-2028) builds on previous efforts, focusing on enhancing the effectiveness of SDG coordination, review, and follow-up processes. It emphasizes participatory approaches, the generation of disaggregated data for improved monitoring, and collaboration with local authorities to ensure comprehensive SDG implementation at the local level (PSB, 2023).

By examining the historical trajectory and current dynamics of Türkiye's development strategies, Chapter 3 provides a comprehensive understanding of the country's efforts to balance economic, environmental, and social objectives, highlighting key milestones and shifts toward sustainable development policies. This analysis establishes a foundation for exploring energy sector strategies and policy interventions in Chapter 4, offering critical insights into how sustainable development goals can be operationalized effectively.

CHAPTER 4

SUSTAINABILITY OF ENERGY SECTOR IN TÜRKİYE

Chapter 3 explored the integration of sustainability within Türkiye’s national development strategies by conducting a detailed analysis of twelve NDPs spanning from 1963 to 2024. Building upon these insights, Chapter 4 provides a comprehensive analysis of Türkiye’s energy sector, exploring trends in energy production, consumption, and import dependency. It further examines the integration of domestic energy resources into the energy mix. Additionally, the chapter evaluates Türkiye’s energy-related international relations and national energy policies and strategies, highlighting their role in advancing sustainable development.

Türkiye is an upper middle-income country according to World Bank classification and experiencing a rapid development with rising employment and income. Türkiye’s gross domestic product (GDP) per capita increased from $12,536 in 1990, to $14,839 in 2002 and to $33,150 in 2022 (Figure 4.1) (World Bank, 2024a).

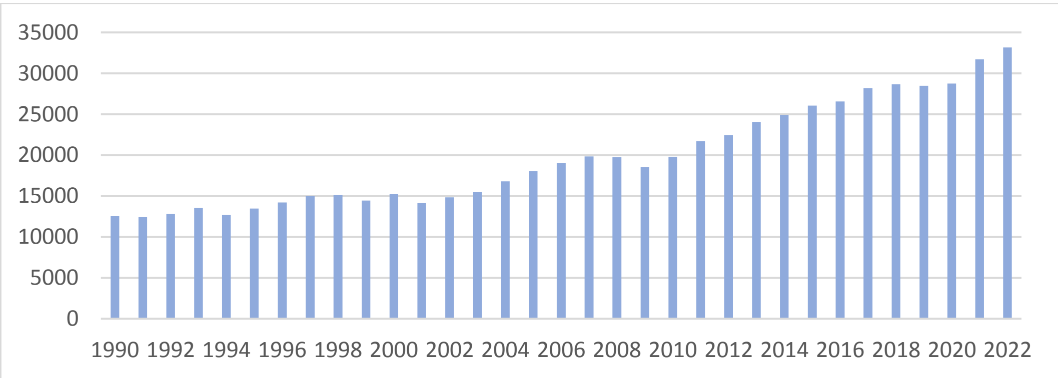


Figure 4.1. GDP per Capita of Türkiye, PPP (constant 2017 international $)

Source: World Bank (2024a).

In 2022, Türkiye is the world's 19th largest economy considering the GDP in current prices ($906 billion). The GDP growth rate (annual) increased from 0.8% in 2008 to 5.5% in 2022 (Figure 4.2), (World Bank, 2024a).

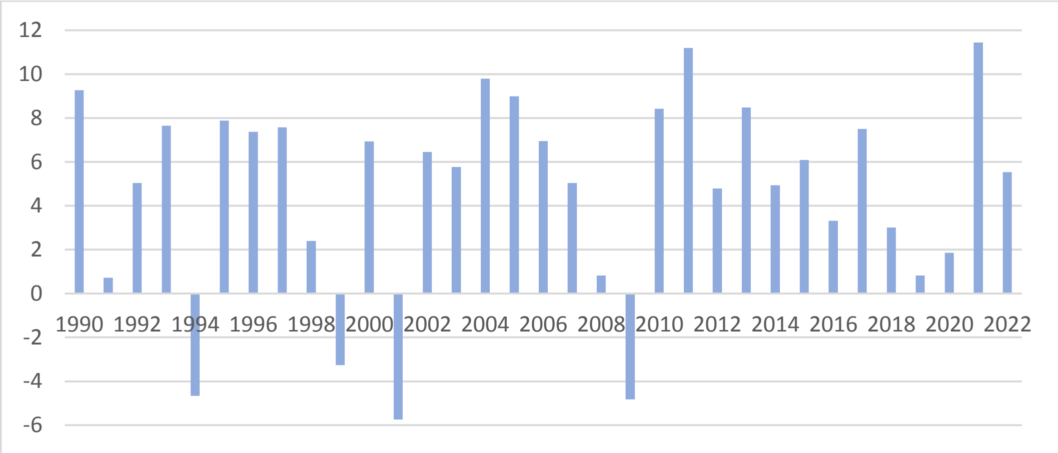


Figure 4.2. Annual GDP Growth Rate of Türkiye, (%)

Source: World Bank (2024a).

Türkiye's economy is transitioning from an agriculture-based economy to one focused on the industrial and services sectors. By 2022, the services sector occupied 55.6% of the employment, while agriculture and industry employed 16.7% and 27.7%, respectively (Figure 4.3) (World Bank, 2024a).

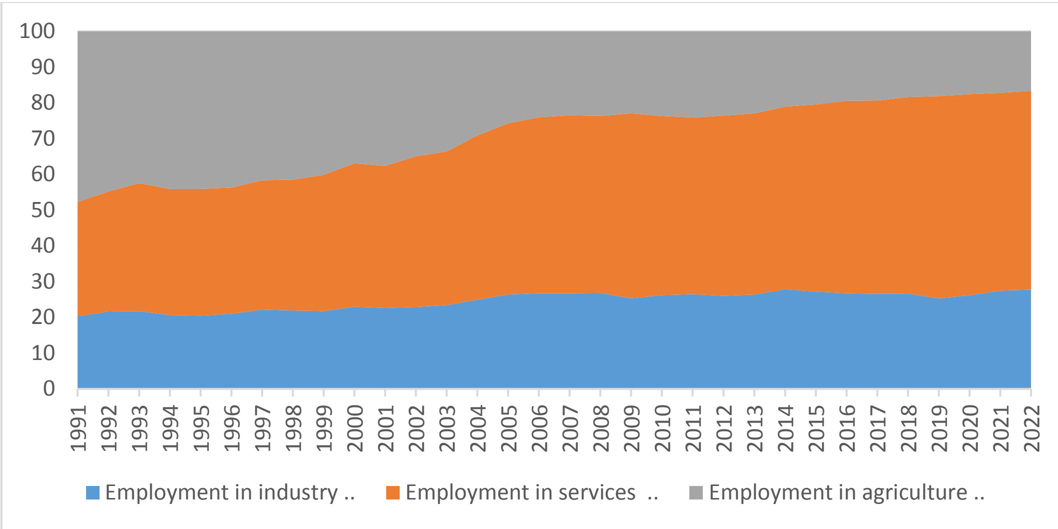


Figure 4.3. Sectoral Employment, Türkiye, (% of Total Employment, modeled ILO estimate)

Source: World Bank (2024a).

Türkiye has diverse natural resources, though few are found in large quantities. While the country has significant coal deposits, it remains heavily reliant on imported oil and gas. However, Türkiye is expanding its energy partnerships internationally and is working to increase the use of domestic energy sources, including renewables, coal, and nuclear. Considering its geostrategic position, Türkiye aims to become a key trading hub for energy between Europe, Russia, the Middle East, Central Asia, and other markets (IEA, 2021a).

Supplying safe and sustainable energy, which is the essential input of socioeconomic development, with competitive costs and minimizing the impact of energy on household budget, industry costs and current account deficit is the main goal for Türkiye (Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2014).

Türkiye’s energy strategy emphasizes energy supply security due to its reliance on gas and oil imports. Key aspects include enhancing domestic exploration and production, diversifying supply sources and infrastructure. Increasing renewable energy production and improving energy efficiency are also significant components of this strategy. Regarding natural gas supply, Türkiye has notably expanded its options through new discoveries, pipelines, liquefied natural gas (LNG) terminals, and storage capacity (IEA, 2023a).

Türkiye's energy mix has been diversified with renewables considerably in the past decade. With the completion of the construction of Türkiye's first nuclear power plant (NPP), the first unit of which planned to be commissioned in 2025, country's energy mix will be further diversified (Anadolu Agency, 2024). Continuation of this trend will be advantageous for decreasing greenhouse gas (GHG) emissions supporting the energy sector's decarbonization.

4.1 Energy Sector in Türkiye

Energy sector in Türkiye is depicted according to the supply and consumption figures in the following sections.

4.1.1 Primary Energy Supply

Energy system of Türkiye is predominantly based on fossil fuels, which constituted 81.2% of the total primary energy supply (TPES) in 2022 and 73.2% of total final consumption (TFC) in 2021. The remainder of the energy sources consists of geothermal, hydro, wind, and solar power. While Türkiye imports approximately all its natural gas and oil, 47% of coal and all renewable energy sources are produced domestically. In 2022, domestic energy production covered 31.9% of TPES. Since 1990, renewable energy production has nearly tripled from 404,362 TJ to 1,202,854 TJ in 2022, with substantial growth in geothermal, hydro, wind, and solar energy, though the use of traditional bioenergy for residential heating has decreased (IEA, 2024a).

Türkiye's energy supply has consistently expanded to accommodate its rapidly growing economy. From 1990 to 2022, the TPES increased by 198% (Figure 4.4). Fossil fuels have consistently dominated TPES, maintaining a share of no less than 81% since 1990 (Figure 4.5). As a recent figure in 2022, fossil fuels accounted for 81.3% of TPES, making it the ninth highest country among IEA members (IEA, 2024a).

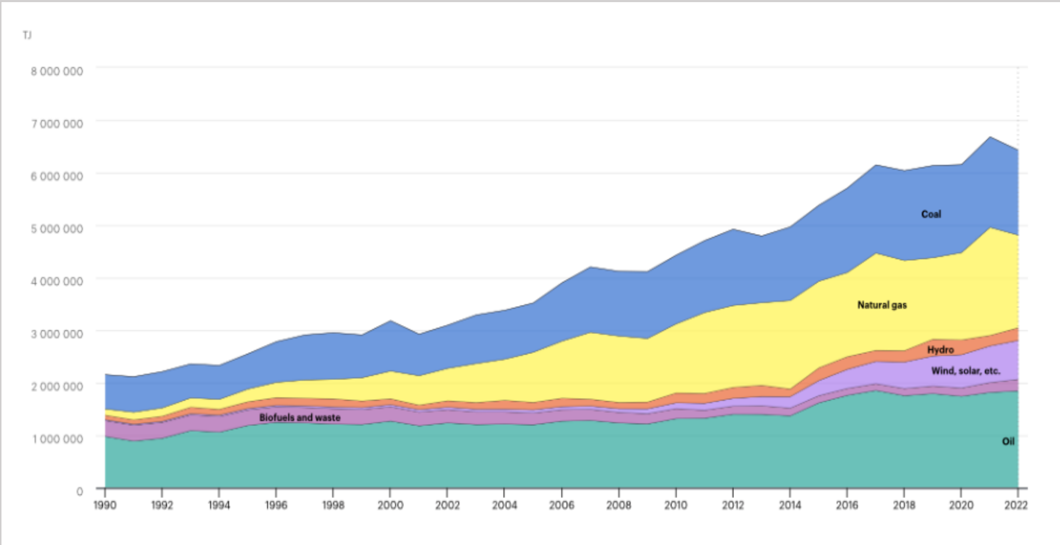


Figure 4.4. Total Primary Energy Supply of Türkiye, by Source, (TJ)

Source: IEA (2024a), IEA World Energy Statistics and Balances 2022 (database), www.iea.org/statistics. TES here excludes electricity and heat trade. Coal also includes peat and oil shale where relevant.

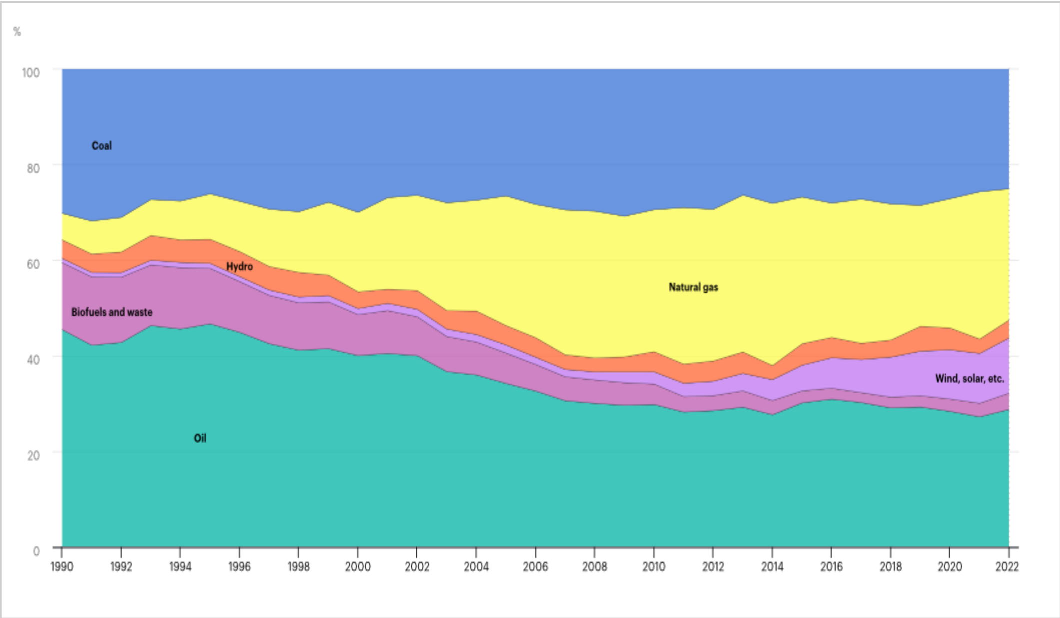


Figure 4.5. Total Primary Energy Supply of Türkiye, by Source, (%)

Source: IEA (2024a), IEA World Energy Statistics and Balances 2022 (database), www.iea.org/statistics. TES here excludes electricity and heat trade. Coal also includes peat and oil shale where relevant.

Industry is the largest energy-consuming sector, with 31.9% of TFC in 2021, followed by transport (26.0%), residential (20.6%) and services (12.2%) and agriculture (4.3%) (Figure 4.6). The industry sector consumes mainly electricity (479,825 TJ), natural gas (461,275 TJ) and coal (356,319 TJ). Oil has the highest share in transport’s energy consumption, though electricity and natural gas stand out in the energy consumption of residential and service sectors (IEA, 2024a).

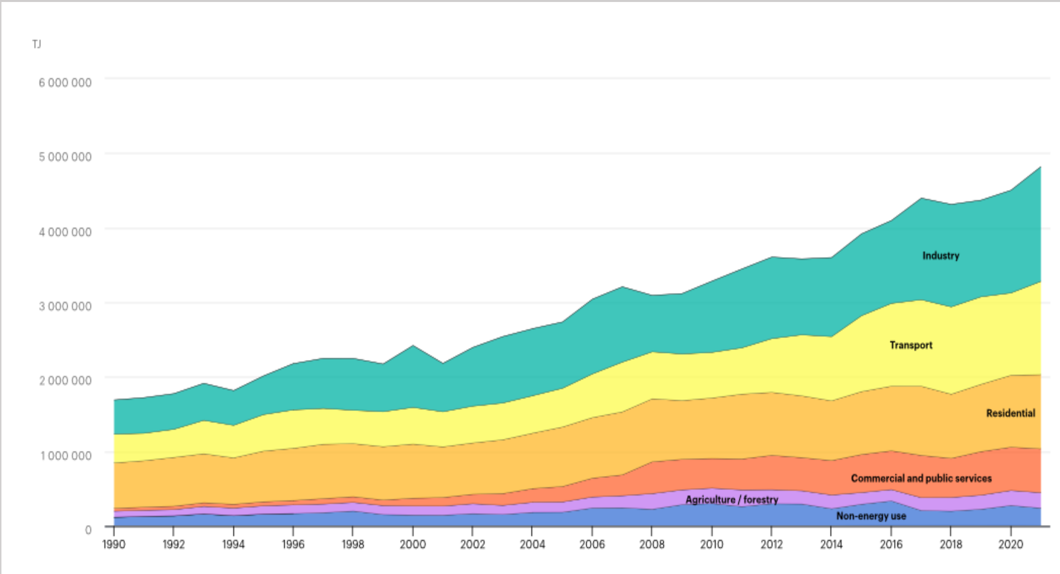


Figure 4.6. Total Final Energy Consumption (TFC) of Türkiye, by Sector, (TJ)

Source: IEA (2024a), IEA World Energy Statistics and Balances (database), www.iea.org/statistics. Electricity imports and exports are not shown in the chart.

4.1.2 Domestic Energy Production Trends and Dependency on Imports

In recent years, domestic energy production in Türkiye has surged, increasing from 1040 PJ (1990) to 2053 PJ (2022) (Figure 4.7). As seen in Figure 4.8, renewable energy sources has a role in this growth and made up 58.6% of total energy production in 2022. Coal production has also risen in recent years, except in 2020 and 2022, and accounted for 33.3% of total energy production in 2022 (IEA, 2024b). Although Türkiye does not yet have an operating NPP, it has initiated a nuclear power program, with the first unit expected to be operational in 2025 (Anadolu Agency, 2024).

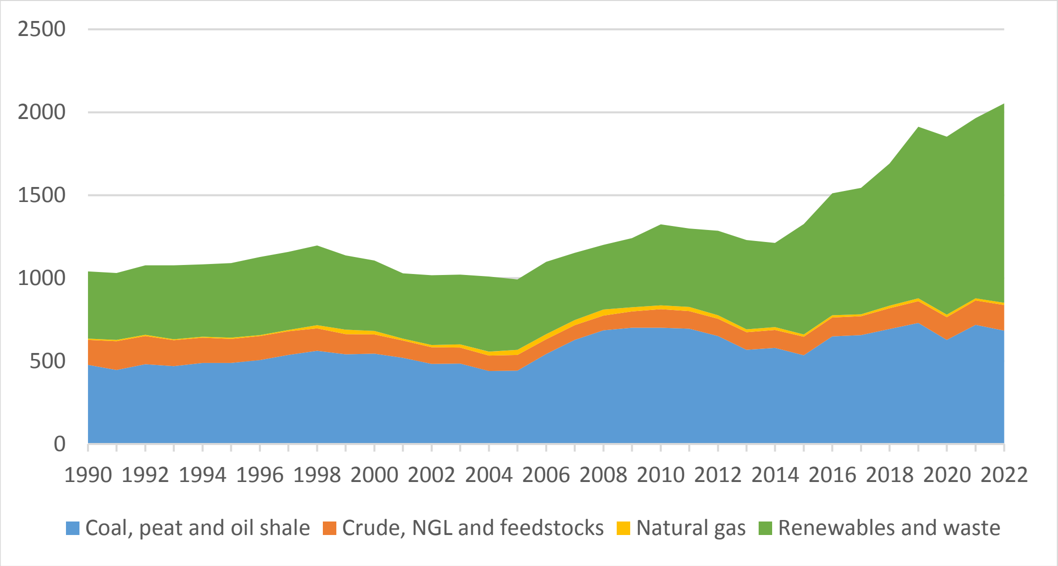


Figure 4.7. Domestic Energy Production of Türkiye, (PJ)

Source: IEA (2024b).

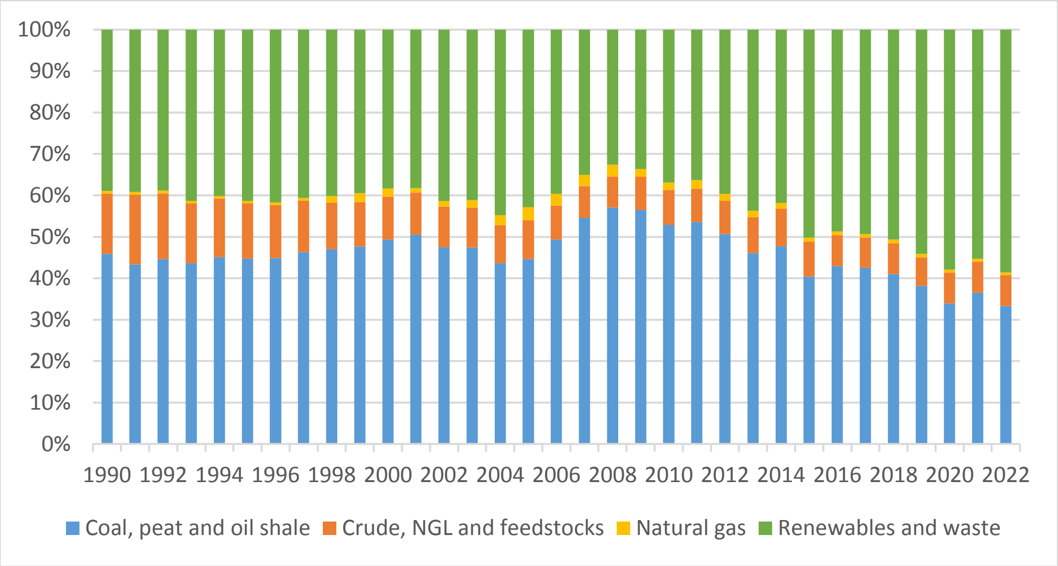


Figure 4.8. Domestic Energy Production of Türkiye, (%)

Source: IEA (2024b).

Despite the fast expansion in domestic energy production as shown in Figure 4.7, Türkiye still remains heavily reliant on energy imports (Figure 4.9). Net energy imports accounted for 73.6% of the total energy supply (TES) in 2022 (Figure 4.10). While this dependency had been decreasing in recent years, it began to rise again after 2020. Almost all of the natural gas is imported, and production of domestic oil makes up only 8% of the total energy supply, including international bunkering. Although domestic coal production has increased, Türkiye still depends on coal imports for 58% of its coal supply (Figure 4.11) (IEA, 2024b).

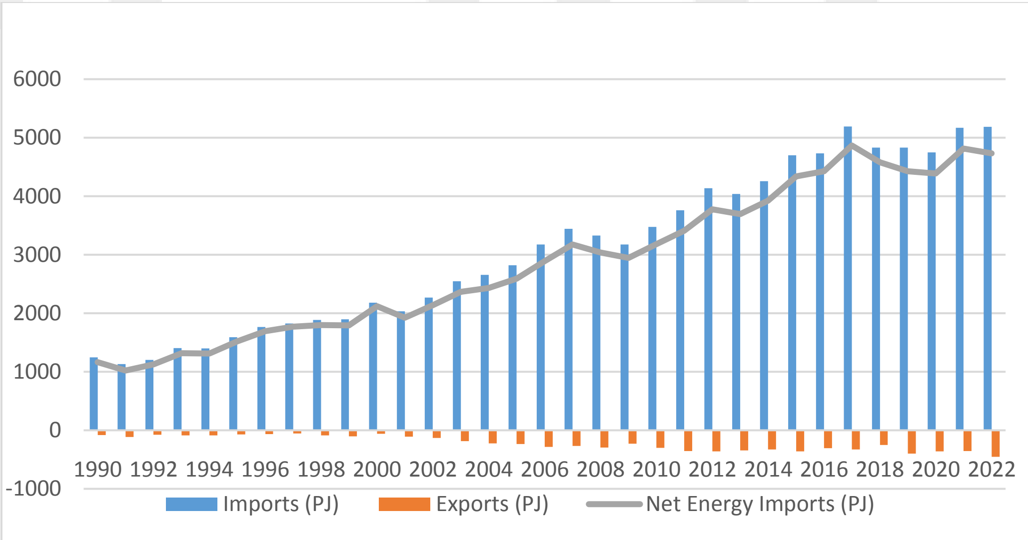


Figure 4.9. Energy Trade of Türkiye (1990-2022)

Source: IEA (2024b).

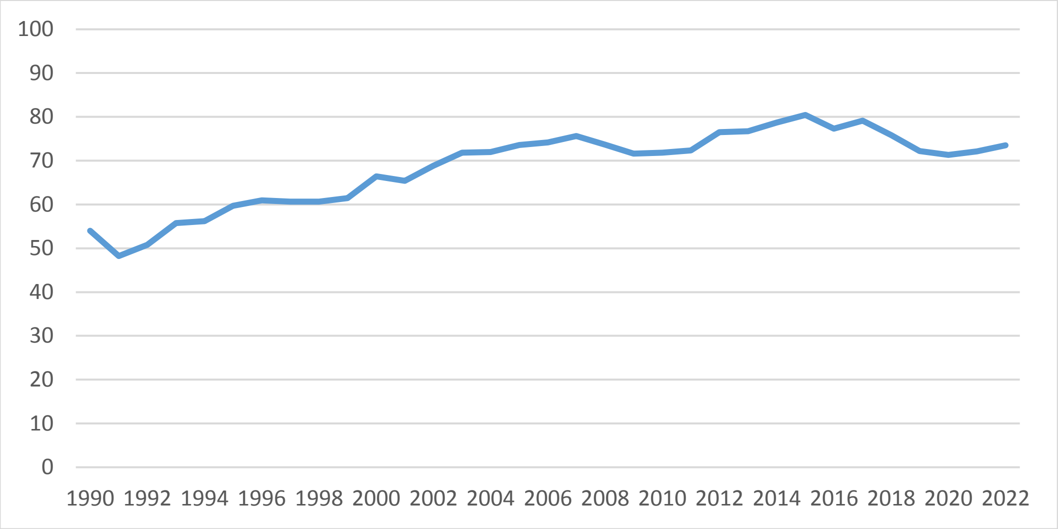


Figure 4.10. Net Energy Imports/TES of Türkiye, (%)

Source: IEA (2024b).

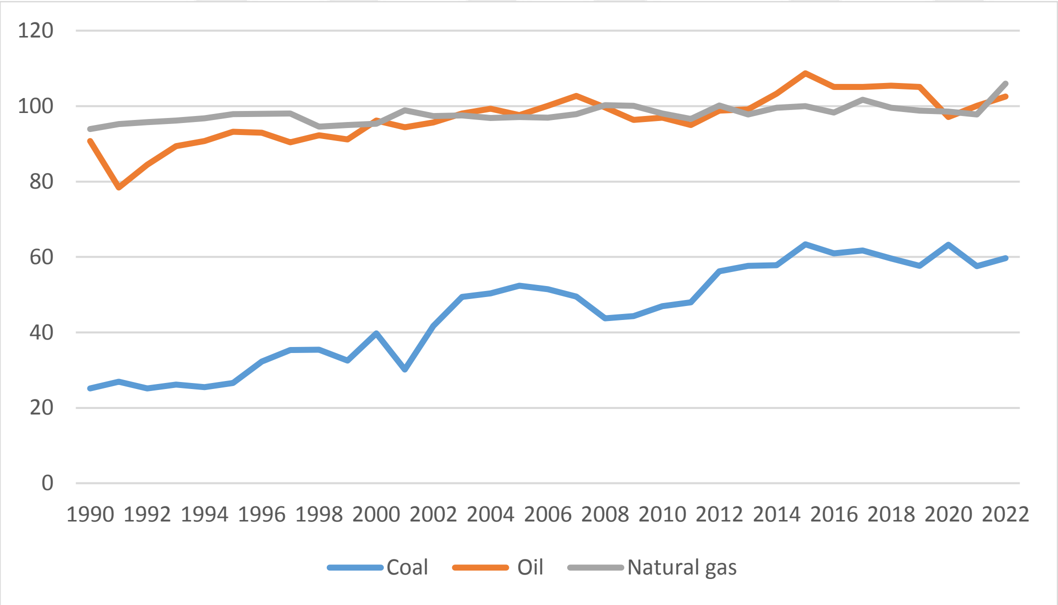


Figure 4.11. Net Energy Imports/Energy Supply of Türkiye, by Fuel Type, (%)

Source: IEA (2024b).

4.1.3 Energy Consumption Trends

In 2021, Türkiye's TFC was 4820 PJ, representing 72.2% of TPES (Figure 4.12). Industry sector has the highest share in TFC of 31.9% in 2021, followed by transport (24.5%), residential (21.4%) and services (17.5%), including agriculture and fishing (Figure 4.13). Türkiye's energy demand has increased 185% since 1990. When looked at the sectors from 1990 to 2021, energy consumption in transport increased by 186%, in industry by 201%, and in services and residential by 145% and 58%, respectively.

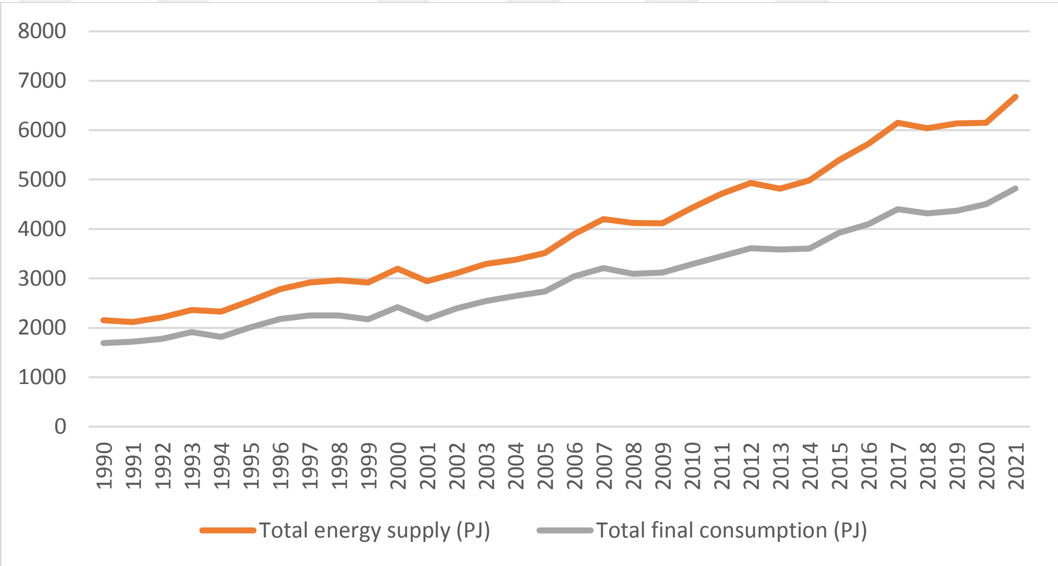


Figure 4.12. Total Energy Supply vs. Total Final Consumption, (PJ)

Source: IEA (2024b).

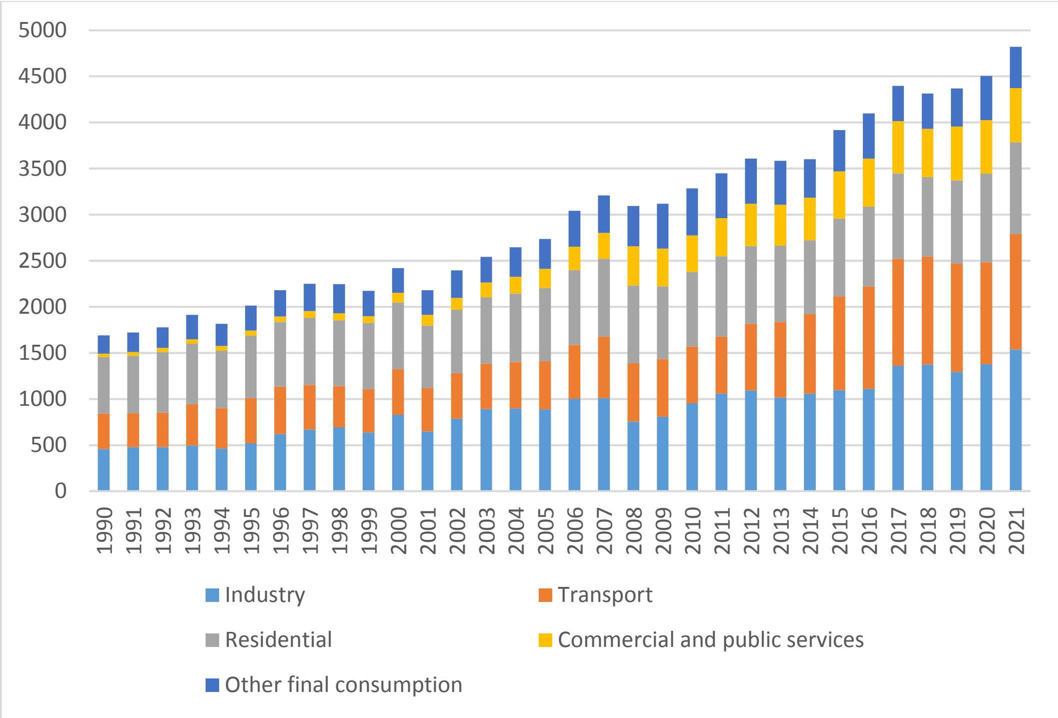


Figure 4.13. Sectoral Total Final Consumptions of Türkiye, (PJ)

Source: IEA (2024b).

When the energy source types in TFC are considered, a blend of oil, gas, coal and electricity is used in industry as shown in Figure 4.14. In the transport sector, oil is the main energy source being consumed, by 98.3% of the consumption in 2021 (Figure 4.15). Natural gas covers more than half of total demand in the residential sector (Figure 4.16). In commercial and public services sectors (including fisheries and agriculture), electricity has the highest share in TFC (Figure 4.17) (IEA, 2024b).

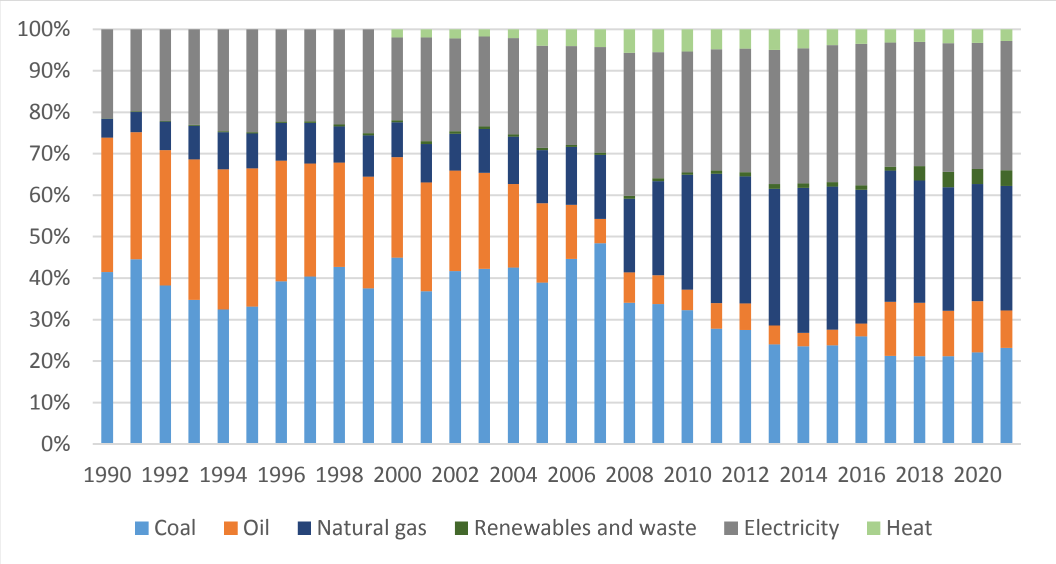


Figure 4.14. TFC by Source, Industry Sector of Türkiye (%)

Source: IEA (2024b).

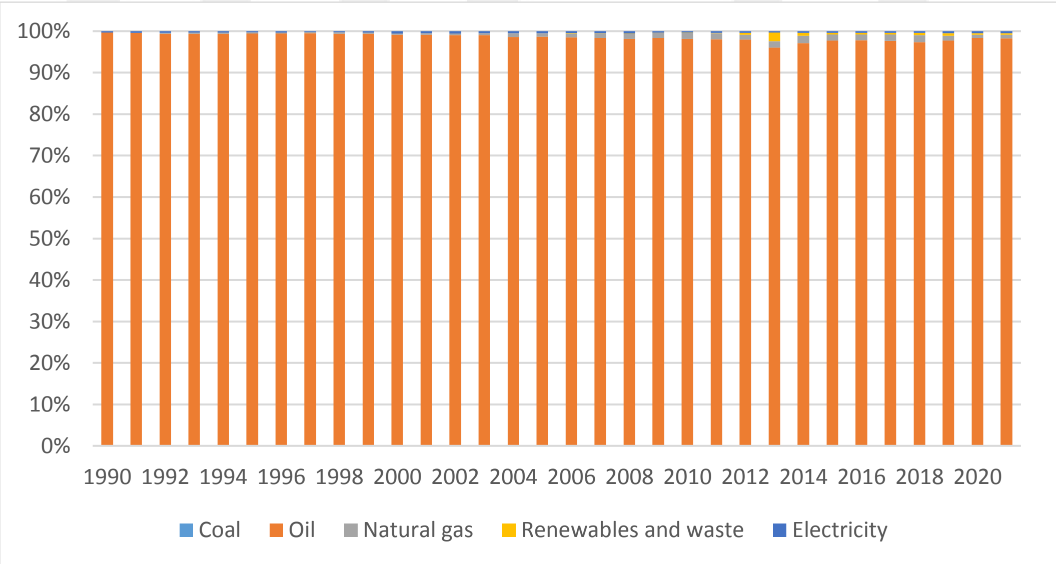


Figure 4.15. TFC by Source, Transport Sector of Türkiye (%)

Source: IEA (2024b).

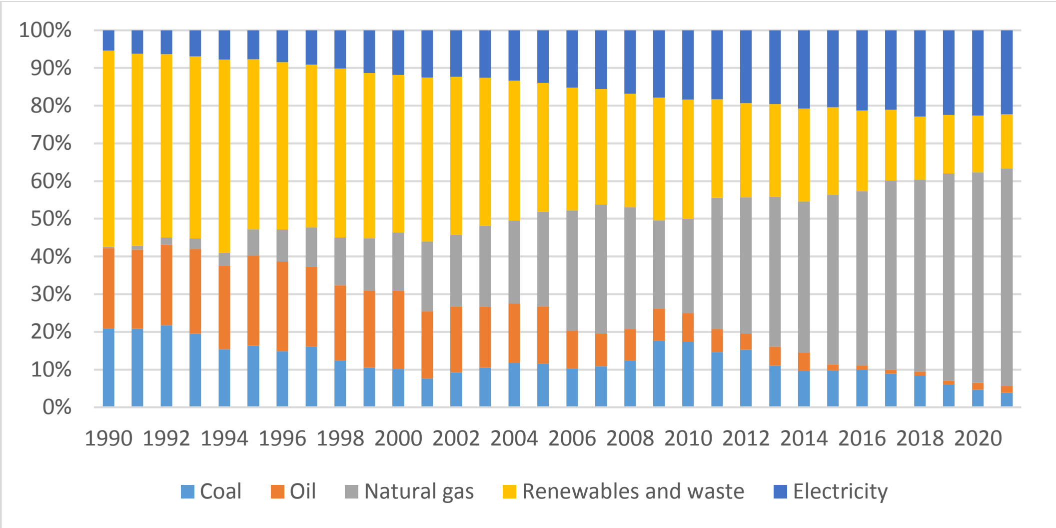


Figure 4.16. TFC by Source, Residential Sector of Türkiye (%)

Source: IEA (2024b).

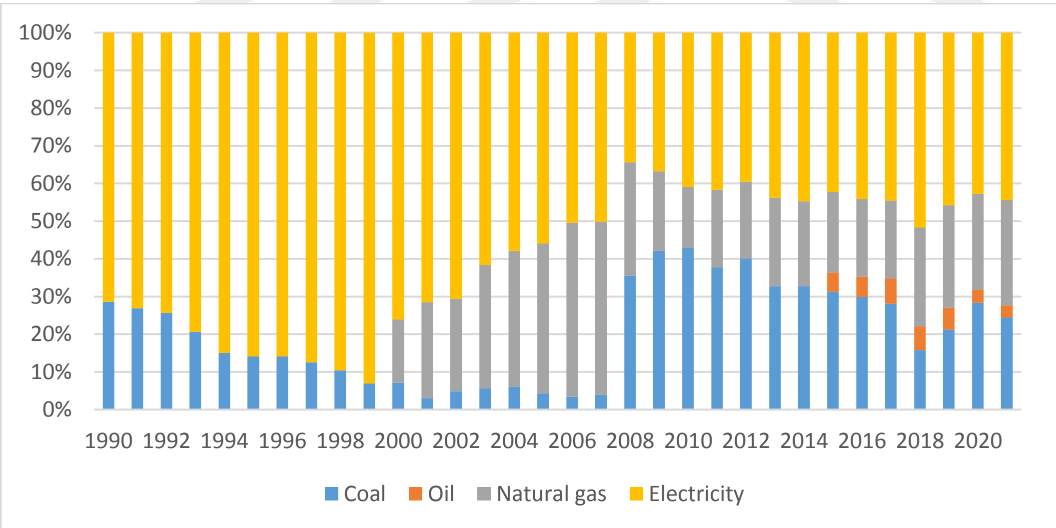


Figure 4.17. TFC by Source, Commercial and Public Services Sector of Türkiye (%)

Source: IEA (2024b).

4.2 Energy Related International Relations of Türkiye

Türkiye plays a key role in international energy relations due to its strategic position as a major energy importer and transit country for natural gas flowing from the Caucasus and Central Asia to the EU (European Commission, 2024b; IEA, 2023a). The cooperation between EU and Türkiye on energy aims to integrate the Turkish gas and electricity markets into internal energy market of EU and to assist Türkiye in achieving its 2053 net zero emission targets. Additionally, Türkiye is an observer of the Energy Community, an international organization focused on integrating the energy markets of its members with the EU's internal energy market (European Commission, 2024b).

Türkiye's international energy strategy aims to modernize, liberalize, and expand domestic production capacity, with an emphasis on diversifying its energy mix and decreasing import dependency. Over the past decade, electricity generation from renewables has tripled, and Türkiye's energy sources will be further diversified with the launch of first NPP. Despite these efforts, fossil fuels remain central to Türkiye's economy, with significant reliance on imports, particularly for oil and gas (Republic of Türkiye Ministry of Foreign Affairs [MFA], 2024a).

Türkiye's energy-related international relations include partnerships with neighboring countries to enhance energy security and sustainability. On April 15, 2015, Türkiye signed a long-term agreement to integrate the European and Turkish electricity markets (MFA, 2024a). Additionally, Türkiye has secured agreements with Iran to import natural gas and with Iraq for crude oil imports (Siccardi, 2024). The country has also collaborated with Russia on projects such as the Blue Stream and Turkish Stream pipelines and negotiated a 6% discount on natural gas imports (Ukşal & Mikail, 2021).

As a crucial transit country, Türkiye plays a significant role in transporting natural gas from the Caspian region and the Middle East to Europe. It has developed a pipeline network to carry natural gas from Azerbaijan, Iran, and Russia to Europe and plans to construct new pipelines, such as the Trans-Anatolian Natural Gas Pipeline (TANAP), which will carry gas from Azerbaijan to Europe through Türkiye (Republic of Türkiye Ministry of Energy and Natural Resources [MENR], 2024a).

In addition to these, Türkiye is a member of various international and regional organizations, including the Organization of the BSEC, which focuses on enhancing energy security by developing infrastructure and promoting cooperation among member states. As a member of the IEA, Türkiye gains access to resources and expertise in energy policy and technology, supporting its goals of energy security, economic growth, and environmental sustainability (IEA, 2021a). In 2015, Türkiye chaired the Group of Twenty (G20) and significantly advanced the G20 energy agenda, emphasizing renewable energy deployment, energy access and collaboration between emerging and industrialized countries (IEA, 2016).

International agreements are another key component of energy relations. Türkiye has signed several international agreements related to energy and sustainability. Information is given for the notable ones below:

1. United Nations Framework Convention on Climate Change (UNFCCC): The UNFCCC is an international treaty designed to prevent harmful human impacts on the climate system. It serves as a political forum where countries can discuss their interests and challenges in enhancing climate change mitigation and adaptation efforts. The treaty establishes general obligations for all signatories to reduce greenhouse gas emissions and adapt to climate change (United Nations Framework Convention on Climate Change [UNFCCC], 2024; International Institute for Sustainable Development, 2024). It acknowledges the principles of “common but differentiated responsibilities” and “respective capabilities”, recognizing that states have varying capabilities and levels of historical responsibility for greenhouse gas emissions. The Convention, which came into effect in 1994, has over 190 member countries (London School of Economics and Political Science

Grantham Research Institute on Climate Change and the Environment [LSE], 2022).

Türkiye's initial classification under the UNFCCC included it in Annex I and Annex II lists both, reflecting its OECD membership. However, despite having a low historical responsibility for emissions, its name was removed from UNFCCC's Annex-II list in 2001, but not in the Annex-I list due to its inclusion at the outset of the process (MFA, 2024b). Türkiye ratified the UNFCCC on 24 May 2004, following the Law No. 4990 dated 16 October 2003 (Directorate of Climate Change [DCC], 2024a). Türkiye sought recognition of its special circumstances in subsequent Conference of Parties (COP) decisions, highlighting the need for support in implementing the convention (MFA, 2024b). As an Annex I country within the scope of the UNFCCC, Türkiye is obliged to submit National Communication on Climate Change to the UNFCCC Secretariat every 4 years. Türkiye has already submitted 8th National Communication and 5th Two-Year Report (DCC, 2024b).

The Convention has led to the adoption of several subsequent agreements, including the Kyoto Protocol and the Paris Agreement, which have established concrete targets for greenhouse gas emissions reduction (UNFCCC, 2024).

2. Kyoto Protocol: Adopted in 1997, the Kyoto Protocol aimed to set mandatory emission reduction targets for developed countries. Türkiye became a party to the protocol in 2009 but was not subject to binding emission reduction targets, as it had not endorsed the UNFCCC when the protocol's Annex B list was created and was considered a developing country at that time (DCC, 2024c).

3. Paris Agreement: Adopted in 2015, the Paris Agreement marked a significant milestone in global climate action, aiming to "limit global warming to well below 2°C above pre-industrial levels" (LSE, 2022).

The agreement requires countries to submit nationally determined contributions (NDCs) that outlines climate action plans. According to the decisions numbered 1/CP.19 and 1/CP.20, Türkiye submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC on September 30, 2015, stating its goal to achieve “up to a 21% reduction in GHG emissions from the Business-as-Usual level by 2030” (Republic of Türkiye, 2015). Türkiye signed the agreement in 2016 and ratified it in 2021, following the publication of the Law on Approval of the Paris Agreement in the Official Gazette on 7 October 2021 (No. 31621) (DCC, 2024d). Upon approval, the government declared a net zero target for 2053. At the 26th Conference of the Parties of UNFCCC in 2022, Türkiye declared in its updated NDC that the greenhouse gas reduction target increased from 21 percent, set in 2015, to 41 percent for 2030 (Republic of Türkiye, 2023).

In its updated NDC, Türkiye’s primary mitigation strategy for the energy sector by 2030 is described as maximizing energy efficiency and renewable energy potential while ensuring feasibility, market viability, and energy security. The Renewable Energy Sources Support Mechanism (YEKDEM) and the By-Law on Renewable Energy Resource Areas (YEKA) are indicated as the main incentives that played a crucial role in accelerating investments in renewable energy, particularly in wind and solar power. Additionally, various policies and regulations have been implemented to enhance energy efficiency in buildings and the industrial sectors (Republic of Türkiye, 2023).

The Turkish government is enacting a comprehensive set of new policies and strategies to achieve its net zero target. This includes the 12th National Development Plan (2024-2028) and the development of a long-term strategy extending to 2053. These initiatives aim to align climate goals with economic growth while enhancing the country’s climate ambitions (Republic of Türkiye, 2023).

4. Energy Charter Treaty (ECT): The ECT is a multilateral energy cooperation framework, focusing on improving energy security in line with sustainable development principles. Signed in 1994 and effective from 1998, the ECT has 53 parties, including the EU and Euratom. ECT aims to promote energy cooperation and investment security. It sets up a multilateral framework for energy cooperation, trade, transit, and investment protection. Türkiye signed the ECT in 1994 and ECT entered into force in the country in 2001 (International Energy Charter, 2019).

5. Convention on Long-range Transboundary Air Pollution (CLRTAP):

To address air pollution and its transboundary effects in Europe, 32 countries in the pan-European region cooperated to reduce air pollution by signing the CLRTAP in 1979. This treaty, effective from 1983, established international cooperation principles and an institutional framework for addressing air pollution. Over time, the Convention has expanded to cover more substances, including ground-level ozone, particulate matter, persistent organic pollutants, and heavy metals. These substances are mainly related to the emissions of thermal power plants and fossil fuel use. Türkiye signed the CLRTAP in 1979 and ratified it in 1983 (United Nations Economic Commission for Europe, 2024).

Türkiye's participation in these agreements reflects its commitment to addressing global environmental challenges and promoting sustainable energy and sustainable development.

4.3 Energy Policies in National Policy Documents

In this part energy policies in development plans, national and institutional strategies covering 1990-2024 are analyzed considering sustainability notions. In this period, there has been seven NDPs adopted started with the Sixth NDP.

The Sixth NDP (1990-1994) aimed to provide on-site, timely, reliable, cheap and high-quality energy to all user segments to support socioeconomic development in a healthy way (DPT, 1990). It was focused on the use of all domestic or imported energy resources, provided that they are economical in the sector; benefiting from all investment and financing segments and opportunities at home and abroad, public and private so that it is targeted to meet the primary and secondary energy demands in the most economical way for the country and the user within a reliable supply structure and within this framework, a balanced supply diversification will be made in terms of source and supply location. Despite the importance and priority given to the development of domestic resources during the Sixth NDP period, the demand for high quality imported resources was foreseen to continue as a result of the limited reserves and low quality of these resources, and the weight of imported resources in total consumption to continue in the medium and long term.

The Sixth NDP's targets were increasing primary energy demand by 8%, expanding the use of natural gas, increasing the electricity power plant installed capacity by 7.9% reaching 22,650 MW. The ratio of renewable energy use was targeted at 40 percent of the electricity production from hydraulic power plants. Taking necessary measures for greater utilization of renewable energy sources such as solar and geothermal energy, particularly hydro was prioritized in this Plan Period. Studies to introduce nuclear energy was planned for the diversification of energy sources. Energy efficiency was also a policy priority in this Plan that ensuring efficient use of energy resources with proper technologies at all stages from production to consumption and incentivizing energy saving projects were the related policies (DPT, 1990).

During the Sixth NDP period, primary energy production increased by 3.2 percent per year and reached 32.6 million tons of oil equivalent (Mtoe) by 1994. The most important developments in production were seen in hydroelectric and oil. By the end of 1994, total primary energy consumption reached 64.0 Mtoe. Petroleum products constituted the largest item with a share of 40% in the sector's consumption, which was based on imported resources at a rate of approximately 49%. While the share of residences in consumption decreases over time, the share of power plants and industry increases. The share of these two sectors in total consumption was around 30%. As of the end of 1994, the installed power of the power plants reached 20,857 MW and the generation capacity reached 101 billion kWh. As of 1994, the demand was close to 78 billion kWh (DPT, 1995).

In the Sixth NDP period, the energy investments realized insufficiently counting the needs of the developing economy and the increasing population. Investments made after 1990, although need doubled, decreased to half of the investments made between 1977 and 1987. The problems in the current environmental legislation and implementation was seen as one of the reasons in this result apart from the failure to provide the expected contributions from the privatization works and the private sector and the reduction of public investments. High rate of losses and leakages in electricity distribution lines and networks was an important problem in the sector that causes insufficiency in electricity supply (DPT, 1995).

In the Seventh NDP (1996-2000**)**, the energy sector's main objective was defined as to meet the energy demands of expanding economy and growing population reliably and continuously while minimizing costs (SPO, 1995). During this period, environmental regulations were viewed as an impediment to energy sector investments, which indicates sustainability considerations were not internalized in the energy sector. The Seventh NDP projected a 5.3% annual increase in total energy demand, anticipating it would reach 85.8 Mtoe by the year 2000.

Long-term electricity demand growth scenario alternatives were taken into account in the Plan indicating that demand would have reached from 120-130 billion kWh in 2000 and 240-270 billion kWh in 2010. An addition of 6.650 MW installed capacity in this period is targeted so that the production capacity would rise to 138 billion kWh. Distribution and network investments were prioritized to reduce losses and improve networks. With these developments, per capita energy consumption would reach 1.285 kg oil equivalent (kep) and per capita electricity consumption to 1.825 kWh by the year 2000 (SPO, 1995).

During the Seventh NDP, Türkiye aimed to create a reliable and cost-effective energy system by increasing the use of domestic energy resources, diversifying energy sources, and investing in mining and renewable energy. Energy efficiency and conservation were prioritized to address the insufficiency and high cost of domestic and imported energy sources and to mitigate environmental impacts. A new decision-making mechanism and institutional structure were planned to oversee the sector's activities, protect consumer rights, and ensure effective investment in various energy policies. (SPO, 1995).

At the end of the Seventh NDP period, energy consumption had grown by 4.5% annually, reaching 78.8 million toe. Primary energy output rose by 1.3% annually, and the electricity sector saw an increase in installed capacity and generation with 5165 MW and 34.3 billion kWh of additional capacity. Despite these advancements, by the end of 1999, energy consumption per capita (1.158 kg kep) and electricity supply per capita (1.840 kWh) remained below global averages (1.500 kep and 2.200 kWh per capita, respectively) (SPO, 2000).

The Eighth NDP (2001-2005) included a comprehensive long-term strategy aimed at transforming Türkiye into a prominent global power by 2023. This strategy is designed to align with Atatürk's vision of surpassing contemporary civilization standards, with goals including achieving high cultural and civilizational standards, producing goods that meet world standards, and ensuring equitable income distribution. A major focus of the strategy is to enhance Türkiye's role as a significant energy distribution hub, leveraging its strategic location to transport natural gas and crude oil from the region to global markets while meeting domestic energy needs (SPO, 2000).

In this direction, the Eighth NDP envisions Türkiye becoming a major energy center, supported by the pipelines transporting crude oil and natural gas extracted from the region that will not only fulfill domestic demand but also supply global markets. Investment priorities will shift over time, with sector investments in transport, energy and communication maintaining their levels until 2010, after which education, health, and communication sector investments are expected to increase (SPO, 2000).

The Eighth NDP underscores the importance of energy for economic and social development, stressing the need to consume energy efficiently and economically. It addresses issues such as high production and supply costs, long planning and investment periods, substantial financing needs, dependency on fossil fuels and imports, and environmental pollution. Measures are proposed to ensure reliable and low-cost energy supply while tackling global pollution and promoting common global policies (SPO, 2000).

In the Eighth NDP, privatization and liberalization of the energy sector are prioritized, with the goal of increasing private sector participation and establishing autonomous regulatory boards to protect consumer rights and foster competition. The Baku-Tbilisi-Ceyhan Petroleum Pipeline Project is highlighted as a key initiative, completed within the plan period, which supports Türkiye's position as a critical energy transit country. The Trans-Caspian Pipeline Project is also mentioned, although it remains a proposed project for future development (SPO, 2000).

During the Eighth NDP period, economic growth and population increase led to considerable rises in energy consumption in Türkiye. By 2005, primary energy consumption reached 92.5 million tons of oil equivalent (mtoe), growing annually by an average of 2.8%, while electricity consumption rose to 160.8 billion kWh, increasing annually by 4.6%. These increases became particularly obvious after 2003, when the economy recovered and stabilized following the 2001 economic crisis, leading to accelerated annual growth rates of 5.7% for primary energy consumption and 6.7% for electricity consumption (SPO, 2006).

In the Ninth NDP (2007-2013), Türkiye focused on aligning its planning process with the EU budget cycle. The plan prioritized energy investments and aimed to improve infrastructure quality, enhance access, and reduce infrastructure service costs, with a significant role assigned to the private sector in these investments (SPO, 2006).

Türkiye’s strategic location was also highlighted in the Ninth NDP as crucial for becoming a key energy distribution center, leveraging its position in the transit of oil and natural gas from post-Soviet countries to international markets. Strengthening economic and commercial relations with neighboring countries was regarded essential for this goal (SPO, 2006).

The Ninth NDP outlined key energy policy factors, including ensuring supply security by considering alternative energy sources such as nuclear power, minimizing environmental impacts, and enhancing international competitiveness through a competitive energy industry. Priorities included reducing dependency on imports, timely infrastructure investments, and maintaining adequate storage and refining capacities. The Plan also emphasized energy sector liberalization and competition, with the private sector expected to make investments while the government focused on supervision and monitoring (SPO, 2006).

During the Ninth NDP period, energy consumption in Türkiye increased, highlighting the sector’s importance to the economy and external balances. Primary energy consumption grew by 2.8% annually from 2007-2011, and electricity consumption by 5.6% annually from 2007-2012. Despite efforts to secure supply, rising oil prices pressured the economy. Significant progress was made in liberalizing electricity and natural gas markets, increasing private sector participation. Initiatives were undertaken to support renewable energy, improve energy efficiency, and develop domestic energy resources, including coal, nuclear, and geothermal. Additionally, exploration activities led to increased reserves of lignite, with ongoing efforts to enhance oil and natural gas production especially at the offshore areas. As a result, the known reserves of lignite increased to 12.8 billion tons from 8.3 billion tons at the end of Ninth NDP period. In addition, during the Plan period, preparations for two nuclear power plants (Akkuyu NPP - 4800 MW and Sinop NPP - 4480 MW) were initiated by signing contracts between Russian Federation and Japan. Establishment of Ceyhan and Karapınar Energy Specialty Industrial Zones was a significant development in connection of energy and industry (MoD, 2014).

Despite these efforts in the Ninth NDP period, Türkiye faced challenges, such as increased energy consumption, unresolved supply security issues, and rising petroleum prices impacting the economy. To resolve these challenges, the Tenth NDP (2014-2018) aimed to develop a competitive energy system that maximizes the use of domestic and renewable energy resources, incorporates nuclear technology for electricity production, promotes a reduction in the energy intensity of the economy, and minimizes waste and environmental impact. Additionally, it aimed to ensure a continuous, reliable, and cost-effective energy supply to end-users while diversifying energy sources and bolstering the country's strategic role in international energy trade (MoD, 2014).

The Tenth NDP focused on fostering a competitive energy market with public sector oversight to ensure supply security, intervening as an investor only when needed. The energy policies aimed to complete the privatization of state-owned electricity generation and distribution while maintaining public control over non-privatized plants, transmission, and wholesale activities. Polices on diversification of energy sources was also prioritized, emphasizing domestic and renewable resources (MoD, 2014).

State-owned transmission investments were geared toward integrating renewables securely. The Tenth NDP included creating emergency oil and natural gas reserves and expanding transmission and distribution networks. Significant projects like the Salt Lake Natural Gas Underground Storage and network expansions in Thrace were mentioned in the Plan. Nuclear energy development was highlighted, targeting completion of the Akkuyu NPP's first unit, initiation of a second plant in Sinop, and preparation for a third one. Policies on regulatory and waste management frameworks were also set in the Plan for the safe management of nuclear waste (MoD, 2014).

Policies also promoted private-sector-led, eco-friendly use of domestic coal, particularly from the Afşin-Elbistan basin. On energy efficiency, implementation of the Energy Efficiency Strategy during the Tenth NDP period emphasized to ensure energy savings across sectors. Rehabilitation of the state-owned thermal and hydroelectric plants was also aimed together with the reduction of electricity losses and illegal uses (MoD, 2014).

Additionally, the Tenth NDP aimed to establish a power exchange market to facilitate the formation of reference prices in a liberalized market, aiding investment and operational decisions. Leveraging Türkiye's geostrategic position emphasized with becoming a key transit and terminal hub for energy trade. In this direction, transforming Ceyhan into a major international oil distribution point was targeted. Expansion of Türkiye's involvement in gas trade and transmission to Europe was another target of the Tenth Plan, with necessary infrastructure to increase electricity trade with neighboring countries. Projects like the TANAP pipeline, full integration with the European Network of Transmission System Operators for Electricity (ENTSOE) system, and high-voltage electricity transmission lines with neighboring countries are mentioned as priority projects (MoD, 2014).

Türkiye's energy demand has been high due to its growing economy, with primary energy consumption rising by an average of 6.4% between 2014-2017 and electricity demand by 3.9% from 2014-2018. The electricity market liberalization led to the private sector's significant involvement, accounting for 85% of electricity generation in this period. Renewable energy's share in electricity generation increased from 28.9% in 2013 to 32.5% in 2018, while electricity from indigenous coal grew from 12.6% to 14.9%. In 2017, Türkiye completed auctions for Renewable Energy Resource Areas (YEKA) with a 2,000 MW capacity for wind and solar projects, encouraging domestic production of generation equipment. Efforts to enhance energy security included boosting renewable energy, utilizing local coal, and expanding natural gas storage. The foundation for the Akkuyu Nuclear Power Plant was laid in 2018, with plans for further nuclear developments (PSB, 2019).

Experiencing these progresses in the energy sector of the country, in the Eleventh NDP (2019-2023), it was aimed to ensure uninterrupted, high-quality, sustainable, reliable and affordable energy supply. Although the aspects of sustainability have been mentioned in a progressive manner in the objectives of energy chapters of the NDPs after 1990, the term “sustainable” was used firstly in the objective of energy sector in the Eleventh NDP. This improvement led to more targeted and strategic planning progress so that more concrete policy frameworks were formed to ensure economic growth, energy security, and environmental sustainability in a holistic way. These policies reflect a multidimensional approach that emphasizes market liberalization, resource diversification, technological advancement, and infrastructural development (PSB, 2019).

The Eleventh NDP prioritizes a competitive and transparent energy market to attract investment and optimize resource use. Policies such as cost-based pricing, demand-side participation, and energy efficiency improvements aim to create a stable energy market framework. Expanding access to natural gas, enhancing energy infrastructure, and increasing domestic energy production were prioritized to reinforce energy security. Türkiye’s efforts to position itself as a regional energy hub through projects like TANAP and the Turkish Stream would strengthen its geostrategic location, promising economic gains through cross-border energy trade (PSB, 2019).

The emphasis on renewable energy expansion in the Eleventh NDP highlights alignment with SDGs. The integration of renewable sources into the grid, supported by energy storage systems such as pumped storage hydroelectric power plants, was planned to reduce reliance on fossil fuels and support decarbonization. Modernization of electrical networks and smart grid applications would improve operational efficiency and security. Initiatives promoting energy-efficient buildings and public infrastructure reflect a commitment to reducing energy demand and greenhouse gas emissions (PSB, 2019).

However, the Eleventh NDP’s continued reliance on domestic lignite coal and the inclusion of nuclear energy raise questions about its environmental impact. While coal policies focus on employment generation and meeting environmental standards, the associated carbon emissions challenge Türkiye’s climate commitments.

Similarly, nuclear energy's potential for low-carbon electricity comes with risks related to safety, waste management, and dependency on foreign expertise, requiring robust governance to ensure alignment with sustainability principles (PSB, 2019).

On the social front, policies to expand access to energy resources and reduce electricity losses contribute to equity and public welfare. Programs to raise awareness and incentivize efficiency foster sustainable energy consumption patterns, promoting long-term societal benefits (PSB, 2019).

During the Eleventh Plan period, Türkiye's primary energy consumption grew annually by 3.5% (2018–2021), while electricity demand rose by 2.1% annually (2018–2022). Electricity market liberalization significantly increased private sector participation, reaching around 86% of total electricity generation. Between 2018 and 2022, electricity generation from domestic coal slightly decreased (from 16.5% to 15.7%), whereas renewable energy's share in electricity generation remarkably increased (from 32.4% to 42.4%). Efforts to increase renewable energy included the completion of solar and wind Renewable Energy Resource Areas (YEKA) tenders totaling 5,850 MW (PSB, 2023).

Building on sustainable development approach, the Twelfth NDP (2024-2028) is the latest development plan, which outlines Türkiye's comprehensive strategy for achieving a competitive, sustainable, and secure energy sector while aligning with the 2053 net-zero emissions target. Emphasizing its importance in sustainable development, the energy sector is one of the priority development areas of the Plan. The Plan aims to "achieve a competitive structure that maximizes self-sufficiency in energy by utilizing domestic and renewable energy resources, uses nuclear technology in electricity generation, increases energy efficiency, prioritizes localization in energy technologies, integrates new technologies, and strengthens our strategic position in international energy trade, based on the uninterrupted, high-quality, sustainable, reliable and affordable supply of energy, source diversification in energy supply and the 2053 net zero emission target" (PSB, 2023). When the objective of the Plan is analyzed, energy sustainability and its economic, social and environmental dimensions are highlighted strongly in the objective. The primary objective seems to maximize self-sufficiency through the utilization of domestic and renewable energy resources, integration of nuclear technology, and advancements in energy efficiency. Localization of energy technologies, adoption of new innovations, and strengthening Türkiye's strategic position in international energy trade are also emphasized. Ensuring an uninterrupted, reliable, and affordable energy supply while diversifying energy sources remains a core focus as same as previous NDPs.

To foster a robust energy market, the Twelfth NDP prioritizes the creation of a transparent, predictable, and competitive investment environment. Cost-based pricing for electricity and natural gas will be implemented, complemented by financial support for low-income consumers. Demand-side participation will be encouraged through new legislation, and the energy efficiency agenda will be pursued across sectors, particularly in public and residential buildings. Measures include promoting energy-efficient buildings powered by renewable energy, expanding energy performance contracts, and introducing district heating and cooling systems where feasible (PSB, 2023).

Energy supply security is addressed through continued utilization of domestic coal with environmentally sensitive practices, alongside efforts to incorporate nuclear energy into the electricity mix. The Akkuyu Nuclear Power Plant is set to become operational, with plans to expand nuclear capacity and explore next-generation technologies like small modular reactors. Simultaneously, renewable energy deployment will be scaled up through initiatives such as Renewable Energy Resource Area (YEKA) projects, including offshore ventures, while grid infrastructure will be enhanced to support increasing electrification and intermittent renewable energy sources (PSB, 2023).

Natural gas security remains a critical component of the Plan, with activities focused on developing domestic reserves like the Sakarya Gas Field and expanding storage capacities in facilities such as the Tuz Lake Underground Storage Project. Türkiye also seeks to enhance its role as an energy trade hub by leveraging its geostrategic position and expanding infrastructure like the TANAP to connect energy producers and consumers across regions (PSB, 2023).

Innovation in energy technologies forms another pillar of the Twelfth NDP. Türkiye aims to advance renewable energy, nuclear, hydrogen, and energy storage technologies through R&D and localization initiatives. Green hydrogen production and infrastructure will be supported, including efforts to develop domestic electrolyzers and enhance hydrogen transportation and storage capabilities. Furthermore, the plan highlights the importance of raw material security and recycling to minimize environmental impacts, promoting circular economy practices for equipment like solar panels and batteries (PSB, 2023).

Finally, human resource development is prioritized to meet the evolving needs of the energy sector. Higher education programs will align with emerging technologies, while training and internships in energy-related fields will be enhanced. The Twelfth NDP also aims to increase the employment of highly qualified professionals, ensuring that Türkiye’s workforce is equipped to drive the energy transition and sustain its competitiveness (PSB, 2023).

When the energy policies described above in those NDPs are analyzed as a whole in terms of sustainability, parallel to the integration of sustainable development in NDPs as depicted in Chapter 3, NDPs progressed significantly towards a sustainable energy transition, particularly focusing on renewable energy development, energy efficiency, and market reforms in recent ones. Between 1990-2000 the NDPs focused on meeting growing energy demand through infrastructure development and increasing the capacity of domestic sources, especially lignite and hydropower. After 2000, NDPs put more emphasis on domestic energy production, energy efficiency, and market liberalization. In the NDPs after 2014, in line with SDGs, policies have shifted towards a greener and more sustainable energy future with greater investment in renewable energy, nuclear technology, and aligning policies with global climate targets.

Due to the high dependency on energy imports to meet energy demand, the current account deficit is adversely affected, especially during periods of rising energy prices. Consequently, all Development Plans and programs prepared since 2000 have included targets such as increasing the share of domestic energy resources in energy production, reducing energy intensity, and achieving energy savings by enhancing energy efficiency.

However, the environmental trade-offs from coal and nuclear policies highlight the need for a more aggressive shift toward clean energy sources. Balancing economic priorities with environmental concerns should be important for Türkiye to fully align its energy policies with global sustainable development goals.

In general, the primary objective of the energy sector in these Development Plans has been set as ensuring the energy needs of the growing population and developing economy are met continuously, uninterruptedly, and with quality at the lowest possible costs. Throughout the NDPs after 1990, Türkiye's main energy policy evolved to have a comprehensive framework that could be depicted in Figure 4.18.

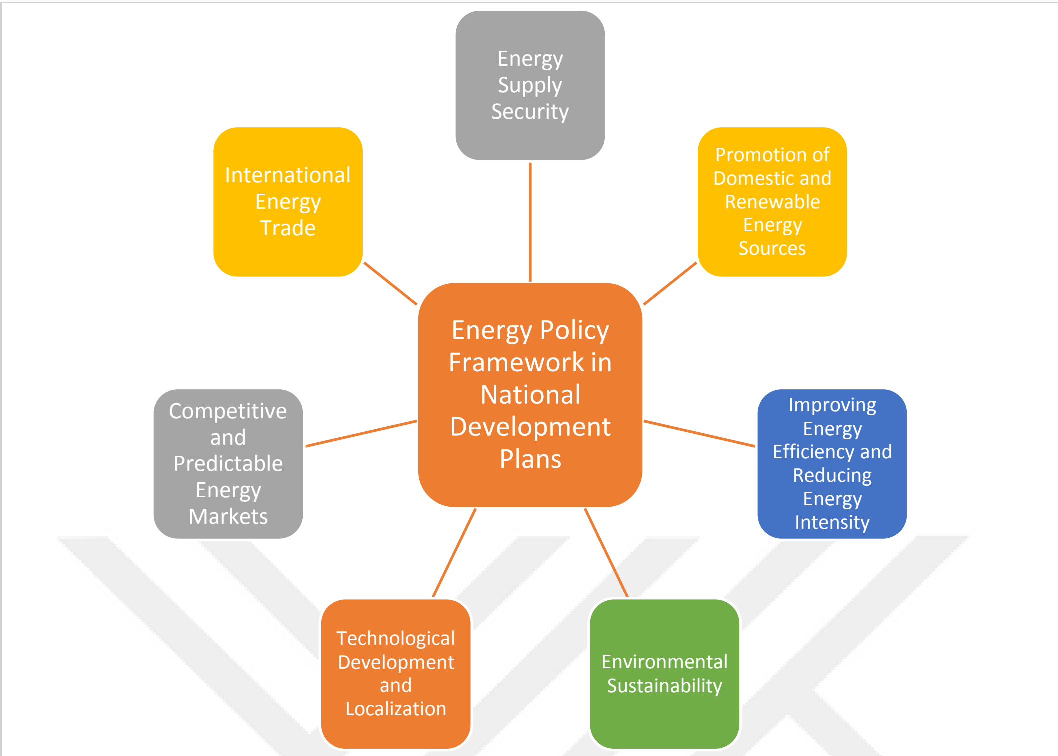


Figure 4.18. Energy Policy Framework in the NDPs.

Source: Prepared by the author

Key themes and priorities as depicted in this framework (Figure 4.18) is explained as follows:

- *Energy Supply Security*: Ensuring the continuous, uninterrupted, and affordable supply of energy to meet the increasing demand of country has been a primary goal in all NDPs.
- *Promotion of Domestic and Renewable Energy Sources:* A strong focus has been placed on maximizing the use of domestic resources such as coal, hydropower, solar, and wind energy. Policies have increasingly aimed to reduce import dependency by encouraging renewable energy investments.

- *Improving Energy Efficiency and Reducing Energy Intensity*: Since the early 2000s, reducing energy intensity of the economy (measured as energy consumption per unit of GDP) has been a consistent goal in NDPs. Enhancing energy efficiency across sectors (industry, transportation, and buildings) has been highlighted to achieve economic and environmental benefits.
- *Environmental Sustainability*: Plans emphasize minimizing the environmental impacts of energy production and consumption. This includes addressing climate change by promoting cleaner technologies and reducing greenhouse gas emissions.
- *Technological Development and Localization*: Significant attention has been given to localization efforts, including the development and use of advanced technologies in energy production (e.g., solar panels, wind turbines) and adopting nuclear energy as a strategic source for electricity generation.
- *Competitive and Predictable Energy Markets*: Developing transparent and predictable energy markets has been prioritized to attract private sector investments and foster competition in the energy sector.
- *International Energy Trade*: Türkiye's geostrategic position as an energy corridor connecting East and West has been leveraged in development plans. Policies aim to strengthen its role in regional and global energy trade, particularly in natural gas and oil transit.

NDPs have consistently emphasized achieving energy sustainability while addressing the challenges of a growing population, economic development, and dependency on energy imports. In line with the NDPs, there has been adopted sectoral strategies in energy sector. It is also important to assess the sustainability in these strategies such as Türkiye's National Energy and Mining Policy and the National Energy Efficiency Action Plans.

Türkiye's National Energy and Mining Policy (2017-2023), which was introduced in 2017, aimed to achieve progress in various areas of the energy sector, including production, consumption, distribution, and transmission, while ensuring the country's ongoing transformation and change in a stable manner (Karagöl et al., 2017; IEA, 2021a). This policy was structured around three main pillars:

1. *Security of Supply:* This pillar emphasized reducing dependence on energy imports by enhancing domestic oil and gas exploration and production, diversifying energy sources, and improving energy efficiency. Efforts included boosting domestic oil and gas exploration, diversifying oil and gas supply sources and infrastructure, and reducing energy consumption through increased energy efficiency.

2. *Localization (increasing the use of domestic resources):* Türkiye aimed to increase the share of renewable energy in total energy production to at least 30% and reduce energy intensity by 20% by 2023 compared to 2008 levels. This involved strategies such as promoting local production, research and development, and utilizing Renewable Energy Resource Areas (YEKA) to support renewable energy projects. In addition, it was aimed to increase the share of nuclear power plants in electricity generation by at least 10 percent according to the forecasts for 2023.

3. *Predictability of Markets (ensuring stability and transparency in energy markets):* To create a stable and transparent energy market to attract investment and ensure sustainable development, this pilar included regulatory reforms and establishing a competitive environment to enhance market efficiency (Karagöl et al., 2017; IEA, 2021a).

Overall, the National Energy and Mining Policy serves as a foundation for Türkiye's long-term energy vision by outlining the country's energy vision for the future and reflects Türkiye's commitment to achieving a sustainable energy supply to support both economic growth and national security. However, Türkiye's policy demonstrates both strengths and challenges from a sustainability perspective. On one hand, the rapid development of renewable energy projects and the diversification of the energy mix signify progress toward reducing fossil fuel dependency. Studies indicate significant growth in installed renewable capacity, particularly in wind and solar energy, over the past decade (Çakmak, 2024). On the other hand, research highlights that Türkiye's economic and energy strategies often outweigh its environmental policies, resulting in rising carbon emissions and ecological vulnerabilities, for instance, reliance on coal and limited prioritization of proactive climate measures could hinder alignment with global climate goals. (Canan, 2023; Atvur & Vural, 2022).

Türkiye's energy efficiency journey began with the enactment of the Energy Efficiency Law in 2007, marking the start of significant transformation (Official Gazette, 2007). Energy efficiency is accepted as an area that complements and crosscuts such national strategic goals as easing the burden of energy costs on the economy, ensuring energy supply security, alleviating risks arising from external dependency, transition to low carbon economy and protection of environment. The increased importance of sustainable development also increases the value of efforts in energy efficiency. In 2012, the Energy Efficiency Strategy Document (2012-2023) set ambitious goals, including reducing energy intensity by 20% by 2023 compared to 2011 levels. In line with these targets, the National Energy Efficiency Action Plan (NEEAP) for the period of 2017-2023 was prepared by the Ministry of Energy and Natural Resources (MENR, 2017).

This Plan aimed to reduce the primary energy consumption of Türkiye by 14% by 2023 through 55 actions defined in 6 categories namely: buildings and services; energy; transport; industry and technology; agriculture; and cross-cutting (horizontal) areas. It is also projected to achieve savings of 23.9 million tons of oil cumulatively by 2023, which would lead to a reduction of 66.6 million tons of CO_2 emissions. 10.9 billion USD of investment was planned to be made but by the end of 2023, Türkiye had invested $8.47 billion, surpassing targets with 24.6 million-ton equivalent of petroleum (MTEP) energy savings and 68.62 million tons of CO_2 reduction, while creating 44,880 jobs. The cumulative savings by 2033 will be 30.2 billion USD at 2017 prices, where the effect of certain savings will continue through 2040. The average payback period for actions is 7 years (MENR, 2017).

Türkiye reached its 2023 energy intensity reduction target early, achieving a 20.4% reduction in energy intensity by 2022. This was a result of consistent efforts to align energy efficiency policies with economic growth, as demonstrated by a 5.5% GDP increase in 2022 while primary energy supply decreased by 1%. This accomplishment highlights the effectiveness of targeted investments and strategic planning in achieving both economic and environmental objectives (MENR, 2024b).

To continue these efforts, the Energy Efficiency 2030 Strategy and II. NEEAP (2024-2030) was adopted in 2023 by the Ministry. With a planned 20.2 billion USD investment, The new strategy and II. NEEAP sets ambitious goals such as achieving cumulative savings of 37.1 MTEP, a 16% reduction in primary energy consumption, and a reduction of 100 million tons of CO_2 emissions. This strategy covers seven sectors, including energy, transportation, industry, agriculture, and digitalization, with a total of 61 actions. These efforts are aligned with national policy documents, such as the 12th Development Plan (2024-2028), and global commitments under the European Green Deal and UNFCCC (MENR, 2024b).

Türkiye's energy efficiency policies of II. NEEAP would deliver measurable cost savings but also generate significant environmental and social benefits. Energy efficiency investments are projected to yield more than 2 times their value in returns (46 billion USD in energy savings by 2040), while contributing to decarbonization, sustainability, and international climate commitments. These initiatives will support Türkiye's 2053 net-zero emissions commitment to a greener, more efficient, and resilient energy future (MENR, 2024b).

As the NDP's and national strategy papers set the national level macro policies and targets, institutions are preparing their strategic plans in line with the NDPs. Strategic plans guide the institutions actions, projects and budget use therefore it is important to look at the strategic plans of the institutions functioning in the energy sector such as Ministry of Energy and Natural Resources, Turkish Electricity Generation Corporation.

The Strategic Plan of Ministry of Energy and Natural Resources (2024-2028) outlines seven strategic goals, including ensuring sustainable energy supply security, reducing import dependency, advancing a net-zero carbon energy transition, promoting safe and sustainable mining, enhancing the competitiveness of energy and mining markets, supporting local energy technologies, and improving institutional capacity (MENR, 2024c).

It incorporates 30 targets and 131 performance indicators, with periodic monitoring and evaluation processes. A key focus is on increasing renewable energy, energy efficiency, and technological development while aligning with global environmental standards (MENR, 2024c). When this strategic plan evaluated on sustainability, it seem to reflect a strong commitment to energy sustainability through several key measures:

1. *Sustainable Energy Security:* Focuses on increasing local and renewable energy sources, such as solar, wind, and hydro, to reduce dependency on imports and ensure stable energy supply. Targets include:

    - Increase domestically produced electricity, from 57% to 63% of total energy production to come from local resources by 2028.
    - Increase renewable energy's share in total electricity production from 43% to 50% by 2028.
    - Expand Solar capacity from 15,613 MW to 33,100 MW by 2028.
    - Increase Wind capacity from 11,806 MW to 19,300 MW by 2028.
    - Add 4,800 MW of nuclear capacity by 2028.

2. *Net zero carbon emissions focused energy transition:* Aligns with net-zero carbon goals by promoting green energy, electrification (e.g., electric vehicles), and energy efficiency. Targets include:

    - Reduce energy-related carbon emissions by supporting green hydrogen and renewable gas technologies.

- Achieve cumulative energy savings of 7.4 million tons of oil equivalent (Mtoe) through efficiency measures by 2028 from the pre-plan value of 0.9 Mtoe.

3. *Technological Development:* Supports local innovation in renewable energy and energy storage technologies and develop their infrastructure including hydrogen and nuclear energy.

4. *Mining Sustainability:* Promotes safe and environmentally conscious mining with higher added value for critical minerals (MENR, 2024c).

The strategic plan aims to strengthen Türkiye's pathway towards sustainable energy development, aligned with global sustainability standards and Türkiye's climate goals but requires consistent monitoring, resource allocation, and alignment with global standards to meet these goals effectively.

The Strategic Plan of Turkish Electricity Generation Corporation (EÜAŞ) (2024-2028) focuses on six strategic goals, emphasizing renewable energy expansion, local and national energy technologies, digital transformation, and sustainable resource utilization. Key objectives include enhancing hydroelectric and natural gas power plants' efficiency, developing hybrid and renewable energy systems, and increasing domestic coal production for energy generation. The plan also prioritizes digital automation and modernization of facilities, aiming for greater sustainability, energy security, and economic contribution (Turkish Electricity Generation Corporation [EÜAŞ], 2024).

The plan emphasizes the development of domestic and national power plant technologies, to reduce dependence on imported systems. Notably, it highlights the use of hybrid models and renewable technologies, such as solar and wind power, as critical components of future energy production (EÜAŞ, 2024). This effort aligns with global sustainability trends and supports Türkiye's broader climate commitments.

EÜAŞ also prioritizes occupational safety and risk management, introducing disaster preparedness measures and structural analyses to mitigate risks at production facilities. These initiatives underline a dedication to social sustainability by ensuring the safety and well-being of employees and also communities around the facilities. The strategic plan's commitment to digital transformation marks a forward-thinking approach, aiming to adopt advanced technologies and automation to make electricity production more effective and sustainable (EÜAŞ, 2024).

While these measures aims to align energy generation with energy sustainability, the provisions on expanding the use of coal resources for electricity generation poses sustainability challenges. While this addresses short-term energy needs, it would harm environmental sustainability, given the associated greenhouse gas emissions. Balancing this reliance on coal with the goals of green transformation will be crucial for long-term success. Overall, the 2024-2028 Strategic Plan of EÜAŞ provides a solid framework for sustainable energy production, but its success will depend on balancing economic, environmental, and social objectives effectively.

4.4 Chapter Review

This chapter provides a comprehensive overview of Türkiye's energy sector, highlighting its evolution in response to economic growth, sustainability challenges, and geopolitical imperatives. As an upper-middle-income country undergoing rapid socioeconomic development, Türkiye faces the dual challenge of meeting the growing energy needs of its population and industry while transitioning to sustainable energy practices.

Türkiye's energy sector is marked by a significant reliance on fossil fuels, which constituted 81% of the total primary energy supply (TPES) in 2022 (IEA, 2024a). This reliance poses challenges for achieving greenhouse gas emission reductions and meeting Türkiye's net-zero emissions target by 2053 (Republic of Türkiye, 2023). At the same time, this reliance underscores the country's dependency on imported natural gas, oil, and coal, which collectively accounted for 73.6% of total energy supply in the same year. Despite this, domestic energy production has risen to 31.9% of TPES, driven by renewable energy and increased coal production (IEA, 2024a).

Renewable energy production is one of the notable advancements in Türkiye's energy landscape. Nearly tripled since 1990, with geothermal, hydro, wind, and solar resources, renewable energy constitutes 58.6% of domestic production in 2022, reflects Türkiye's commitment to sustainability (IEA, 2024a). Notable projects like the Renewable Energy Resource Area (YEKA) initiatives have been boosting advancements in wind and solar energy capacity. Improving grid infrastructure and storage capacity is prioritized to utilize the full potential of renewables (PSB, 2023). On the other hand, ongoing development of Türkiye's first NPP, set to become operational in 2025, reflects a strategic shift toward diversifying energy sources and reducing import reliance (Anadolu Agency, 2024).

Türkiye's geostrategic location has positioned it as a vital energy corridor, connecting Europe, Asia, and the Middle East. Infrastructure projects such as the TANAP and Turkish Stream pipelines underscore its role in regional energy trade and security (PSB, 2019; MENR, 2024c).

Additionally, Türkiye's engagement in international agreements, including the Paris Agreement, aligns domestic policies with global climate goals. Commitments to reduce greenhouse gas emissions by 41% by 2030 and achieve net-zero emissions by 2053 highlight the integration of global standards into national energy strategies (Republic of Türkiye, 2023).

Energy policies pronounced in the National Development Plans (NDPs), energy sector strategies and strategic plans have been instrumental in addressing challenges such as import dependency, energy security, and sustainability. Key strategies on sustainability include:

- Renewable Energy Expansion: Renewables constituted 58.6% of domestic energy production in 2022, supported by policies to increase their share in electricity production to 50% by 2028 (MENR, 2024c).
- Energy Efficiency: Türkiye exceeded its 2023 energy intensity reduction target early, achieving a 20.4% reduction by 2022 through cross-sectoral initiatives (MENR, 2024b).
- Technological Localization: Policies promoting domestic manufacturing of renewable energy technologies, such as solar panels and wind turbines, are enhancing self-sufficiency and reducing reliance on imports (MENR, 2024c).

Türkiye's energy sector has made significant progress in aligning with global sustainability goals while addressing the demands of a growing economy. The integration of renewable energy, advancements in energy efficiency, and strategic policy frameworks reflect a proactive approach to energy transition. However, persistent reliance on fossil fuels, uneven sectoral decarbonization, and gaps in policy implementation pose significant challenges of Türkiye to achieving the 2053 net-zero emissions target, which will be elaborated together with the global energy challenges in the Chapter 5.

CHAPTER 5

ENERGY SUSTAINABILITY CHALLENGES OF TÜRKİYE

As depicted in Chapter 4, Türkiye's energy sector has undergone significant transformation over the past three decades, demonstrating a notable transition towards sustainability while ensuring economic resilience and energy security. However, Türkiye’s energy sector faces significant sustainability challenges, encompassing issues such as greenhouse gas (GHG) emissions, energy poverty, resource depletion, and environmental degradation. This chapter explores the challenges Türkiye encounters, examining their underlying reasons within the framework of SDGs. These challenges encompass global energy issues alongside Türkiye-specific obstacles, such as dependence on fossil fuels, environmental degradation, and concerns about energy security. The discussion situates these challenges within the framework of international sustainability agreements, highlighting the intricate task of reconciling economic development with environmental responsibility. By identifying key areas for improvement and outlining actionable strategies, this chapter seeks to facilitate a transition towards a more sustainable energy landscape in Türkiye.

5.1 Global Energy Sustainability Challenges

Energy sustainability is fundamental to global development, directly influencing environmental, social, and economic objectives. As global energy demand increases due to industrialization, urbanization, and population growth, achieving sustainability becomes increasingly crucial. The energy sector is pivotal in addressing key Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). However, several complex and interconnected challenges impede progress on sustainability, necessitating coordinated global efforts to transition to sustainable energy systems. In this context, the core challenges linked with related SDGs could be described as below:

1. Climate Change and GHG Emissions (SDG 13 - Climate Action): Energy sector through use of fossil fuels like coal, oil, and natural gas for energy production is a major source of GHG emissions, worsening climate change leading to more frequent and severe climate events such as hurricanes, droughts, and floods (IEA, 2023b). Fossil fuel combustion for electricity, heat, and transportation is a primary driver of climate change, with countries like China relying on coal for 61% of their energy mix, making it the largest emitter of GHGs globally with 10613.171 Mt CO_2 emissions from fuel combustion in 2022 (IEA, 2024c). Furthermore, transportation alone accounts for 26% of global CO_2 emissions, emphasizing the need for advancements in clean energy and public transit systems together with behavioral change (Chapman, 2007).

2. Resource Depletion (SDG 12 - Responsible Consumption and Production): As a result of high demand for energy, the overexploitation of non-renewable energy resources such as coal, oil, and natural gas has led to significant environmental and sustainability problems. Unsustainable extraction rates deplete finite reserves and contribute to ecosystem damage (Ansari & Koderma, 2017). Countries like Saudi Arabia, heavily reliant on oil exports, have initiated programs such as Vision 2030 to reduce dependence on oil and diversify their energy portfolios (Al-Gahtani, 2024).

3. Energy Access Inequality (SDG 7 - Affordable and Clean Energy): A huge portion of the global population lacks access to reliable and affordable modern energy sources. 733 million (one in ten people) people do not have access to electricity and 2.3 billion people (%29 of the global population) continue to rely on unsafe and polluting fuels for cooking (UN, 2023). Energy poverty refers to the lack of access to sufficient, clean, affordable, and

reliable energy sources, posing significant risks to global health and leading to adverse environmental, social, and economic consequences. The problem affects approximately 2.8 billion people, predominantly in Asia, Latin America, and Sub-Saharan Africa, with Sub-Saharan Africa and South Asia experiencing the highest levels of energy poverty (Kumar et al., 2019).

4. Water Scarcity (SDG 6 - Clean Water and Sanitation): Water and energy systems are deeply interconnected. The water industry relies heavily on energy for processes such as desalination, pumping, and wastewater treatment, while the energy industry consumes significant amounts of water. For example, in the United States, approximately 27% of non-agricultural water consumption is attributed to energy production. Water is essential for resource extraction (oil, gas, coal, biomass), energy conversion (refining and processing), transportation, and power generation. Water availability, on the other hand, significantly impacts energy infrastructure decisions, including the choice of technology and facility location. For instance, coal-fired power plants with once-through cooling systems consume much more water than the coal itself, making it more economical to transport coal to water-rich sites rather than the reverse. Thermal electricity generation, which requires large volumes of water for cooling, has always been constrained by water availability. Additionally, the growing use of biofuels from irrigation-dependent agriculture has intensified water demands in fuel production. Unlike energy, which is globally traded, water remains a local resource with distinct characteristics, emphasizing the need for regional strategies to manage this critical water-energy nexus (Mielke et al., 2010).

5. Biodiversity and Land Use (SDG 15 - Life on Land): Large-scale energy infrastructure projects, such as dams, solar and wind energy farms, can significantly impact ecosystems and biodiversity. Habitat destruction, species loss, disruption of species' natural behaviors. and ecosystem fragmentation are common consequences of energy infrastructure development (Gasparatos et al., 2017). For example, the Three Gorges Dam in China displaced over a

million people and caused extensive ecological impact (Wu et al., 2004). The extraction of resources for energy production, especially mining, can also contribute to biodiversity loss (Cabernard & Pfister, 2022). Large-scale renewable energy projects, such as solar and wind farms, require vast land areas, often leading to conflicts with alternative land uses like farming, tourism, and fishing (Seetharaman et al., 2019).

6. Social Equity and Inclusion (SDG 10 - Reduced Inequalities): Inequalities in energy access disproportionately affect low-income households, rural areas, and marginalized groups, perpetuating poverty and inequality. Transitioning to clean energy sources may cause temporary price shocks, disproportionately impacting low-income groups. Public clean energy incentive schemes and infrastructure investments often prioritize large-scale projects, neglecting small-scale, off-grid solutions that benefit poorer households (UN, 2019). Fossil fuel-dependent regions on the other hand, experience economic and social disruptions, including job losses and declining public revenues as a result of clean energy transition. The benefits of sustainable energy transition must be distributed equitably, ensuring that vulnerable populations have equitable access. Adaptive strategies including workforce training, economic diversification, and targeted energy assistance programs like the US Low-Income Home Energy Assistance Program would mitigate the adverse effects of the energy transition (Carley & Konisky, 2020; Adom et al., 2021).

7. Social Acceptance and Public Awareness: Lack of awareness and resistance to change might impede the adoption of sustainable energy practices. Limited public awareness about the environmental benefits of renewable technologies and feasibility of transitioning from fossil fuels to renewable energy hinders adoption. Public reluctance often stems from fears of insecurity, high-risk perceptions, and misconceptions about the cost and efficiency of renewable energy. The “Not in My Backyard” (NIMBY) syndrome further amplifies opposition of renewable energy adoption, as

individuals may support renewable energy in principle but resist local installations such as dams, solar and wind farms due to concerns about environmental degradation, landscape impact, population displacement and inadequate community consultation. Addressing these barriers through public awareness campaigns and inclusive community engagement, government programs is crucial for advancing sustainable energy deployment (Seetharaman et al., 2019; Yadav et al., 2020).

8. Technological and Infrastructure Barriers (SDG 9 - Industry, Innovation, and Infrastructure): The transition to sustainable energy sources faces significant technological barriers, including limited infrastructure, high initial costs, and insufficient grid integration, particularly in developing countries. A lack of knowledge in operations and maintenance, coupled with inadequate availability of spare parts and components, further escalates costs and inefficiencies. Insufficient investment in research and development (R&D) slows down technological advancements, keeping renewable energy less competitive with fossil fuels. Additionally, the lack of established standards, procedures, and guidelines for renewable energy technologies affects their reliability, durability, and performance, limiting large-scale adoption. Energy storage remains a major challenge, as the intermittent nature of renewable resources like wind and solar necessitates the development of large-scale storage solutions to balance supply and demand. Addressing these barriers through enhanced infrastructure, R&D investment, and advanced storage solutions is essential for the widespread adoption of sustainable energy technologies (Luthra et al., 2015; Seetharaman et al., 2019).

9. Policy and Regulatory Issues (SDG 17 - Partnerships for the Goals): Policy and regulatory challenges remain significant barriers to achieving global energy sustainability. Key factors on policy barriers include the absence of strong national policies, bureaucratic inefficiencies, insufficient incentives, and impractical government targets. Ineffective regulatory frameworks could lead to confusion among departments and prevent consistent integration of

renewable energy technologies with global markets. A lack of fiscal incentives, such as subsidies or tax exemptions for renewable energy equipment, makes renewable technologies less competitive with fossil fuels, while the absence of feed-in tariffs raises costs and restrains industry growth. Bureaucratic complexities, such as planning delays, long authorization times delay project timelines and discourage investments. The absence of clear standards and certifications complicates operations, leading to compliance issues (Seetharaman et al., 2019). In developing nations, challenges include lack of political commitment, policy inertia driven by vested interests and short-term considerations, and resistance from the fossil fuel industry. These factors contribute to delays in implementing sustainable energy measures and discourage long-term investments due to the absence of transparent and reliable regulatory frameworks (Falcone, 2023).

Many of abovementioned challenges are interconnected in nature, requiring a holistic approach and collaboration among governments, businesses, and civil society to address them effectively.

5.2 Energy Sustainability Challenges of Türkiye

Türkiye’s growing demand for energy and natural resources is driven mainly by population growth and economic development. In response, Türkiye’s energy policies have strategically shifted towards prioritizing sustainability, energy security and efficiency, as explained detailly in Chapter 4.

The country has made substantial progress in promoting renewable energy sources, enhancing energy security and reducing import dependency while ensuring transparency and reliability in its operations. As a result, Türkiye became twelfth in the world and fifth in Europe in terms of installed capacity of renewable energy (MFA, 2024a). In its Updated First Nationally Determined Contribution to UNFCCC, the country has also committed to attaining net-zero emissions by 2053

(Republic of Türkiye, 2023). In 2021, energy demand in Türkiye increased by 4.6%, which is above pre-pandemic levels, primarily due to higher economic activity. In 2021, the demand for electricity and natural gas rose, with electricity increasing by more than 8% and natural gas by around 21%. To meet this demand and reduce foreign dependence, new investments have been made to increase installed electricity capacity and diversify natural gas sources. Renewables and energy efficiency have become increasingly important for climate change mitigation, with Türkiye aiming to minimize reliance on fuel imports and reduce greenhouse gas emissions (World Energy Council [WEC], 2022).

Compared to other countries, Türkiye's energy policies exhibit distinct characteristics and challenges when considering environmental impacts. Some key points having environmental impacts include:

- High dependence on fossil fuels (IEA, 2021a).
- Heavy reliance on imported oil and gas (IEA, 2021a; MFA, 2024a).
- Substantial growth in renewable energy, primarily driven by hydro, solar, and wind sources (IEA, 2021a; MFA, 2024a).
- Commencement of a nuclear power program, with the first nuclear power facility scheduled to begin operations in 2025 (MFA, 2024a; Anadolu Agency, 2024).
- Significant environmental consequences, including air pollution, carbon emissions, and water resource management challenges (Kaygusuz, 2002; Kentel & Alp, 2013).
- Ambitious climate goals, such as a 2053 carbon neutrality target and a National Climate Change Strategy (MFA, 2024a; Republic of Türkiye, 2023; Elgendy & Tastan, 2022).

However, despite notable achievements in renewable energy and ambitious climate goals, Türkiye's overall environmental performance remains below that of many developed nations. For example, Türkiye's carbon intensity is around IEA averages but greater than the IEA Europe average. Additionally, Türkiye's per capita greenhouse gas emissions are low relative to the IEA average but are growing quickly (IEA, 2016).

Greenhouse gas emissions in Türkiye have been on the rise, with a significant increase of 7.7% in 2021 compared to 2020, according to official figures released by the Turkish Statistical Institute (TURKSTAT, 2023). In 2021, Türkiye's total GHGs were recorded at 564.4 MtCO_2eq, representing an increase of 157.1% between 1990 and 2021 (Figure 5.1). In 1990, the CO_2 emission per capita was 4 tons CO_2eq, which rose to 6.3 tons CO_2eq in 2020 and further increased to 6.7 tons CO_2eq per capita in 2021. Energy sector accounted for 71.3% of all CO_2 emissions in Türkiye in 2021, while industrial processes contributed 13.3%, and agriculture had a 12.8% share in the country's carbon emissions (TURKSTAT, 2023). These statistics show the significance of the impacts of energy on emissions and imply the urgency of the measures to decrease energy related emissions considered the global climate regime.

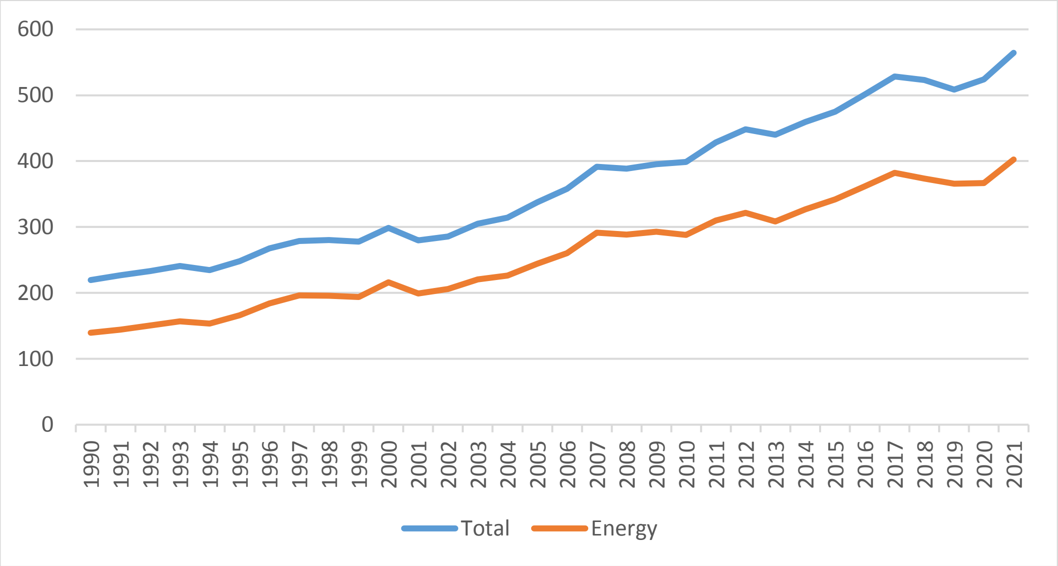


Figure 5.1. GHG Emissions of Türkiye (MtCO_2eq)

Source: TURKSTAT (2023).

Türkiye's per-capita greenhouse gas emissions are higher than the world average, 4.66 tons in 2022. The share of country's cumulative CO_2 emissions in global emissions is estimated at about 0.66% of the world's cumulative total, considering Türkiye's population is approximately 1% of the world population (Ritchie et al., 2023).

Türkiye as a developing country, has undergone various improvements in energy sector considering environmental sustainability. Türkiye's energy policies depicted in the previous section demonstrate a balance between economic growth and environmental considerations result in more sustainable energy systems compared to the past decades. The country's commitment to renewable energy and climate goals indicates a willingness to address environmental challenges, although the success of these endeavors may depend on significant foreign financing and investment (MFA, 2024a; Elgendy & Tastan, 2022).

The most important challenge to sustainability in Türkiye's energy sector is the substantial reliance on non-renewable fossil energy sources, particularly natural gas, oil, and coal in energy production (IEA, 2021a; Khan, 2021; Özdil, 2023). Despite progress in reducing economic carbon intensity, Türkiye is heavily relied on fossil fuels, which account for 81.2% of its primary energy demand (IEA, 2024a). Historical energy policies and infrastructure investments and the availability of domestic coal and natural gas resources have contributed to this dependence. While the availability and affordability of fossil fuels have made them a convenient choice for meeting Türkiye's energy needs, they come with detrimental environmental and public health consequences. Due to their high particulate emissions, this dependence also contributes to air pollution impacting public health and urban sustainability. Increased urbanization, industrial activities, and the concentration of energy-intensive sectors contribute to air quality issues. Among the main energy use sectors, the transportation sector, which heavily depends on oil, poses environmental challenges in cities together with use of coal for electricity production (IEA, 2021a).

The government's projections indicate a potential sharp rise in carbon emissions if current trends persist, highlighting the need for cleaner energy sources (Elgendy & Tastan, 2022).

Reliance of fossil fuels on the other hand poses another challenge as Türkiye heavily depends on imports for natural gas and oil (99% and 93%, respectively). Limited domestic energy resources and growing energy demand have led to a reliance on imports, particularly for natural gas and oil. Rising fossil fuel prices in the international markets could lead to a higher energy import bill showing the country's vulnerability to price fluctuations, which emphasize the need to reduce dependency on imports and accelerate the transition towards renewable energy sources (IEA, 2021a). Türkiye faced significant energy import costs, exemplified by a record $97 billion spent on imports in 2022 due to high global energy prices exacerbated by geopolitical conflicts like the Ukraine War (Özdil, 2023).

As exemplified above, being a net energy importer would make its energy supply vulnerable to geopolitical fluctuations. Türkiye's geopolitical landscape, including tensions with neighbors like Greece, Syria, Iraq, Iran, Armenia, and Greek Cyprus poses challenges for regional cooperation in the energy sector. Geopolitical conflicts and instabilities in neighboring region can hinder Türkiye's energy ambitions (Novikau & Muhasilović, 2023).

Renewable energy transition is a great opportunity on the other hand a challenge for Türkiye. While Türkiye has made significant progress in using renewable energy sources like hydroelectric, solar, wind, and geothermal energy in electricity generation, the country still faces challenges in increasing the renewable energy's share in its energy mix and there is a need to expand this transition beyond electricity to address environmental concerns associated with fossil fuel consumption and to diversify its energy sources and to reduce dependency on fossil fuels. Challenges include grid infrastructure limitations, the high initial investment costs associated with renewable energy technologies, regulatory complexities, and a need for more comprehensive policies to incentivize renewable energy development (Acar et al.

2023; Çakmak, 2024; Dilli & Nyman, 2015). Overcoming these challenges is especially important for Türkiye committed to combatting climate change includes joining the Paris Agreement and setting a 2053 carbon neutrality target indicated as indicated in Chapter 4.

Balancing economic development with climate commitments presents a dilemma for the country. Achieving decarbonization requires significant financial investment on clean energy technologies and foreign finance due to the country's high savings deficit (Acar et al. 2023; Elgendy & Tastan, 2022). According to Acar et al. (2023), the energy transition requires a doubling of investments in clean energy ranging from $6 billion to $12.3 billion annually. In another study, Türkiye needs an annual investment of $5.3-7 billion until 2030 for its energy transition, necessitating an average annual financing of $3.6 to 4.5 billion (Shura Energy Transition Center, 2019). Securing foreign finance and investments is therefore crucial for Türkiye's decarbonization efforts.

In addition, Türkiye's focus on economic growth and political complexities poses challenges to achieving a swift transition to cleaner energy sources. As indicated in previous chapter, Türkiye's energy policies have been primarily focusing on ensuring supply security, resulting in substantial investments of infrastructure such as pipelines and storage facilities and expanded energy imports (Novikau & Muhasilovic, 2023). While these measures could mitigate short term supply risks, this approach may not be sustainable in the long term, as it would increase dependency on fossil fuels and inadequately address transition to cleaner energy sources for climate change mitigation. Stimulating investment in clean energy technology and energy infrastructure together with facilitating access to clean energy research and innovation could effectively support the country's energy transition and meet its increasing energy demand (Acar et al, 2023).

While Türkiye has made some progress in energy efficiency, particularly in the industrial sector, there is still room for improvement in residential and commercial sectors (MENR, 2024b). Energy efficiency has a critical role in Türkiye's energy transition. Through the implementation of energy efficiency measures and the electrification of end-use sectors, Türkiye can reduce total electricity demand by 10% by 2030. Improving energy efficiency would also provide a substantial economic and social opportunity, significantly contributing to Türkiye’s broader sustainable development and net-zero emission goals (Acar et al. 2023).

Türkiye has made considerable advancement in the access to electricity, with nearly 100% of its population having access to electricity. However, affordability and quality of energy services remain significant challenges, particularly in rural areas. Socioeconomic disparities including varying income levels, unemployment, housing conditions, and infrastructure quality also affect access to adequate energy services causing barriers for low-income and vulnerable households, that exacerbates social inequalities (Korkmaz & Senyel Kurkcuoglu, 2025). Addressing these disparities through tailored local policies and infrastructure improvements is therefore crucial for ensuring social inclusion in Türkiye’s ongoing energy transition.

Vulnerable to climate change impacts, Türkiye’s limited water resources is a significant challenge as well. The rapid development of hydropower projects without sufficient environmental assessments would exacerbate water scarcity and trigger severe ecological problems including deforestation and habitat loss and disruptions in local water systems (Kentel & Alp, 2013; Dilli & Nyman, 2015). Effective management of water resources is crucial for the country due to uneven distribution of water resources and the potential effects of climate change on water availability (European Environmental Agency, 2015).

Nuclear power expansion is regarded as a strategic priority for the Türkiye’s energy security and climate change mitigation efforts. Türkiye aims to add nuclear power to its energy mix for diversification and energy independence as well as decreasing negative climate change impacts of energy production (MFA, 2024a). While nuclear power provides advantage in reducing carbon emissions compared to fossil fuel based energy production, it also introduces substantial challenges, particularly in nuclear waste management, environmental safety, risk management, and public acceptance (Aydın, 2020).

In the context of SDGs, the challenges faced by Türkiye in achieving energy sustainability are intricately linked to SDG 7, which focuses on clean and affordable energy. Among the challenges discussed above, two key challenges, namely the heavy dependence on fossil fuels and the limited development of renewable energy sources, could directly impact Türkiye's progress towards SDG 7.

5.3 Chapter Review

Globally, energy sustainability faces critical challenges, including climate change, resource depletion, water scarcity, social equity, and technological barriers (IEA, 2023b; Ansari & Koderma, 2017; Mielke et al., 2010; UN, 2019; Luthra et al., 2015; Seetharaman et al., 2019). Climate change remains the foremost challenge, driven by greenhouse gas emissions from energy-intensive industries and fossil fuel dependency (IEA, 2023b). Resource depletion, including the overexploitation of fossil fuels and rare earth materials coupled with the environmental impacts of energy production such as impacts on biodiversity and land use changes further threatens long-term sustainability (Ansari & Koderma, 2017; Gasparatos et al., 2017; Cabernard & Pfister, 2022). Water scarcity, compounded by water-intensive energy production, poses severe risks to both human and ecological systems (Mielke et al., 2010). Social equity issues, such as energy poverty and unequal access to resources, exacerbate disparities between developed and developing regions (Kumar et al., 2019; UN, 2019). Technological and infrastructure barriers hinder the widespread adoption of renewable energy systems and decarbonization efforts (Luthra et al., 2015; Seetharaman et al., 2019). Finally, policy and regulatory challenges, including weak national policies, bureaucratic inefficiencies, insufficient incentives, and ineffective regulatory frameworks, hinder global energy sustainability by creating market uncertainty, delaying renewable energy adoption, and discouraging investments in clean technologies (Seetharaman et al., 2019).

In Türkiye, these global challenges are mirrored and intensified by local dynamics. As explained in this chapter, Türkiye's energy challenges revolve around reducing fossil fuel dependency, transitioning to renewable energy sources (Acar et al., 2023; IEA, 2021a; Özdil, 2023; Çakmak, 2024; Dilli & Nyman, 2015), balancing economic growth with climate commitments (Acar et al., 2023; Elgendy & Tastan, 2022), addressing geopolitical tensions (Novikau & Muhasilović, 2023), securing financial investments for decarbonization, and reducing energy import dependency (IEA, 2021a; Acar et al. 2023; Elgendy & Tastan, 2022; Shura Energy Transition Center, 2019).

The country faces high dependency on fossil fuel imports, limited diversification of renewable energy resources, and rising energy demands, placing strain on its energy systems (IEA, 2021a; Özdil, 2023). The heavy reliance on imported natural gas and oil, which constitute 99% and 93% of its energy sources respectively, leaves it vulnerable to global market fluctuations and geopolitical tensions (IEA, 2021a; Novikau & Muhasilović, 2023). Social and economic disparities in energy access further compound these issues, particularly in rural communities (Korkmaz & Kurkcuoglu, 2025). Despite these challenges, the government of Türkiye has made progresses in sustainable energy by prioritizing energy security, enhancing energy efficiency, and expanding renewable energy infrastructure, placing Türkiye among the global leaders in renewable energy installed capacity (MFA, 2024a; WEC, 2022). Türkiye's ambitious 2053 carbon neutrality target and commitments under the Paris Agreement highlight the urgency of transitioning from fossil fuels to clean and sustainable energy systems (Republic of Türkiye, 2023; Elgendy & Tastan, 2022).

Addressing sustainability challenges requires Türkiye to adopt a comprehensive and integrated approach that aligns with global strategies while addressing local priorities. Such approach should include renewable energy development, energy efficiency measures, and inclusive policies that consider both environmental and social aspects (Acar et al., 2023; Korkmaz & Kurkcuoglu, 2025). Expanding access to clean energy for rural communities through inclusive policies and improving infrastructure can reduce energy poverty and promote social equity (Korkmaz & Kurkcuoglu, 2025; Kumar et al., 2019; UN, 2019).

To combat climate change, Türkiye has set ambitious targets in its Updated First Nationally Determined Contribution including comprehensive measures for transition to renewable energy and improving energy efficiencies in main sectors such as industry, transport, and buildings (Republic of Türkiye, 2023). Transitioning towards cleaner and more sustainable energy options will not only reduce the country's carbon footprint but also enhance energy security and resilience against global energy market fluctuations (Özdil, 2023; Elgendy & Tastan, 2022). By promoting renewable energy investments and implementing supportive policies, Türkiye can overcome the challenges associated with its heavy reliance on fossil fuels and move towards a more sustainable energy future aligned with the SDGs and 2053 carbon neutrality target (Acar et al., 2023; Republic of Türkiye, 2023). To do so, investing more in research and development of renewable energy technologies, as well as in the necessary infrastructure to support renewable deployment is crucial (Acar et al., 2023; Shura Energy Transition Center, 2019; Luthra et al., 2015; Seetharaman et al., 2019). It is important to continue implementing supportive financial policies, including feed-in tariffs, tax incentives, and subsidies, to foster the utilization of renewable energy sources (Dilli & Nyman, 2015; Seetharaman et al., 2019).

On a global scale, Türkiye's sustainability challenges associate also with those faced by other nations, underscoring the importance of international cooperation. Ongoing international collaborations and partnerships on energy and climate change presented in Chapter 4 could provide financial and technical support for energy infrastructure development and climate adaptation measures (European Commission, 2024b; IEA, 2021a; IEA, 2016; International Energy Charter, 2019; UN, 2023).

Improving the alignment of its policies with international sustainability frameworks such as the SDGs and the Paris Agreement, Türkiye could better deal with local and global challenges and position itself as a leader in sustainable development. In this respect, through effective policymaking and multi-sector collaboration and coordination, Türkiye can achieve a balanced approach to economic growth, environmental preservation, and social well-being, securing a sustainable future for the nation and contributing to global sustainability efforts.

To conclude, this chapter addresses the challenges in achieving energy sustainability, including global energy sustainability challenges and Türkiye-specific issues such as reliance on fossil fuels, environmental degradation, and energy security concerns. Contextualizing these challenges within the broader sustainability goals outlined in international agreements, this chapter provides a clearer picture of the structural and policy barriers with some recommendations to overcome these barriers for a more sustainable energy system, contributing the formulation of the policy recommendations proposed in Chapter 8.

While Türkiye faces significant challenges in achieving energy sustainability, many countries with diverse economic structures, policy frameworks, and resource endowments have also been navigating similar obstacles in their transition toward sustainable energy systems. A comparative perspective is therefore important to offer practical recommendations for enhancing Türkiye's sustainable energy policies and aligning them with global sustainability standards. The next chapter, Chapter 6 provides a comparative assessment of Türkiye's standing in sustainable development and energy sustainability to explore its achievements and to identify areas requiring improvement.

CHAPTER 6

COMPARISON OF TÜRKİYE WITH OTHER COUNTRIES

To further contextualize Türkiye's energy sustainability performance presented in previous chapters, this chapter provides a comparative assessment of Türkiye's performance in sustainable development and energy sustainability relative to selected countries, including Spain, Poland, Mexico, South Korea, and South Africa. Utilizing indices such as the SDG Index, Ecological Footprint, and the World Energy Council's Trilemma Index, this chapter benchmarks Türkiye's achievements in energy sustainability and sustainable development, highlights areas requiring improvement, and derives insights from international comparison. This cross-country evaluation helps contextualize Türkiye's progress in terms of identifying strengths and weaknesses.

Understanding the transition to sustainable development requires clear metrics to set specific goals and track progress. Accurately measuring sustainability is essential for achieving sustainable development goals at all levels. Over the past decade, there have been many academic studies accomplished to quantify sustainability concepts into indicators or metrics in literature. Using frameworks and aggregation methodologies from academic literature, various organizations have developed tools, indices, and scorecards to measure, monitor, and evaluate progress in sustainability (Cohen et al., 2015).

Indicators and composite indicators (indices) have gained recognition as valuable tools for policymaking and public communication, effectively communicating information about performances of countries regarding main dimensions of sustainable development areas. Indicators are typically quantitative measures that represent the state of economic, social, or environmental development within a specific country or region. When these indicators are aggregated, they form composite indicator in other words an index. Indicators and indices enable the tracking of long-term sustainability trends from a retrospective perspective if continuously measured over long periods. Analyzing these trends would help scientist and policy makers to make short-term projections and informed decisions for the future (Ness et al., 2007; OECD et al., 2008).

The primary role of indicators is to simplify complex environmental dynamics into clear, manageable, and meaningful information. By visualizing data and highlighting trends, indicators facilitate analysis, quantification, and communication of complicated phenomena (Singh et al., 2009). Indicators ought to possess the following attributes: simplicity, broad applicability, measurability, facilitation of trend analysis, responsiveness to change, and detection of trends timely (Ness et al., 2007). There is a broad consensus on the necessity for individuals, organizations, and societies to identify models, metrics, and tools that can clearly demonstrate the degree and nature of unsustainability in current actions (Bebbington et al., 2007).

The measurement of sustainable development is a dual-stage process. Initially, progress within specific domains is assessed through sustainable development indicators. Then, the overall advancement toward sustainable development is evaluated by integrating these individual domains, considering their interconnectedness (Singh et al., 2009).

In assessing sustainability two main methodologies are utilized in general: a monetary aggregation approach favored by mainstream economists, and a physical indicators approach preferred by scientists and researchers across different disciplines. Economic approaches encompass methods such as integrating environmental factors into GDP calculations, resource accounting based on their functions, modeling sustainable growth, and delineating weak and strong sustainability criteria (Singh et al., 2009).

Economists view sustainable growth as integral to economic sustainable development and often prioritize monetary valuation due to its reflection of resource scarcity. However, Spangenberg (2005) critiques this limited economic perspective, arguing that solely relying on monetary valuation restricts the analytical capacity of economics. He highlights criticisms regarding the assumption of strong substitutability between different types of capital in economic models, ultimately concluding that there cannot be a single comprehensive measure or index of sustainability from a scientific standpoint (Spangenberg, 2005).

Ness et al. (2007) developed a comprehensive framework for sustainability assessment, divided into three main categories:

1. “Indicators and Indices”: This includes non-integrated and integrated measures.
2. “Product-Related Assessment Tools”: Focused on the material and energy flows of products or services from a life cycle perspective.
3. “Integrated Assessment”: Tools aimed at policy change or project implementation (Ness et al., 2007).

Arthur Lyon Dahl, President of the International Environment Forum, notes that no standard sustainability metric has yet emerged. While academics have engaged in theoretical work to comprehend sustainability measurement systems and indicators, and various entities across sectors have developed practical tools, there remains a lack of universally accepted definitions and indicators for assessing sustainability (Cohen et al., 2015).

Indicators for assessing sustainability can be categorized and assessed based on several key dimensions:

– What feature of sustainability does the indicator address?
– The methods used for constructing the index, whether subjective or objective, quantitative or qualitative, cardinal or ordinal, and whether it is unidimensional or multidimensional.
– Whether the indicator compares sustainability measures across space or time, and whether it does so in a relative or absolute manner.

- Whether the indicator focuses on inputs or outputs in measuring sustainability.
- The clarity and simplicity of the indicator in terms of its objective, methodology, content, comparative application, and focal point.
- The availability of data for the indicator across various times and locations.
- The indicator's flexibility in accommodating changes in purpose, methodology, and comparative application (Singh et al., 2009).

6.1 Sustainability Indices

Since the concept of sustainable development, in which the link between the welfare of today's generation and the welfare of future generations is built, is extremely comprehensive with its economic, social and environmental dimensions, the effects of changes in these areas are also multi-dimensional. This feature makes it difficult to perceive and evaluate sustainability. Therefore, it needs to be measured using enough economic, social and environmental variables and appropriate methods. It is inevitable to use a wide range of indicators and indices, from traditional macro-economic measures such as GDP and productivity to environmental indicators such as green areas, water consumption and GHG emissions, and social statistics such as poverty rate, average life expectancy and education level (Yıkmaz, 2011).

Numerous efforts have been made to integrate various dimensions of economy, nature, and society into a single indicator or index. These alternatives aim to supplement traditional national accounting measures like GDP, which is frequently used to assess overall human welfare. However, GDP can mislead decision-makers about genuine sustainability as it fails to account for critical factors such as income distribution, resource overuse, public safety, and other negative externalities that are not generally reflected in conventional metrics (Ness et al., 2007).

The concept of GDP is at the center of these discussions. It is stated that the use of GDP as an indicator for economic wealth leads to the inability to measure various social and environmental problems. Due to these shortcomings of GDP, various assessment tool alternatives have been formulated such as the Index of Sustainable Economic Welfare or the Ecological Footprint as alternative or complementary to GDP (Yıkmaz, 2011). However, due to methodological problems, instead of these indices, some countries have started to develop and adopt sets of sustainable development indicators that depict selected economic, social and environmental aspects of sustainable development. In many studies, sustainable development indicator sets have been adopted as the standard way to monitor progress towards sustainable development in Europe and other parts of the world (Eurostat, 2007; Yıkmaz, 2011).

Indices based on accounting frameworks are based on monetary and social values. They aim to measure the level of human welfare by determining values. This kind of indexes include Sustainable Economic Welfare Index (ISEW), Genuine Progress Indicator (GPI), and “Green” national income indices such as the World Bank Real Savings (Yıkmaz, 2011).

The ISEW and the GPI, developed by an NGO in the 1990s, covers economic, social, and environmental dimensions of sustainable development. These tools adjust national accounting methods to include a wider range of welfare factors, deducting for environmental damage, natural capital depreciation and military expenditures (Ness et al., 2007).

Adjusted Net Savings, or Genuine Savings, is an alternative method for evaluating national sustainability, often linked with the World Bank. This metric considers resource depletion, environmental harm, and various other factors like technological advancements and education investments. It offers a clear indication of a country’s developmental direction, with positive values signaling progress toward sustainability and negative values indicating otherwise (Ness et al., 2007).

The Ecological Footprint (EF) serves as a tool for gauging resource consumption and waste assimilation needs in relation to land area for a population or economy. This involves estimating annual consumption across various categories, calculating the corresponding land requirements, and aggregating them to determine per capita land use. While primarily used for national sustainability assessments, it has also been applied at city and regional levels. However, it solely addresses the environmental dimension of sustainable development, disregarding social and economic aspects. Components include forest, cropland, grazing land, built-up area, fishing ground, and energy land (Wackernagel et al, 1997).

The Environmental Sustainability Index (ESI) was developed to determine the collective journey towards environmental sustainability across 146 nations. Its 2005 version of the index comprises 21 indicators drawn from 76 underlying datasets spanning five distinct categories: the condition of environmental systems (air, water, soil, ecosystems, etc.), mitigating pressures on these systems, diminishing human susceptibility to environmental changes, societal and institutional capability to tackle environmental challenges, and adherence to international agreements and standards. ESI primarily emphasizes environmental sustainability but also incorporates social and institutional aspects. Its goal is to facilitate country comparisons and aid in environmental decision-making (Yale Center for Environmental Law and Policy et al., 2005).

The Environmental Performance Index (EPI), jointly developed by Yale and Columbia University, measures sustainability performance of 180 countries across 40 indicators within three key policy objectives: climate change, environmental health, and ecosystem vitality. Updated in 2022, the EPI serves as a global scorecard, summarizing countries' progress towards established environmental goals and providing guidance to inform sustainable policy decisions (Wolf et al., 2022).

The Wellbeing Index, used for evaluating the 2002 World Summit for Sustainable Development, includes data from 180 countries. It consists of two components: the Human Wellbeing Index (HWI) and the Ecosystem Wellbeing Index (EWI). The

HWI assesses factors like health, wealth, and social equity, while the EWI covers environmental aspects such as land, water, air quality, and biodiversity. Both indices are combined equally to form the Barometer of Sustainability (Prescott-Allen, 2001).

The Human Development Index (HDI), produced by the United Nations Development Programme (UNDP), is a widely utilized composite measure of social and economic progress. It evaluates three dimensions: health (life expectancy at birth), education (mean and expected years of schooling), and living standards (Gross National Income per capita). The HDI ranges from 0 to 1 and provides a comprehensive assessment of well-being. Although it has been calculated for UN member and some non-member countries since 1975, comparisons over time are challenging due to a significant reform in 1999 (UNDP, 2024a; Lind, 2004).

The Better Life Index, developed by the OECD, evaluates well-being across 11 dimensions, including housing, income, jobs, and education, environment, civic engagement, health, life satisfaction, safety, and work-life balance, for 34 developed countries. Unlike the HDI, it considers subjective well-being but lacks guidelines for improvement and does not account for inequalities within countries. Each indicator is equally weighted, and the index scores range from "0" (worst) to "1" (best) (OECD, 2020; Kwatra et al., 2020).

To assess the status of different countries, the Sustainable Development Solutions Network (SDSN) and the Bertelsmann Stiftung have come out with Sustainable Development Goal Index (SDG Index) to compare countries on the global scale. A mixed approach has been used where stakeholder consultations have been done to identify the final set of indicators to be used in composite SDG Index in which 97 global indicators have been used (Sachs et al., 2023).

The World Energy Trilemma Index (ETI) is a country ranking system that aims to measure their ability to provide a stable, affordable, and environmentally sensitive energy system by showing the aggregate effect of energy policies applied over time in the context of each country. Since 2010, ETI, which compares the energy systems of 126 countries, is prepared annually by the World Energy Council (WEC). This index is based on three core dimensions: Energy Security, Energy Equity, and Environmental Sustainability of Energy Systems. Balancing these dimensions forms the "Trilemma", essential for fostering prosperity and competitiveness among individual countries. It offers an assessment of a country's energy system performance, highlighting its balance and robustness across the three Trilemma dimensions (WEC, 2024a).

6.2 Comparison of Selected Countries Using Indices

In this part, energy sustainability of Türkiye will be compared with Spain and Poland (Europe), Mexico (America), Korea (Asia) and South Africa (Africa)) using most common indices of sustainability: Human Development Index, Ecological Footprint, Environmental Performance Index, SDG Index and WEC's Trilemma Index. Before comparison, index methodologies were described detailly to provide methodological insights for the indices developed in the next chapter in this study.

6.2.1 Comparison of Selected Countries by Human Development Index

The Human Development Index (HDI) is a commonly used composite index of well-being by the United Nations Development Programme (UNDP) for evaluating social and economic progress indifferent countries. It consists of three general dimensions: health, education, and standard of living. Health is measured by life expectancy at birth; education is measured by a combination of the expected years of schooling and mean years of schooling. Finally, the standard of living is measured by gross national income (GNI) per capita as shown in Figure 6.1 (UNDP, 2024b).

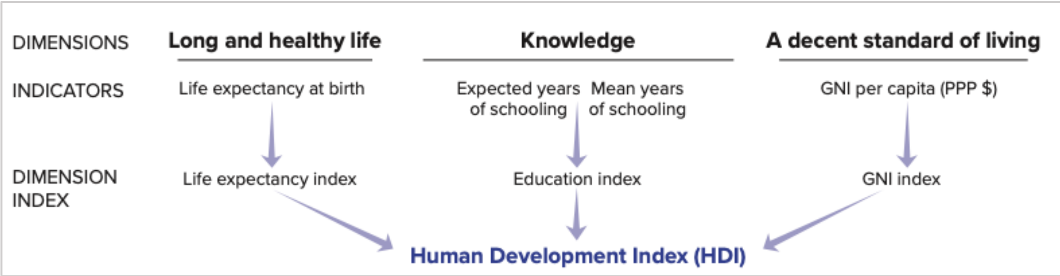


Figure 6.1. Human Development Index Calculation Framework

Source: UNDP, 2024b.

The HDI is the geometric mean of normalized indices for each of the three dimensions and has a possible range of 0 to 1 according to the formula (1) below:

$$HDI = (I_{Health} . I_{Education} . I_{Income})^{1/3} \quad (1)$$

Until 2010 "arithmetic mean" is used in the calculation of HDI. Since 2010, this method changed with "geometric mean" to account for the fact that the three dimensions are not interchangeable and have different scales. The geometric mean is used to reflect the following trade-offs between dimensions: imperfect substitutability, reward of balance, and higher impact of deficient performance. The arithmetic mean, which was traditionally used to compute the HDI, did not accurately reflect these trade-offs and made it difficult to compare the trade-off between life expectancy and years of education. The geometric mean, on the other hand, penalizes differences in value between indicators and rewards balanced achievement in all dimensions, making it a more appropriate method for calculating the HDI (Aguña & Kovacevic, 2010).

After defining the minimum and maximum values for each indicator, the dimension indices are calculated using the formula (2) below:

$$Dimension\ Index = \frac{Actual\ value - Minimum\ value}{Maximum\ value - Minimum\ value} \quad (2)$$

Minimum and maximum values in this formula are set to transform the indicators expressed in different units into indices between 0 and 1. Minimum values function as “the natural zeros” while the maximum values as “aspirational targets,” in standardization. For the education dimension, the above equation is first applied to each of the two indicators, and then the arithmetic mean of the two resulting indices is taken. For income, the natural logarithm of the actual, minimum and maximum values is used because the transformation function from income to capabilities is likely to be concave (UNDP, 2024b).

The HDI was invented by Pakistani economist Mahbub ul Haq and introduced in 1990. It is one of the indices aiming to solve the limitations of national income, or GDP in accounting for the social or human dimensions of development. HDI has been used by the UNDP to assess human development annually and it has been a widely used indicator in sustainable development studies (UNDP, 1990).

However, HDI has some limitations in reflecting other components of sustainable development such as ecological sustainability. To overcome this limitation, some scholars made various attempts to integrate environmental dimensions into HDI. Türe (2013) incorporated ecological footprint with HDI. Biggeri and Mauro (2018) have proposed an alternative index that integrates environment (CO_2 emissions) and freedom (defined as the political rights and civil liberties) in HDI. Hickel (2020) also developed an alternative index retaining the base formula of the HDI but places a sufficiency threshold on per capita income and divides by two key indicators of ecological impact: CO_2 emissions and material footprint.

HDI values ranges 0 to 1 where human development level increases through 1. In the 2014 Human Development Report, there is a system of fixed cutoff points for the four categories of human development achievements (Table 6.1). The cutoff points are the HDI values calculated using the quartiles (q) from the distributions of the component indicators averaged over 2004–2013.

Table 6.1. Human Development Index Categories

Very high human development	0.800 and above
High human development	0.700–0.799
Medium human development	0.550–0.699
Low human development	Below 0.550

Source: UNDP, 2024b.

The trends in HDI values of the countries are shown in the Figure 6.2 below. In this figure the trends of selected countries are shown in differentiating low, medium, high and very high human development levels so that respective global positions would also be seen.

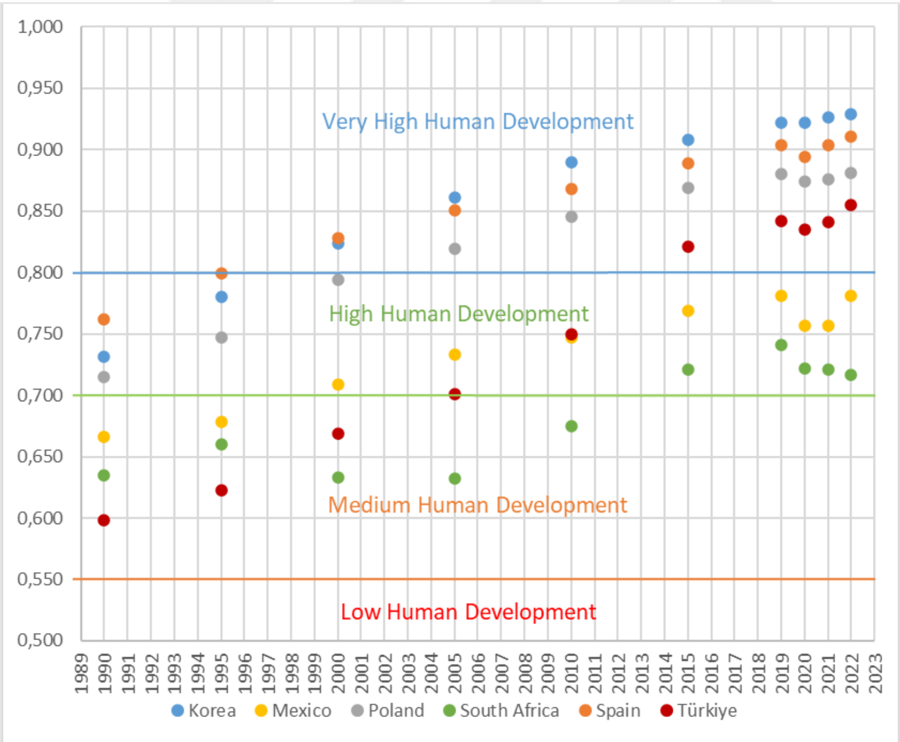


Figure 6.2. HDI Comparison of Selected Countries

Source: UNDP (2024a).

When the Figure 6.2 analyzed, Türkiye showed noteworthy progress between 1990-2022 in HDI overall when compared with the world average. In comparison with the relatively more developed countries as Spain, South Korea and Poland, Türkiye has been getting closer to their level showing a faster progress in HDI (9 place up in ranking). As a result of this pace, Türkiye has passed South Africa and Mexico in terms of human development and reached high human development.

In 2020, a new metric introduced in the HDI report, namely Planetary pressures–adjusted Human Development Index (PHDI) that adjusts the HDI to account for the ecological impact of carbon emissions and resource use on a per capita basis. It is calculated as the product of the HDI and (1 – index of planetary pressures), where (1 – index of planetary pressures) is an adjustment factor that reflects the country's level of carbon dioxide emissions and material footprint per capita (Figure 6.3). The adjustment factors of PHDI are related to SDG 8.4, 9.4 and 12.2 (UNDP, 2024a).

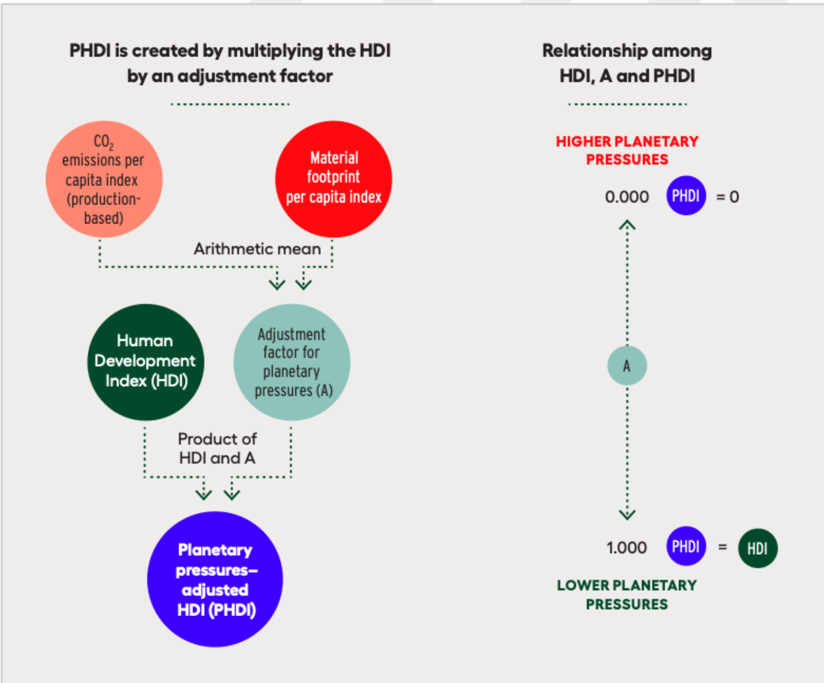


Figure 6.3. PHDI Representation and Comparison with HDI

Source: UNDP (2020a).

The PHDI serves as a compass for navigating the challenges of the Anthropocene era. It facilitates the evaluation of necessary changes and encourages actions that promote both human development and environmental sustainability (UNDP, 2020a).

The PHDI aims to encourage transformation towards sustainable development by signaling the need to reduce carbon emissions and close material cycles. However, the PHDI has some limitations, such as not accounting for individual countries', current or historical responsibilities and not implying that other environmental concerns are less crucial (UNDP, 2020a).

Over the past thirty years, countries have followed varied development trajectories based on their level of human development. Countries with low to medium levels of human development have significantly enhanced their socioeconomic conditions without causing considerable environmental impacts. Conversely, countries categorized under high and very high human development exhibit a lower PHDI compared to their HDI, primarily due to elevated carbon emissions and greater material footprints (UNDP, 2020a).

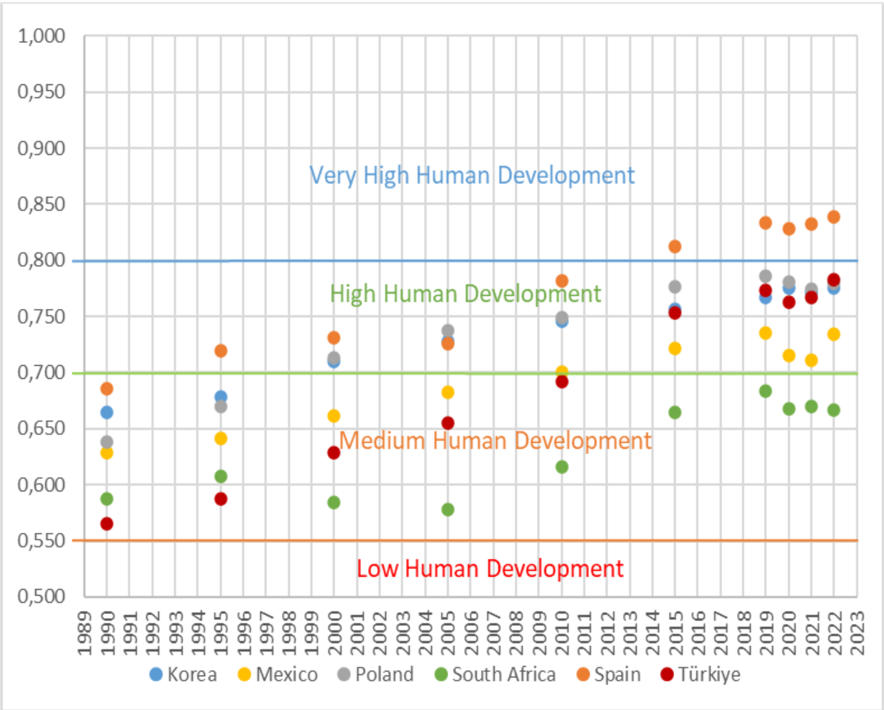


Figure 6.4. PHDI Comparison of the Selected Countries

Source: UNDP (2020b).

As seen from Figure 6.4 the PHDI scores are lower for most of the countries. Only Spain achieved to protect its classification as high human development country in PHDI. Türkiye, Poland and Korea degraded to the high development from very high. Among them Türkiye seem to perform better compared to HDI scores.

6.2.2 Comparison of Selected Countries by Ecological Footprint

The Ecological Footprint (EF) is an accounting tool that estimates the resource consumption and waste absorption requirements of a given population or economy in terms of a corresponding land area. It quantifies the supply and demand of Earth's biocapacity considering that Earth has a finite amount of biological production that supports all life on it (Lin et al., 2018). EF measures aggregate biologically productive land and sea area for an individual, population, or activity requires to produce all the resources it consumes and to absorb the waste it generates.

The most widely used application of Ecological Footprint accounting is the National Footprint Account (NFA), initiated by Wackernagel et al. (1997). NFAs provide annual accounts of bio-capacity and the Ecological Footprint for the world and all countries. In globally, EF of countries has been calculated within the NFA by Global Footprint Network since 2003 (Lin et al., 2018).

Calculating the EF is a multi-stage process as depicted in formula below A country's consumption is calculated by combing EF of national production with net EF of trade (Lin et al., 2018).

$$EF_{Consumption} = EF_P + (EF_I - EF_E) \quad (3)$$

where:

- EF_P is the is the Ecological Footprint of production,
- EF_I is the Ecological Footprint of imports, and
- EF_E is the Ecological Footprint of exports

EF of production is the sum of all bio-productive within a country needed to support the actual harvest of primary products (cropland, grazing land, fishing grounds) and built-up land (roads, cities, etc.) and the area needed to absorb all CO_2 emissions for a product is calculated in mass per time and translated into global hectares through the following equation (Lin et al., 2018):

$$EF_{Production} = \frac{P}{Y_w} \times EQF \quad (4)$$

- Where P is the production (or harvest) in tons per year,
- Yw is the world average yield in tons per hectare, per year, and
- EQF is the equivalence factor (the ratio of a given land type's average global productivity divided by the average global productivity of the entire planet's productive surfaces).

For each country, the Ecological Footprint of production (EFp) of a footprint category (cropland, grazing land, fishing grounds, forest for forest products, built-up land, and carbon footprint) is calculated by summing all products of that footprint category (i.e., rice, wheat, corn for cropland). Then the total EFp of a country is the sum of the six Ecological Footprint components (Lin et al., 2018).

Similarly, biocapacity is calculated for five biocapacity land-use category (cropland, grazing land, fishing grounds, forests, and built-up land) (Lin et al., 2018).

$$Biocapacity = A_n \times \frac{Y_n}{Y_w} \times EQF \qquad (5)$$

where:

- A_n is the area in country "n" for this land-use category in hectares, and
- Y_n is the national average yield for this land-use category in tons per hectare and year.
- Y_w is the world average yield in tons per hectare, per year, and
- EQF is the equivalence factor (the ratio of a given land type's average global productivity divided by the average global productivity of the entire planet's productive surfaces).

The NFA framework that is explained above is graphically represented in Figure 6.5.

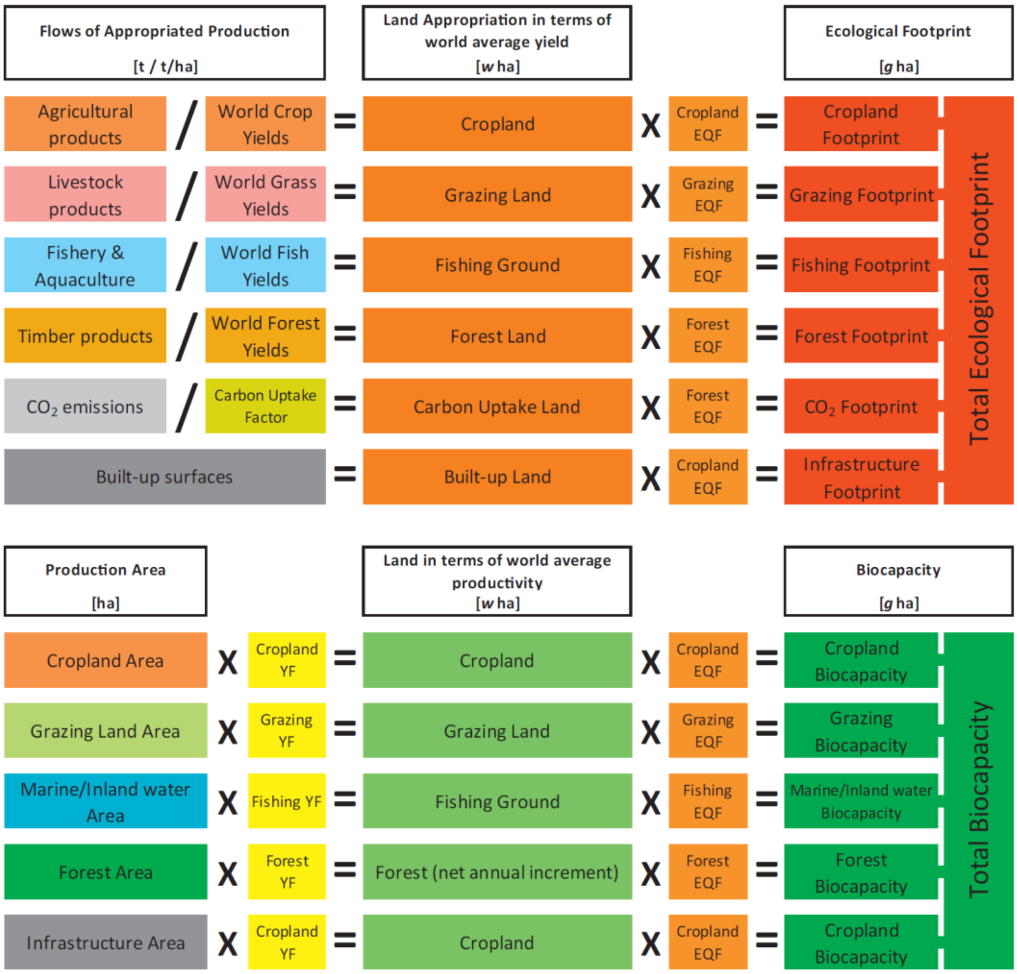


Figure 6.5. National Footprint and Biocapacity Accounts (NFA) Accounting Framework

Source: Borucke et al. (2013).

As the calculations of this index are based on the total land and water resources a country consumes to meet its needs and to dispose of the waste produced by the country, it only considers the environmental dimension of sustainable development.

Sustainability progress can be measured and assessed using Ecological Footprint accounts, which define the minimal conditions for living within the regenerative capacity of the planet's ecosystems. Keeping humanity's EF within the biocapacity of the planet is the foundational minimum threshold for enabling human activities to persist rather than decline (Borucke et al., 2013).

The Ecological Footprints of the selected countries are shown below Figure 6.6:

a.

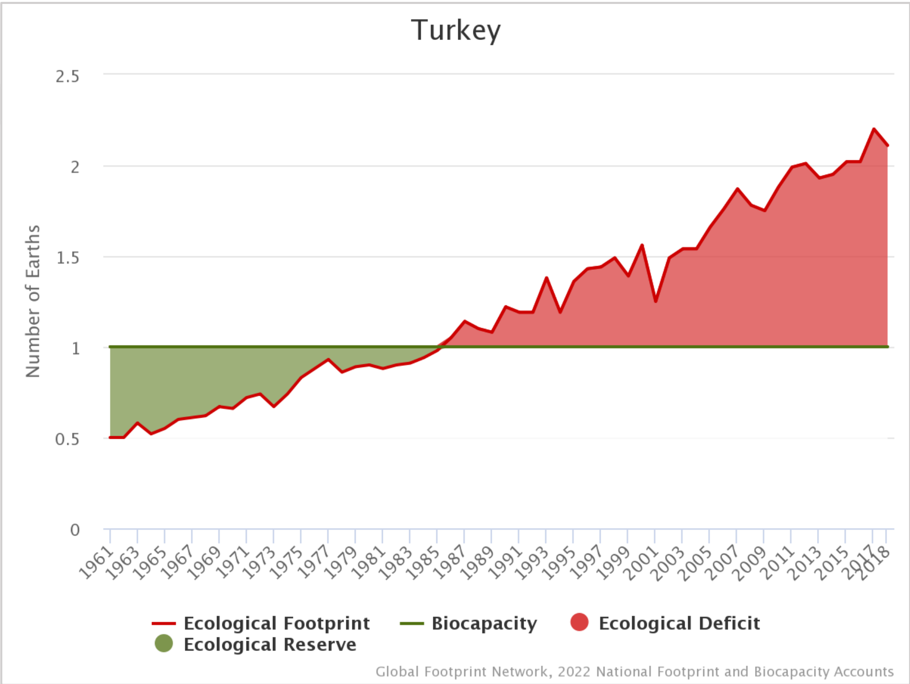
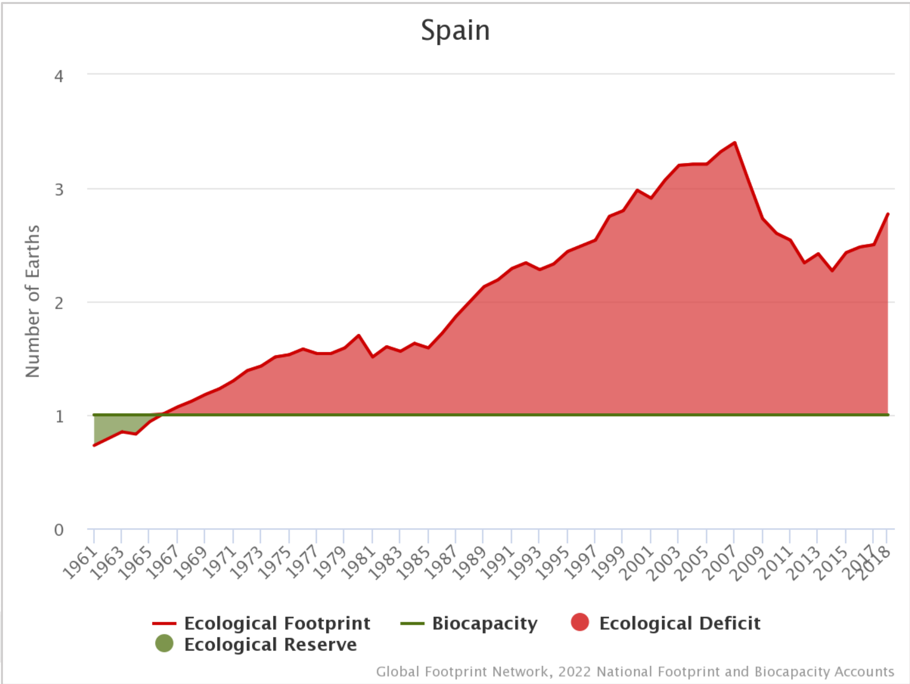


Figure 6.6. Ecological Footprints of the Selected Countries (1961-2018)

Source: Global Footprint Network (2022). National Footprint and Biocapacity Accounts. Accessed from https://data.footprintnetwork.org/

b.



c.

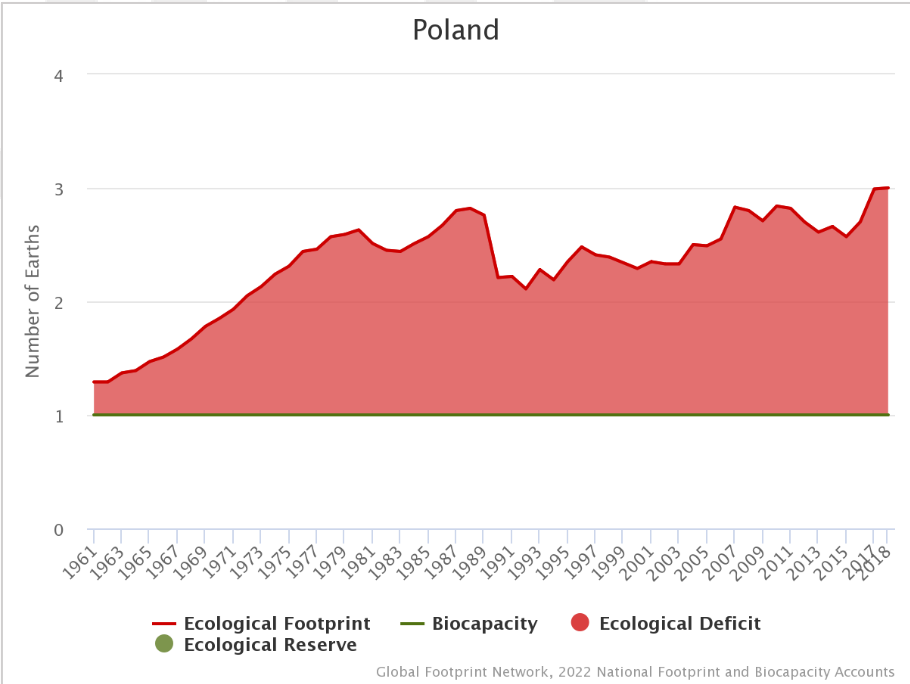
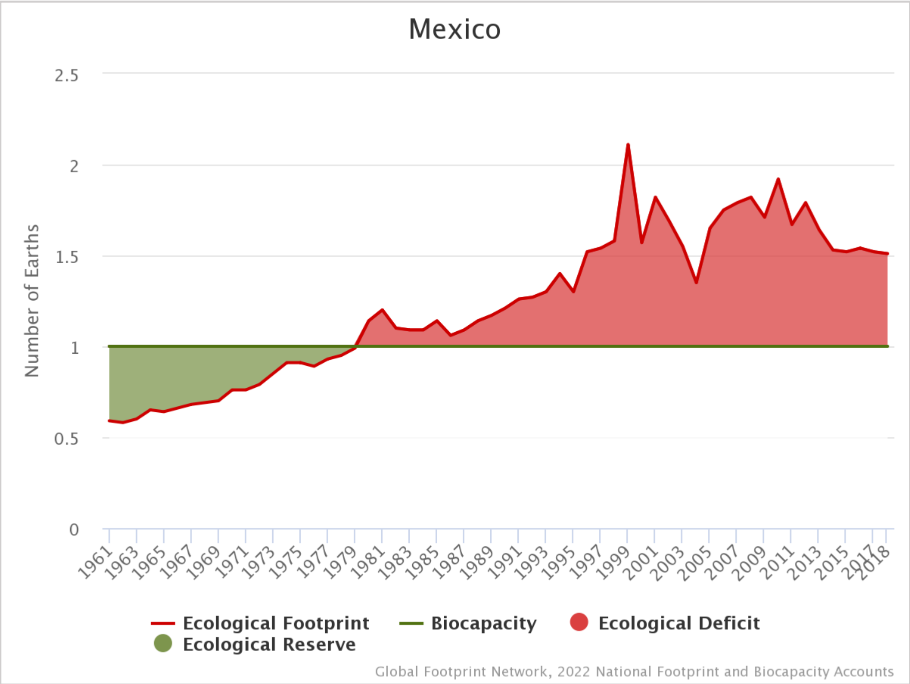
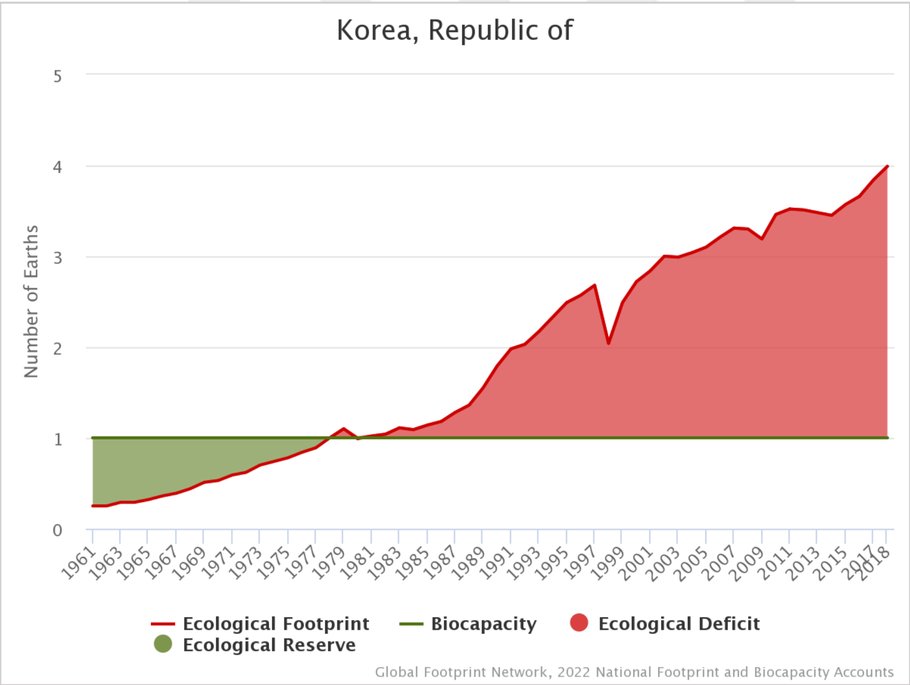


Figure 6.6. (continued) Ecological Footprints of the Selected Countries (1961-2018)

Source: Global Footprint Network (2022). National Footprint and Biocapacity Accounts. Accessed from https://data.footprintnetwork.org/



d.



e.

Figure 6.6. (continued) Ecological Footprints of the Selected Countries (1961-2018)

Source: Global Footprint Network (2022). National Footprint and Biocapacity Accounts. Accessed from https://data.footprintnetwork.org/

f.

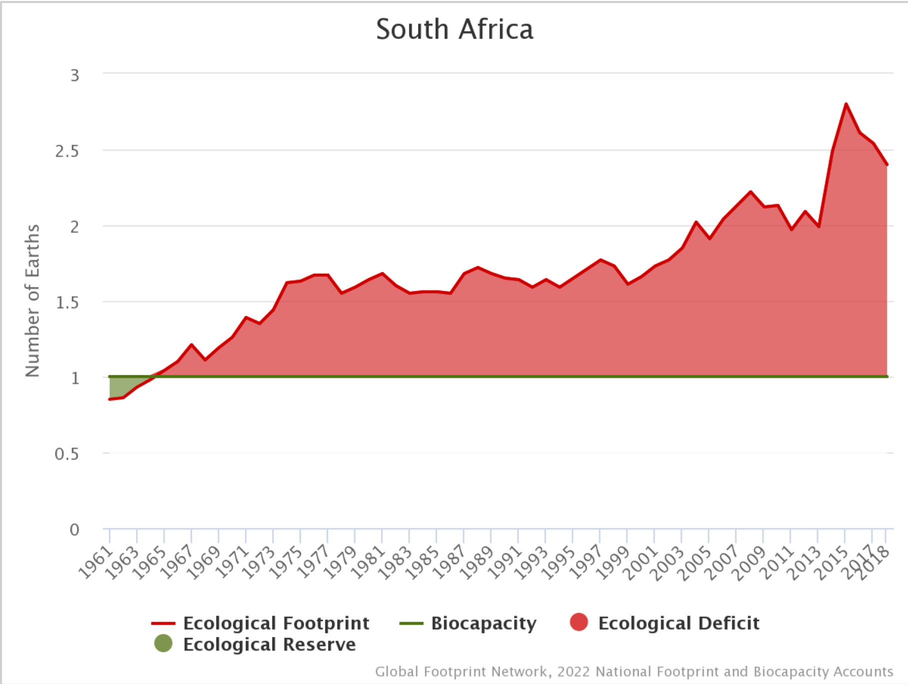


Figure 6.6. (continued) Ecological Footprints of the Selected Countries (1961-2018)

Source: Global Footprint Network (2022). National Footprint and Biocapacity Accounts. Accessed from https://data.footprintnetwork.org/

When looked the figures above it could be clearly seen that no country has been at the ecological reserve state, meaning that their EFs are all passed their biocapacity but in separate times. Türkiye is the latest country among them that passed its biocapacity. When the 2022 figures are compared, Mexico and South Africa have less ecological deficit than Türkiye while South Korea, Spain and Poland are more deficits. Among all Korea has the largest deficit while Mexico has the lowest.

The detailed comparisons were made according to EF and its components within 5-year intervals starting 1990 and ending with 2018 (Figure 6.7).

Figure 6.7. Detailed EF Comparisons of the Selected Countries (1990-2018)

Source: Global Footprint Network. (2022). National Footprint and Biocapacity Accounts. Accessed from https://data.footprintnetwork.org/

According to the Figure 6.7, South Korea is the worst performer with a steady increase in EF compared to other countries. Türkiye together with Mexico have had the lowest EF values during 1990-2018. When the components of EF are analyzed, carbon footprints are relatively high in Korea and South Africa.

6.2.3 Comparison of Selected Countries by Environmental Performance Index

The Environmental Performance Index (EPI) is a composite index providing a summary of the state of sustainability among countries. It helps track performance across environmental domains in order to develop comprehensive sustainability policies. The main function of this index is to provide a scorecard that highlight the environmental performance of the countries and provides practical guidance for them to move toward a sustainable future (Wolf et al., 2022).

The latest version of this index is published in 2022. It is jointly developed by the Yale Center for Environmental Law & Policy and the Center for International Earth Science Information Network at Columbia University’s Earth Institute. In the EPI, a composite index, 40 performance indicators are used under 11 subject categories, the EPI ranks 180 countries on 3 policy objectives as climate change performance, environmental health, and ecosystem vitality (Figure 6.8). These indicators indicate at a national scale of how close countries are to established environmental policy targets (Wolf et al., 2022). The data used in this index come from international organizations (the World Bank, the Potsdam Institute for Climate Impact Research, etc.), NGOs, and academic researchers. These data validated by the sustainability experts used in the analyses.

The EPI Scores for indicators range from the worst to the best performance. A perfect 100 score indicates that a country has achieved an internationally recognized sustainability target or the expert consensus of satisfactory performance. Totally 180 countries are included in this index and for each country 40 indicators are weighted and aggregated into the 3 categories and policy objectives. In the recent index, an enhanced emphasis on climate performance is made considering the significance of the climate crisis on human and environmental wellbeing, so “climate change” added as a new policy objective. A world scorecard is also developed to account global trends for each indicator (Wolf et al., 2022).

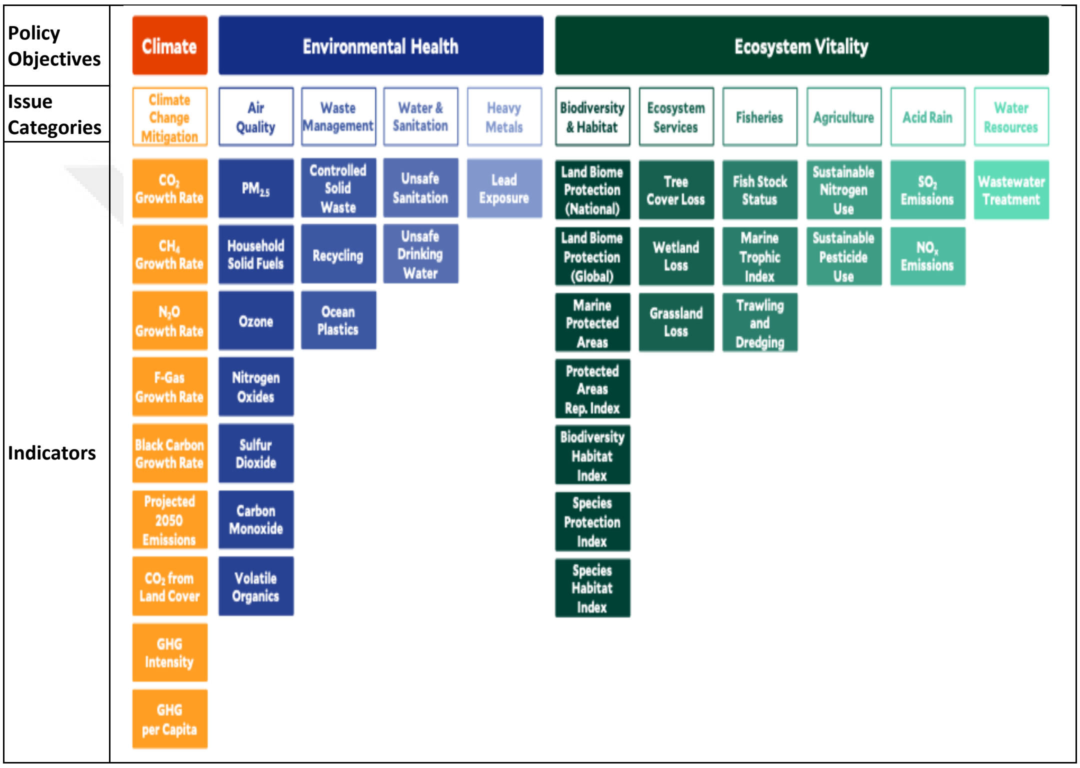


Figure 6.8. EPI 2022 Framework

Source: Wolf et al. (2022).

When the results of EPI 2022 are analyzed, Denmark achieved highest score with 77.9 points while India is the worst performer with 18.9 points. Among selected countries in this study, Spain observed as the best performer with 56.6 points among all. Türkiye seems not achieved good scores especially in the latest years indices. Türkiye is the 172nd in the 2022 EPI, with a score of 26.3, it dropped 8 positions

(Figure 6.9). Türkiye's EPI score decreased by -0.5 point compared to last 10 years period, this brought Türkiye to a score of 26.3. Türkiye scores below the average of all selected countries. Furthermore, it has not increased as much as the average of all countries (Figure 6.10).

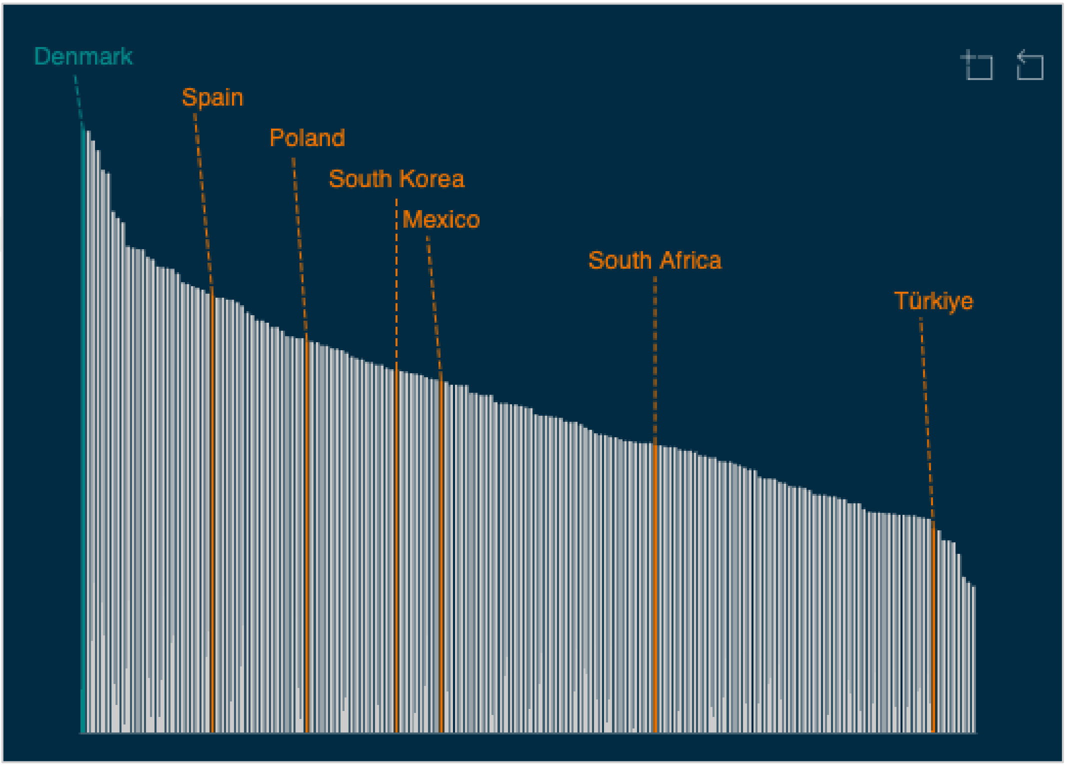


Figure 6.9. EPI 2022 Comparison of the Selected Countries

Source: EPI Data visualization tool, (2022), https://global-reports.23degrees.eu/epi2022/root

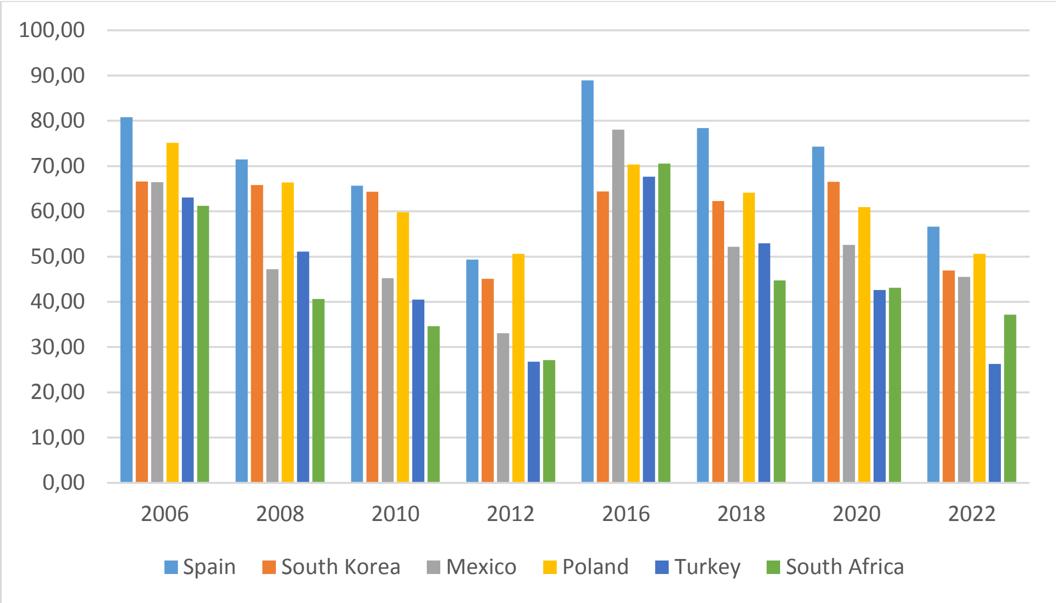


Figure 6.10. EPI Scores of Countries in Comparison

Source: Yale University, 2022. EPI 2022 Results. Retrieved from https://epi.yale.edu/downloads/ epi2022results05302022.csv

The situation of Türkiye's ranking in this index needs a detailed look into the components. Regarding the first component of EPI, Ecosystem Vitality, it measures how well countries are preserving, protecting, and enhancing ecosystems and the services they provide. It comprises 60% of the total EPI score and is made up of six issue categories: Biodiversity, Ecosystem Services, Fisheries, Acidification, Agriculture, and Water Resources. Under this component Spain takes the lead again with 60.3 points. Türkiye comes latest with 20.3. Türkiye take low points especially from Biodiversity issue categories. Austria takes the lead globally with 73.9 points (Wolf et al., 2022).

The Environmental Health policy objective measures how well countries are protecting their populations from environmental health risks. It comprises 40% of the total EPI score and is made up of four issue categories: Air Quality, Sanitation &

Drinking Water, Heavy Metals, and Waste Management. Here figures change in favor of Türkiye, it takes 47.8 points and placed 4th place overtaking South Africa and Mexico. Here in this component, Spain takes the led again. Global leader in this component is Iceland with 94.7 points (Wolf et al., 2022).

Climate Change Policy Objective consists of the Climate Change Sub-Dimension and represents the impact of various emissions along with greenhouse gas. The Climate Change issue category measures progress to combat global climate change, which exacerbates all other environmental threats and imperils human health and safety. It is composed of eight indicators: adjusted emission growth rates for four greenhouse gases (CO_2, CH_4, F-gases, and N_2O) and one climate pollutant (black carbon); growth rate in CO_2 emissions from land cover; greenhouse gas intensity growth rate; and greenhouse gas emissions per capita. Under this component, Türkiye places last with 21.5 points however the other countries are not so distant from Türkiye considering the scores taken. The nearest country comes before Türkiye is South Korea with 30.9 points while the leader Spain takes 41.3 points. Global leader in this component is Denmark with 92.4 points (Wolf et al., 2022).

6.2.4 Comparison of Selected Countries by SDG Index

The Sustainable Development Goal (SDG) Index produced annually since 2016 by the Bertelsmann Stiftung and the Sustainable Development Solutions Network (SDSN). Developed by Sachs et al (2024), it evaluates the progress of 193 UN member states toward achieving the 17 SDGs. The SDG Index Score reflects each country's overall progress, with 100 representing full achievement of all SDGs. The index provides valuable insights into global sustainability trends, helping policymakers understand progress and gaps in sustainable development (Sachs et al., 2024).

The SDG Index follows a structured weighting and aggregation methodology to ensure a balanced and comprehensive assessment of a country's sustainability performance. According to Lafortune et al. (2018), equal weighting is used both at the indicator level (within each SDG) and at the goal level (across SDGs), and aggregation is done using the arithmetic mean at both levels.

In the indicator-level aggregation within each SDG, each indicator's normalized score contributes equally to the SDG score through an arithmetic mean. Once individual SDG scores are computed for a country, they are aggregated into the final SDG Index Score using the arithmetic mean. Arithmetic mean ensures that the final SDG score is an average of all indicators, rather than penalizing low performance disproportionately. Similarly, equal weighting is applied to all 17 SDGs, ensuring that each goal contributes equally to the final index score. Aggregating all 17 SDGs each country receives an overall SDG Index score, ranging from 0 to 100, where 100 means the goal is fully achieved and 0 indicates no progress or a severe shortfall (Lafortune et al., 2018).

Equal weighting was chosen for several reasons:

- The 17 SDGs are considered equally important in the 2030 Agenda, preventing policy distortion.
- Alternative weightings (Principal Component Analysis, expert-based weights) were evaluated but rejected due to inconsistent correlations.
- Avoids policy cherry-picking, ensuring that countries prioritize all sustainability areas equally (Lafortune et al., 2018).

The index incorporates data from internationally recognized sources, including UN agencies, World Bank, World Health Organization (WHO), OECD, and national statistical offices. It relies mostly on official indicators defined by the UN as well as additional indicators developed by research institutions (Sachs et al., 2024).

The SDG Index addresses missing data through various statistical methods such as trend extrapolation, (using past data to estimate missing values), regional benchmarks, (substituting missing values with regional averages), and proxy indicators, (replacing unavailable UN indicators with alternative data sources) (Lafortune et al., 2018).

The 2023 SDG Index scores of the focused countries (Poland, Spain, South Korea, Türkiye, Mexico, and South Africa) are shown in the Table 6.2 and historical trends presented in Figure 6.11 below.

Table 6.2. Comparison of the Countries Based on 2023 SDG Index

Country	SDG Index Score	Global Rank
Poland	81.69	10th
Spain	80.70	14th
South Korea	77.33	33rd
Türkiye	70.47	72nd
Mexico	69.28	80th
South Africa	63.44	115th

Source: Sustainable Development Report 2024. Rankings. Accessed from https://dashboards.sdgindex.org/rankings

When the Table 6.2 analyzed, Poland ranks the highest among the selected countries in 2023 SDG Index, indicating strong sustainability progress and effective policy implementations. Spain closely follows Poland, maintaining a high sustainability performance with consistent improvements over the years as shown in Figure 6.11. South Korea is performing well but still lags behind its European counterparts in achieving the SDGs. Türkiye and Mexico are in a middle-tier group, signifying moderate progress but notable gaps that need further attention. South Africa ranks the lowest, reflecting significant sustainability challenges, particularly in social and environmental areas (Sachs et al., 2024).

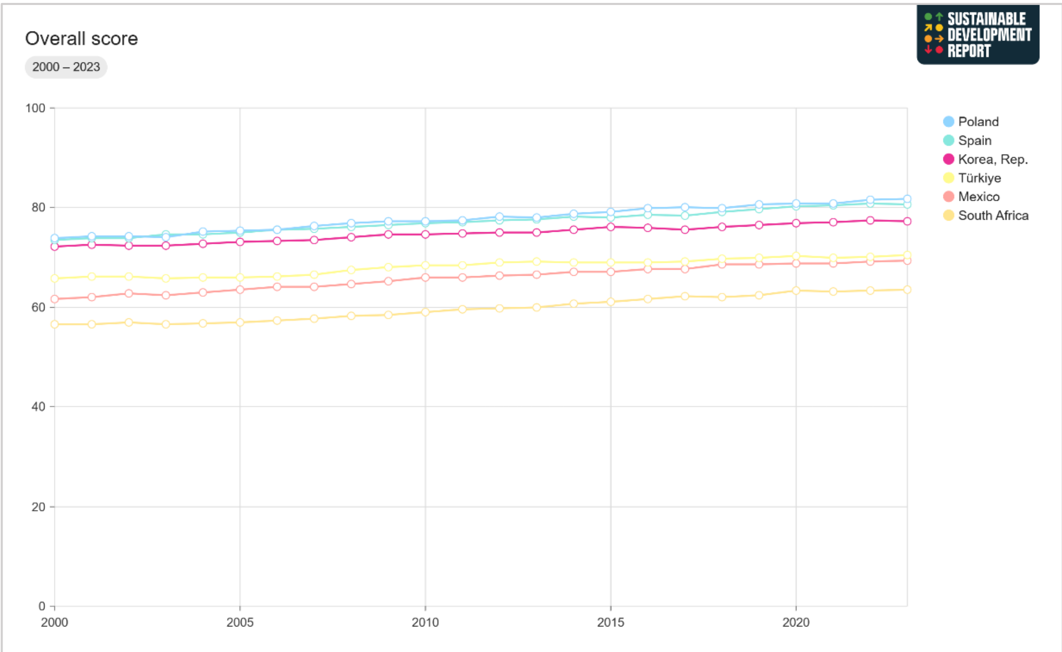


Figure 6.11. Comparison of Selected Countries Based on SDG Index

Source: Sustainable Development Report 2024. Data Explorer. Accessed from https://dashboards.sdgindex.org/explorer?visualization=line

When the SDG Index trends between 2000-2023 are evaluated, all countries have shown progress in sustainable development since 2000 (Figure 6.11). But Poland and Spain become best performing countries between the years 2000-2023, with Poland surpassing Spain in recent years, highlighting strong governance and policy continuity. South Korea had remarkably close index scores with Poland and Spain at the beginning of this period however after 2015 lagged behind Spain and Poland. Türkiye and Mexico show moderate but steady growth, yet remain significantly below their European counterparts, indicating ongoing structural and policy challenges. South Africa is the weakest performing country towards SDGs among the selected countries, yet exhibits gradual progress over time, which suggests slow but steady policy advancements (Sachs et al., 2024).

It is important to assess the SDG index score of Türkiye in detail. The radar chart (Figure 6.12) shows Türkiye's average performance across SDGs as measured in the 2023 SDG Index.

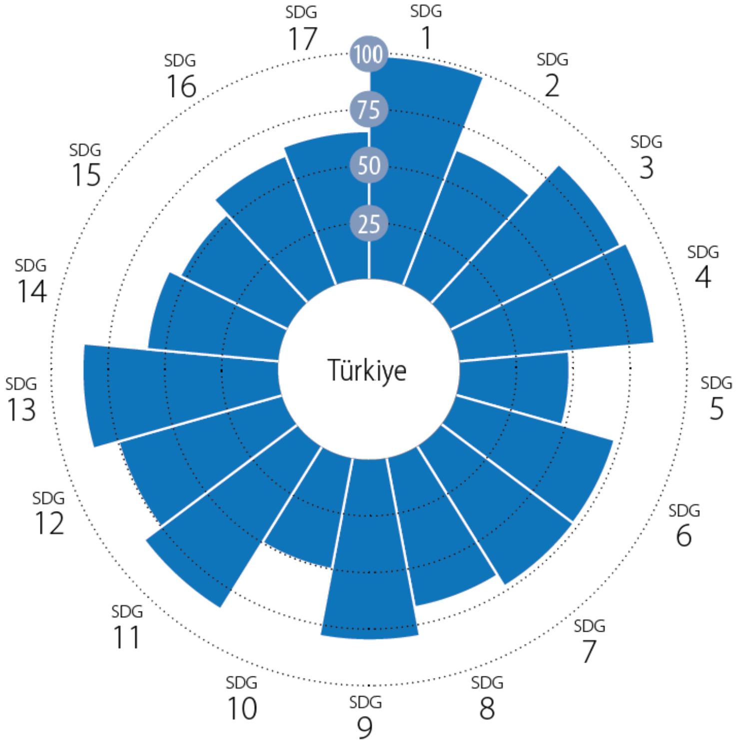


Figure 6.12. Türkiye's Average Performance by SDG

Source: Sachs et al. 2024.

When Figure 6.12 analyzed,

- Türkiye is performing strongly (over 75 points) in: SDG 1, SDG 3, SDG 4, SDG 9, SDG 11, and SDG 13 which means it achieved significant progress in poverty reduction, healthcare, education, industry, infrastructure, urban planning, and climate action. Especially, Türkiye is remarkably close to reach SDG 1. These areas reflect effective policy interventions and sustained improvements.
- Moderate progress is seen in SDGs 2, 6, 7, 8, 12, 14, 15, 16 and 17 which indicates modest progress in food security, clean water, renewable energy, decent work, responsible consumption, marine biodiversity, land protection, and governance. However, environmental conservation (SDGs 14 and 15) is at the lower end of this range, requiring stronger sustainability efforts.
- Weak performance exists in SDGs 5 and SDG 10, which indicates Türkiye has critical gaps in women's empowerment, income equality, and social inclusion policies. These areas require urgent intervention.

6.2.5 Comparison of Selected Countries by World Energy Council's Trilemma Index

The World Energy Council's Energy Trilemma Index ETI is a tool that assesses and ranks the energy performance of 126 countries. This Index has been published annually by the WEC since 2010, and the latest one represents 2024. The index aims to highlight the balance and robustness of countries' energy systems in promoting prosperity, competitiveness, and sustainability. The assessment helps countries identify areas for improvement in their energy policies and systems to achieve a more secure, equitable, and environmentally sustainable energy transition (Marti & Puertas, 2022).

ETI has 4 dimensions as described below together with the weight of each pillar in the calculation of the overall index score:

1. Energy Security (30%): This dimension evaluates a nation's ability to meet current and future energy demand reliably, withstand system shocks, and ensure minimal energy supply disruption. It considers factors such as the effective management of domestic and external energy sources, the reliability of energy infrastructure, and the resilience of the energy system to extreme events.
2. Energy Equity (30%): Energy Equity dimension assesses a country's capacity to provide universal access to reliable, affordable, and abundant energy for both domestic and commercial use. It covers basic access to electricity and clean cooking fuels, access to levels of energy consumption that support prosperity, and the affordability of energy sources like electricity, gas, and fuel.
3. Environmental Sustainability (30%): Sustainability dimension focuses on the transition of a country's energy system towards mitigating environmental harm and addressing climate change impacts. It considers factors such as productivity and efficiency of energy generation, transmission, and distribution, decarbonization efforts, and air quality improvements.
4. Country Context (10%): This dimension measures macroeconomic and governance conditions and the stability of the economy and the government, as well as the country's attractiveness to investors and capacity for innovation (WEC, 2024a).

By considering these dimensions, countries are scored out of 100 based on their performance in each area. The top-ranking countries demonstrate a strong balance across these criteria, reflecting their commitment to sustainable energy policies that promote economic prosperity while preserving environmental resources for future generations.

As an index used to rank countries based on their energy sustainability performance, the WEC's Trilemma Index calculated using a methodology with following steps:

1. Data Collection: The Index uses the latest published data to calculate performance at a snapshot in time. It relies on global and national data sources to assess historic past energy policy performance and the impact of current events.
2. Performance Assessment: Each country's performance is assessed based on its ability to balance the three Trilemma dimensions: Energy Security, Energy Equity, and Environmental Sustainability.
3. Ranking and Scoring: Countries are ranked and scored out of 100 based on their performance in each area. The top-ranking countries demonstrate a strong balance across these criteria, reflecting their commitment to sustainable energy policies that promote economic prosperity while preserving environmental resources for future generations.
4. Transparency and Flexibility: The methodology aims to be transparent and flexible, allowing countries to adapt the Trilemma framework to their national and local realities (Šprajc et al., 2019; WEC, 2024a).

Based on the ETI 2024, the top ranked countries in terms of energy sustainability are Denmark and Sweden shares 1st place, Finland 2nd, Switzerland 3rd, Canada 4th and Austria 5th place. These countries excel in balancing energy security, energy equity, and environmental sustainability. Sweden retains the top spot due to its low energy consumption relative to GDP and low levels of emission, mainly from hydroelectricity, nuclear power, and solar and wind energy (WEC, 2024a). Figure 6.13 shows a global view of the ETI scores of the countries.

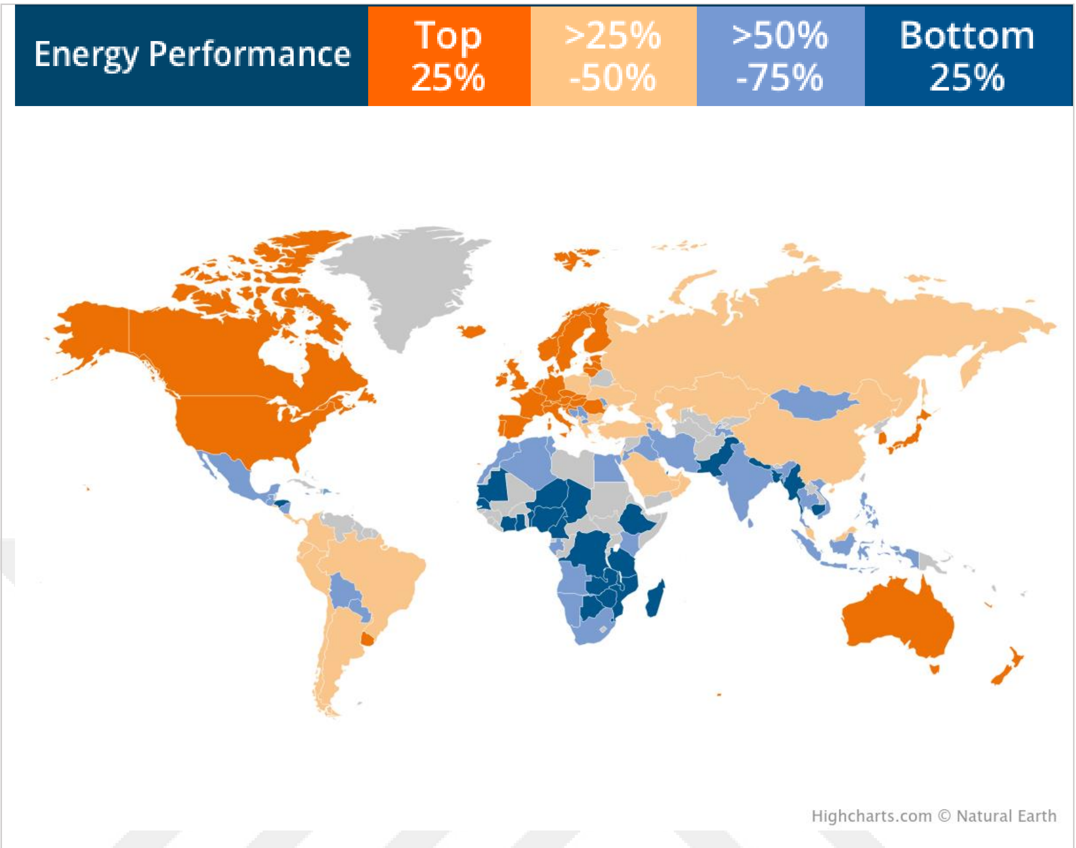


Figure 6.13. Map of WEC's Energy Trilemma Index Scores

Source: WEC Energy Trilemma Index Tool, Accessed from https://trilemma.worldenergy.org/

In 2024, Türkiye ranks 46th position among 126 countries in the WEC's Trilemma Index globally. Türkiye scored 57.3 in Energy Security, 76.1 in Energy Equity, and 68.2 in Environmental Sustainability (Figure 6.14). According to the trends in index scores of 2000-2023 as shown in the Figure 6.15 and 6.16, Türkiye improved its scores mostly in the energy equity dimensions of the index. In energy sustainability dimension, trends show a declining pattern in the recent years due to increasing energy intensity and CO_2 emissions. However, energy security component shows a stable pattern in spite of increasing renewable energy production (WEC, 2024b).

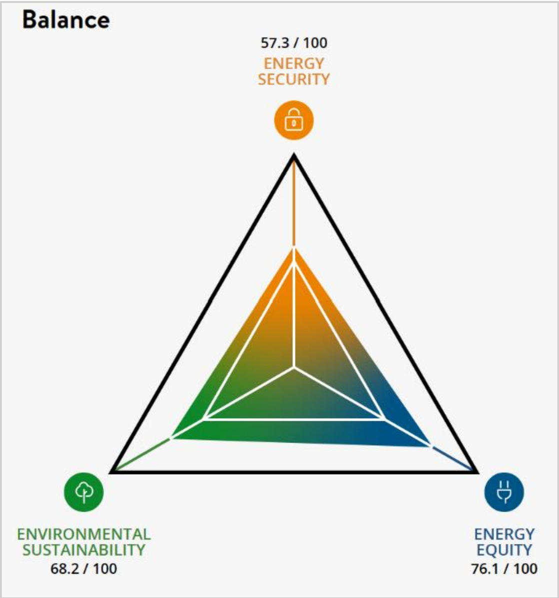


Figure 6.14. Energy Trilemma Index Component Scores of Türkiye

Source: WEC ETI Tool (2024). Accessed from https://trilemma.worldenergy.org/

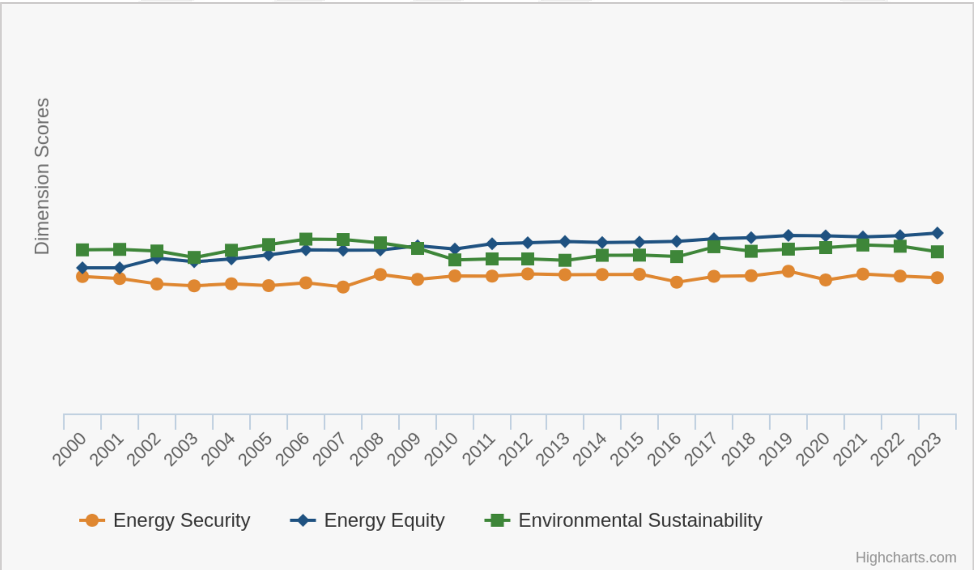


Figure 6.15. Trends in Energy Trilemma Index Components of Türkiye

Source: WEC ETI Tool (2024). Accessed from https://trilemma.worldenergy.org/

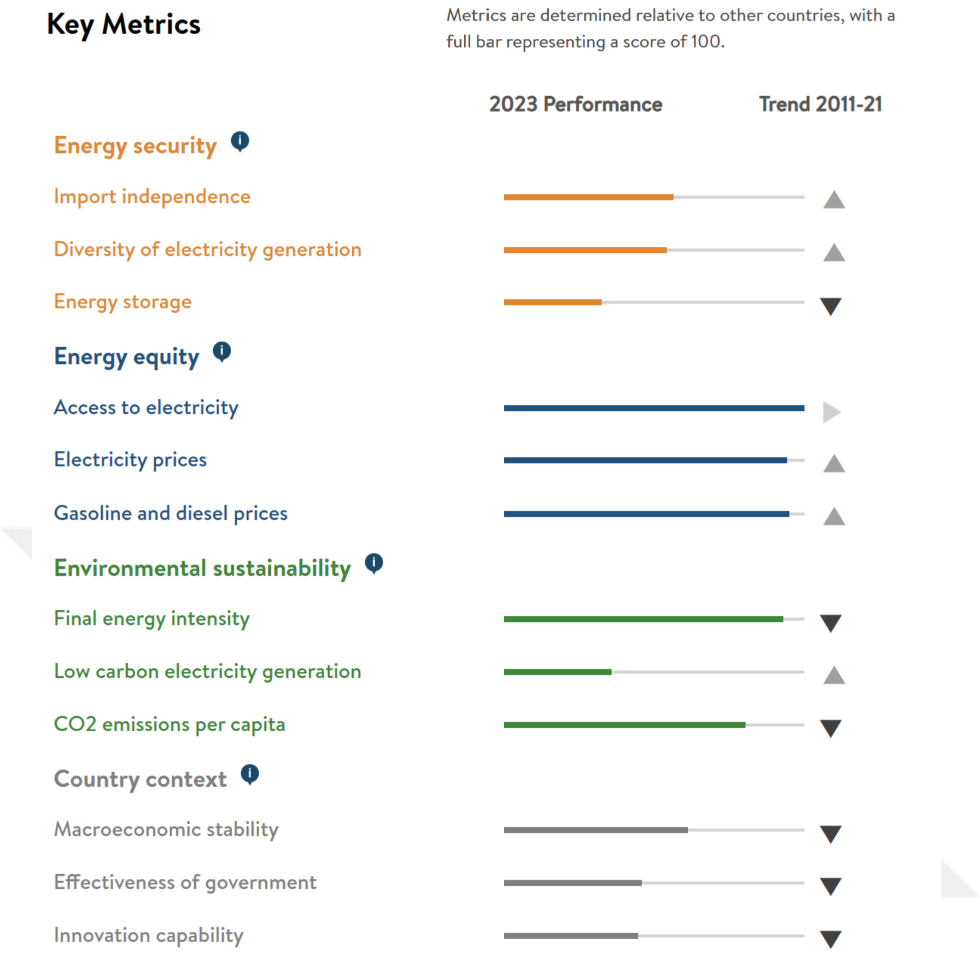


Figure 6.16. Scores of Türkiye Under Each Metrics of ETI

Source: WEC ETI Tool (2024). Accessed from https://trilemma.worldenergy.org/

Türkiye compared with the other selected countries with ETI, and the results shown in Table 6.3:

Table 6.3. Comparison of Countries Based on ETI

Country	Overall Score	Overall Rank	Energy Security	Energy Equity	Environmental Sustainability	Balance Grade
Spain	77.8	13	67.3	91.4	79.9	ABA
South Korea	73.1	27	62.2	95.9	63.9	BBC
Poland	70.7	28	65.1	85.5	65.3	ABC
Türkiye	**64.6**	**46**	**57.3**	**76.1**	**68.2**	**BBB**
Mexico	63.6	49	53.4	70.7	71.8	CBB
South Africa	57.6	69	54.5	61.4	58.4	CCC

Source: WEC Energy Trilemma Index Tool (2024), Accessed from https://trilemma.worldenergy.org/ #!/energy-index.

In Table 6.3 "Balance Grade"s are also added into the comparisons. The Balance Grade signifies a country's performance across various dimensions. The highest possible grade is (AAA), and the lowest is (DDD). The first letter stands for Energy Security, the second for Energy Equity, and the third represents the Environmental Sustainability of Energy Systems. According to the table, Türkiye ranks below Spain, South Korea and Poland while placed above Mexico and South Africa. Compared to its peers, it performs moderately balanced (BBB) across all dimensions. Spain ranks the highest (16^{th}) among these countries, demonstrating a well-balanced sustainable energy system (ABA) however it has some room for improvement in Energy Equity as ranked (B grade). South Korea ranks 27^{th} and although having highest score in Energy Equity component among focused countries but seem to have a room for improvement in Environmental Sustainability component. Poland ranks as 28^{th} and scores high in Energy Security (A grade) but have some room for improvement in Energy Equity component (B grade) and seems facing challenges in Environmental Sustainability (C grade). Mexico scores relatively moderate and close to Türkiye in Energy Equity (B grade) and Environmental Sustainability (B grade) but lower scores in Energy Security (C grade). South Africa ranks the lowest, struggling across all three indicators (CCC grade) (WEC, 2024a).

Considering the recent developments in the energy sector in Türkiye and the index structure, it can be guessed that the index scores could be improved in such way. Türkiye's energy demand has been on the rise, driven by improving living standards, population growth, and a growing economy since the 1980s. This increasing demand reflects economic activity and growth in the country (Erat et al., 2021). Türkiye ranks 5th in Europe in terms of renewable installed capacity, indicating a significant focus on renewable energy sources like hydroelectricity, solar, and wind power (MFA, 2024a). This could improve the scores on environmental sustainability and energy security dimension of the index. Committed to achieving net-zero emissions by 2053, Türkiye is demonstrating a strong commitment to environmental sustainability and climate change mitigation efforts (Presidency of the Republic of Türkiye, 2023). This ambitious goal aligns with global efforts to reduce greenhouse gas emissions and could improve environmental sustainability scores of the index. Türkiye's energy efficiency initiatives such as National Energy Efficiency Action Plan, aimed at reducing primary energy consumption and CO_2 emissions and the investments in energy efficiency could contributed to sustainability dimension of the index too.

Türkiye's ongoing investment in nuclear power indicates a diversification of energy sources and a strategic approach to meeting energy demand while reducing foreign dependence which would increase energy security scores in the index. The Turkish electricity market has undergone significant transformation over the past two decades, becoming more functional and responsive to changing energy needs. This transformation could support the efforts to enhance energy security and efficiency within the country. As a result, these developments could collectively contribute to Türkiye's ranking in the ETI, reflecting its progress towards achieving a balanced and sustainable energy system that addresses key dimensions of energy security, equity, and environmental sustainability.

6.3 Chapter Review

Sustainability indices are essential tools for measuring and benchmarking progress toward sustainable development. They provide insights into a country's performance across economic, social, and environmental dimensions, aiding policymakers and researchers in evaluating achievements, identifying gaps, and formulating strategies.

This chapter has thoroughly compared Türkiye's performance in sustainable development and energy sustainability with other countries, specifically Spain, Poland, Mexico, South Korea, and South Africa. Comparative assessment utilized indices such as the Human Development Index (HDI), Ecological Footprint (EF), Environmental Performance Index (EPI), Sustainable Development Goal (SDG) Index, and the WEC's Energy Trilemma Index (ETI), emphasizing their methodologies, applications, and relevance to sustainable development.

The findings reveal key strengths and weaknesses in Türkiye's performance by the indices:

1. Human Development Index (HDI): The HDI, developed by UNDP, evaluates health, education, and standard of living dimensions using a geometric mean of normalized indicators (UNDP, 2024a). While it effectively captures human development, it lacks environmental considerations. Innovations like the Planetary pressures–adjusted HDI (PHDI) attempt to integrate ecological impacts, but limitations remain in addressing country-specific environmental responsibilities (UNDP, 2020a).

Türkiye demonstrated significant progress in human development index, moving into the "high human development" category. However, its adjusted score, considering planetary pressures (PHDI), revealed vulnerabilities related to ecological impacts, such as carbon emissions and material footprint.

2. Ecological Footprint (EF): The EF measures the biocapacity required to support a country's resource consumption and waste assimilation. It highlights ecological deficits and reserves, focusing exclusively on environmental dimensions (Lin et al., 2018). Although useful for understanding a country's environmental sustainability, the EF does not account for social or economic factors, limiting its comprehensiveness.

When Türkiye's EF compared to other countries, its ecological deficit remains moderate compared to peers, with carbon footprints and biocapacity as critical areas for improvement. Türkiye has managed to maintain a relatively low EF compared to other countries like South Korea but still faces challenges in reducing its ecological overshoot.

3. Environmental Performance Index (EPI): EPI, developed by Yale University and other partners, evaluates climate change performance, environmental health, and ecosystem vitality. It uses 40 indicators under three policy objectives, offering a comprehensive view of environmental sustainability (Wolf et al., 2022). Its emphasis on climate change aligns with global priorities, but the index is limited by the variability and quality of data across countries.

In EPI, Türkiye ranks near the bottom among the selected countries, primarily due to low scores in ecosystem vitality and biodiversity. While its scores in environmental health are more favorable, overall improvements are urgently needed in climate policy and biodiversity conservation.

4. *SDG Index:* The SDG Index assesses progress toward achieving the 17 SDGs using equal weighting and aggregation of indicators (Sachs et al., 2024). It provides a holistic view of sustainability but faces challenges with missing data and contextual differences across countries.

Türkiye's overall SDG Index performance reflects moderate progress, with strong achievements in poverty reduction, education, and industry. However, disparities in social inclusion, equality between women and men, and environmental goals highlight areas requiring immediate attention.

5. Energy Trilemma Index (ETI): ETI measures energy systems across three dimensions: energy security, energy equity, and environmental sustainability. It provides a balanced assessment of a country's energy policies and systems (WEC, 2024a).

In ETI, Türkiye shows a moderately balanced energy system with a "BBB" grade, reflecting a mix of strengths in energy equity and moderate performance in energy security and environmental sustainability indicates the need for improvements in these areas. Renewable energy developments and nuclear power investments suggest promising areas for future growth.

Each sustainability index has its strengths and limitations, offering unique perspectives on the multi-dimensional concept of sustainability. While indices like the HDI and SDG Index provide holistic insights into social and economic aspects, indices like the EF and EPI focus primarily on environmental sustainability. The Energy Trilemma Index bridges the gap between energy policy and sustainability but does not directly link these aspects to broader development goals like poverty reduction or economic resilience. Combining the results of these indices enables a more nuanced understanding of sustainability challenges and opportunities, guiding countries like Türkiye toward comprehensive and balanced development strategies.

An overall analysis of the sustainability indices for Türkiye and the selected countries (Spain, Poland, Mexico, South Korea, and South Africa) provides a comprehensive overview of their respective achievements, challenges, and opportunities in sustainable development and energy sustainability.

Türkiye has demonstrated remarkable progress in human development, achieving the "high human development" category with significant advancements in education, healthcare, and income levels. HDI highlights this success, although challenges persist regarding environmental impacts as reflected in the PHDI. Türkiye's efforts to expand access to affordable energy and increase renewable energy sources have also bolstered its performance in energy equity, as evidenced by its strong ranking in the ETI.

In terms of sustainable development goals, Türkiye has achieved considerable progress in poverty reduction (SDG 1), education (SDG 4), and climate action (SDG 13), reflecting effective policy measures. When compared to peers such as South Africa and Mexico, Türkiye demonstrates stronger performance in key indices, including the HDI and ETI, highlighting moderate but steady progress across several dimensions.

Environmental sustainability remains one of Türkiye's most significant challenges, as shown by its low ranking in the EPI. The country's weaknesses in biodiversity conservation and ecosystem vitality underscore the need for more robust environmental policies. Furthermore, EF reveals Türkiye's ecological deficit, emphasizing the urgency of addressing carbon emissions and improving resource management.

Social inequalities also present ongoing challenges. Türkiye's weak performance in SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities) indicates persistent gaps in empowering women and addressing income disparities. These issues impede broader sustainability progress. In addition, while Türkiye performs well in energy equity, its energy security and environmental sustainability rankings in the ETI highlight areas requiring improvement, such as energy diversification and efficiency.

Despite these efforts, Türkiye lags behind advanced countries like Spain and South Korea in several indices, including the SDG Index, EPI, and ETI. Spain, in particular, serves as a benchmark, with balanced progress across environmental, social, and energy dimensions.

Türkiye's growing commitment to renewable energy provides a substantial opportunity for improvement. With its net-zero emissions target by 2053 and ranking 5th in Europe for renewable energy capacity, Türkiye is well-positioned to enhance energy security and sustainability. Investments in solar, wind, and hydroelectric energy sources could further strengthen its sustainability profile.

Adopting best practices from higher-performing countries, particularly in biodiversity conservation and ecosystem protection, can also help Türkiye overcome its environmental challenges. Additionally, accelerating progress in social inclusion, equality between women and men, and responsible consumption (SDGs 5, 10, and 12) will contribute to a more balanced and comprehensive approach to sustainability.

In conclusion, comparative analysis presented in this chapter regarding Türkiye's sustainability performance highlights key strengths as well as critical areas requiring improvement in achieving a balanced and sustainable development trajectory. This analysis also underlines the necessity of a more integrated approach to measuring progress. While global indices used in this chapter provide valuable benchmarks, they often assess sustainability dimensions individually or broadly rather than capturing the complex interlinkages between economic, social, and environmental factors. Specifically, these indices do not always explicitly measure the synergies and trade-offs between energy sustainability (SDG 7) and other SDGs, indicating a clear need for a more comprehensive approach.

In response to this need, Chapter 7 introduces an index explicitly incorporating SDG interlinkages. Rather than evaluating SDG 7 independently, the proposed framework systematically analyze its interactions with other SDGs enabling a holistic and multidimensional assessment of energy sustainability. This methodology ensures that energy policies and sectoral developments align closely with broader sustainability objectives, providing a more nuanced and strategic pathway toward achieving sustainable development in an integrated and systemic manner.

CHAPTER 7

DEVELOPMENT OF SDG ENERGY SUSTAINABILITY INDEX

Considering theoretical framework, insights from international comparisons and index methodologies in previous chapters, Chapter 7 completes the comparative analysis (Chapter 6) by introducing a novel SDG Energy Sustainability Index to holistically assess Türkiye’s energy sustainability performance, responding the need for comprehensive approach indicated previously. Chapter 7 provides an in-depth examination of the interconnections between SDG 7 and other SDGs, the index methodology, selection of indicators, and the weighting system used to construct the index. The findings are analyzed to evaluate Türkiye’s performance in energy sustainability, identifying key strengths and areas requiring improvement.

Among SDGs, SDG 7 “Ensure access to affordable, reliable, sustainable and modern energy for all” is at the focus of the index development. SDG 7 comprises five targets across four main themes. The first theme emphasizes equitable energy distribution, secure energy supply, and universal access to clean energy. The second theme seeks to expand share of renewable energy while progressively reducing reliance on fossil fuels. The third theme focuses on improving efficiency across all aspects of energy consumption. The final theme aims to facilitate access to technology and foster investment in clean energy, particularly by enhancing international financial support to assist developing countries in adopting renewable energy solutions (UNDESA, 2024).

The targets of SDG 7 are indicated below:

- “Target 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services.
- Target 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix.

- Target 7.3 By 2030, double the global rate of improvement in energy efficiency.
- Target 7.A By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
- Target 7.B By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support" (UNDESA, 2024).

Access to energy is a precondition for access to health and education, and to increase wealth of nations, therefore very crucial to achieve all SDGs. When the targets listed under SDG 7 are examined, it is seen that meeting these targets is possible with the achievement of all related SDGs, as SDG 7 is directly or indirectly interact with other SDGs. Therefore, in the next section, the interactions of SDG 7 targets with other SDGs are analyzed.

7.1 Interlinkages Between SDG 7 and the Other SDGs

Interlinkages of SDG 7 and its targets with other SDG targets are analyzed by considering the relations among the targets. Official descriptions of SDGs and their targets are taken from the 2030 Agenda for Sustainable Development document and used in this section (UN, 2015). Firstly, the interactions between related SDG with SDG 7 are explained briefly and then the relationship of related SDG's targets and the targets of SDG 7 are indicated with arrows. The right arrow (→) indicates that target influences the indicated targets on the right side while the left arrow (←) means the target is affected by the targets on the right side. The results of this SDGs based interlinkage analysis are presented below:

SDG 1: “End poverty in all its forms everywhere”.

Access to basic energy services is a necessity for poverty eradication. Social assistance is important to decrease the burden of energy expenditure on poor. However, some social assistance provisions for energy support, such as coal distribution to poor, would negatively impact air quality, climate change and renewable targets (IEA et al., 2023). So, with the help of the delivery of clean and affordable energy services to all segments of society, including the poor, the welfare of the nations would be improved. In this respect, interlinkages between the targets of SDG 1 and SDG 7 are indicated below:

- Target 1.2 “By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions” ← Targets 7.1, 7.3, and 7.b.
- Target 1.3 “Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable” → Target 7.1.
- Target 1.4 “By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance” ← Targets 7.1, 7.3, and 7.b.
- Target 1.5 “By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters”→ Targets 7.1, 7.2, and 7.3.

SDG 2: “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”.

Sustainable energy is essential throughout all stages of the food supply chain, especially in supporting digitized modernization, mechanization, and post-harvest operations such as storage, processing, and transportation. These improvements help enhance resilience, support livelihoods, and significantly reduce food losses. Agriculture and energy sectors also have interactions on biofuel production. Waste residues from food systems represent significant potential for bioenergy production, provided their use does not negatively impact food security or compete excessively with other essential uses such as soil management, animal feed, or other bioproducts (UN, 2021). Land use for agriculture and energy sectors would come across and should be optimized to consider economic, environmental and social benefits (Seetharaman et al., 2019). Energy prices could affect food prices as it is one of the cost inputs in food production so efficient use of energy becomes important for sustainable agriculture (IEA et al., 2023). In this respect, interlinkages between the targets of SDG 2 and SDG 7 are shown below:

- Target 2.3 “By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment”: ←Target 7.1, → Target 7.3.
- Target 2.4 “By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality”: ←Target 7.1, → Target 7.2.

- Target 2.5 “By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed”: ← Target 7.1.

SDG 3: “Ensure healthy lives and promote well-being for all at all ages”.

Achieving universal health care and key development objectives, such as reducing child mortality, enhancing maternal health, and effectively treating and preventing diseases, is not possible without reliable electricity access. Electricity is crucial in healthcare facilities for providing essential lighting and operating critical, life-saving medical equipment (UN, 2021). Moreover, air pollution resulting from fossil fuel combustion in thermal power plants, residential heating and transport would impact public health by causing respiratory diseases. In addition, the use of traditional biomass for cooking would endanger the health of people living in the house, particularly women and children (IEA et al., 2023; UN, 2021). In this respect, interlinkages between the targets of SDG 3 and SDG 7 are indicated below:

- Target 3.4 “By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being”: ← Target 7.1.
- Target 3.9 “By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination” ← Target 7.1.

SDG 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all".

Affordable, reliable, and modern energy services are crucial for quality education and educational attainment. In a world becoming increasingly digital, energy plays particularly vital role in using digital technologies such as computers and, internet. In addition to that, energy is important for quality education to provide the functioning properly of the educational facilities, i.e., heating and lightning of the schools (Nerini et al., 2018). On the other hand, raising individuals through education and training to develop awareness and sensitivity to global warming and environmental issues could improve energy saving and efficiency behaviors (UN, 2012). In this respect, interlinkages between the targets of SDG 4 and SDG 7 are shown below:

- Target 4.1 "By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes": ← Target 7.1.
- Target 4.3 "By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university". ← Target 7.1.
- Target 4.7 "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development". → Target 7.3.
- Target 4.a "Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all" ← Target 7.1.

SDG 5: “Achieve gender equality and empower all women and girls”.

Lack of access to modern energy has disproportionate negative impacts on women’s and girls’ health and safety such as exposure to indoor air pollution as a result of using biomass in cooking, especially in least developed countries. Instead, implementation of renewable energy policies could provide women new and better green employment opportunities (UNDP, 2017). Women stand to benefit significantly from improved energy access, as it reduces time spent on unpaid labor, enhances education opportunities, and enables economic participation (UN, 2019). In this respect, interlinkages between the targets of SDG 5 and SDG 7 are indicated below:

- Target 5.1 “End all forms of discrimination against all women and girls everywhere” ← Target 7.1.
- Target 5.c “Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels” ← Target 7.1.

SDG 6: “Ensure availability and sustainable management of water and sanitation for all”.

Within the water-energy nexus, achieving sustainable management policies requires carefully balancing the inputs and consumption of both water and energy resources to ensure mutual acceptability and sustainability (UN, 2012). Protection and effective use of water resources are important for sustainable natural resource management and for the energy production from renewables such as hydropower and geothermal. When the energy supply is considered, conventional power generation plants have a significant water requirement (Mielke et al., 2010). In this respect, interlinkages between the targets of SDG 6 and SDG 7 are shown below:

- Target 6.1 “By 2030, achieve universal and equitable access to safe and affordable drinking water for all”: ← Target 7.1.

- Target 6.2 “By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations” → Target 7.1.
- Target 6.3 “By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally” → Targets 7.1 and 7.2.
- Target 6.4 “By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity” → Targets 7.2 and 7.3.
- Target 6.5 “By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate” → Targets 7.1 and 7.a.
- Target 6.6 “By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes” ← Target 7.3.

SDG 8: “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”.

Increase in energy sector investments would lead to sector’s growth, which could mean new job and employment opportunities and stimulation of economic growth, not only within the energy sector but across various other economic sectors as well (UN, 2021). On the other hand, with sustainable economic growth, the investments in the energy sector would also continue at a certain pace. The developments in the technology-intensive industry sector would contribute to the use of advanced technology in the energy sector and to the improvement of investment costs and energy efficiency. The reduction of energy intensity of economic growth is crucial for energy sustainability in terms of energy efficiency (IEA et al., 2023). In this respect, interlinkages between the targets of SDG 8 and SDG 7 are indicated below:

- Target 8.1 “Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries” ↔ Targets 7.1, 7.a, and 7.b.
- Target 8.2 “Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high value added and labour-intensive sectors” → Targets 7.1 and 7.3.
- Target 8.3 “Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services” → Targets 7.1, 7.2, and 7.3.
- Target 8.4 “Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead” → Targets 7.1, 7.2 and 7.3.
- Target 8.5 “By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value” ← Target 7.1
- Target 8.8 “Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment” ← Target 7.1
- Target 8.9 “By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and product” ← Targets 7.1 and 7.3.
- Target 8.10 “Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance, and financial services for all” → Target 7.3.

SDG 9: “Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation”.

Energy infrastructure, which is one of the most important factors in achieving the goal of accessible clean energy, is a specific branch of infrastructure investments. On the other hand, reducing energy costs by improving energy efficiency would play support the growth of the manufacturing industry, increasing profitability (UN, 2021). In addition, increasing the level of technology in industrial production would contribute to energy efficiency by decreasing the energy need per unit of production (IEA et al., 2023). Achieving resilient and sustainable infrastructure depends on reliable energy systems that minimize environmental harm and help reduce the impacts of climate change (Nerini et al., 2018). In this respect, interlinkages between the targets of SDG 9 and SDG 7 are shown below:

- Target 9.1 “Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all” ← Target 7.2 → Targets 7.1, 7.2 and 7.3.
- Target 9.2 “Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry’s share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries” → Targets 7.1 and 7.3.
- Target 9.3 “Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets” → Targets 7.1, 7.2, and 7.3.
- Target 9.4 “By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities” → Targets 7.1, 7.2, and 7.3.

- Target 9.5 “Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending” → Targets 7.1 and 7.2 ← Targets 7.1 and 7.a.
- Target 9.a “Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States” → Targets 7.a and 7.b ← Target 7.a.
- Target 9.b “Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities” → Targets 7.1,7.2, and 7.3, ← Target 7.1.
- Target 9.c “Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020” → Targets 7.1,7.2 and 7.3.

SDG 10: “Reduce inequality within and among countries”.

Energy poverty, including lack of electricity and clean cooking fuels, affects about 800 million people, disproportionately impacting marginalized groups. Poor households spend a higher percentage of their income on energy, often using inefficient fuels and technologies, exacerbating inequalities (UN, 2019). The improvement in the SDG 7 targets by programs and projects could contribute to the elimination of inequalities to some extent. For example, distributed generation would help bring energy to all areas, including rural areas, and reduce inequalities within countries (IEA et al., 2023). In this respect, interlinkages between the targets of SDG 10 and SDG 7 are indicated below:

- Target 10.1 “By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average” ← Target 7.1.
- Target 10.2 “By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status” ← Target 7.1.

SDG 11: “Make cities and human settlements inclusive, safe, resilient and sustainable”.

Smarter cities, energy efficient buildings, and sustainable urban transportation systems could help increase energy efficiency, limiting energy consumption in cities (IEA et al., 2023). Activities in cities on energy efficiency and improving energy infrastructure will contribute to the reduction of energy inequalities supporting the SDG 7’s target of universal access to energy services and will support the reduction of negative environmental impacts caused by urban energy consumption (Korkmaz & Kurkcuoglu, 2025). In this respect, interlinkages between the targets of SDG 11 and SDG 7 are shown below:

- Target 11.1 “By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums” → Targets 7.1 and 7.3.
- Target 11.2 “By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons” → Targets 7.1, 7.2, and 7.3.
- Target 11.3 “By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries” → Targets 7.1 and 7.3.
- Target 11.4 “Strengthen efforts to protect and safeguard the world’s cultural and natural heritage” ← Targets 7.1 and 7.2.

- Target 11.5 “By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations” → Target 7.1, ← Target 7.2.
- Target 11.6 “By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management” → Target 7.2, ← Targets 7.1 and 7.2.
- Target 11.b “By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels” → Targets 7.1, 7.2, 7.3, and 7.a.

SDG 12: “Ensure sustainable consumption and production patterns”.

A circular economy provides significant opportunities to reshape production and consumption patterns, promoting universal access to sustainable, affordable, and reliable energy. By emphasizing energy and resource efficiency, effective waste management, eco-design, responsible consumption, and “reduce, re-use, recycle” practices, a circular economy approach simultaneously advances SDGs, supports climate change mitigation, and enhances environmental sustainability (UN, 2021). Sustainable production and consumption of renewable energy equipments is also critical for sustainability. For example, solar energy plays a critical role in global energy transitions and achieving SDGs 7 and 13 on clean energy and climate action. However, the expected increase in end-of-life solar panels, projected to reach over 212 million metric tons globally by 2050, presents significant waste management challenges. By recycling solar panels, substantial amounts of critical materials like silver, aluminum, copper, glass, and silicon could be recovered (IEA et al., 2023). On the other hand, reaching sustainable management and efficient use of natural resources requires transforming energy systems to use resources more efficiently and reduce negative environmental impacts (Nerini et al., 2018).

In this respect, interlinkages between the targets of SDG 12 and SDG 7 are indicated below:

- Target 12.1 “Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries” → Targets 7.1 and 7.3.
- Target 12.2 “By 2030, achieve the sustainable management and efficient use of natural resources” → Targets 7.1 and 7.2.
- Target 12.4 “By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment” → Targets 7.1 and 7.3.
- Target 12.5 “By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse” → Target 7.2.
- Target 12.6 “Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle” → Target 7.a.
- Target 12.7 “Promote public procurement practices that are sustainable, in accordance with national policies and priorities” → Target 7.2.
- Target 12.8 “By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature” → Targets 7.1 and 7.3.
- Target 12.a “Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production” → Target 7.a.

- Target 12.c “Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities” → Target 7.2.

SDG 13: “Take urgent action to combat climate change and its impacts”.

The interlinkage between energy and climate change is very strong, as greenhouse gas emissions resulting from energy production significantly contribute to atmospheric warming. Achieving the Paris Agreement targets requires adoption of renewable energy and improving energy efficiency (UN, 2021). Significant progress towards achieving SDG 7 and SDG 13 can be accomplished by rigorously evaluating the interconnections between energy systems and climate change. While energy supply based on fossil fuels affects climate change, promotion of renewable energy and energy efficiency will support CO_2 emission reduction. Climate change policies prioritizing the renewables and energy efficiency will support progress in SDG 7 (Nerini et al., 2018). In this respect, interlinkages between the targets of SDG 13 and SDG 7 are shown below:

- Target 13.1 “Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries” ←Targets 7.1, 7.2, 7.3, 7.a, and 7.b.
- Target 13.2 “Integrate climate change measures into national policies, strategies and planning” → Targets 7.1, 7.2, 7.3, 7.a, and 7.b.
- Target 13.3 “Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning” ← Target 7.a.

- Target 13.a “Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible” → Targets 7.1, 7.2, 7.3, 7.a, and 7.b.
- Target 13.b “Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities” ↔ Target 7.b.

SDG 14: “Conserve and sustainably use the oceans, seas and marine resources for sustainable development”.

Oceans and seas are important natural resources for human life by providing transportation, energy supply, tourism and many ecosystem services of the planet (such as carbon, nutrient cycles, climate regulation, oxygen production) (Costanza, 1999). The oceans and seas can be used for marine power (e.g., offshore wind). Energy systems can influence natural resources both directly, through local pollution or land-use competition with energy infrastructure and indirectly, by contributing to broader environmental challenges such as ocean acidification and climate change. These impacts affect the conservation, restoration, and sustainable use of terrestrial and marine ecosystems (Nerini et al., 2018). Therefore, protection of these sources from pollution and overuse is particularly important in energy production. In this respect, interlinkages between the targets of SDG 14 and SDG 7 are indicated below:

- Target 14.2 “By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans” ←Targets 7.1 and 7.2.

- Target 14.5 “By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information” ←Targets 7.1 and 7.a.

SDG 15: “Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss”.

SDG 15 is closely linked to energy transitions, particularly in regions where people's incomes rely on ecosystem goods and services. Limited access to modern energy services can lead to ecosystem degradation and loss, such as deforestation and forest damage caused by reliance on fuelwood for energy needs. Impact of energy projects on forests and terrestrial and inland freshwater ecosystems would also be significant. Site selection of energy projects with careful planning of the energy portfolio is important to avoid a negative impact of energy on biodiversity and ecosystems (Dilli & Nyman 2015. By recognizing these interconnections and the diverse environmental benefits and values, energy systems can be designed to reduce negative effects on ecosystems and biodiversity (Nerini et al., 2018). In this respect, interlinkages between the targets of SDG 15 and SDG 7 are shown below:

- Target 15.1 “By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements” ←Targets 7.1 and 7.2, → Target 7.1.
- Target 15.2 “By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally” ↔ Target 7.2.
- Target 15.9 “By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts” ←Targets 7.1 and 7.2.

SDG 16: “Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels”

Effective, inclusive and accountable institutions are crucial for a well-functioning energy sector. SDGs strongly emphasize enhancing governance within energy systems, advocating for equitable institutions, strengthened rule of law, accountability, improved public participation, and reduced corruption. Poor governance, notably insufficient consultation with affected communities, has led to social and political conflicts surrounding large hydropower projects, biofuel land-use decisions, and extraction activities of coal, gas, and oil. These issues underscore the essential role effective governance of natural resources plays in supporting social well-being and sustainability. Improved access to energy could enhance safety and security, helping to reduce incidents of violence, such as by providing adequate street lighting at night in urban areas that would help people feel safe (Nerini et al., 2018). In this respect, interlinkages between the targets of SDG 16 and SDG 7 are indicated below:

- Target 16.1 “Significantly reduce all forms of violence and related death rates everywhere” ←Target 7.1.
- Target 16.3 “Promote the rule of law at the national and international levels and ensure equal access to justice for all” → Target 7.1.
- Target 16.5 “Substantially reduce corruption and bribery in all their forms” → Targets 7.1 and 7.3.
- Target 16.7 “Ensure responsive, inclusive, participatory and representative decision-making at all levels” → Targets 7.1 and 7.2.
- Target 16.b “Promote and enforce non-discriminatory laws and policies for sustainable development” → Target 7.1.

SDG 17: "Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development"

SDG 17 is a complementary goal that aims to ensure that the necessary resources, infrastructure and institutional capacity for the other SDGs are not only on a national scale but on a global scale. Achieving SDG 7 and related SDGs demands deeper, multi-stakeholder cooperation focused on advancing emerging sustainable energy technologies from early stages to widespread commercial adoption. Such partnerships facilitate innovation by addressing common challenges, sharing best practices, improving efficiency, and reducing costs. Promoting the development, transfer, dissemination and diffusion of environmentally sound technologies would significantly support adoption of renewable energy and energy efficiency applications in developing countries. However, stronger financial and organizational commitments are essential for reaching SDG objectives (UN, 2021). These issues are getting priority in financial support provided to developing countries by international organizations, particularly development banks such as World Bank and European Investment Bank. Development banks play a crucial role by coordinating global efforts, facilitating dialogue among stakeholders, monitoring and measuring progress, and providing essential financial support to advance sustainable energy initiatives (Nerini et al. 2018). Considering significant amount of financing requirements of energy infrastructure investments, it is important to provide cost-effective financing especially for developing countries to encourage these investments. In this context, interlinkages between the targets of SDG 17 and SDG 7 are shown below:

- Target 17.3 "Mobilize additional financial resources for developing countries from multiple sources" → Targets 7.1,7.2, and 7.3.
- Target 17.7 "Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed" → Target 7.1, 7.2, and 7.3.

The aims within the scope of SDG 7 also have a relationship with each other, prioritizing these objectives by considering the relations between them is important in terms of being able to be implemented in the most effective way. For instance, the increase in population and industrial production on a global scale triggers the increase in living standards and energy demand; parallel to this, energy demand and energy investments are increasing. Increasing energy demand as the global trade volume increases; accelerates the emergence of new energy technologies and energy efficiency investments.

An interlinkage graph showing the relationship of SDG 7 targets with other SDG targets is generated using the relationships described previously in detail (Figure 7.1).

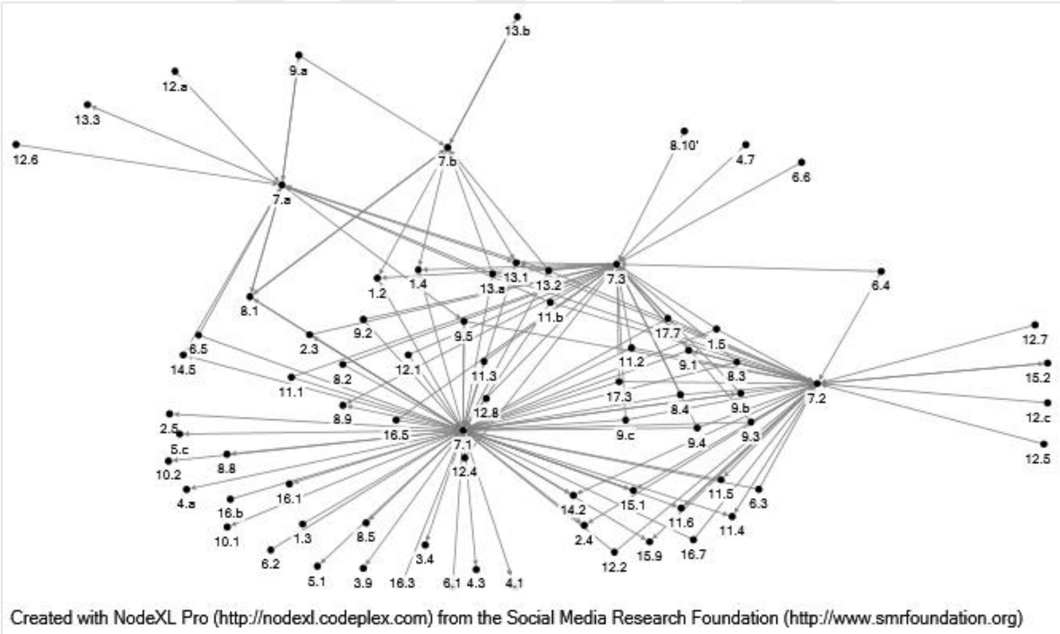


Figure 7.1. Interlinkages Between SDG 7 Targets with Other SDG Targets

Source: Prepared by using NodeXLPro (Social Media Research Foundation).

As the relationship of SDG 7 targets with other SDG targets was analyzed, the highest interacting targets and SDGs were found based on this consolidation. SDG 7 targets are more affected by other targets (99 linkages) than influence them (53 linkages). SDG target 7.1 (universal energy access) is the most interlinked one with 63 linkages (affected: 34, influences: 29). Then the SDG target 7.2 (renewable energy) comes with 34 linkages (affected: 24, influences: 10) and SDG target 7.3 (energy efficiency) with 31 linkages (affected: 27, influences: 4). The horizontal targets 7.a and 7.b have 14 (affected: 8, influences: 6) and 10 (affected: 5, influences: 5) linkages, respectively.

Considering the number of linkages between SDG targets, the main SDGs that interlinked with SDG 7 are identified by counting more than 10 linkages as SDG 9: “Industry, Innovation and Infrastructure” (26 linkages), SDG 8: “Decent Work and Economic Growth” (19 linkage), SDG 11: “Sustainable Cities and Communities” (18 linkage), SDG 13: “Climate Change” (18 linkages), and SDG 12: “Responsible Consumption and Production” (13 linkage).

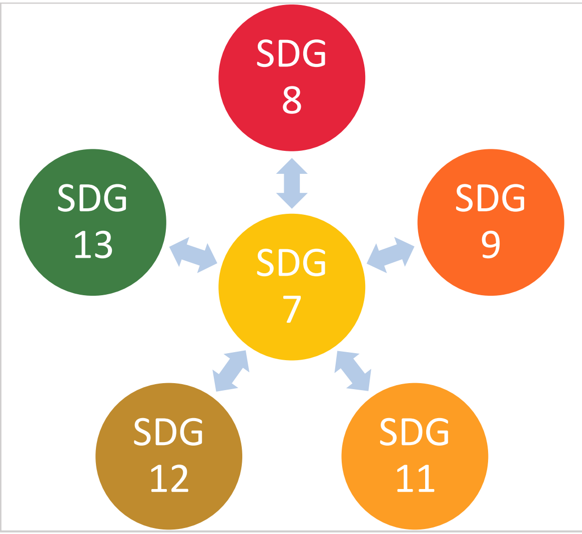


Figure 7.2. Major Interlinkages of SDG 7 with Other SDGs

Source: Prepared by Author.

There are other studies on the interlinkages between the SDGs. One of them is the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)'s study that analyzes SDG 7 targets and the targets of other SDGs. Figure 7.2 illustrates the interconnections between SDG 7 and the other 16 SDGs, highlighting a cause-and-effect relationship among these targets based on an analytical method developed by UNESCAP. This method, launched in 2016, uses a systems thinking approach to analyze how targets within SDG 7 relate to those across the other SDGs. The causal loop diagram shows the positive, reinforcing relationships among these targets, which helps guide synchronized and integrated SDG implementation (United Nations Economic and Social Commission for Asia and the Pacific [UNESCAP], 2019).

Figure 7.3. Visualization Map of Interlinkages between SDG 7 and Other SDGs

Source: UNESCAP (2019).

The analysis reveals that universal access to affordable and modern energy (SDG target 7.1) is vital for achieving other goals, such as providing access to clean water (SDG target 6.1), healthcare (SDG targets 3.7 and 3.8), education (SDG target 4.1), and safe housing (SDG target 11.1). It also supports reducing poverty (SDG target 1.2) and enhances safety and security (SDG target 16.1). Increased use of renewable energy (SDG target 7.2) strengthens climate resilience (SDG target 13.1) and reduces pollution (SDG target 12.4), leading to fewer health issues from pollution (SDG target 3.9). Energy efficiency (SDG target 7.3) aids economic growth (SDG target 8.4) while improving productivity (SDG target 8.2) and supporting economic diversification. Investments in clean energy technologies drive innovations in water efficiency (SDG target 6.4), job creation (SDG target 8.5), and environmental sustainability (SDG targets 12.a, 12.c, 13.2), with added benefits for women's participation in energy infrastructure (SDG targets 5.a and 5.b) (UNESCAP, 2019).

7.2 Indicator Framework for the SDG Energy Sustainability Index

As defined in chapter 2, sustainable energy is "meeting present energy needs without compromising the ability of future generations to meet their own needs" (Ediger, 2009). Resembling the sustainable development definition made by Brundtland Report 2023, this definition could emphasize the use of energy resources in a way that is environmentally, economically, and socially sustainable. Energy sustainability should ensure long-term energy security and minimal environmental impact together with supporting social development.

Energy sustainability plays a critical role in addressing global challenges such as climate change, resource depletion, and energy security. It is crucial in achieving SDGs especially the SDG 7: "Affordable and Clean Energy". However, as SDG 7's interlinked with nearly all SDGs, it is important not only to focus on SDG 7 but also the other SDGs.

The conceptual framework of the SDG Energy Sustainability Index focusses on energy sustainability with a comprehensive approach as it considers the SDG 7 with its interlinkages between the other SDGs. Considering the interlinkages between SDGs and the concept of energy sustainability and sustainable development, the following 25 indicators related to 17 goals, are selected to be included in the index (Table 7.1).

Table 7.1. SDG Energy Sustainability Index Indicator Framework

SDGs*	Number of interlinkages with SDG 7	SDG Indicator**
SDG 7 Affordable and Clean Energy”	-	Population with access to electricity, (%)
		Population with access to clean fuels and technology for cooking, (%)
		Share of renewable energy in total primary energy supply, (%)
		CO_2 emissions from fuel combustion per total electricity output, ($MtCO_2/TWh$)
SDG 1 No Poverty	10	Poverty headcount ratio at $3.20/day (%)
SDG 2 Zero Hunger	5	Cereal yield (tons per hectare of harvested land)
SDG 3 Good Health and Well-being	2	Age-standardized death rate attributable to household air pollution and ambient air pollution (per 100,000 population)
SDG 4 Quality Education	4	Net primary enrollment rate, (%)
SDG 5 Gender Equality	2	Ratio of female-to-male labor force participation rate (%)
SDG 6 Clean Water and Sanitation	9	Population using at least basic drinking water services, (%)
SDG 8 Decent Work and Economic Growth	19	Adjusted GDP growth, (%)
		Unemployment rate (% of total labor force, ages 15+)
SDG 9 Industry, Innovation and Infrastructure	26	Mobile broadband subscriptions (per 100 population)
		Expenditure on research and development (% of GDP)

Source: *UN (2015), **Sachs et.al (2022).

Table 7.1 (continued) SDG Energy Sustainability Index Indicator Framework

SDGs*	Number of interlinkages with SDG 7	SDG Indicators**
SDG 10 Reduced Inequalities	2	Gini coefficient
SDG 11 Sustainable Cities and Communities	18	Proportion of urban population living in slums (%)
		Annual mean concentration of particulate matter of less than 2.5 microns in diameter (PM2.5) (µg/m³)
SDG 12 Responsible Consumption and Production	13	Production-based SO_2 emissions (kg/capita)
		Production-based nitrogen emissions (kg/capita)
SDG 13 Climate Action	18	CO_2 emissions from fossil fuel combustion and cement production (tCO_2/capita)
		CO_2 emissions embodied in fossil fuel exports (kg/capita)
SDG 14 Life Below Water	4	Mean area that is protected in marine sites important to biodiversity (%)
SDG 15 Life on Land	7	Mean area that is protected in terrestrial sites important to biodiversity (%)
SDG 16 Peace, Justice and Strong Institutions	7	Population who feel safe walking alone at night in the city or area where they live (%)
SDG 17 Partnerships for the Goals	6	Either one of the indicators below is used for SDG 17. - For high-income and all OECD Development Assistance Committee (DAC) countries: International concessional public finance, including official development assistance (% of GNI) - For other countries: Government revenue excluding grants (% of GDP)

Source: *UN (2015), **Sachs et.al (2022).

In selecting the indicators, SDG indicators and their data availability across countries are considered together with the interlinkages analyses done in previous section between SDGs. As the SDG 7 interlinked to all other SDGs, at least one indicator is selected to represent all SDGs. In addition, to represent the number of interlinkages between SDG 7 and other SDGs, one more indicator is selected for the major SDGs interlinked with SDG 7. The indicator framework includes total 25 indicators that cover interlinkages between SDG 7 (Affordable and Clean Energy) and all other SDGs, ensuring a holistic evaluation of energy sustainability. While the indicators such as access to electricity, CO_2 emissions per electricity output, and share of renewable energy are appropriately emphasized, directly addressing energy sustainability, social and environmental indicators, such as poverty headcount, air pollution-related deaths, and Gini coefficient, provide insights into the broader socioeconomic impacts of energy use.

The indicators are selected and retrieved from the Database of the Sustainable Development Report 2022 (Sachs et al., 2022). This database, including 94 global indicators for 163 countries as well as 26 additional indicators specifically for OECD countries, is one of comprehensive SDG specific databases. The database of the Sustainable Development Report is used due to its coverage, being standardized and data availability. Being specifically designed to measure the progress on sustainable development is another reason for the selection for the data source. The basic characteristics of this database are:

- Whenever possible, official SDG indicators approved by the UN Statistical Commission are used in this database.
- To address data gaps where there is insufficient data for an official indicator, additional metrics from both official and unofficial sources are included (Sachs et al., 2022).

Data in this database gathered by Sachs and his friends (2022) from various sources:

- The majority of the data is sourced from international organizations such as OECD, United Nations Children’s Fund (UNICEF), WHO, FAO, ILO, and the World Bank, all of which employ broad and rigorous data validation processes.

- Approximately one-third of the data is derived from less traditional statistics, including household surveys like the Gallup World Poll; civil society organizations and networks, such as Oxfam, Reporters sans Frontières; as well as peer-reviewed journals, which are used, for example, to track international spillovers (Sachs et al., 2022).

While including indicators in that database, five criteria were considered by Sachs et al. (2022):

1. Global relevance and applicability across diverse country contexts.
2. The chosen indicators provide valid and dependable measurements (Statistical reliability).
3. The indicators are current and released on a reasonably regular schedule (Timeliness).
4. Data available for at least 80% of UN Member States with populations exceeding one million (Coverage).
5. Ability to measure progress toward targets to determine the optimal performance (Sachs et al., 2022).

Being developed according to these criteria, the reliance on database of the Sustainable Development Report 2022 ensures that the data is robust, validated, and internationally comparable (Sachs et al., 2022). This improves the reliability of the index scores and rankings.

7.3 Index Methodology

After selecting the indicators to be included in the index, the overall index is calculated as the simple arithmetic average of the indicators. The normalized scores calculated by Sachs et al. (2022) in the Sustainable Development Report database are used in the SDG Energy Sustainability Index calculations. In calculating the normalized scores for the indicators firstly performance thresholds was established after removal of extreme values from the distribution of each indicator. After that the data was normalized by rescaling the data from 0 to 100 where 0 denotes worst possible performance while 100 indicates optimum performance. Normalized values for each indicator is based on the formula (6) below:

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)} \times 100 \qquad (6)$$

By normalizing indicator scores (0 to 100) and applying uniform thresholds, the methodology ensures cross-country comparability. The performance thresholds used for the indicators are presented on Table 7.2 below:

Table 7.2. Performance Thresholds of the Indicators

SDG	**Indicator**	**Optimum (= 100)**	**Justification for Optimum**	**Lower Bound (=0)**
1	Poverty headcount ratio at $3.20/day (%)	0	SDG Target	51.5
2	Cereal yield (tons per hectare of harvested land)	7	Average of best performers	0.2
3	Age-standardized death rate attributable to household air pollution and ambient air pollution (per 100.000 population)	0	SDG Target	368.8
4	Net primary enrollment rate (%)	100	SDG Target	53.8
5	Ratio of female-to-male labor force participation rate (%)	100	SDG Target	21.5
6	Population using at least basic drinking water services (%)	100	Leave no one behind	40
7	Population with access to electricity (%)	100	Leave no one behind	9.1
7	Population with access to clean fuels and technology for cooking (%)	100	Average of best performers	2

Source: Sachs et al. (2022).

Table 7.2. (continued) Performance Thresholds of the Indicators

SDG	Indicator	Optimum (= 100)	Justification for Optimum	Lower Bound (=0)
7	CO_2 emissions from fuel combustion per total electricity output ($MtCO_2$/TWh)	0	Technical Optimum	5.9
7	Share of renewable energy in total primary energy supply (%)	51	Average of best performers	3
8	Adjusted GDP growth (%)	5	Average of best performers	-14.7
8	Unemployment rate (% of total labor force, ages 15+)	0.5	Average of best performers	25.9
9	Mobile broadband subscriptions (per 100 population)	100	Leave no one behind	1.4
9	Expenditure on research and development (% of GDP)	3.7	Average of best performers	0
10	Gini coefficient	27.5	Average of best performers	63
11	Proportion of urban population living in slums (%)	0	Leave no one behind	90
11	Annual mean concentration of particulate matter of less than 2.5 microns in diameter (PM2.5) (µg/m³)	6.3	Average of best performers	87
12	Production-based SO_2 emissions (kg/capita)	0	Average of best performers	525
12	Production-based nitrogen emissions (kg/capita)	2	Average of best performers	100

Source: Sachs et al. (2022).

Table 7.2. (continued) Performance Thresholds of the Indicators

SDG	Indicator	Optimum (= 100)	Justification for Optimum	Lower Bound (=0)
13	CO_2 emissions from fossil fuel combustion and cement production (tCO_2/capita)	0	Technical Optimum	20
13	CO_2 emissions embodied in fossil fuel exports (kg/capita)	0	Technical Optimum	44000
14	Mean area that is protected in marine sites important to biodiversity (%)	100	Technical Optimum	0
15	Mean area that is protected in terrestrial sites important to biodiversity (%)	100	Technical Optimum	0
16	Population who feel safe walking alone at night in the city or area where they live (%)	90	Average of best performers	33
17	For high-income and all OECD DAC countries: International concessional public finance, including official development assistance (% of GNI)	1	Average of best performers	0.1
	For other countries: Government revenue excluding grants (% of GDP)	40	Average of best performers	10

Source: Sachs et al. (2022).

The thresholds in Table 7.2 were determined using statistical methods, such as the mean and standard deviations, and expert consultations. The thresholds are set in absolute terms and are applied to all countries (Sachs et al., 2022).

The SDG Energy Sustainability Index is formed by aggregating the normalized values of 25 indicators. A variation is made in index development using different weights to indicators of SDG 7 to put emphasis on SDG 7 indicators as the index is an energy focused one. Simple arithmetic averages are used in calculating the index. In the index development 2 different weighting methods applied in aggregations so that 2 different indices are formed:

- SDG Energy Sustainability Index No 1: Equal weights are given to all 25 indicators included in index 1. Weights of each indicator is therefore equal to 1/25.
- SDG Energy Sustainability Index No 2: In the second index higher weights to energy (SDG 7) targets (4 SDG-7 indicators: 12.5% each (total 50%), remaining 21 indicators: 2.38% each (total 50%)).

The introduction of two weighting schemes provides complementary perspectives on sustainability. While Index 1 maintains a holistic view, Index 2 prioritizes SDG 7, offers insights into energy-related progress while still reflecting interconnections with other SDGs.

7.4 Results of SDG Energy Sustainability Index

The SDG Energy Sustainability Index scores can be interpreted as the percentage of achievement to energy sustainability considering SDG 7 and its linkages. The difference between 100 and countries' scores is therefore the distance in percentage that needs to be completed in achieving energy sustainability. For example, a country with an index score of 75 suggests that the country is on average 75% of the way to the best possible level of energy sustainability. Consequently, the gap between any given score and the maximum value of 100 represents the percentage points remaining to reach optimal energy sustainability performance.

The scores and the rankings of both SDG Energy Sustainability Indices are calculated using the methodology described in the previous section. With these indices Türkiye is compared with Spain and Poland (Europe), Mexico (America), Korea (Asia) and South Africa (Africa). This comparison provides insights into Türkiye's relative position across both geographical and income groups. All of these countries except South Africa is a member of OECD (South Africa is a partner country) (OECD, 2024). These countries represent diverse economic contexts and geographical regions (World Bank, 2024b), enabling a comprehensive evaluation of Türkiye's energy sustainability:

- Spain, Poland and South Korea are high-income countries from Europe and East Asia, showcasing advanced energy and socioeconomic policies.
- Mexico and South Africa, which are upper-middle-income countries from Latin America and Sub-Saharan Africa respectively, shares Türkiye's development challenges but operates in a different geographical and policy context, highlighting energy sustainability challenges in a developing region with resource constraints.

The neighboring countries of those countries are also included in the index calculations to observe their relative performance too. The list of the neighboring countries are presented as follows:

- Türkiye shares borders with the following countries: Greece (to the northwest). Bulgaria (to the northwest), Georgia (to the northeast), Armenia (to the east), Azerbaijan (to the east), Iran (to the east), Iraq (to the southeast), and Syria (to the south).
- South Korea shares its borders and surroundings with North Korea, located directly to the north. But in this study, because of insufficient data availability for North Korea, South Korea's neighbors are selected as the countries close to it China (across the Yellow Sea to the west) and Japan (across the Korea Strait to the southeast).

- Poland shares borders with the following countries: Germany (to the west), Czechia (to the southwest), Slovakia (to the south), Ukraine (to the east), Belarus (to the east), Lithuania (to the northeast), Russia (to the north.
- Spain shares borders with the following countries: Portugal (to the west), France (to the northeast), Andorra (to the northeast) and Morocco (to the south). Because of insufficient data availability, Andorra is not included in the indices.
- Mexico shares borders with the following countries: United States (to the north), Guatemala (to the southeast), and Belize (to the southeast).
- South Africa shares its borders with the following countries: Namibia (to the northwest), Botswana (to the north), Zimbabwe (to the north), Mozambique (to the northeast of South Africa), Eswatini (old name is Swaziland) (surrounded by South Africa in the east), and Lesotho (encircled by South Africa in the southeast).

Including the neighboring countries provides valuable context for Türkiye's performance and allows for comparative analyses across regions and development levels. The two energy sustainability indices and the SDG Index scores for Türkiye and the selected countries are shown in Table 7.3.

Table 7.3. Scores of Energy Sustainability Indices

Country	**2022 SDG Index Score**	**SDG Energy Sustainability Index 1 Score**	**SDG Energy Sustainability Index 2 Score**
Germany	82.2	84.9	81.6
France	81.2	84.1	81.1
Poland	**80.5**	**78.1**	**74.9**
Czechia	80.5	77.7	76.2
Spain	**79.9**	**78.1**	**77.8**
Portugal	79.2	81.1	81.7
Slovakia	78.7	75.8	75.6
Belarus	76.0	70.6	70.3
Ukraine	75.7	71.7	70.9
Lithuania	75.4	75.6	70.9
Russia	74.1	67.1	66.4
Morocco	69.0	63.1	66.1
Japan	79.6	81.8	77.9
South Korea	77.9	79.0	75.5
China	72.4	64.3	64.1
Greece	76.8	75.3	74.7
Bulgaria	74.3	76.1	74.9
Azerbaijan	73.5	68.2	68.0
Georgia	73.4	71.1	73.9
Armenia	71.1	67.8	70.3
Türkiye	**70.4**	**65.0**	**69.1**
Iran	68.6	65.1	64.8
Iraq	62.3	53.1	57.6
Syria	57.4	41.6	49.9

Source: Sachs et.al, 2022 (for SDG Index) and Author (for the SDG Energy Sustainability Indices).

Table 7.3. (continued) Scores of Energy Sustainability Indices

Country	2022 SDG Index Score	SDG Energy Sustainability Index 1 Score	SDG Energy Sustainability Index 2 Score
United States	74.6	76.0	74.6
Mexico	**70.2**	**67.9**	**68.1**
Belize	65.7	62.4	63.4
Guatemala	61.0	62.1	69.7
South Africa	**63.7**	**58.3**	**59.1**
Namibia	62.7	57.1	52.0
Botswana	61.4	53.3	53.4
Zimbabwe	56.8	54.7	57.6
Lesotho	55.1	41.0	34.0
Eswatini	54.6	43.0	46.2
Mozambique	53.6	56.0	55.4

Source: Sachs et.al, 2022 (for SDG Index) and Author (for the SDG Energy Sustainability Indices).

According to Table 7.3, Türkiye's SDG Index score of 70.4 places it in the lower-middle tier of the 168 countries assessed in the Sustainable Development Report 2022 (Sachs et al., 2022), reflecting moderate progress across all SDGs. In comparison to this, Türkiye scores 65.0 in SDG Sustainable Energy Index 1 where equal weights applied. It is ranking below most of the comparison countries such as Korea (79.0), Spain (78.1), Poland (78.1) and Mexico (67.9), and most of its neighbors as Bulgaria (74.9), Greece (74.7), Georgia (73.9), Armenia (70.3) and Azerbaijan (68.2). This result is due to having lower scores in socioeconomic and environmental indicators like economic growth, unemployment, research and development, inequalities, air pollution, emissions and protected areas. However, in SDG Sustainable Energy Index 2, in which SDG 7 indicators are relatively weighted more, Türkiye's score improves to 69.1, indicating that key SDG 7 metrics, such as access to electricity, clean cooking fuels, renewable energy integration, and CO_2 emissions from electricity generation contribute positively to Türkiye's standing in this index. However, it still lags behind Spain (77.3), Korea (75.1) and Poland (74.4) among the focus countries and Bulgaria (74.3), Greece (74.1), Georgia (73.1) and Armenia (69.4) among its neighbors. Iraq and Syria scores lower across all indices, reflecting less progress on both SDG goals and energy-specific indicators. Iran on the other hand has close scores on SDG Index and Index 1 but Türkiye performed better in the Index 2 as a result of renewable share and CO_2 emissions.

The disparity between these scores highlights Türkiye's relatively better performance in energy-related areas, such as electricity access and renewable energy adoption, compared to its broader sustainable development challenges, including economic growth, unemployment, air pollution and social inequalities.

When compared with focus countries, Poland stands out with the highest SDG Index score of 80.5, coupled with scores of 77.2 in Index 1 and 74.4 in Index 2. It lost its leading position to Korea in Index 1 and Spain in Index 2, which can indicate its energy sustainability performance is not going in hand with socioeconomic performance. Türkiye's scores in energy indicators such as renewable energy and emission related indicators are slightly better than Poland, but Poland has higher scores in environmental indicators such as protection of nature, air pollution and some socioeconomic indicators such as women's participation in workforce, mobile broadband subscription.

Similarly, Spain with an SDG Index score of 79.9 demonstrates its advancement in reaching sustainable development goals. In parallel to this, Spain achieved 78.1 in Index 1 and 77.8 in Index 2, becoming the leader in the Index 2. This could be a result of Spain's better alignment between its energy policies and overall SDG progress, especially in renewable energy implementation and emissions reduction as indicated in the scores of related indicators. Türkiye falls behind Spain significantly in the indicator scores of socioeconomic inequalities, air pollution and marine and terrestrial protected areas perception of safety in the streets at night.

Being a European country, Poland and Spain, both fall behind Germany and France in all index scores. Germany and France are the only countries scored above 80 points in all indices. Although Portugal has an SDG Index score slightly below Poland and Spain, it performs better than them in Index 1 and 2 due to higher renewable share in primary energy and lower pollutant and CO_2 emissions.

It should be noted that developed countries like Germany, France, and Portugal rank among the top performers in all indices, reflecting their strong policies on energy access, renewable integration, and low emissions intensity.

South Korea, on the other hand, with an SDG Index score of 77.9, excels in both Energy Sustainability Indices (78.2 in Index 1 and 75.1 in Index 2) becoming leader among focus countries in the Index 1. Although Türkiye scores significantly better in the share of renewable energy and CO_2 emissions indicators, due to having lower scores in other environmental and socioeconomic indicators such as cereal yield, women's participation to workforce, unemployment, research and development expenditure, marine and terrestrial protected areas, safety perception indicators. This reflects South Korea's stronger focus on clean energy technologies and innovation. Among its neighboring countries, Japan performed better in all indices while China worse than South Korea especially in Index 1 and 2 indicating China's weaker position in energy sustainability.

Mexico scores close points to Türkiye in nearly all indices. It performed slightly better than Türkiye only in Index 1. This is due to having higher scores in some environmental indicators such as marine and terrestrial protected areas and air pollution and unemployment scores. When compared with its neighboring countries, Mexico has lower scores than USA in all indices but better results than Belize and Guatemala in Index 1 and 2 except Guatemala surpasses Mexico in Index 2 with higher renewable share in primary energy and emission scores.

South Africa scores the lowest among the comparison countries. Compared to South Africa's lower scores across all indices (SDG Index: 63.7, Index 1: 58.3, Index 2: 59.1), Türkiye scores higher across all indices, particularly in energy-specific metrics

(Index 2: 69.1 vs. 59.1), which reflects its relative advantage in infrastructure and policy development. The index results of South Africa indicate significant challenges in energy access, emission reduction, renewables and socioeconomic development such as multidimensional poverty, unemployment, income inequality. The comparison underscores the need for more targeted efforts to close the gap with higher-performing nations. Compared with its neighboring countries, South Africa is performing better than all neighbors.

The differences between Türkiye’s rankings in the indices suggest its energy sector is performing better than its broader socioeconomic development metrics. This is especially evident in Index 2, where energy-specific indicators, especially renewable energy adoption, lifting Türkiye’s ranking. However, small gaps remain in access to clean fuels and technology for cooking, but significant gaps remain particularly in some of the socioeconomic and environmental indicators.

The selected countries are also compared with the regional and income country groups. This comparative approach evaluates Türkiye’s performance in the SDG Energy Sustainability Indices relative to countries in similar and contrasting income and regional groups. When calculating SDG Energy Sustainability Index No 1 and 2, population weighted averages for the income groups and regions in the world for the same indicators in the SDG Index database were used. The results are shown in Table 7.4 and 7.5:

Table 7.4. Comparison with Income Groups

Country Groups*	**2022 SDG Index Score**	**SDG Energy Sustainability Index 1**	**SDG Energy Sustainability Index 2**
Poland	**80.5**	**78.1**	**74.9**
Spain	**79.9**	**78.1**	**77.8**
South Korea	**77.9**	**79.0**	**75.5**
High-income Countries	77.5	79.0	77.2
Upper-middle-income Countries	71.5	70.2	69.5
Türkiye	**70.4**	**65.0**	**69.1**
Mexico	**70.2**	**67.9**	**68.1**
South Africa	**63.7**	**58.3**	**59.1**
Lower-middle-income Countries	61.8	59.5	62.5
Low-income Countries	51.6	49.5	50.9

Source: Sachs et al., (2022) (for SDG Index) and Author (for the SDG Energy Sustainability Indices).

* Country groupings are done according to World Bank country classification (Income levels) (World Bank, 2024b).

According to Table 7.4, Spain, Poland, and South Korea represent high-income countries and demonstrate good performance. Although their SDG index scores are above high-income countries average, this performance changes in SDG Energy Sustainability Index 1 and 2. Achieving energy sustainability scores of 78.1 (Index 1) and 77.8 (Index 2), Spain is slightly below income group's average in Index 1, but it performs better than the high income averages in Index 2. Its advanced renewable energy adoption and socioeconomic development policies place it among the top performers. Poland scores slightly higher in the SDG Index (80.5), but lower in Index 1 (78.1) and Index 2 (74.9) that due to challenges in emissions reduction and renewable energy integration as observed from the indicator scores. South Korea on the other hand leads with 79.0 (Index 1) and 75.5 (Index 2), only fall below high income averages in Index 2.

As an upper middle income country, Türkiye scores close to its income group averages except in Index 1 where there is approximately 5 points below the averages. Türkiye aligns closely with the upper-middle-income group average in Index 2 (69.1 vs. 69.5) but falls short in Index 1 (65.0 vs. 70.2), indicating weaknesses in broader socioeconomic and environmental indicators. It lags significantly behind those high-income peers. The disparities highlight Türkiye's slower progress in socioeconomic and environmental dimensions compared to the advanced policies of Spain, Poland, and South Korea.

Mexico, as an upper middle income country, performs similarly to Türkiye, scoring 70.2 (SDG Index), 67.9 (Index 1), and 68.1 (Index 2). While Türkiye slightly outperforms Mexico in Index 2, Mexico's higher scores in protected areas and air quality metrics reflect stronger environmental performance.

South Africa, though classified as upper-middle-income, scores significantly lower across all indices (SDG Index: 63.7, Index 1: 58.3, Index 2: 59.1), remarkably close to lower middle income countries. This highlights its challenges in energy access, renewable energy integration, and socioeconomic inequality.

Table 7.5. Comparison with Geographical Groups

Country Groups*	**2022 SDG Index Score**	**SDG Energy Sustainability Index 1**	**SDG Energy Sustainability Index 2**
Poland	**80.5**	**78.1**	**74.9**
Spain	**79.9**	**78.1**	**77.8**
South Korea	**77.9**	**79.0**	**75.5**
OECD members	77.2	77.2	76.1
Eastern Europe and Central Asia	71.6	66.0	64.9
Türkiye	**70.4**	**65.0**	**69.1**
Mexico	**70.2**	**67.9**	**68.1**
Latin America and the Caribbean	69.5	69.9	75.8
Middle East and North Africa	66.7	58.8	61.2
East and South Asia	65.9	63.9	64.8
Small Island Developing States	65.3	50.8	50.6
South Africa	**63.7**	**58.3**	**59.1**
Sub-Saharan Africa	53.6	51.7	52.7
Oceania	52.3	38.4	36.7

Source: Sachs et al. (2022) (for SDG Index) and Author (for the SDG Energy Sustainability Indices).

* Country groupings are done according to World Bank country classification (major world regions) (World Bank, 2024b).

When the comparison made with the regional groups in Table 7.5, Türkiye as an OECD member, its scores (70.4 in SDG index, 65.0 in Index 1 and 69.1 in Index 2) are below the group averages (77.2 in SDG index and Index 1, 76.1 in Index 2). Among OECD comparison countries, Spain, Poland, and South Korea significantly outperform Türkiye. They are above OECD averages in SDG Index and Index 1, with strong energy and socioeconomic policies however Poland and South Korea drops below group average while only Spain stays above the OECD averages.

Türkiye is also below Europe and Central Asia averages in SDG Index and Index 1; however, it surpass the averages in Index 2 having better scores in energy indicators.

Although Mexico and Türkiye have better performance in SDG index compared to the regional averages for Latin America, they both fall behind in the Index 1 and Index 2, suggesting the presence of stronger performers in the region, such as Brazil and Chile.

South Africa scores 63.7 (SDG Index), 58.3 (Index 1) and 59.1 (Index 2), above the Sub-Saharan Africa averages (SDG Index: 53.6, Index 1: 51.7, Index 2: 52.7), reflecting advancement in energy sustainability and socioeconomic development in its region.

In order to observe the trends in these indices, index scores of SDG Energy Sustainability Index 1 and 2 for the period 2000-2021 are also calculated and compared with SDG Index scores for the focus countries using the database of Sustainable Development Report 2022 (Sachs et al., 2022). The resulting graphs are presented in Figure 7.4.

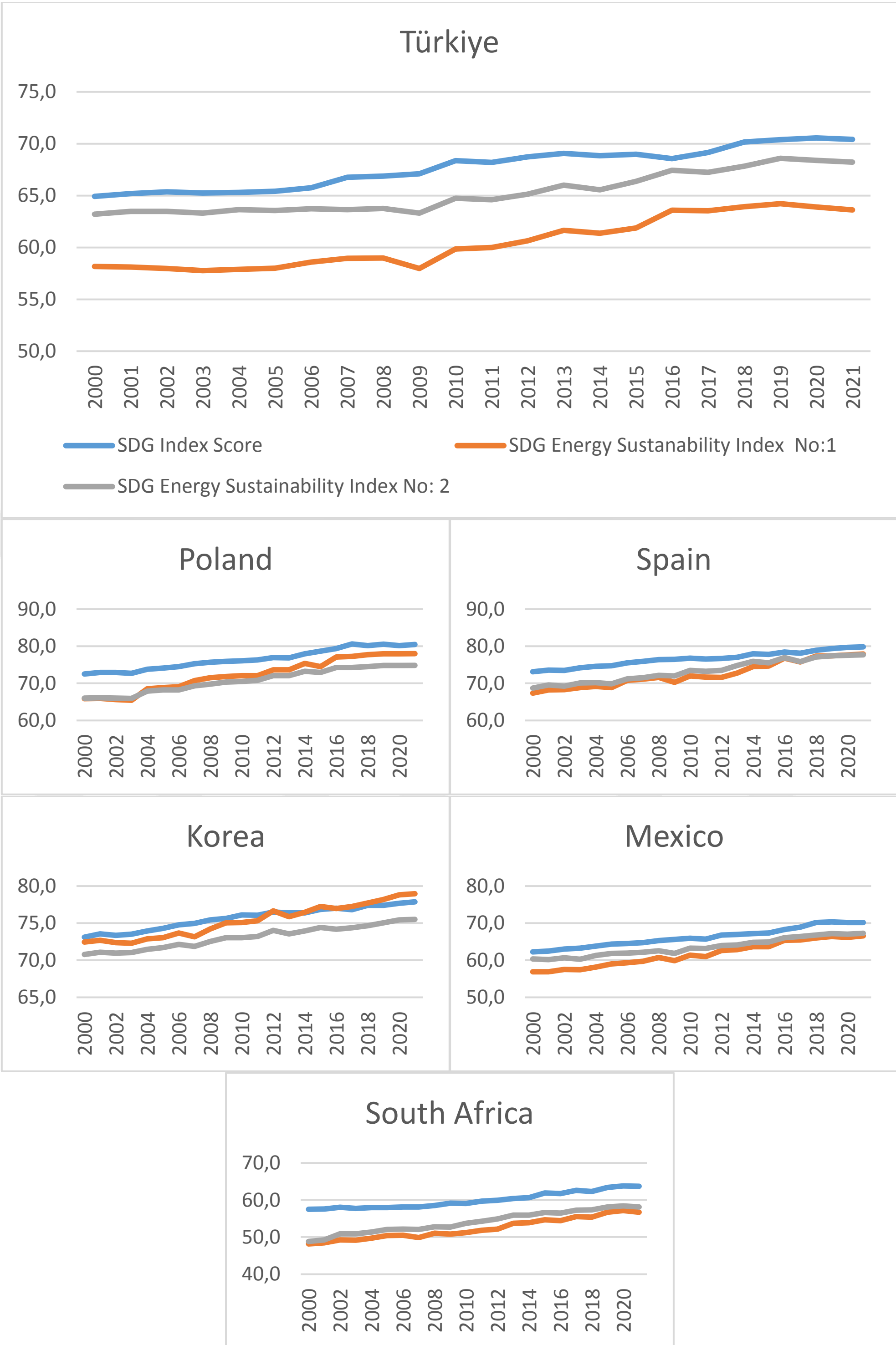


Figure 7.4. Historical Trends in the Indices

Source: Sachs et al. (2022) (for SDG Index) and Author (for the SDG Energy Sustainability Indices).

The trends presented in Figure 7.4 provide insights into the historical progress of SDG Energy Sustainability Index 1, SDG Energy Sustainability Index 2, and the SDG Index for Türkiye and the selected focus countries (Spain, Poland, South Korea, Mexico, and South Africa) over the period 2000–2021. These trends highlight variations in progress and emphasize specific areas of strength and challenge for Türkiye compared to its peers.

All focus countries demonstrate gradual improvement in SDG Index scores, reflecting progress across economic, social and environmental dimensions of sustainable development. High-income countries such as Spain, Poland, and South Korea consistently outperform Türkiye and other peers, with South Korea and Spain showing notable jumps in the last decade.

The trends for Index 1 (Equal weighted) and Index 2 (Energy weighted) reveal differences in how countries perform when more emphasis is placed on energy-specific indicators (Index 2). Türkiye, Poland, and South Korea show broader gap between both indices suggesting relative strengths in energy metrics compared to broader SDG indicators. However, Spain, Mexico and South Africa show a narrower gap between the two indices, indicating the more balanced progress between energy indicators and socioeconomic indicators.

Türkiye's SDG Index score reflects slow but steady progress in socioeconomic and environmental sustainability. The slower growth compared to high-income countries underscores Türkiye's need to address broader challenges like poverty, inequality, and urban air pollution.

Türkiye's performance in Index 1 has shown steady improvement since 2000, but it remains significantly below that of Spain, Poland, and South Korea. The slower growth reflects Türkiye's persistent socioeconomic and environmental challenges, such as unemployment, inequality, and air pollution, which are equally weighted with energy indicators in this index. While Türkiye outpaces South Africa in this index, it struggles to catch up to Mexico, which performs slightly better in socioeconomic indicators.

Türkiye shows stronger growth in Index 2, narrowing the gap with Poland and South Korea. This reflects Türkiye's progress in energy-specific metrics, such as renewable energy adoption, CO_2 emissions reductions, and electricity access.

However, the gap between Türkiye and Spain remains significant, highlighting the need for accelerated adoption of clean energy technologies and further reductions in emissions.

Spain consistently leads in all indices, with marked improvements in Index 2 over the past two decades. This indicates the success of its renewable energy policies and emissions reductions. Türkiye's gap with Spain in both indices emphasizes the need for more ambitious energy transition strategies and more improvement in social policies.

Poland exhibits significant growth in Index 1, driven by improvements in socioeconomic metrics, such as women's workforce participation and air pollution control. In Index 2, Poland shows steady progress, but Türkiye's faster growth highlights its relative strength in energy-specific metrics.

South Korea shows remarkable stability and consistent improvement across all indices. Its leadership in clean energy innovation is reflected in Index 2, where it consistently scores higher than Türkiye.

Mexico's trends are similar to Türkiye's, with slower growth in Index 1 and more substantial progress in Index 2. Both countries face challenges in socioeconomic development, but Türkiye have achieved relative success in renewable energy adoption and emissions reduction.

South Africa lags behind all focus countries, with minimal growth in both indices. While Türkiye's growth outpaces South Africa's, the gap between the two countries has widened significantly since 2010, underscoring Türkiye's comparative progress in energy sustainability.

In summary, Türkiye shows progress in energy sustainability but faces challenges in bridging the gap with high-performing nations like Poland and Spain. By addressing key areas of improvement, Türkiye can solidify its position as a leader in sustainable energy transitions within its region.

Türkiye's lower Index 1 score (65.0) indicates challenges in socioeconomic indicators, such as inequality, unemployment, and environmental protection, when compared to OECD and upper-middle-income averages. Therefore, Türkiye falls short of high-income countries like Spain, Poland, and South Korea, emphasizing the need for improved socioeconomic policies and environmental protection to close the gap. However, Türkiye's performance in Index 2 (69.1) demonstrates progress in renewable energy adoption and emissions reductions and performs moderately well within the upper-middle-income group, outpacing South Africa but remaining close to Mexico in energy-specific metrics. Türkiye's performance in energy-specific metrics positions it above many developing regions, including Sub-Saharan Africa and parts of Eastern Europe.

7.5 Chapter Review

Chapter 7 presents a comprehensive framework for assessing energy sustainability through the lens of the SDGs. It emphasizes the critical role of SDG 7, which focuses on affordable, reliable, sustainable, and modern energy, and its complex interconnections with other SDGs (UN, 2015).

The chapter begins by detailing the conceptual foundation of SDG 7 and its five key targets, which address energy access, renewable energy adoption, energy efficiency, international cooperation, and infrastructure development. This section underscores the essential nature of energy access in advancing poverty reduction, economic growth, health, and education. The subsequent analysis of interlinkages between SDG 7 and the remaining SDGs reveals the interconnected nature of energy policies and their wide-reaching impacts on social, economic, and environmental outcomes.

Using a systems-thinking approach, it maps the cause-and-effect relationships between energy sustainability and socioeconomic development. This analysis reveals that energy access and efficiency directly influence outcomes like reducing inequalities, enhancing infrastructure, and promoting sustainable consumption and production. By employing visualization tools (Figure 7.1), the chapter highlights the multidimensional impact of energy policies and their effects on other developmental goals.

A key contribution of the chapter is the development of the SDG Energy Sustainability Index, which is built with a rigorous and transparent methodology, and 25 indicators reflecting energy access, renewable integration, environmental sustainability, and socioeconomic development. These indicators are derived from a globally recognized dataset, the Sustainable Development Report (Sachs et al., 2022), to ensure reliability and cross-country comparability. Two distinct weighting systems are employed: one offering equal weights to all indicators for a balanced and holistic perspective (Index 1) and another prioritizing SDG 7 metrics to emphasize energy-specific outcomes (Index 2). This approach provides complementary insights into energy sustainability, balancing broader development goals with energy-focused priorities.

However, there are some limitations in the methodology that could be improved in future studies. While the two weighting schemes used in the development of indices provided flexibility, the static nature of weights may overlook context-specific priorities. Different or more sophisticated weighting schemes would be developed in future studies to improve the reflection of specific nuances of sustainability. Although there are 25 indicators, limited to the context of SDG Index Database, used to cover as much of the energy sustainability areas, certain key metrics, such as energy efficiency, grid reliability, and the role of private sector contributions, are not explicitly included in the indices. This would cause potentially missing important aspects of energy sustainability in the indices that would be improved in the future studies by addition of new indicators to the database. Indicators for region-specific challenges (e.g., Türkiye’s energy dependency, geopolitical factors affecting neighboring countries) could also be identified and included in these indices to contextualize the scores further. Although missing data is well considered in the SDG Index database, differences in data availability would be an issue, particularly for developing regions like Sub-Saharan Africa, may introduce biases in cross-country comparisons. Development of data collection and statistical systems in the developing countries would improve data availability in these countries.

Türkiye's performance in energy sustainability is examined through the lens of this index, benchmarked against such as Spain, Poland, South Korea, Mexico and their regional peers. While Türkiye demonstrates relative strengths in renewable energy adoption and CO_2 emissions reduction, it lags in socioeconomic and environmental indicators like inequality, air pollution, and research and development. Comparative trends from 2000 to 2021, as shown in Figure 7.4, further illustrate Türkiye's progress in sustainable energy development and SDGs.

Comparative analysis with countries like Spain, Poland, and South Korea illustrates areas where Türkiye can improve, particularly in aligning its energy policies with broader sustainability goals. The key results of this analysis are presented as:

- Energy-Specific Strengths: Türkiye's stronger growth in SDG Energy Sustainability Index 2 compared to Index 1 indicates that its energy-specific policies (e.g., renewable energy, CO_2 reductions) are more effective than its broader socioeconomic policies.
- Challenges in Broader Sustainability: The slower growth in Türkiye's Index 1 and SDG Index scores highlights persistent gaps in socioeconomic and environmental areas, such as poverty reduction, employment, inequality, and air pollution.
- Catch-Up Opportunities: While Türkiye follows high-income countries like Spain, Poland, and South Korea, its faster growth in Index 2 suggests potential for closing the gap with further investments in clean energy and emissions reduction technologies.

Türkiye’s performance highlights strengths in energy-specific metrics but also exposes weaknesses in socioeconomic and environmental areas. Countries like Korea, Poland and Spain offer actionable insights for Türkiye to improve its energy sustainability strategies. Incorporating these learnings, Türkiye could aim to enhance renewable energy adoption, reduce emissions, increase research and development particularly in renewable energy and emission reduction, enlarge its nature protection areas and improve integration of energy goals with broader socioeconomic development goals in its development plans.

CHAPTER 8

CONCLUSION

The transition towards sustainable energy systems represents one of the most urgent challenges of our time, particularly for developing countries such as Türkiye. As global energy demands rise, nations face the dual challenge of ensuring energy security while minimizing environmental impacts. In this context, the evolution of Türkiye’s energy sector captures the complex balance between sustainability and development, a central paradox explored throughout this thesis.

This study aimed to investigate Türkiye’s progress towards achieving energy sustainability by analyzing how Türkiye’s energy and development policies, and their results align with global sustainable development frameworks such as the United Nations Sustainable Development Goals (SDGs) and comparing its trajectory since the 1990s with selected countries: Spain, Poland, Mexico, Korea, and South Africa. By examining Türkiye’s historical energy and development policy evolution, sectoral challenges, and global standing using comparative benchmarking and sustainability indices, this thesis provides insights into the broader paradox of balancing development and sustainability.

This thesis answers the main research question that “Has Türkiye aligned its energy and development policies in a sustainable manner, particularly in the post-cold war era since 1991 in addition how could Türkiye’s performance be evaluated in comparison to the performances of other comparable cases since 1991”.

Contrary to some views asserting that there is a weak coherence between energy policies and sustainability principles in Türkiye, this thesis argues that the country has made significant progress in integrating sustainability into its energy and development strategies. In particular, Türkiye has substantially aligned its policies with global frameworks such as the SDGs. In parallel to the development of sustainability frameworks at global level, sustainability has gradually become a core component of Türkiye’s national development plans and energy strategies. Main findings of the thesis chapters in support of this argument are discussed in the following paragraphs.

Chapter 2 laid the theoretical foundation by examining the historical evolution of sustainability and its intersection with energy policies. This chapter highlighted the multidimensional and evolving nature of sustainable development, emphasizing the interdependence of its economic, environmental, and social dimensions. While these dimensions are interconnected, they often involve trade-offs, particularly when balancing renewable energy adoption with socioeconomic costs. By exploring key frameworks, debates, and alternative perspectives, this chapter emphasized the critical need for integrated policymaking that balances short-term gains with long-term ecological and social sustainability. This foundation set the stage for analyzing how these theoretical constructs are applied in practice, particularly in the evolution of sustainability strategies within national contexts.

Chapter 3 investigated the integration of sustainability in Türkiye’s national development strategies by analyzing twelve national development plans (NDPs) from 1963 to 2024. Supporting the argument of the thesis, results of the analysis of the national development plans showed significant advancement in aligning national policies with global sustainability frameworks in the form of transition from economic-centric to integrated sustainability-focused planning. While early NDPs (1963–1990) prioritized industrialization with minimal environmental considerations, the Sixth NDP (1990-1994) marked a turning point by introducing environmental protection as a key policy goal. Subsequent NDPs expanded these principles, addressing energy efficiency, renewable energy, and environmental protection. The Tenth NDP (2014-2018), particularly, emphasized green growth, climate change mitigation, and renewable energy adoption, reflecting stronger alignment with global sustainability objectives. The Eleventh NDP (2019-2023) deepened this commitment by incorporating SDG implementation strategies, institutional coordination mechanisms, and monitoring frameworks such as the

National Sustainable Development Coordination Board and TURKSTAT's SDG portal. The Twelfth NDP (2024-2028) further enhances SDG monitoring, participatory governance, and local-level implementation to ensure a more systematic and inclusive approach to sustainability.

Chapter 4 conducted a sectoral analysis of Türkiye's energy landscape, examining its evolution in response to economic growth, sustainability challenges, and geopolitical factors. In parallel to the development policies, the evolution of Türkiye's energy policies has followed a dual approach, prioritizing industrialization and economic expansion in its earlier stages, while more recent strategies and polices especially after 2015, have focused on energy security and environmental sustainability. Supporting the argument, the sectoral analysis revealed that Türkiye's energy sector has evolved significantly over the past three decades, with a notable shift towards integrating sustainability principles into national energy policies. Since the 1990s, Türkiye has undertaken substantial reforms liberalizing its energy markets and expanding its renewable energy infrastructure. The National Development Plans and strategic policies such as the Renewable Energy Law and Energy Efficiency Law have played a crucial role in shaping this transition.

Renewable energy production, particularly wind, solar, and hydropower, has nearly tripled since 1990, making up 58.6% of domestic production and 43% of electricity production, which is a significant progress in diversifying energy mix. Key policies promoting renewable energy, such as the Renewable Energy Resources Support Mechanism (YEKDEM) and Renewable Energy Resource Areas (YEKA) and advancements in wind and solar energy, have driven progress. Large-scale renewable energy projects, supported by targeted incentives, have significantly increased installed capacities, helping to reduce greenhouse gas emissions and enhance energy security. The development of Türkiye's first nuclear power plant (planned to be operational in 2025) has also marked a strategic move towards energy diversification and reduced import dependency. In addressing energy efficiency, Türkiye has implemented initiatives such as the National Energy Efficiency Action Plan (NEEAP), which achieved measurable reductions in energy. These advances demonstrates Türkiye’s commitment to SDG 7, which emphasizes affordable, reliable, and sustainable energy access.

Türkiye’s geostrategic location strengthens its role as a regional energy hub, exemplified by projects such as TANAP and Turkish Stream. Commitments to international climate agreements, including the Paris Agreement, reinforce its pledge to reduce emissions by 41% by 2030 and achieve net-zero by 2053. National policies emphasize renewable energy expansion, energy efficiency improvements, and technological localization, with significant progress in reducing energy intensity and developing domestic manufacturing of renewable technologies. These efforts showcase Türkiye’s commitment to aligning its energy sector with global sustainability goals while ensuring economic resilience and energy security.

Chapter 5 explored the challenges hindering Türkiye’s energy sustainability, including global energy challenges and Türkiye-specific issues such as fossil fuel dependency, environmental degradation, and energy security risks.

Globally, energy sustainability is challenged by climate change, resource depletion, water scarcity, social equity issues, and technological barriers. High dependence on fossil fuels, inefficient resource use, and limited renewable energy infrastructure continue to hinder progress toward sustainable energy transitions. Türkiye faces these global challenges alongside unique domestic issues, including heavy reliance on fossil fuel imports (99% of natural gas and 93% of oil), rising energy demand, and climate-related risks such as droughts and extreme weather events.

Despite these obstacles, Türkiye has emerged as one of the leaders in renewable energy adoption, significantly increasing its installed capacity in solar, wind, and hydroelectric power. Commitments to the Paris Agreement and the 2053 carbon neutrality target reflect Türkiye’s long-term vision for energy sustainability, while requiring better policy coordination and investment specifically in the renewables and energy efficiency applications in the future to fully realize these goals.

Chapter 6 presented a comparative analysis of Türkiye’s sustainable development and energy performance relative to selected countries, including Spain, Poland, Mexico, South Korea, and South Africa. Using established sustainability indices such as the Human Development Index (HDI), Ecological Footprint (EF), Environmental Performance Index (EPI), Sustainable Development Goal (SDG) Index, and the Energy Trilemma Index (ETI), this chapter benchmarked Türkiye’s progress, identifies strengths and areas for improvement, and provides insights into best practices from other nations.

The results of the comparative analysis with these countries also supported the argument revealing that Türkiye made significant progresses in energy sustainability especially in renewable energy deployment and electricity access. Türkiye has performed better in renewable energy adoption compared to countries like South Africa and Mexico but lagged behind Spain and South Korea in energy efficiency and emissions reduction. Spain and Korea demonstrated more advanced energy transitions due to policy coherence, technological innovation, and effective governance mechanisms, prioritizing decarbonization. The reliance on fossil fuels and high import dependency is thought to place Türkiye at a disadvantage at this point. Türkiye’s progress in renewable energy adoption and net-zero commitments provides strong opportunities for improvement. With its 5th ranking in Europe for renewable energy capacity, Türkiye seems well-positioned to enhance its sustainability profile by investing in solar, wind, and hydroelectric power. Lessons from higher-performing countries such as Spain, particularly in biodiversity conservation and ecosystem protection, can help address environmental sustainability gaps. Continuing the existing trends, better inclusion of the sustainability considerations in the energy and development policies in the direction of SDGs will have positive effects in filling these gaps. Additionally, accelerating efforts in social inclusion and resource efficiency will contribute to a more holistic sustainability strategy.

Chapter 6 also highlighted the limitations of existing indices, especially in capturing interlinkages between SDG 7 “Ensure access to affordable, reliable, sustainable and modern energy for all” and other goals. While global indices such as HDI, EF, EPI, SDG Index, and ETI provide valuable benchmarks, they often assess sustainability dimensions separately or broadly rather than capturing the complex interlinkages between economic, social, and environmental factors. They does not always explicitly measure the synergies and trade-offs between energy sustainability (SDG 7) and other SDGs. To address this, a new index was developed in Chapter 7 to offer a systemic and multidimensional assessment incorporating SDG interconnections for a more holistic and integrated sustainability measurement framework.

Chapter 7 introduced a novel SDG Energy Sustainability Index tailored to the SDG framework. This chapter detailed the methodology, selection of indicators, and weighting system used in constructing the index. The SDG Energy Sustainability Index was developed using 25 indicators derived from the Sustainable Development Report for global reliability and comparability. Two weighting systems were applied: Index 1 gave equal weight to all indicators for a holistic view, while Index 2 prioritized SDG 7 metrics to emphasize energy-specific outcomes. In the SDG Sustainable Energy Index 1, Türkiye scores 65.0, ranking below most peer countries due to lower performance in socioeconomic and environmental indicators. However, in SDG Sustainable Energy Index 2, Türkiye’s score improves to 69.1, benefiting from strong renewable energy adoption and lower CO_2 emissions. Considering these scores and the trends over the period 2000–2021, Türkiye outpaced South Africa, performed similar to Mexico but lagged behind high-performing high-income nations like Spain, Poland, and South Korea. Türkiye’s performance aligns closely with its upper-middle-income peers in Index 2 but remains below the average in Index 1, highlighted its challenges in broader sustainability dimensions.

Benchmarking Türkiye’s performance against countries in comparison revealed strengths in renewable energy adoption and CO_2 emissions reduction but weaknesses in social and environmental indicators, such as inequality, air pollution, and research and development. The analysis with SDG Energy Sustainability Index showed that

Türkiye’s progress in energy sustainability and SDGs in support of the argument but also highlighted the need for aligning energy policies with broader sustainability goals.

The findings of the analyses in Chapters 4-7, in general, supported the argument of this thesis by providing qualitative and quantitative evidences on country’s notable progress in energy sustainability as well as insights for improving Türkiye’s energy sustainability framework and advancing its transition toward a low-carbon, sustainable energy future.

This thesis makes significant contributions to the academic literature on energy sustainability, sustainable development, and comparative energy policy analysis. By addressing the relationship between Türkiye’s energy sector evolution and global sustainability frameworks, the study contributes and fills several gaps in existing research.

First, this thesis contributes literature by providing energy transition experience of Türkiye, a developing country with a rapidly growing economy, high energy demand, and significant reliance on fossil fuel imports. By situating Türkiye’s energy transition within the broader discussion on sustainable development, this research highlights the unique challenges and opportunities faced by developing nations in achieving energy sustainability.

This thesis also provides a longitudinal analysis of Türkiye’s policy trajectory, tracing its alignment with international sustainability commitments and identifying key policy shifts. The research enriches the literature by offering a comprehensive historical perspective on Türkiye’s energy and development policy governance and its intersection with global sustainability trends.

One of the most novel contributions of this thesis is the development of SDG Energy Sustainability Index, quantitatively assess Türkiye’s progress in energy sustainability. The SDG Energy Sustainability Index incorporates SDG interlinkages, providing a more nuanced, systemic and multidimensional assessment of energy sustainability. This methodological advancement offers scholars and policymakers a new framework for assessing energy sustainability in a holistic manner.

Comparative analysis of Türkiye’s energy sustainability performance in relation to other nations is also a significant contribution to the literature. This cross-country evaluation helps contextualize Türkiye’s progress in terms of identifying strengths and weaknesses. By considering the results of the analysis, the thesis provides insights into how Türkiye can refine its strategies to better align with sustainable development priorities.

By integrating policy analysis and comparative benchmarking with indices, this thesis adopts an integrated approach to energy sustainability studies. This methodological approach enriches the literature by demonstrating how different research perspectives, such as sustainability science, energy policy, and development studies, can be combined to produce a more comprehensive analysis of energy sustainability.

While significant progress has been made, the journey toward a fully sustainable energy system requires continued innovation, investment, and collaboration. By embracing a holistic approach that integrates economic, environmental, and social dimensions, Türkiye can further align its energy policies with global sustainability goals and serve as a valuable model for inclusive and resilient energy transitions for other developing nations navigating similarly. This research highlighted the need for a comprehensive and integrated energy policy framework. In this context, considering the sustainability challenges identified in the Chapter 5 and the findings of comparative analyses in Chapters 6 and 7, the following policy recommendations are proposed to enhance energy sustainability while aligning with global sustainability goals:

1. Reduce dependence on fossil fuels and enhance renewable energy deployment through accelerating the transition to a diversified and sustainable energy mix by expanding investments while increasing grid reliability and storage capacity for renewable integration.
2. Improve energy efficiency across all sectors, including industry, transportation, and residential energy consumption, through stringent efficiency standards and smart grid integration.
3. Expand clean energy research and development (R&D) investments in renewable energy, energy efficiency, and cleaner fossil fuel technologies and energy storage technologies (such as battery storage and hydrogen solutions) in partnerships with universities and research institutions.
4. Expand financial incentives, such as feed-in tariffs and tax benefits to attract both domestic and foreign investment in clean energy projects.
5. Ensuring equitable access to clean and affordable energy particularly in rural and underserved communities, improving energy affordability and economic development.
6. Strengthen socioeconomic policies to address unemployment and inequality by ensuring that the energy transition supports inclusive job creation and workforce training programs.
7. Enhance environmental sustainability through emission reduction and biodiversity protection measures such as implementing advanced air pollution control, expanding protected natural areas and ensuring compliance with environmental regulations.
8. Improve policy coordination across governmental bodies ensuring the energy and development policies align with international sustainability frameworks and advance monitoring systems with effective use of indicator and indices to track progress in achieving SDG-aligned energy policies.
9. Strengthen collaboration with international partners on research, knowledge exchange, and joint clean energy projects to integrate best practices and advance technological development.

Among these policy proposals, reducing fossil fuel dependence, strengthening renewable energy infrastructure, enhancing efficiency, and improving policy coherence with sustainability should be priority for ensuring long-term resilience and sustainable development. Improved policy governance and coordination between various institutions is utmost critical for effective implementation of energy sustainability policies sustainability goals. These efforts will not only enhance Türkiye's energy security but also contribute to global efforts in combating climate change, accelerating the sustainable and inclusive energy transition in line with global sustainable development goals.

In future studies, it is advisable to further investigate the socioeconomic impacts of sustainable energy transitions in other developing countries such as Brazil and Indonesia to improve generalizability of findings to other regions.

Future research could explore the intersection of energy transitions and social equity, particularly in the context of Türkiye's regional and global positioning. For example, the socioeconomic impacts of renewable energy transitions on social groups such as the poor and women within Türkiye would be a precious contribution. Additionally, expanding the scope of sustainability frameworks to include resilience and adaptive capacity would be beneficial in addressing the dynamic and interconnected challenges of sustainable development.

Pairwise country reviews could offer valuable insights by complementing quantitative comparisons with experience-based analyses, enabling the development of more nuanced and effective sustainability strategies. Additionally, conducting sector-specific assessments, such as evaluating the impact of transportation and industry sectors on energy sustainability, would provide a more detailed understanding of Türkiye's energy transition. Furthermore, advanced modeling studies would be crucial in examining the long-term implications of Türkiye's recent energy and development policies together with climate targets such as 2053 net-zero emission target, particularly their effects on the economy, society, and environment, to support the formulation of data-driven and forward-looking policies.

Regarding the methodology of SDG Energy Sustainability Index, future studies could explore more dynamic or advanced weighting approaches to enhance the representation of regional and sectoral nuances in energy sustainability. Expanding the indicator set from other databases in future research would improve the index's ability to capture more aspects of energy sustainability such as energy efficiency, grid reliability, and private sector contributions. Moreover, the inclusion of region-specific challenges, such as Türkiye's energy import dependency and geopolitical influences, could further contextualize the scores and provide more targeted insights.

In conclusion**,** this thesis demonstrates that Türkiye has made notable progress in aligning its energy and development policies with sustainable development objectives, particularly within the framework of global initiatives such as Sustainable Development Goals, providing insights for other nations in their journeys towards energy sustainability.

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CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Yıkmaz, Rıza Fikret

Nationality: Turkish (TC)

EDUCATION

Degree	Institution	Year of Graduation
PhD in Earth System Science	Middle East Technical University, Ankara, Türkiye	2025
MPA in Development Practice	Columbia University, School of International and Public Affairs, New York, USA	2015
MSc in Geodetic and Geographical Information Systems	Middle East Technical University, Ankara, Türkiye	2010
BSc in Environmental Engineering	Middle East Technical University, Ankara, Türkiye	2005
High School	50. Year High School (Foreign Language Intensive), Ankara, Türkiye	2000

WORK EXPERIENCE

Date	Institution	Position
June 2021-Continuing	Presidency of the Republic of Türkiye, Presidency of Strategy and Budget, Ankara, Türkiye	Head of Department of Employment, Working Life and Social Services
August 2018- June 2021	Presidency of the Republic of Türkiye, Presidency of Strategy and Budget, Ankara, Türkiye	Strategy and Budget Expert
May 2015-August 2015	Columbia University, School of International and Public and Affairs, New York, USA	Staff Associate
June 2014-September 2014	UNDP Headquarters, New York, USA	Research Intern
June 2011-August 2018	Ministry of Development, Ankara, Türkiye	Planning Expert
Nov 2010-June 2011	State Planning Organization (SPO) of Prime Ministry of Republic of Türkiye, Ankara, Türkiye	Planning Expert
June 2008-December 2008	Research Commission of Turkish Grand Assembly on Identification of Measures for Sustainable Environmental Policy by Investigating Environmental Problems in Türkiye, Ankara, Türkiye	Commission Expert
Dec 2005 – Nov 2010	State Planning Organization (SPO) of Prime Ministry of Republic of Türkiye, Ankara, Türkiye	Assistant Planning Expert

FOREIGN LANGUAGES

English (Advanced), German (Beginner).

PUBLICATIONS

Books

Strateji ve Bütçe Başkanlığı. (2019). *Sürdürülebilir Kalkınma Amaçları Değerlendirme Raporu*. İ Arı, **R. F. Yıkmaz**, B. Üstünışık, M. Rahmanlar, S. Altınsoy, S. Arlı Yılmaz, S. Dilekli ve M. Bulut (Editörler). Yayın No:0013, Ankara. ISBN: 978-605-7751-13-3.

Yıkmaz, R.F. (2011). *Sürdürülebilir Kalkınmanın İzlenmesi ve Türkiye İçin Yöntem Geliştirilmesi*. Planlama Uzmanlığı Tezi, DPT Müsteşarlığı, Ankara.

Yıkmaz, R.F. (2010). *Development of GIS Based Trajectory Statistical Analysis Method to Identify Potential Sources of Regional Air Pollution*. Master Thesis, Middle East Technical University, Ankara, Türkiye.

Book chapters

Topçu, P. ve **Yıkmaz, R. F.** (2023). Sürdürülebilir Tarım ve İklim Değişikliği. İ. Arı (Ed.), *Sürdürülebilir Kalkınma ve İklim Değişikliği: Bağıntılar ve Örnekler*, İçinde (s. 133-152). Gazi Kitabevi.

Eraslan T. ve **Yıkmaz, R. F.** (2023). İklim Değişikliği ve Adil Geçiş. İ. Arı (Ed.), *Sürdürülebilir Kalkınma ve İklim Değişikliği: Bağıntılar ve Örnekler*, İçinde (s. 173-192). Gazi Kitabevi.

Ari, I. & **Yikmaz, R. F.** (2019). Greening of industry in a resource- and environment-constrained world. In S. Acar and E. Yeldan (Eds.) *Handbook of Green Economics*, (208 pp.), Academic Press, Paperback ISBN: 9780128166352, eBook ISBN: 9780128166444.

Yıkmaz R. F. (2018). Türkiye'nin İklim Değişikliği Konusundaki Politika, Mevzuat ve Kurumsal Yapılanmasının Analizi. İ. Arı (Ed.), *İklim Değişikliği ve Kalkınma*. Strateji ve Bütçe Başkanlığı.

Articles

Ari, I. & **Yikmaz, R. F.** (2019). The role of renewable energy in achieving Turkey's INDC. *Renewable and Sustainable Energy Reviews, 105*(1):244-251. ISSN 1364-0321.

Ari, I. ve **Yikmaz, R. F.** (2018). Türkiye'de Konutlardaki Elektrik Tüketiminin Sıcaklığa Bağlı Hassasiyetinin İl Bazında Değerlendirilmesi, *Enerji, 2* (9), 20-31.

Referred Article in Conference Proceedings

Yıkmaz, R. F. (2010). *Potansiyel Hava Kirliliğinin Kaynaklarının Belirlenmesi için Etki Kaynak Bölgeleri Yönteminin Denenmesi*. Birinci Uluslararası Meteoroloji Sempozyumu, Ankara.

PROJECTS

Years	Name of Project	Position in the project
2023-2024	Research on Youth Not in Education, Employment, or Training	Project Manager
2017-2018	Türkiye's Current Situation Analysis within the Scope of Sustainable Development Goals	Project Coordinator
2011-2012	Supporting Türkiye's Preparations for the Rio+20 Summit	Project Team Member
2009-2010	Identification of Rational Steps in Combating Climate Change Report	Project Team Member
2006-2008	Integration of Sustainable Development into Sectoral Policies (EU Project)	Project Team Member

HOBBIES

Computer Technologies, Cars, Motor Sports.